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EDITORS: V. TANČIN, Š. MIHINA & M. UHRINČAĽ
APRIL 2005

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Physiological and Technical Aspects of Machine Milking

**Proceedings of the International Conference
held in Nitra, Slovak Republic,
26 - 28 April 2005**

Editors: V. Tancin, S. Mihina & M. Uhrincat

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Foreword

Ladies and Gentlemen,

Welcome to Nitra, the main centre for Slovak agriculture, and thank you for accepting the invitation of the organisers to participate in this conference.

I am pleased to note that half of those attending are from abroad. This proves that the problems the conference will target are topical not only for our specialists but also for foreign specialists. International contact is a good basis for interesting and stimulating discussion, in the course of which one can share opinions and experiences and gain new inspiration for further work.

I also believe that, in addition to the interesting subject matter, the international prestige of our scientific and research institutes, in this case mainly of the Research Institute for Animal Production, has influenced your decision to come to Nitra. The Research Institute for Animal Production, in which this conference takes place, is one of the most experienced in international activities. It is the location of the international laboratory for biotechnologies, and was given the status of Centre of Excellence in the 5th Framework Programme of the EU.

Science and research play increasingly important roles in modern society. Progress in knowledge and the development of new technologies is the basis for advancement in the sphere of the economy and ultimately also in the social sphere. In this process, all of the links in the chain are of the equal importance. Specialist knowledge and new information from seemingly heterogeneous spheres are very often related and impact upon each other. Therefore it is not possible to advance without adequate communication between individual disciplines. From this point of view, we appreciate the broad range of related subjects that are to be found in the specialist contributions at this conference. Furthermore, communication between specialists from the same discipline but different countries is also very important. The international attendance of specialists at this event suggests that in this respect also we can expect many new pieces of knowledge. I believe that only in this way is it possible to become acquainted with the various aspects of a given problem, and to gain a comprehensive understanding of the subject.

Dear participants in the conference,

I trust you will rate your participation in this event as having been useful, and go home full of new knowledge and ideas for further work. I hope you will find new personal as well as professional contacts in Slovakia since, through personal co-operation, the opportunity of becoming acquainted with different views on things is very often the greatest stimulus towards advancement. I wish you much energy for your work, the acquisition of much new knowledge, and a pleasant stay in the Slovak Republic.

Ing. Zsolt Simon
Minister of Agriculture of the Slovak Republic

Machine milking research in Slovakia

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As in other countries, machine milking research and development in Slovakia have been influenced by dairy cow industry developments. The beginning of machine milking in Slovakia is associated with the establishment of agricultural cooperatives and the nationalisation of former large estates after 1950. Larger herds were created at that time. In the fifties, cowsheds were built for approximately 100 dairy cows. There were usually two or more on any one dairy farm. Later, mainly in the seventies, specialised farms, already equipped with modern milking parlours, were built. At the beginning of the milking parlour era, there were tandem and herringbone parlours. Later on, rotary milking parlours emerged. All of these types, with various modifications, continue to be used today. In the past, and also at present, herringbone milking parlours were the most widespread ones among breeders in Slovakia because of simplicity, and particularly of reliability of operation. At the turn of the sixties and seventies, rotary milking parlours were already being imported, and later on they were being manufactured in the former Czechoslovakia. More recently, parallel parlours have found their place on Slovak farms.

The size of dairy cow herds on Slovak farms points to milking parlours as being the only possible option at present. The most common capacity is 300 - 800 dairy cows in one location.

Generally, the level of machine milking research depends on

- genetic progress in the biological material,
- increasingly strict demands for quality in milk and milk products for consumption,
- the need to raise the living standards of breeders,
- new possibilities resulting from general technological advances (in materials, hardware, software, etc.).

In Slovakia, three basic breeds are kept at present: the Slovak Pied (Simmental), Slovak Pinzgau, and Holstein breeds and their crosses. Changes in breed structure were affected by fashion and political changes as well as by the import of milking equipment. To improve milking efficiency and productivity, there was successive use of the Danish Red,

Introduction

Machine milking research framework

Ayrshire, Lowland Black, and Black or Red Holstein breeds. A significant change in the proportion of Holsteins occurred over the past 15 years. In 1989, there were 121,000 dairy cows of the Slovak Pied breed, 40,000 of the Pinzgau breed, and 26,000 Holsteins. The number of Slovak Pied cows has decreased to 36,000 and of Pinzgau cows to 4,000 at present. There are 124,000 Holstein cows, including crosses with a high proportion of Holstein blood. The milking efficiency and productivity of cows rose as a result. However, the demands for quality in milking technology also rose.

The pressure for innovation in milking technology in Slovakia is caused mainly by demands for higher milk quality. During the past 15 years, the criteria for milk quality evaluation have changed several times. The outdated evaluation criteria (Resasurin test) were changed first. Then the criteria used in EU countries were gradually made more strict. Somatic cell counts (SCC) and total bacterial counts (TBC) are at present the main criteria for milk quality evaluation. Maximum counts are 300,000 SCC and 50,000 TBC for Q class milk, and 400,000 SCC and 100,000 TBC for 1st class milk. In addition, the milk must not contain inhibitory substances. In the year 2004, milk of Q or 1st quality was produced in 94 % of herds. During the past 10 years, considerable modernisation has taken place on Slovak dairy farms. In 1989, only 12% of dairy cows were kept in loose housing and milked in milking parlours. At present, this figure is approximately 50 %.

**Machine milking
research subjects
in Slovakia**

For more than 50 years, machine milking research in Slovakia has been targeted on both biological and technical subjects.

The main objective of the introduction of machine milking is first of all to save working time. Therefore quite a lot of effort was devoted to research into increasing labour productivity. The work routines that were studied varied according to the type and equipment of milking plants. Other decisive factors were the number, qualifications and skills of the milkers and, not least, the traits of the dairy breeds used for milk production at the time. The work routines of milkers were evaluated not only in relation to labour productivity but also in relation to hygiene standards achieved at milking and acceptable ways of handling cows. The evaluation of work routines was aimed mostly at preparation of the udder before milking. Optimum work routines for practice were recommended on the basis of ergonomic studies.

Milking equipment is one of the largest investment costs on a dairy farm. Therefore, economic research was also applied to milking. Optimum numbers of stands in milking parlours, optimum numbers of stands operated by one milker, and optimum layouts of milking parlours were determined. First of all, methods of calculating economic efficiency of capital were looked for.

Because of the size of dairy farms in Slovakia, it was also necessary to consider the rationalisation of energy consumption. Milking could not be omitted from the technological processes evaluated. On the basis of measurements, recommendations were made on optimum configurations for technological processes, and components with lower electrical power consumption were proposed. With regard to milking, most studies were on combinations of vacuum pumps, compressors and milking pumps. Efficiency of utilisation of vacuum pump capacity was the main object of research.

Since the sixties, quite extensive research had already been done on the behaviour of animals. The welfare of dairy cows was evaluated at times of change in milking conditions, e.g. at the changeover from milking in tied stalls to milking in a milking parlour, at the introduction of rotary milking parlours, and also later when using rapid exit facilities for dairy cows on large capacity farms. Very useful study results were obtained of social behaviour in waiting pens before milking, and of behaviour in cows subjected to changed milking methods during their lactation, e.g. from individual tandem boxes into herringbone milking parlours in which the cows got a new feeling of close contact with each other, and from herringbone to rotary milking parlours.

At one time on Slovak farms, a system dairy cows were milked in tied stalls at the beginning of their lactations and then transferred into a milking parlour. With such a system of husbandry, a whole range of new knowledge about the behaviour of dairy cows in relation to milking letdown was obtained.

Variety in the afore-mentioned breed composition of dairy herds also manifested itself in the milking letdown of the cows; in other words, in the response of different breeds to new milking conditions. Very important results were obtained on amounts of machine strippings and complete milking while using the automatic end-off milking system that came into use in Slovakia at the beginning of the seventies. In addition to biological problems, aspects of technical improvement in the automatic end-off milking devices were studied. Recent research is aimed at increasing the critical milk flow in end-off milking equipment.

As in other countries, much time was devoted to looking for optimum settings for pulsation and vacuum. The effects of various levels of pulsation and vacuum, and of various combinations of these levels, on the normal course of milking were evaluated. Experiments were done in which the possibilities of adjusting pulsation parameters in relation to the milkability of the cows were investigated. Also, measures of vacuums and pressures in the teat cups and other parts of the milking cluster and unit were analysed in detail. Results of this research into the parameters of milking cluster operation were used directly in the manufacture of milking equipment produced in the former Czechoslovakia.

A separate part of the research effort focussed on the hygiene of milk production, not only in the milking parlour but also on the whole farm. Research in the design of housing was undertaken to facilitate minimum cleaning of dairy cows before milking. Parameters of cubicle design were established for the reconstruction and modernisation of old cowsheds. The studies of work routines mentioned earlier also paid attention to hygienic factors. Those routines that were not very labour demanding but provided a high level of hygiene were recommended to the breeders. A large section of research was aimed at circulation cleaning and disinfecting of equipment of both classic and automated types. Also, non-traditional methods, such as ultrasound, were looked at.

The evaluation of milk quality measured the effects of machine milking, milk composition, microbial purity and wholesomeness. At one time in Slovakia, milking systems were constructed with over-long and articulated pipelines for milk transport using powerful milk pumps. This resulted in the so-called 'induced lipolysis' that had a considerable effect on the content of free fatty acids, i.e. the quality of milk fat. More gentle methods were proposed on the basis of research measurements.

Research also paid attention to the feeding of concentrates in the milking parlour, from the viewpoint of both economy and dairy cow stimulation. During the seventies and eighties, observation of milk flow from individual quarters of the udder was done mainly to support selection programmes aimed at providing equal distribution of milk in all quarters of the udder. At present, the research is more detailed; knowledge about the patterns of milk flow in individual quarters is obtained and, based upon these patterns, traits indicating the state of health of the udder are looked for. For a short period of time, research was devoted to damage of teat tips in relation to vacuum level, speed of milking, age, stage of lactation and breed.

State of health was evaluated under various methods of milking. Ways of rapid detection of health problems were looked for. The research was mostly aimed at utilisation of the electrical conductivity of milk.

For the present, there are no automatic milking systems in Slovakia. However, we have at our disposal knowledge from studies performed abroad, and we did take part in a study of aspects of milk letdown physiology in robotised systems in Western Europe.

High quality, extensive research on the physiology of milk recovery is undertaken in Slovakia. The overall focus is first of all on the physiological reaction to machine milking. The main topics are:

- the effect of milking and breeding environments and the handling [?] of cows on their milk letdown efficiency during machine milking or suckling. ("Release of oxytocin, milk flow parameters, residual milk volume")
- aetiology of milk letdown disturbances

- the importance of opioid and noradrenergic systems in milk letdown path physiology
- the response of the hypothalamic-pituitary-adrenal axis to milking. (“Release of cortisol, ACTH and prolactin”)

Research into the machine milking of sheep in Slovakia is also important. We should point out that the Slovaks were pioneers in this sphere. During the sixties, machines already milked quite a high number of sheep. Milking equipment of good quality was developed and produced here. Later, research in this sphere and in the milking of sheep ceased because of lack of interest of the breeders and society. In recent years, research was resumed in biological and technical aspects.

Technical research was aimed first of all at the improvement of technical reliability in milking equipment, and at systems of reliability testing and service. Surface damage to teat-cup liners was measured, and measuring instruments to evaluate the vacuum, pulsation and milk flow were developed. So-called ‘rapid control methods’ of technical parameters were developed. A separate part of technical research was aimed at preventive maintenance.

The above summary shows that research in milking was always directed mainly at fulfilment of the breeders’ needs. One consequence was the fact that, apart from milking equipment for sheep, no other milking equipment was produced in Slovakia. Before 1990, there was quite broad co-operation between Slovak research institutions, mainly the Research Institute for Animal Production in Nitra and the Slovak Agricultural University in Nitra, with Agrostroj Pelhřimov, which was the only producer of milking equipment in the former Czechoslovakia.

International co-operation had, and still has, an important role in the fulfilment of research objectives. In the past, it took place not only in Czech institutes and universities but also in Hungary and Eastern Germany, where research co-operation was also undertaken with the milking equipment manufacturer Impulsa. At present, the largest co-operation is with TU Munich Freising Weihenstephan, Germany, especially in the milk letdown research mentioned earlier. With Agrotechnology and Food Innovations BV, Wageningen, we have co-operation in quarter milk flow research. Currently UMR INRA/AGROCAMPUS, France, is our new partner for co-operation in research into sheep and goat milking.

The importance of adrenergic receptors in the bovine udder for milk removal

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Alpha- and β -adrenergic receptors are present in most mammalian organs. They are mediating the tissue-specific activity of the sympathetic nervous system with noradrenalin as neurotransmitter or the systemic endocrine action of adrenalin released from the adrenal medulla. Adrenergic receptors belong to the family of G-protein-coupled receptors which are located in the cell membrane and have seven stretches of hydrophobic transmembrane spanning domains (Gether, 2002). Alpha- and β -adrenergic receptors are pharmacologically classified into the receptor types α_1 and α_2 , and β_1 , β_2 and β_3 , respectively. Between these receptor types there are functional differences and often antagonistic effects, e.g. vasoconstriction mediated by α_1 and α_2 -receptors and vasodilation mediated by β_2 -receptors (Bruckmaier et al. 1991; Inderwies et al. 2003b, c).

Within the bovine mammary gland, adrenergic receptors have first been detected in the teat smooth muscle layer (Roets et al. 1984; Roets & Peeters, 1985; Roets & Peeters, 1986). Later, α - and β -adrenergic bindings sites were also found in the tissue surrounding the gland cistern and the large milk ducts whereas almost no binding was detected in the secretory parenchyma free of larger milk ducts (Hammon et al. 1994). Based on quantitative analysis of the mRNA encoding for the different receptor types and subtypes eight of nine currently known receptor subtypes could be detected in the udder of dairy cows (Wellnitz et al. 2001; Inderwies et al. 2003a). mRNA expression of α_1 and α_2 receptors was highest for the α_{1A} and α_{2A} subtypes, respectively. Within the β receptors, the β_2 receptor type was most highly expressed.

Experiments demonstrated an inhibition of milk ejection and milk flow in response to the administration of adrenalin or noradrenalin (Cochrane, 1949; Naito et al. 1964; Vorherr, 1971; Sibaja & Schmidt, 1975). These results led to the hypothesis that catecholamines and amongst them mainly adrenalin are responsible for disturbed milk ejection under practical conditions which was clearly contradicted in several investigations in the 1990th.

Presence of adrenergic receptors in the bovine mammary gland

Alpha-adrenergic receptor stimulation inhibits milk ejection and milk removal

The importance of α - and β -adrenergic receptors for this inhibitory effect could not be evaluated in these studies because the natural catecholamines adrenalin and noradrenalin stimulate both receptor types albeit the respective effect is dose-dependent and the experimentally administered dosages were always in a supraphysiological range. Therefore, additional studies were necessary where adrenalin was administered together with receptor-type specific blocking agents or receptor-type specific agonists were administered as far as available (Blum et al. 1989; Bruckmaier et al. 1991). These studies proved that the inhibitory effect on milk ejection and thus reduction of milk yield was mediated by α -adrenergic receptor stimulation, whereas β -adrenergic receptor stimulation caused an increased milk flow, however, without any effect on milk yield. The inhibition of milk ejection as induced by α -adrenergic receptor stimulation could not be overcome by oxytocin administration even in very high pharmacological dosages but by an α -receptor blocking agent (Bruckmaier et al. 1997). In addition, it could be shown that despite inhibition of milk ejection, α -adrenergic receptor stimulation does not inhibit but rather augment the milking-related release of oxytocin from the posterior pituitary (Bruckmaier et al. 1997). Thus, the experimental inhibition of milk ejection via α -adrenergic receptor stimulation is not based on a suppression of oxytocin release or on an interaction with the oxytocin receptors of the myoepithelial cells. Obviously, the inhibition of milk ejection occurs on the level of the milk duct system where many subtypes of adrenergic receptors have been detected in high density (Hammon et al. 1994; Wellnitz et al. 2001; Inderwies et al. 2003a). Smooth muscles of the milk ducts have the potential to close the ducts in response to intensive α -adrenergic stimulation (Inderwies et al. 2003b). Surprisingly, the longitudinal contraction of the teats which is also visible in response to α -adrenergic stimulation seems to have almost no inhibitory effect on milk ejection and milk flow (Bruckmaier et al. 1997; Inderwies et al. 2003b). In conclusion, the inhibitory action of α -adrenergic stimulation is solely located in the milk duct system and acts in a dose-dependent manner (Inderwies et al. 2003b; 2003c).

**Beta-adrenergic
receptor
stimulation
increases milk
flow but not milk
yield**

Selective β -adrenergic receptor stimulation either by a β -adrenergic agonist (Bruckmaier et al. 1991) or by adrenalin administered together with an α -adrenergic blocking agent (Blum et al. 1989) caused an augmentation of milk flow rates, most pronounced of peak flow rate, but no simultaneous increment of milk yield. Obviously, β -adrenergic receptor stimulation facilitates the transfer of milk from the alveolar tissue into the cisternal cavities to be available for milk removal. It has been demonstrated that milk ejection is a continuous process throughout the entire milking (Bruckmaier et al. 1994). Most likely, the milk ejection rate can be a limiting factor for milk flow rate. Consequently, a relaxation of the large milk ducts may result in increased milk flow rates. Because

adrenergic receptors are not present in the secretory tissue (Hammon et al. 1994) the β -adrenergic stimulation does obviously not interact with myoepithelial contraction thus explaining a lack of effect on milk yield.

Based on the effects of pharmacological stimulation of α - and β -adrenergic receptors it seems likely that the distribution of α - and β -adrenergic receptors and their various subtypes influences the course of milk ejection and hence milk flow during machine milking. Studies by Roets et al. (1989) showed that milkability traits are correlated with the ratio of β_2/α_2 receptors in the teat muscle layer and in blood cells. Further studies even showed a significant correlation between the β_2/α_2 receptors on blood cells of bulls and the milkability of their daughters (Roets et al. 1995). Recently it could be demonstrated that the peak flow rate is negatively correlated with the expression level of the α_2A receptor in the tissue around the large milk ducts both on a mRNA and a protein level whereas no relation between the expression of other adrenergic receptor subtypes and peak flow rate could be found (Inderwies et al. 2003c). Without adrenergic drug treatment the adrenergic receptors are stimulated by the neurotransmitter noradrenalin from the sympathetic neurons or by circulating catecholamines released from the adrenal medulla. Thus, the sympathetic tone of the milk duct system seems to have a considerable influence on the milk ejection rate and thus availability of alveolar milk for the milking machine and milk flow.

Despite contradictory reports in many text books it has to be clearly stated that spontaneous inhibition of milk ejection in dairy farms was never shown to be related with adrenergic receptor stimulation in the mammary gland. All types of disturbed milk ejection under practical conditions such as in primiparous cows after parturition and during milking in unfamiliar surroundings (Bruckmaier et al. 1992; 1993, 1995; Macuhova et al. 2001) are based on reduced or lacking release of oxytocin from the pituitary. This effect is not induced by catecholamines such as adrenalin because they would rather stimulate than inhibit the release of oxytocin (Blum et al. 1989; Bruckmaier et al. 1997). Expectedly, during spontaneously disturbed milk ejection in unfamiliar surroundings with lacking oxytocin release, the administration of α - and β -adrenergic blocking agents were without any beneficial effect on the milk ejection (Bruckmaier et al. 1997). However, there may be an evolutionary advantage in the possibility of immediate total milk duct closure in response to very high concentrations of adrenalin in wild animals. In contrast to the situation on dairy farms, wild animals can come in the situation of a "fight and flight" response, also called the „acute stress response“ which was first described by the Harvard physiologist Walter Cannon in the 1920s as a theory that animals react to threats with a general discharge of the sympathetic nervous system. This reaction is related to the release of huge amounts of adrenalin. If such conditions should occur during suckling the offspring, it is a clear advantage to

Adrenergic receptors and milkability

Adrenergic receptors in the udder do not mediate spontaneous inhibition of milk ejection in practical dairy farming

interrupt immediately the transfer of milk from the ventral to more proximally located regions and to simultaneously contract the teats in longitudinal direction in order to gain more distance between the mammary gland and the ground.

In conclusion, under practical conditions in dairy farms, the distribution of adrenergic receptor types and blood concentration of catecholamines or sympathetic activity may influence the rate of milk ejection and hence milkability. Contrary reduced or lacking milk ejection is not induced by adrenergic receptor stimulation.

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Machine milking ability in goats: genetic variability and physiological basis of milk flow rate

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This review presents the results of 4 years of studies on machine milking ability in French Alpine and Saanen goats. This research aimed : 1- to validate measurements of milking ability; Milk flow parameters measured by automatic electronic jar and teat end characteristics measured by vacuumeter and cutimeter seemed very convenient for that, 2- to describe inter-animal variability on the basis of milk flow rates and other characteristics of milk emission kinetics; The variability is very important and correlated between peak and mean milk flow rate and teat sphincter resistance. A high number of high yielding goats of the two breeds presented too long milking duration due to low milk flow rate suggesting a big capability of improvement of total milking rate of milking for breeders, and 3- to investigate the physiological basis for this variability; The teat characteristics and especially the teat sphincter resistance and tonus before milking explained the main part of the variability of milk flow rate. The milk ejection reflex, attested by oxytocin release around milking, was never correlated to milk flow parameter suggesting that oxytocin discharge is non essential for milk ejection in dairy goats.

Keywords : Milking ability, goats, milk flow, teat, oxytocin

Because of increase in herd size and productivity per goats, compliance with new requirements about milk quality, and the lack of specialised workforce, we notice an increase in workload on the goat family-run

Summary

Introduction

farms. Thus, despite advances in automation, milking remains the heaviest commitment on farms, requiring about 55% of the daily working time of farmers. It is necessary to increase the hourly productivity of milking personnel (more than 200 to 250 goats/ hour/ milker), while respecting milk quality and the health status of udders. However, this work is difficult because of the considerable heterogeneity of milking times observed between animals and between farms.

This heterogeneity between animals has a genetic component. The existence of a major gene influencing the „first minute“ milking flow was first postulated by Ricordeau et al. (1990), and this is now possible to measure this parameter by use of automatic milking jar on a larger scale. Different anatomical and physiological parameters concerning these variations in milking times may be the source of these inter-individual variations: 1)- The existence or not of a milk ejection reflex, which can be measured objectively based on oxytocin release (Marnet and McKusick, 2001) could suggest that some animals may be not enough stimulated. 2)- The considerable heterogeneity of udder morphology, renders difficult any adaptation to modern milking machines. 3)- Teat characteristics may be of a major importance. Indeed, Le Du and Benmederbel (1984) showed that the teat canal in goats seems to be more difficult to open than that of cows, and the vacuum necessary to achieve a flow of milk is correlated negatively with the milk flow and positively with the milking time. In addition, the milk flow seems to be easier from teats with a narrow, supple and compressible extremity.

This work thus describes the variability and genetic determinism of the milking rate in goats, while attempting to find explanatory factors through the study of some of its anatomical and physiological foundations.

Material and methods

Measurement of milk emission characteristics during milking

Measurements on commercial farms

Measurements on experimental farms

The measurement of milk emission kinetics (Labussière and Martinet, 1964), used different automatic control devices designed by INRA. These devices, connected in the same way as standard milking control jar, all contained a probe equipped at 0.5 cm intervals with electromagnetic switches with flexible blades and a sliding flotation device which ensured contact with these switches (Le Du et al, 1983).

The measurements of variability in performance were made on 27 commercial farms, and during more than 1000 milking sessions on different goats from Alpine (n=806) and Saanen (n=217) breeds, chosen at random throughout the different lactations from 1996-1997 until 1998-1999. Machine adjustments were homogeneous (38 to 40 kPa of vacuum, 80 to 90 pulsations per min. and a ratio of 50 to 60%), and a single type of milking cluster was used (Caprilac from Gascoigne-Melotte) for measurements.

Measurements on experimental farms aimed to clarify the most relevant factors for genetic variability and zootechnical data to be taken into account when measuring performance. They were repeated several times

in each goat. We chose electronic jar and the same machine adjustments as in commercial farms, but the milking clusters differed (Almatic from DeLaval). Thus 1596 milking sessions on 133 Alpine goats, checked six times under standard conditions, made it possible to validate the criteria chosen and establish the factors for variations in milking characteristics. At the Moissac goat farm, 2493 milk flow measurements, performed between 1985 and 1997 on 1421 Alpine goats, the offspring of 93 fathers, made it possible to carry out a genetic study. As from 1998, these measurements were supplemented by recordings of milk emission kinetics and all other productive and anatomical data were collected by Caprigène on all goats on the farm. 80 goats with a comparable level of milk production were pre-selected and 20 goats amongst them, selected for their different lag times and milk flow rates, were chosen to study the physiological determinism of variations in milk flow and milking time.

Blood was sampled (10 ml) via an intra-jugular silicone catheter implanted under aseptic conditions a few days prior to measurement. The sampling protocol was: Subject in barn, subject in the milking parlour (5 min prior to cluster attachment), at (T0) and then 0.5, 1, 1.5, 2, 3, 6 and 12 min after cluster application. Plasma was frozen until analysis of oxytocin levels using the EIA technique (Marnet et al. 1994).

The morphology was scored from 1 to 9 (Piacère et al. 1999) for teats: angle, implantation, orientation, shape (length and diameter of teats were measured in cm) and for udders: shape of udder halves, base length of udder suspension, position of attachment and profile.

Teat end thickness was measured by the same person before and after evening milking using a HAUPTNER cutimeter. It is a spring-loaded calipers which measure the thickness of tissue under a constant force (2.4 kPa). The teat canal resistance at opening was achieved using a vacuumeter. This device comprises a rigid, transparent cup connected to a vacuum pump which creates a vacuum increasing by approximately 1 kPa /s . The level of vacuum (kPa) corresponding to the flow of the first drop of milk indicated the resistance of the teat canal to opening. This measurement was performed daily, at a fixed time from the normal time of milking for each goat.

The results are presented by sampled population (Saanen or Alpine), the notion of population including both the breed and its environment.

The quantity of milk produced by goats was 1.62 ± 0.52 l in the Alpine population and 1.74 ± 0.65 l in the Saanen population. The mean total milking time was 181 ± 76 s in the Alpine population and it was 213 ± 96 s in the Saanen population. The lag time, i.e. the time elapsing between the application of teat cups and the first recording of milk emission, was on average around 15 to 20 s in all animals in the two populations. The

**Physiological
(OT) and
morphological
measurements
(udders and teats)**

Results

**Measurements on
commercial farms**

overmilking time, measured from the time when the milk flow fell from 200 ml/min to 0 at the end of milking, was an average of 25 to 30 s per animal in the Alpine population and 10 to 25 s per animal in the Saanen population. On average, this represented nearly 20% of machine milking time in the Alpine population. However, the variability was very marked as a function of farms and animals. Thus, it was observed overmilking time which was equal to or longer than the actual milk flow time. In contrast, incomplete milking, interrupted when the milk flow was still high (at around 0.6 l/min) were demonstrated on most farms. Analysis of the quantities of milk collected at the end of milking shows that they were very small below a flow rate of 200 ml/min for an additional period of around 10 s per animal. Thus further kinetic analysis only took account of the machine milk fraction, in order to standardise the notion of the end of milking. The real mean flow rate was 0.79 ± 0.25 l/min in the Alpine population and 0.64 ± 0.22 l/min in the Saanen population. The peak flow rate of goats in the Alpine population was 1.28 ± 0.41 l/min and it was 1.11 ± 0.43 l/min in Saanen goats. The first minute milk flow was 0.72 ± 0.33 l/min in Alpine goats and only 0.56 ± 0.33 l/min in Saanen animals. The real first minute milk flow, which corresponded to the quantity of milk produced from the first recording and not from the teat cup attachment, was 0.90 ± 0.3 l/min in the Alpine population and 0.72 ± 0.31 l/min in the Saanen population. The highest first minute milk flow among Alpine goats was 1.016 l/min. It was markedly lower in the Saanen population (0.767 l/min). The maximum milk flow plateau appeared on average about 35 to 40 s after cluster application. A few difference was seen between the two populations. However, unlike the peak flow rate which was fleeting, the plateau lasted on average for approximately 1 min in Alpine goats and more than 1.5 minutes (101.5 s) in Saanen goats.

The correlations between the different milking parameters were relatively similar in the two populations studied (Table 1). It was possible to determine 3 categories of milk emission kinetics based on peak flow rates and milking times (Figure 1) and on the lag time (Figure 2). Thus, based on flow rates and milking times, 21.3%, 69.4% and 9.3% of kinetics in Alpine goats and 11.3%, 62.4% and 26.3% of kinetics in Saanen goats were found in groups 1, 2 and 3, respectively. Based on lag times, 61.8%, 28.2% and 10% of Alpine kinetics versus 46.2%, 28% and 25.8% of Saanen goat kinetics were distributed in groups A, B and C, respectively.

**Physiological
determinism of
inter-animal
variations in milk
flow**

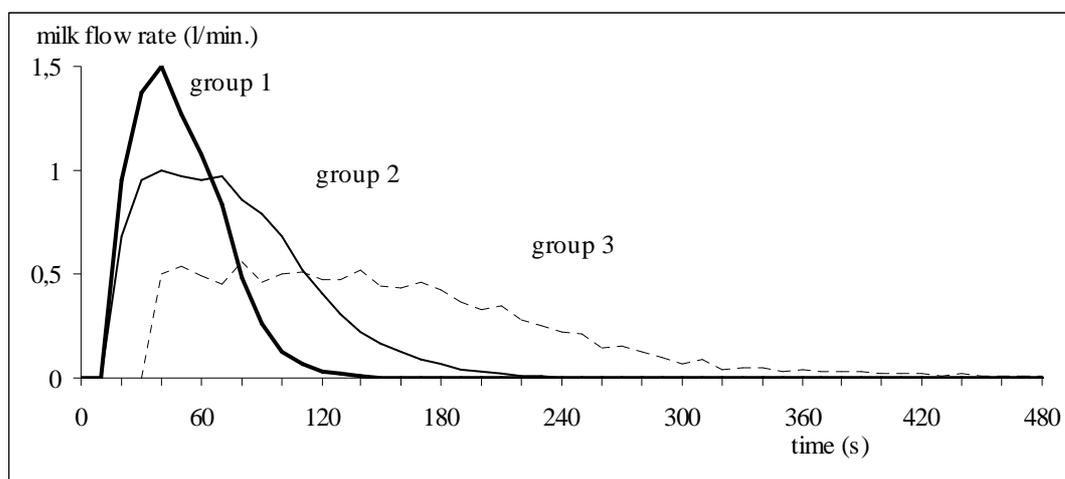
The 80 goats studied have been selected for their equivalent milk production (1.73 ± 0.27 Kg). The baseline oxytocin concentration was 12.6 ± 7.5 pg/ml and did not differ significantly between goats. It was closely correlated with the machine milk quantity and the thickness of teat tissues ($r^2 = 0.61$ and 0.5 respectively, $p < 0.01$). Peak concentrations of oxytocin, which varied considerably between and within animals at 56.2 ± 45.5 pg/ml, did not correlate with lag time categories. The total

Table 1. Phenotypic correlation between milking parameters in Alpine and Saanen goats.

		Alpine Goats (n = 710)						
		MP	TMT	LagT	MaxMF	1 st MF	R1 st MF	PlatMF
Saanen goats (n = 186)	MP	1.00	0.51 ***	-0.09 *	0.26 ***	0.26 ***	0.37 ***	0.24 ***
	TMT	0.63 ***	1.00	0.49 ***	-0.51 ***	-0.55 ***	-0.46 ***	-0.55 ***
	LagT	0.07	0.49 ***	1.00	-0.47 ***	-0.72 ***	-0.44 ***	-0.51 ***
	MaxMF	-0.11	-0.35 ***	-0.38 ***	1.00	0.86 ***	0.86 ***	0.91 ***
	1 st MF	-0.06	-0.57 ***	-0.75 ***	0.57 ***	1.00	0.89 ***	0.89 ***
	R1 st MF	0.1	-0.54 ***	-0.55 ***	0.60 ***	0.91 ***	1.00	0.88 ***
	PlatMF	-0.1	-0.55 ***	-0.54 ***	0.65 ***	0.86 ***	0.87 ***	1.00

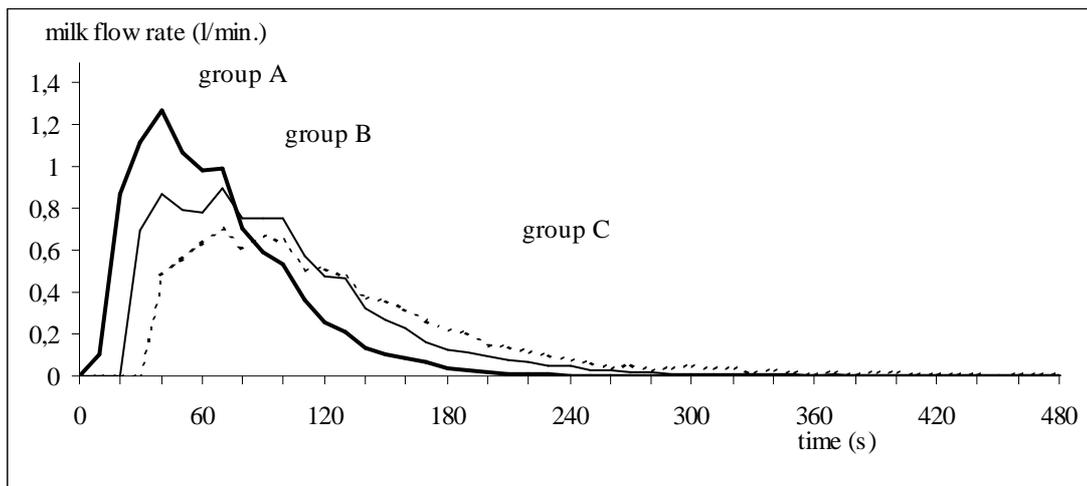
*** : significant correlations $P < 0.001$; ** : significant correlations $P < 0.01$; * : significant correlations $P < 0.05$

MP: Milk production ; TMT: Total milking time ; LagT: time between cup attachment and first recording of milk ; MaxMF : maximum or peak milk flow ; 1stMF : first minute milk flow ; R1stMF : Real first minute milk flow without lag time ; PlatMF : milk flow during plateau of maximum flow.



Group 1: peak flow $> 1\text{l/min}$ and total milking time $\leq 2\text{ min}$; Group 2: 3 min^3 total milking time $\leq 2\text{ min}$; Group 3: peak flow $< 1\text{l/min}$ and total milking time $\geq 3\text{ min}$.

Figure 1. Classification of milk emission kinetics based on peak flow rates and milking times in Alpine goats ($n=710$).



Group A: lag time ≤ 10 s; Group B: $20 \leq \text{lag time} \leq 10$ s; Group C: lag time ≥ 20 s.

Figure 2. Classification of milk emission kinetics based on lag time in Alpine goats (n=710).

quantities discharged and the time to reach peak oxytocin levels also exhibited considerable variability and a lack of significant relationship with categories of goats and other criteria.

The vacuum necessary to open teat sphincters was on average 26.1 ± 4.8 kPa. It was significantly higher in the two categories with the longest lag times (31.9 ± 7.4 and 41.8 ± 6.2 kPa respectively for lag times between 12.5 and 17.5 s and more than 17.5 s). This parameter was strongly correlated with lag time, with the total milking time and with the mean and peak flow rates ($r^2 = 0.61; 0.7; -0.59$ and -0.61 , respectively, $p < 0.05$). For the same milk production, latency was the variable most strongly correlated with milking time, mean and peak flow rates ($r = 0.89; -0.71$ and -0.066 respectively, $p < 0.05$). Teat end thickness was 5.4 ± 0.9 mm, without difference between lag time or flow rate categories. Teat end thickness before milking was weakly but significantly correlated with lag time, milking time, milk quantity and the vacuum necessary to open teats ($r^2 = 0.3, 0.37, 0.34$ and 0.26 respectively, $p < 0.01$). No variations in thickness were measured after milking, whatever the category of goat.

Genetic determinism of inter-animal variations in milk flow

The correlations between criteria measured on experimental farm were equivalent to those measured on commercial farms.

The sources of variations in milking ability was studied. Statistical analyses (Ilahi et al., 1999), carried out on evening and morning milking sessions, and including effects of „lactation stage“, „lactation number“, their interactions and the „goat“ effect, confirmed the significant influence ($P < 0.01$) of these factors on milking characteristics. For both morning and evening milking sessions and in all age categories, the flow rate parameters

(first minute flow rate and peak flow rate) diminished during lactation; in contrast, the lag time increased during lactation. The lactation number (lactations 1, 2 and 3 to 7) significantly influenced ($P < 0.01$) milk production ($L1 < L2$ and $L3+$), peak flow and first minute flow rate ($L2 > L1 > L3+$) and lag time ($L3+ > L1 > L2$). Inclusion of the „goat“ effect in the statistical model enabled an estimate of repeatability (correlation between successive measurements in an animal): 0.55 and 0.64 for milk quantities in the evening and morning, 0.72 and 0.74 for first minute milk flow, 0.53 and 0.63 for peak flow rate and 0.59 and 0.68 for lag time. This repeatability suggested that individual variability accounted for a high proportion of the total variability observed during lactation.

Segregation analysis (Hilahi et al., 2000), performed on the basis of 2493 first minute flow rate measurements using a father-mother model confirmed ($P < 0.01$) the segregation of the major gene, which had an effect of 2.3 phenotypic standard deviations on the first minute milk flow. The difference in flow between goats with HdHd and ++ genotypes was approximately 0.6 l/min. The + allele was dominant, with a 60% degree of dominance. The unknown gene explained nearly 60% of the total genetic variability, but a residual heritability of 0.30 suggested that the influence of other genes, represented in this analysis by a polygenic effect, was far from negligible.

Multi-character analysis showed that the genetic correlations between the first minute flow and milking characteristics (total lactations adjusted to 250 days of lactation) were weak: 0.10, 0.01, 0.03, -0.13, -0.07 for milk yields, protein and fat contents, amount of protein and of fat, respectively. As for Somatic Cells counts (SCC) and the morphology of teats and udders, the genealogical structure of the data only allowed an estimate of phenotypic correlations (346 goats followed in 1998). The phenotypic correlations between external morphology, physiological teat characteristics and milk flow characteristics were very weak. The shape and diameter of teats were the most strongly correlated with flow rate criteria (>0.1 ; $P < 0.05$) and with the teat sphincters resistance (>0.3 ; $P < 0.5$). Somatic cell counts (SCC) and the corresponding scores arising from logarithmic transformation (SCCS) were weakly correlated with lag time, 1st minute, maximum and mean flow rates and correlations did not differ significantly from 0 ($P < 0.01$; Table 2).

Table 2. *Phenotypic correlations between SCC and milk flow characteristics (n = 348 goats).*

Characters	LagT	1 st MF	MaxMF	mMF
SCC	-0,03	0,07	0,07	0,00
SCCS	-0,03	0,11	0,11	0,02

SCC : somatic cell count ; SCCS : somatic cell count score after log transformation ; lag time : time elapsed between cup attachment and first recording of milk ; 1stMF : first minute milk flow ; MaxMF : maximum or peak milk flow ; mMF : mean milk flow during milking.

Discussion

Even when they are studied under homogeneous milking situations, goats are very variable with respect to their milking ability. This variability of the goat model is of considerable value to zootechnical, genetic and physiological studies of the mammary system. Furthermore, this variability can be exploited in applied breeding, particularly since automatic devices have proved their efficiency and usefulness in the recording and quantification of different milk emission kinetic parameters on farms.

Although our protocol on commercial farms was not designed to compare different breeds (not the same environmental conditions), the characteristics measured, suggested less good mean milk flow capacities in the Saanen goats. This result needs to be confirmed because of the smaller number of farms working with this breed during our study. In general, flow rate and milking time performances lower during first lactations, thus confirming that mammogenesis is still incomplete after the first parturition.

Our results suggest the existence of common physiological mechanisms which influence the initiation of milk emission and the subsequent flow rate. The anatomical and physiological characteristics of teats (sphincter resistance) are crucial to milk emission kinetics. Indeed, the „lag time“ criterion was always negatively and strongly correlated with „flow rate“ variables. In addition, teat end thickness prior to milking was greater when milk production was higher and in animals with a longer milking time. That suggests the existence of muscle tone as a reaction to intramammary pressure and a limiting role for the tone of teat tissues around the strael canal on milk emission.

The 3 kinetic categories arbitrarily determined from peak flow rates and milking times or lag times confirmed the presence of difficult and lengthy milking sessions. The reason was mainly that a greater vacuum was required to open the sphincter, often at the limit of that supplied by the milking machine. The first minute flow rate, integrating the lag time, was also particularly low in animals exhibiting these kinetics. The weak phenotypic correlation between milk flow criteria and milk production means that this kinetic category corresponded to goats which did not produce significantly less than those in other categories. This could explain their late culling by breeders and thus their non-negligible percentage in herds. To reduce the total working time at milking, we feel it is a high priority to include measurement of this criterion on farms, so as to homogenise milking times down to the shortest value. In contrast, the search for a very high milk flow is questionable. Indeed, weak sphincter resistance combined with the highest flow rates may have a deleterious effect on SCC, as already reported in the dairy cow (Grindal et al, 1991). Moderate and high flow rates may however be less dependent upon teat sphincter resistance, but rather be more sensitive to intrinsic characteristics of the tissue (elasticity), diameter and length of the teat canal, or even the physiological regulation of the tone of this muscle. Indeed, the

innervation and/or adrenergic reactivity of the udder and teat may partly explain some of the variations seen in flow rate, as suggested by Blum et al. (1989), Hammon et al. (1994) and Roets (1995) in the cow. The hypothesis of an important effect for oxytocin on milk flow has been refuted in the goat, because its discharge during milking did not differ as a function of flow rates or latency. These results confirm those obtained by Bruckmaier et al. (1994) (goats) and by Marnet et al. (1998) (ewes) and differ from cows more dependant for OT release for a complete udder emptying. If OT levels during milking cannot explain milking rate performance, the baseline oxytocin levels (between milking sessions), by permitting the transfer of milk from the alveoli towards the cisterns, could prevent negative feedback of milk on milk synthesis and help for milk synthesis, secretion and production.

The first minute flow rate, like the lag time now estimated using automatic recording devices, thus appear to constitute valuable parameters to characterise animals with a view to possible selection.

The variability of goats regarding milking characteristics is very great, according to intra- and inter-lactation repeatability and our estimates of total and residual heritability. The major locus, with two alleles (Hd and +) explains more than half of the total genetic variability, Hd being partially recessive. Future research for identification of this unknown gene must include the determination of molecular markers in a backcross breeding programme („QTL“ approach), and the analysis of transcriptional profiles of teat cells from goats with extreme milking characteristics („Genomic“ approach).

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Stepwise development towards physiological milk harvest - a consequence of suckling technique

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Today's knowledge about suckling is presented. The differences between suckling and machine milking are outlined and summarised in four main areas: (i) number of milk harvests per day, (ii) adaptation of milking conditions to the degree of filling of the quarter cistern, (iii) guarantee of an empty cistern before next ejection, and (iv) adaptation of pressure application. The first three areas are discussed separately. Regular after-milking suckling is presented as a key provision.

Key words: suckling, development, milk harvest

In milking technique and dairy production processes (i) defects are met with re-redesign, often resulting in new defects. (ii) The potentials of development steps or design variants are not used consequently. (iii) Some research efforts reveal low standard: Widely quoted results concerning methodology and subject matters do not hold for control. (iv) Commercial dairy production, milking technique, and mainstream dairy research meet consumers' demands concerning ethics of production defensively. In modern dairying, cow and calf are not accepted as model despite evolution having developed a perfect interaction between mammalian mothers and their offspring. The argument that the „modern dairy cow“ cannot be compared with e.g., beef breeds neglects some facts: (i) The period of breeding is negligible compared with the period of evolution. Even if human selection had aimed towards that „modern dairying cow“, the physiology of which is claimed to be principally different from the original *Bos taurus*, the time of selection would be by far too short. (ii) Evolution has always acted on fitness, whereas man's breeding often approached less central characteristics. (iii) Recent observational and experimental work has revealed details of the cow-calf-model (CCM) that are useful for developing milking technique and dairy production processes.

Summary

Introduction

The objective of this report is to plead for acceptance of CCM. Principles of CCM offer (i) a comprehensive developmental strategy, and (ii) an offensive approach towards ethical demands. (iii) Further, they can be incorporated in today's dairy production and milking technique in a stepwise procedure, where the first steps do not demand radical re-design.

Materials and methods

Results

What do we know today about the cow-calf-model?

Table 1 gives a summary of research concerning the cow-calf-model carried out by our laboratory.

- (i) A calf suckles 4-6 times per day (Sambraus 1978). Three of these meals are fixed in time: one at dawn, one in late afternoon and one around midnight (Sambraus 1978).
- (ii) A calf changes teats 400 to 600 times during a suckling meal (Mayntz & Costa 1998). How long a teat is suckled uninterruptedly (referred to as bout) depends exclusively on the amount of milk available in the corresponding cistern (Mayntz & Costa 1998). There are short bouts during pre-stimulation, and a sudden increase followed by a gradual decrease of bout length during ejection. Harvesting of after-rinsing (referred to as after-stimulation) is carried out with short bouts again. After-stimulation takes about two third of a mealtime, i.e., 12 to 15 minutes on average (Mayntz 1996, Mayntz & Costa 1998).
- (iii) After-rinsing results from the cavern-like milk ducts (Wirz 1913). After-stimulation leaves the cavern completely empty and it probably remains so until the next ejection (Mayntz, unpublished data). After-stimulation is partially non-nutritive (Lidfors et al. 1994) and one part of the information given to the dam concerning the offspring's momentary need (Sederström et al. 2002).
- (iv) The inflow into the cavern is slower than the outflow through the teat canal. Therefore it is an optimal strategy to abandon an empty teat, and to address the other ones while the first is refilled. During refilling, a teat remains un-stretched and under atmospheric pressure.
- (v) A sucking calf applies a pressure difference across the teat canal between 60 and 110 kPa! Peaks of pressure difference last only for a couple of milli-seconds and are applied with a frequency of 2 to 2.4 Hz (Rasmussen & Mayntz 1998). Between those peaks, the pressure difference is decreased to almost null kPa (Rasmussen & Mayntz 1998).
- (vi) The pressure difference consists of about 60 % "under-pressure" beneath the teat tip and about 40 % "over-pressure" in the teat cistern (Rasmussen & Mayntz 1998).
- (vii) The length of ontogeny depends on the amount of the initial over-secretion of the cow. A *peri natal* surplus of colostrum is an evolutionary mechanism, leaving the fundamental test of fitness

mainly to the offspring. That test of fitness prevents heavy investment of the mother during lactation (Fedak & Anderson 1982) into an unfit offspring.

- (viii) After the end of ontogeny, a calf applies the suckling procedure for maximal secretion outlined above on all lactating teat uniformly (Mayntz 1996).

A physiological milk harvest could apply the rules of suckling for maximal secretion from the onset of lactation.

Table 2 summarises the main differences between CCM and milking technique. These differences can be grouped into four major areas: (i) Number of milk harvests per day, (ii) adaptation of milking conditions to the degree of filling of the quarter cistern, (iii) guarantee of an empty cistern before next ejection, and (iv) adaptation of pressure application.

The sequence of the four areas above follows the authors view on human readiness to change thinking. Dairy scientists seem to accept technical re-design easier than new concepts about animal management. An adaptation of the vacuum application of milking technique to CCM violates the promises of no radical re-design. Therefore this area is mentioned only to complete the list. The guarantee of an empty cistern before the next ejection could be implemented easy and fast but it demands substantial change in management thinking.

Increased milking frequency and thereby a substantial increase in milk yield was the main argument at the onset of AMS-development. Compared with those hopes, the results concerning milking frequency in AMS cannot be but disappointing: average milking frequency for all cows is slightly below 2 and reaches seldom individuals values above 3 (Devir et al. 1999).

It seems that we have forgotten that animals can hardly be forced but successfully attracted. Any animal oriented strategy must return to attracting the cow to the milking stable. However, there are reasons to be afraid that culling cows under the verdict: „Unfit for AMS“ will solve these problems instead.

We repress a repulsion of cows against milking technique. In 1987 a laboratory that was fond of the biological potential of voluntary milking imitated the not yet available hardware by a separate cow stand and shift-working students. At first they trained the cows to enter the stand voluntarily by giving concentrates at every visit. After a week they started to combine those voluntary visit with milking. Two results were seen: (i) The cows dropped the frequency of visits by more than 50 % immediately

Differences between cow-calf-model and milking technique.

Discussion

Number of milk harvests per day.

and (ii) teats showed one narrow stripe of infected hyperkeratosis across the tips after a couple of days. The results became another victim of selective publication (Palmer, 2000).

Adapt milk harvest speed on degree of filling.

When phrasing our knowledge about the FIL-mechanism (e.g., Wilde et al. 1988) as a product demand for a milking process, we would say: „Get as much milk as possible over the threshold of capillarity during ongoing ejection“; i.e., speed of milking matters, however, only during those 2 to 4 minutes. Calves fulfil that demand by emptying a quarter before addressing another one and by leaving a completely empty cistern for the next ejection.

During ejection both pulsation frequency and -ratio and potentially even vacuum could be increased. Quarters get empty within a narrow period of time (Mein et al.1973). Therefore a good signal for changing vacuum application could be the cease of milk flow from the first quarter. The remaining milk from other quarters and the after-rinsing from all quarters can be stored in the cistern and harvested slowly.

Guarantee an empty cistern before ejection.

A complete udder emptying supports maximal secretion and is an essential hygienic provision, but the productivity of stripping is too low and machine stripping has revealed negative effects on udder health (IDF 1987).

If we would combine milking and consecutive suckling regularly in an after-suckling-procedure (ASP), we would get (i) a complete udder emptying without concern about productivity or increased new infection risk, (ii) rather an increase in milk yield, (iii) a lower fat content in the delivered milk, and (iii) good arguments concerning ethical production. There are ecological brands e.g., „KRAV“ in Sweden that successfully sell good conscience to consumers. Typically these brands demand (i) that the calf suckles its mothers at least during colostrum period, (ii) that the cow must have the opportunity for isolation during calving, and (iii) that offspring and mother must have the possibility of close contact during the first days *pp* (KRAV 1995). Mostly this result in that the cow is kept in a calving box and stays there together with her calf during the first 5 days *pp*. Thereafter mother and offspring are separated and the usual dairy procedure takes place. Thus, the best intentions result in cruelty: *Peri*-natal death is an evolutionary provision to prevent a mother from making heavy lactation investment in a weak offspring. As closer to birth death occurs, the less the affiliation between mother and offspring. After 5 days, however, cow and calf recognize each other and prefer each other's company (Sambraus 1978). To separate them now means to imitate death. And both show deep grieve in their behaviour after such an event.

There might be one problem involved with ASP: When man and calf competed in stimulation during the same milking, the calf won (e.g., Knowles & Edwards 1983, Sandoval-Castro et al. 1999). However, only once an ASP applied in which the cows were always milked before suckling (Sandoval-Castro et al. 1999). Our own ASP experience (Table 1) is rather encouraging. If ever a man-made pre-stimulation would fail in an ASP, the olfactorial an/ or audio-visual and/or tactile presence of the own calf could help to achieve proper pre-milking ejection (Sambraus 1978). There is no argument, why such a procedure could not be combined with AMS.

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Table 1. Summary of research of author and co-workers on the cow-calf-model.

Objective	Used breed and number of animals	Number of recorded meals and type of recording	Publication
Ontogeny of suckling behaviour	Hereford, 8 Charolais, 1	84, video tape	E.g., Mayntz 1996
Pre-study of restricted access between cow and calf	Hereford, 13 Charolais, 1	26, video tape	Mayntz et al. submitted 2005
Control of ontogeny results	Polish Black & White, 5	83, video tape	Mayntz 1996
Pre-study on the effect of after-stimulation on fat composition	Hereford, 4 Swedish Red & White, 4	10, optical observation	Costa, et al. 1998
Effect of Pharmacologically Induced Changes in Milk Ejection on Suckling in <i>Bos taurus</i>	Hereford, 4	16, video tape	Mayntz and Costa 1998
Change of milk fat composition over a meal and between lactations	Hereford, 20 Swedish Red & White, 8	56, video tape	
Influence of milk fat content on teat preference by the suckling calf	Swedish Red & White, 10	30, video tape	
Control of effect of after-stimulation on fat composition	Hereford, 9	27, optical observation	Sederström, et al. 2002
Pressure in the teat cistern and the mouth of the calf during suckling.	Holstein Frisian, 3	4, video tape	E.g., Rasmussen and Mayntz 1998
Pre-study on the effect of after-stimulation on ejection and udder health	Polish Black & White, 14	280, optical observation	Sender and Mayntz submitted 2004
Influence of milk withdrawal, stable routines and separation from dam on suckling behaviour of calves	Hereford, 12	20, video tape	Mayntz et al., submitted 2005

Table 2. Summary of main differences between the milk harvest technique of the cow-calf-model and machine milking.

Calf	Milking Machine
Applies no pressure difference on a teat, which was judged empty.	Applies a pressure difference during machine-on-time. Machine-on-time can be adapted to the flow rate through the teat canal.
Waits for refilling of the cistern before the next emptying. Waiting about three times as long as emptying. A waiting teat is not stretched and under atmosphere. Smooth muscles can contract during waiting.	The teat is continuously stretched and under vacuum during machine-on-time. Vacuum is also used for different additional purposes, e.g., to keep the cluster on.
Applies pressure differences across the teat canal from 60 to 110 kPa with 2 to 2,4 Hz. A peak of a pressure difference last for 2-3 milliseconds and is followed by a minimum pressure differences between 0 and 10 kPa. The pressure difference consists of about 60 % vacuum and 40 % over-pressure.	Applies a constant pressure difference of about 40 to 50 kPa. The pressure difference consists of vacuum only.
Adopts bout length to amount of milk available in the cistern also during pre- and after-stimulation.	Concerning pre-stimulation you find everything on commercial farms (i) careful farmers, performing as good as the calf, (ii) sometimes superior technique, and (iii) not careful milker.
Empties the cistern fast during ejection and completely during meal.	Empties the cistern during ejection. Cistern not empty after milk harvest.
Practises after-stimulation, no blockage of the udder-teat-passageway.	Builds up blockage of the udder-teat-passageway.
Uses saliva and endogen enzymes for teat cleaning and after-suckling disinfections.	Chemical disinfections mostly before and always after milking.
Harvests milk 4 to 6 times per day.	Harvests milk 1.8 to ca. 3 times per day.
Gives honest information to the cow's physiology about its need.	Gives contradictory information to the cow's physiology.

The quarter milk flow parameters influenced by stage of lactation and milkability in multiparous dairy cows

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The effect of stage of lactation, peak flow rate, parity, bimodality and teat position on quarter milk production and milk flow parameters was studied. A total of 25 Holstein multiparous cows (in their second to sixth lactation) were investigated during ten months of lactation. Quarter milk flows were recorded daily at morning (5:30 h) and evening (15:30 h) milking. In total more than 52 000 of quarter flow curves were obtained. The peak milk yield was reached at second month of lactation. Peak flow rate was relatively stable with slight reduction after seventh month of lactation but mean flow rate continuously reduced. Increase phase tended to increase throughout lactation. Decline phase decreased from the first to second month and then from fourth month continuously increased. Overmilking phase increased from first to third month and then decreased. There was no relation between peak flow and milk yield, milk yield of plateau phase and duration of increase phase. Quarters with high peak flow had longer decline and shorter overmilking as compared with low peak flow ones. All parameters were higher during morning milking except the duration of increase and decline phases, where data were higher during evening milking. Quarter with bimodal milk flow showed lower milk yield and higher peak flow, longer increase and decline phases. Quarter position influenced all parameters of milk yield and milk flow. Front quarter had shorter increase and decline and longer overmilking phases than rear ones. Quarter milk flow traits deserve further investigation to give new knowledge if biological needs of quarter should be considered in developing new machines.

Summary

Key words: cow, quarter, milk, flow, factors

Introduction

The intensive and fast development of new dairy machines with partial or full automation and with very sophisticated control systems of milking process allow us to minimise the possible aversive effects of machine on the animals. However, even with high level of technical development of milking machine, the biological potentials and limitations of the animals have to be considered if milking should be fast, complete and good udder health maintained.

Milk production and parameters of milk flow from whole udder are economically very important for many reasons (Bruckmaier et al., 1995, Thomas et al. 1991, Marnet and McKusick, 2001) indicating the efficiency of milk ejection (Tancin and Bruckmaier, 2001). However, partially earlier and mainly more recent studies have clearly indicated that quarter milk flow recording promises the faster advances in milking technology, efficiency of milk removal and health of udder (Grindal and Hillerton, 1991, Ipema and Hogewerf, 2002). However, due to technical limitation only limited analysis of quarter milk flows are available in literature.

The aim of this work was to study more in detail the effect of stage of lactation, peak flow rate, parity, teat position on the milk production and milk flow parameters at quarter levels.

Material and methods

The trial was conducted at the IMAG experimental farm "De Vijf Roeden" in the Netherlands. A total of 25 Holstein multiparous cows (in their second to sixth lactation), were investigated during ten months of lactation. Cows were free of clinical symptoms of mastitis. The cows were fed *ad libitum* and received additional concentrates according to their milk production levels.

The cows were milked twice daily at 5:30 a.m. and 3:30 p.m. in the 2 x 3 open tandem milking parlour equipped with quarter milk flow recording device (Ipema and Hogewerf, 2002). Quarter milk flows were recorded daily. Premilking udder preparation was performed for a period of about 8-10 s per udder. Milking and pulsation vacuum was set at 43 kPa. Pulsation ratio was 65:35 at a rate of 60 c/min. The cluster (all four teat cups) was automatically removed 4 s after the whole udder milk flow had decreased below 0.3 kg/min for a period of 12 s. The detail explanation of quarter milk flow parameters are described in Tancin et al. (2003).

In total more than 52 000 of quarter milk flow curves were obtained for statistical evaluation (Table I). A general linear model with fixed effects was used to identify the main sources of variation for studied traits in preliminary statistical analyses. Statistical significance of the effects included in the model was tested by using Fisher's F-test. Differences between the levels within effects were tested by Scheffe multiple range test. In statistical model we have tested the effect of stage of lactation, parity, peak flow rate, time of milking (morning, evening), position of

four quarters, bimodality (with or without bimodal milk flow). Stage of lactation was divided into ten periods representing ten months of lactation. Parity represented two groups: second - cows on second lactation, and multi - cows on their third and more lactation. Peak flow factor represents three groups of cows selected on the base of average peak flow rate of whole udder flow during lactation (lower – less than 3.1 kg/min, middle – between 3.2 to 4.1 kg/min, high over 4.2 kg/min). Milk yield and milk flow parameters were analysed by the mixed model (SAS, ver. 8.2, 2001). The statistical model can be written in the following form:

$$y_{ijklmn} = \mu + PAR_i + STAGE_j + PEAK_k + BIMO_l + TIME_m + QUAR_n + Z_u + e_{ijklmn}$$

where: y_{ijklmn} - were the measurements for a milk yield and flow traits, μ - overall mean, PAR_i - the fixed effects of parity ($i=1, 2$), $STAGE_j$ fixed effect of stage of lactation ($j=1, 2, 3, 4, 5, 6, 7, 8, 9, 10$), $PEAK_k$ fixed effect of udder peak flow - milkability ($k=1, 2, 3$), $BIMO_l$ fixed effect of bimodality ($l=1, 2$), $TIME_m$ fixed effect of time of milking ($m=1, 2$), $QUAR_n$ fixed effect of quarter position ($n=1, 2, 3, 4$), u - random effect of cow, $u \sim N(0, I \sigma_c^2)$, e - random error, assuming $e \sim N(0, I \sigma_e^2)$ X, Z - incidence matrices for fixed effects and random cow effect, resp.

The stage of lactation significantly influenced all studied parameters (Table 1). The peak milk yield was reached at second month of lactation and then milk production decreased. Peak flow rate was relatively stable with slight reduction after seventh month but mean flow rate continuously reduced from second month. The duration of increase phase tended to increase but milk yield of increase phase corresponded with the milk yield changes. The duration of decline phase decreased from the first to second month and then from fourth month continuously increased, but milk yield of the decline phase was similar throughout lactation. The duration of overmilking phase increased from first to third month and then decreased.

Parity did not influence measured parameters and data were not shown. There was no relation between milkability and milk yield, milk yield of plateau phase and duration of increase phase (Table 2). Quarters of cows with high peak flow rate had longer duration of decline and shorter overmilking as compared to quarters of cows with low peak flow.

The milking time (morning and evening milking) significantly influenced all studied parameters. All parameters were higher during morning milking except the duration of increase (78s vs. 79s) and decline phases (59s vs. 64s) and milk yield of decline phase (400g vs. 424g), where data were lower (complete data not shown). Quarters with bimodal milk flow showed lower milk yield and higher peak flow rate. Quarters with bimodality had 12s longer increase phase and 11s longer decline phase (Table 2).

Results

Quarter position influenced all measured parameters of milk yield and milk flow (Table 2). Rear quarters had significantly higher milk yield, longer time of milking, higher peak and mean flow rate than front ones. Front quarter had shorter duration of increase and decrease phases than rear ones. The duration of overmilking phase was double for front quarters.

Discussion

From our experimental data we could demonstrate that the stage of lactation significantly influenced all studied parameters. The effect of stage of lactation on milk yield and milking time was similar as published by many other scientists (Rotshchild et al., 1980, Firk et al., 2002). Peak flow rate decreased in the first months of lactation, was then relatively stable during four months and decreased again in the last months of lactation. Mean flow rate significantly reduced in the course of lactation in our data set.

The duration of increase phase and recorded milk yield indicate the milk ejection efficiency in the commencement of milking. Because of short udder preparation by milker the main part of milk ejection reflex developed after cluster attachment resulting in longer duration of increase phase in our cows than it can be expected (Wellnitz et al., 1999). Though there was slight tendency of prolongation of the increase phase, the amount of obtained milk in increase phase significantly reduced from third month. It was found that basal intramammary pressure was stable during first three months of lactation and then decreased intensively (Mayer et al. 1991).

The duration of decline phase decreased from the first to second month and then from fourth month continuously increased during following parts of lactation. The reason for the longer decline phase of quarters at the beginning and end of lactation is not easy to explain. One of the explanations for the beginning of lactation could be related to the possible milk removal disturbances induced by adaptation of cows to milking (Tancin and Bruckmaier, 2001) and readiness of cows for milking (Wellnitz et al., 1999). Last mentioned authors showed in pictures that milking without stimulation prolonged the duration of increase and decline phase. We could also demonstrate the longer duration of decline phase in bimodal milk flows.

Peak flow rate was not affected by milk yield in our study. It is more related to the breed effect or readiness of cows for milking than milk production within breeds (Bruckmaier et al., 1995). Peak flow rate influenced the course of milk flow. Quarters with high peak flow showed the longest decline phase and shortest overmilking phase as we have already demonstrated earlier with limited amount of data (Tancin et al., 2002, 2003). Naumann and Fahr (2000) and Weiss et al., (2004) found the longest duration of decline phase from teats with shortest canal length that also had highest milk flow.

The quarter position influenced all measured parameters of milk yield and milk flow as described by other authors (Rotschild et al., 1980). In our earlier studies (Tanèin et al., 2002, 2003) we have partially confirmed the results obtained in this work that clearly indicated shorter duration of increase and decrease phases and longer overmilking of front quarters than rear ones.

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Table 1. Least squares means of measured parameters during lactation.

	Stage of lactation, months									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Number of quarters	4922	5078	4746	5548	5369	5193	5552	5708	5138	3247
Milk yield, g	4499 ^a 85	5407 ^b 85	5171 ^c 85	4760 ^d 85	4437 ^a 85	4014 ^e 85	3604 ^f 85	3251 ^g 85	2798 ^h 85	2255 ⁱ 85
Total milking time, s	475 ^a 8	536 ^b 8	541 ^b 8	496 ^c 8	465 ^d 8	430 ^e 8	413 ^f 8	388 ^g 8	366 ^h 8	351 ⁱ 8
Milk flow time, s	395 ^a 6	452 ^b 6	456 ^b 6	421 ^c 6	395 ^a 6	365 ^d 6	350 ^e 6	328 ^f 6	309 ^g 6	295 ^h 6
Peak flow, g/min	1021 ^a 46	1008 ^b 46	982 ^c 46	973 ^c 46	967 ^c 46	984 ^c 46	950 ^d 46	935 ^d 46	884 ^e 46	801 ^f 46
Mean flow rate, g/min	700 ^a 29	761 ^b 29	731 ^c 29	718 ^d 29	705 ^a 29	686 ^e 29	644 ^f 29	616 ^g 29	555 ^h 29	471 ⁱ 29
Phases of milk flow, s										
increase	70 ^a 2	76 ^b 2	79 ^{cd} 2	78 ^{bc} 2	77 ^{bc} 2	80 ^d 2	80 ^d 2	80 ^d 2	83 ^{de} 2	84 ^e 2
plateau	243 ^a 5	321 ^b 5	320 ^c 5	288 ^d 5	263 ^e 5	227 ^f 5	209 ^g 5	186 ^h 5	162 ⁱ 5	142 ^j 5
decline	84 ^a 3	53 ^b 3	53 ^b 3	54 ^b 3	55 ^b 3	59 ^c 3	60 ^{ce} 3	62 ^{ef} 3	65 ^{fg} 3	68 ^g 3
overmilking	78 ^a 4	84 ^b 4	86 ^b 4	75 ^a 4	70 ^c 4	64 ^d 4	63 ^d 4	59 ^{de} 4	57 ^e 4	55 ^f 4
Phases of milk flow, g										
increase	548 ^a 15	607 ^b 15	597 ^b 15	567 ^c 15	547 ^{ac} 15	516 ^a 15	478 ^d 15	450 ^e 15	419 ^f 15	348 ^g 15
plateau	3391 ^a 80	4369 ^b 80	4146 ^c 80	3754 ^d 80	3457 ^a 80	3032 ^e 80	2669 ^f 80	2339 ^g 80	1927 ^h 80	1479 ⁱ 80
decline	506 ^a 19	379 ^b 19	384 ^b 19	392 ^b 19	393 ^c 19	425 ^{dg} 19	414 ^{eg} 19	421 ^{fg} 19	413 ^{cg} 19	389 ^{bc} 19

abcdefghij – within one line without a common superscript letter were significantly different at P<0.05

Table 2. Least squares means of measured parameters related to effect of peak flow (milkability), bimodality and quarter position.

	peak flow rate			bimodality		FL	teat position		
	high	middle	low	no	yes		RL	RR	FR
Number of quarters	16391	18353	15793	27557	22963	12579	12689	12659	12594
Milk yield, g	4178	4044	3984	4073 ^a	3967 ^b	3351 ^a	4653 ^b	4511 ^c	3565 ^d
	148	42	150	84	84	84	84	84	84
Total milking time, s	354 ^a	421 ^b	540 ^c	449 ^a	444 ^b	446	446	446	447
	16	16	17	8	8	8	8	8	8
Milk flow time, s	304 ^a	359 ^b	455 ^c	387 ^a	367 ^b	362 ^a	403 ^b	400 ^c	342 ^d
	14	14	14	6	6	6	6	6	6
Peak flow, g/min				904 ^a	1001 ^b	846 ^a	1004 ^b	1004 ^b	953 ^c
				46	46	46	46	46	46
Mean flow rate, g/min				653 ^a	664 ^b	578 ^a	711 ^b	701 ^c	644 ^d
				28	28	28	28	28	28
Phases of milk flow, s									
increase	74	81	79	73 ^a	85 ^b	77 ^a	81 ^b	81 ^b	76 ^a
	3	3	3	2	2	2	2	2	2
plateau	156 ^a	213 ^b	327 ^c	257 ^a	215 ^b	228 ^a	257 ^b	250 ^c	209 ^d
	12	12	12	5	5	5	5	5	5
decline	73 ^a	66 ^a	45 ^b	56 ^a	67 ^b	56 ^a	65 ^b	68 ^c	56 ^a
	5	5	5	3	3	3	3	3	3
overmilking	50 ^a	70 ^b	85 ^b	62 ^a	77 ^b	83 ^a	42 ^b	46 ^c	104 ^d
	6	6	6	4	4	4	4	4	4
Phases of milk flow, g									
increase	651 ^a	519 ^b	359 ^c	446 ^a	568 ^b	426 ^a	569 ^b	559 ^c	473 ^d
	25	24	25	14	14	14	14	14	14
plateau	2930	3041	3175	3216 ^a	2897 ^b	2542 ^a	3600 ^b	3432 ^c	2651 ^d
	146	141	148	80	80	80	80	80	80
decline	550 ^a	444 ^b	257 ^c	374 ^a	449 ^b	328 ^a	455 ^b	484 ^c	345 ^d
	37	34	36	18	18	18	18	18	18

abc – within one line without a common superscript letter were significantly different at $P < 0.05$
 FL, FR - front left and right
 RL, RR - rear left and right

Comparative study of the galactopoietic effect of oxytocin during and between milkings in cows and goats

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Abstract

Oxytocin is released during milking and induces milk ejection i.e. the transfer of alveolar milk into the cistern by contraction of the myoepithelial cells. The galactopoietic action of oxytocin could result of this transfer, but also of a potential effect on the mammary epithelium. Our works aimed to study the galactopoietic effect of oxytocin in ruminants, by developing :

- a zootechnical approach. Increases of milking frequency with and without injections of oxytocin receptor blocking agent were compared to injections of physiological doses of oxytocin in lactating cows and goats, which differ in udder morphology. The galactopoietic effect of oxytocin was different according to the species. In cows, oxytocin doses induced a galactopoietic effect only when they are accompanied by milk removal, whereas they increased milk yield in goats, proportionally to their capacity of cisternal storage. This effect can mainly be explained by the transfer of alveolar milk but also by an additional, limited and unidentified, action of oxytocin on milk yield.
- a tissue/cellular approach to test the hypothesis that oxytocin has a direct effect on the lactating mammary epithelium. Immunohistochemistry studies showed the presence of the oxytocin receptor in rabbit and cow epithelial cells and specific and different effects of oxytocin on epithelial and on myoepithelial cells. Oxytocin provoked an acceleration of the intracellular transfer of caseins throughout epithelial cells into lumen, followed by the contraction of myoepithelial cells.

Our results suggest that oxytocin has an effect on the secretory processes in the mammary gland in addition of its effect of milk ejection.

Key words: *Oxytocin, milking, milk yield, mammary epithelial cell, secretory process, cow, goat, rabbit*

Introduction

In ruminants, milk yield can be modulated by milking frequency. Milking can stimulate milk production by a local effect of milk removal and by systemic effects. Stimulations of the udder during milking provoke the release of oxytocin into the general circulation from the neural lobe of the pituitary. Oxytocin binds to specific receptors located on mammary myoepithelial cells, which surround the alveoli and the small intralobular ductules and induces myoepithelium contraction and milk ejection into the cistern (Ely et al., 1941). It decreases the intra-alveolar pressure due to milk accumulation, which avoid deleterious effects such as crushing of mammary epithelium (Richardson et al., 1947, Stelwagen et al., 2001) and reduces the negative effects of the Feedback Inhibitor of Lactation (Wilde et al., 1987). Milking can also be beneficial to the udder since mammary stimulations cause the release of pituitary lactogenic hormones like prolactin (Kann et al., 1977, Kelly et al., 2002) or oxytocin, which could assume additional role to its effect of milk ejection. Indeed, *in vitro* studies suggested that oxytocin may have effects on cell proliferation (Bussolati et al., 2001) and that lactating mammary epithelial cells could be a target for oxytocin (Kimura et al., 1998, Lollivier et al., 2001, Wagner et al., 1997). Our aim was to elucidate the potential roles of oxytocin on lactating mammary gland and to respond to several questions :

- Did physiological doses of oxytocin have a galactopoietic effect in ruminants ?
- Injections of oxytocin have already been used to study their galactopoietic effect on ruminant. However, extraphysiologic doses were often used, that are described to be deleterious on milk ejection, milk quantity and quality in dairy cows (Allen et al., 1990, Bruckmaier et al., 2003).
- Is this galactopoietic effect different according to species (cow vs goat) ?
- Small ruminants and especially goats have proportionally larger cistern compartment compared to cows. Because of these udder morphology, most of the milk is stored in the cisternal cavities between milkings, which may facilitate the oxytocin effect.
- Is this galactopoietic effect different according to the milk repartition into the udder in goats ?
- Could this galactopoietic effect result from a direct effect on the mammary epithelium, more precisely from an effect on the intracellular process of milk secretion ?

A zootechnical approach (with increases of milking frequency, injections of physiological doses of oxytocin with and without milk removal and milking with injection of an oxytocin receptor blocking agent) and a tissue/cellular approach (with localisation of the oxytocin receptor in rabbit and cow epithelial cells and study of the oxytocin effect on milk secretory processes) were developed.

Zootechnical approach : Oxytocin effect on milk yield and composition in ruminants.

Materials and methods

8 Holstein cows and 20 Alpine goats from the INRA experimental farm of Le Rheu (France) were used. For one week before the beginning of the trials : 1) performance of each animal was recorded during milking at 6.30 and 18.30 as control, 2) cisternal and alveolar milk fractions were measured for each goat by administration of an oxytocin receptor-blocking agent (Atosiban) followed by injection of 2.5 IU of oxytocin. Goats were separated in 2 groups : one with a mean cisternal milk fraction inferior to 80 % of total milk yield and the other with a mean cisternal milk fraction superior to 80 %, 3) individual and physiological doses of oxytocin to inject in order to mimic natural events were determined by measuring for each animal the mean endogenous oxytocin discharge during milking and the oxytocin pharmacokinetic parameters. We decided to inject intravenous (iv) doses varying between 0.1 and 0.6 IU for goats and between 0.25 and 4 IU for cows.

The experiments were conducted according to a Latin Square design with 5x 14-d periods (10 d of treatment and 4 d without treatment i.e. twice daily milking at 6.30 and 18.30). Animals were assigned to 5 treatments :

- TD (twice daily milking at 6.30 and 18.30) as control,
- FD (4 daily milking at unequal intervals i.e. 6.30, 10.30, 14.30 and 18.30) to measure the additional milking effect,
- OT (twice daily milking at 6.30 and 18.30 and 2 iv injections of oxytocin at 10.30 and 14.30), to measure the oxytocin effect without milking,
- AT (twice daily milking at 6.30 and 18.30 and 2 milkings occurring 1 min after Atosiban injection at 10.30 and 14.30), to measure the milking effect without oxytocin,
- C+OT (twice daily milking at 6.30 and 18.30, and 2 udder drainages by canula followed by oxytocin injection at 10.30 and 14.30), to measure the oxytocin effect with udder emptying but with a limited systemic hormonal discharge due to stimulation of the udder.

Animals were fed to provide 110 % of requirements allowing a milk production increase without a negative energy balance.

Daily milk yield, milk composition parameters (protein, fat and lactose contents) and plasma concentrations of oxytocin and of prolactin (to assess normal milk ejection and hypothalamic-pituitary stimulation) were measured.

Analysis of variance were conducted with the general linear procedure of SAS (1990). Daily milk yields were averaged for statistical analysis. All data were analysed with models that included cow, treatment and period and goat, cisternal milk fraction, treatment, period, treatment´cisternal milk fraction and period´cisternal milk fraction.

Tissue/cellular approach : effect of oxytocin on the mammary epithelial cells

Lactating New Zealand female rabbits and Holstein cow were originating from our laboratory.

Rabbits were killed and their mammary glands were excised and cut into fragments, which were incubated for 1 and 7 minutes in the absence or presence of oxytocin (10^{-6} IU/mL).

Cows were injected with 5 IU of oxytocin and fragments of the mammary gland were obtained by biopsy (biopsy needle BSA 14/15, Biosphere Medical, France) before the injection and after 1 and 7 min.

Mammary fragments were treated for morphological (rabbit and cow) and immunohistochemical (rabbit) studies and sectioned. For immunofluorescence, sections were labelled with antibodies (anti-rabbit α_{s1} casein and anti-annexin II).

Some rabbit mammary fragments were used to prepare enzymatically dissociated acini. Acini were stained with Fluo-Oxytocinä and with an antihuman oxytocin receptor monoclonal antibody (Ito et al, 1996).

Results and discussion

Zootechnical approach

Additional milkings increase milk production by 8% (24.19 vs 22.40 kg/d, $P < 0.05$) in cows and by 9% (3.70 vs 3.39 kg/d, $P < 0.05$) in goats, confirming their galactopoietic effect.

In cows, the limitation of systemic hormonal releases other than oxytocin during additional milkings provoke a non significant increase of milk production (+ 4.4%, 23.40 vs 22.40 kg/d, ns). Such a limitation of hormonal discharges other than oxytocin do not inhibit milk yield increase compared to additional milkings in goats (+ 8 %, 3.66 vs 3.39, $P < 0.05$).

Table 1. Effect of the treatments on milk yield and composition in cows (least square means \pm SEM).

	TD	FD	OT	AT	C+OT	SEM	n
Milk (kg/d)	22.40 ^{ab}	24.19 ^c	22.54 ^{ab}	21.91 ^a	23.40 ^{bc}	0.411	39
Fat (g/kg)	41.8	41.4	41.7	42.0	41.8	1.05	39
Protein (g/kg)	32.8	32.7	32.5	32.9	32.7	0.32	39
Lactose (g/kg)	48.2	48.3	47.5	48.4	48.0	0.36	39

TD : twice daily milking, FD : 4 daily milking, OT : TD + 2 injections of oxytocin, AT : TD + 2 milkings with Atosiban, C+OT : TD + 2 teat canulations and 2 injections of oxytocin.

a b c : values within a line differ at $P < 0.05$, SEM : standard error of means, n : number of observations.

Table 2. Effect of the treatments milk yield and composition in goats (least square means \pm SEM).

	TD	FD	OT	AT	C+OT	SEM	n
Milk (kg/d)	3.39 ^a	3.70 ^{bc}	3.75 ^c	3.54 ^{ab}	3.66 ^{bc}	0.072	94
Milk (kg/d)	3.49	3.59	3.50	3.50	3.75	0.107	45
Cisternal capacity < 80%	A	A	A	A	A		
Milk (kg/d)	3.30 ^a	3.80 ^{bc}	4.00 ^c	3.57 ^{ab}	3.57 ^{ab}	0.099	49
Cisternal capacity < 80%	A	A	B	A	A		
Fat (g/kg)	33.2	34.7	34.3	33.8	33.7	0.95	94
Protein (g/kg)	28.9 ^b	27.5 ^a	27.6 ^a	27.5 ^a	28.1 ^{ab}	0.39	94
Lactose (g/kg)	44.9 ^a	45.9 ^b	45.3 ^{ab}	45.8 ^b	45.7 ^{ab}	0.34	94

^{a bc}: values within a line differ at $P < 0.05$, ^{A,B}: values within a column differ at $P < 0.05$

These results suggest a limited role of systemic hormones by comparison to oxytocin effect for the expression of the galactopoietic effect of milking in the medium term (10 d) in goats. On the other hand, a higher sensibility for systemic hormones is shown in cows, maybe due to the lower ability of this species for alveolar milk transfer.

The major effect of oxytocin for the expression of a galactopoietic effect of milking was proven by injections of Atosiban before the additional milkings, that inhibit milk yield increase in cows (21.91 vs 24.19 kg/d, $P < 0.05$) and goats (3.54 vs 3.70 kg/d, $P < 0.05$) compared to additional milkings.

In cows, injections of physiological doses of oxytocin induce an intermediate galactopoietic effect between twice and four daily milking only when they are accompanied by milk removal (22.54 vs 22.40 and 24.19 kg/d, ns), whereas in goats they induce a galactopoietic effect similar to additional milking (+ 10 %, 3.75 and 3.70 vs 3.39 kg/d, $P < 0.05$). Moreover, no significant galactopoietic effect of additional milking or oxytocin injections is observed in the group of goats with the lowest cisternal storage capacity. At the opposite, increases of milk yield reach +15% (3.80 vs 3.30 kg/d, $P < 0.05$) and + 21% (4.00 vs 3.30 kg/d, $P < 0.05$) respectively in groups of goats with the largest cisternal storage capacity. All these results show that the prevention of alveolar milk stasis is primordial to measure a galactopoietic effect and that the transfer of milk from alveoli to cistern is the main effect of oxytocin, probably by reducing the negative effects of milk stasis. An additional role of oxytocin co expressed with alveoli emptying is suggested by the remanent galactopoietic effect observed on morning milking after oxytocin injections.

Tissue/cellular approach : effect of oxytocin on the mammary epithelial cells.

Immunolocalization of oxytocin receptors by immunofluorescence showed that oxytocin receptors are detectable in lactating rabbit mammary epithelial cells. Moreover, oxytocin bound specifically to epithelial cells, as previously shown (Lollivier et al, 2001).

Oxytocin added *in vitro* (to lactating rabbit mammary fragments) and *in vivo* (to lactating cows) provoke after 1 minute a modification of the morphology of the epithelial cells. Moreover, the localization of alpha S1 caseins and proteins associated with the secretory traffic is modified in rabbit mammary epithelial cells, which suggest a striking acceleration of the transport leading to exocytosis. The contraction of myoepithelial cells was only detectable after 7 minutes. These results strongly suggest that oxytocin has a dual effect on lactating mammary gland : an acceleration of the intracellular transfer of caseins in mammary epithelial cells and an emptying of these cells followed by the contraction of myoepithelial cells.

Conclusion

Our study confirmed that physiological doses of oxytocin have a galactopoietic effect in ruminants. This effect is different in cows and in goats, maybe due to the udder morphology. This effect is also different according to the milk repartition into the udder. Indeed, it is more pronounced in animals with larger cisterns. Thus, the galactopoietic effect of oxytocin can mainly be explained by the transfer of alveolar milk, thereby limiting the negative effects of milk stasis. Furthermore, an additional role of oxytocin was shown: it provokes an acceleration of the intracellular transfer of caseins in lactating mammary epithelial cells and an emptying of these cells followed by the contraction of myoepithelial cells.

Our results suggest that oxytocin has an effect on the secretory processes in addition of the effect of alveolar milk transfer, which may together contribute to an optimal milk secretion. This last hypothesis remains to be confirmed.

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Responses of milk removal characteristics of single quarters on different vacuum levels

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The capacity of a milking system is determined by a number of different aspects. This experiment focussed on the possibilities to increase the milk flow rate by increased vacuum levels. However, higher vacuum levels might result in more udder health problems and increased amounts of residual milk. To restrict these negative effects, the suction phase of the milking machine was lowered from 65 to 10% in the low milk flow phases, that occur at the beginning and the end of the milking process. The main objective of this research was to study the effects of milking vacuum level on the milk removal characteristics of single quarters.

During a trial of 18 days with 16 FH/HF dairy cows the effect of vacuum levels 42, 45 and 48 kPa on the milk removal parameters were examined. It was shown that the average milk yield (32-33 kg per day) was not affected through the vacuum level. The mean effective milk flow rate on a quarter base (duration of overmilking was excluded) at 42, 45 and 48 kPa was respectively 696, 741 and 753 grams per minute ($p < 0.05$). The peak quarter milk flow rate was respectively 1027, 1110 and 1141 grams per minute ($p < 0.05$). It was concluded that an increase of the vacuum level from 42 to 45 kPa decreased machine on time with about 6%; a further increase to 48 kPa reduced machine on time with another 2%. However, the responses of several milk removal parameters differed sometimes largely between cows and quarters. It is concluded that a milking machine system should be developed consisting of hardware and software that in a dynamic way takes care of optimal settings per quarter for a fast and sound milk removal.

Key words: Vacuum, milk removal, quarter, milk flow rate

Many factors are affecting the capacity of a machine milking system. This research is focussing on possibilities to increase the milk flow rate. It is known that milkability properties of cows are for a large part heritable.

Summary

Introduction

Further it is known that higher milking vacuum levels can increase the peak milk flow rates considerably. Because of negative effects on the teat condition and on the completeness of milk removal these higher levels are often not applied. For milking installations with low milk transport lines vacuum levels between 40-44 kPa (van der Haven et al., 1996) are generally advised.

Negative effects of higher vacuum levels are especially expected in that phases of the milk removal process in which milk flow rates are low such as the first phase and the last or fourth phase (figure 1). Therefore in this research increased vacuum levels will as good as possible only be applied in the phase in which the milk flow rate is on the steady state level. In order to reduce negative effects of high vacuum on the teats the length of suction phase in a pulsation cycle will be strongly shortened in favour of the rest phase. In the first phase of the milking process often little milk is available (loose milk) and through a short suction period in this phase this milk will only partly be removed. So-called overmilking will be prevented, while the pulsating action of the liner will stimulate milk ejection. Also in the last or fourth phase there will be only little milk available in the udder. Because it is technically not possible to detach the liner from a quarter that was coming into this overmilking phase (imbalance of cluster), it was decided to switch then again to a short suction period and a long rest period of the pulsation cycle. In this way negative effects of overmilking should be restricted.

In the research the effects of different vacuum levels on the duration of the milking process will be tested. Because of the short duration of the research it will not be possible to conclude about any effects on teat and udder health.

Material and methods

The milk- and pulsation vacuum levels in this research were 42, 45 and 48 kPa. The settings for the other milking machine parameters applied during the experiment were 65:35 for the pulsation ratio and a pulsation rate of 58 cycles per minute.

In phase 1 of the milking process (figure 1) the pulsation ratio was adapted three times: during the first 15 s (~during attachment) the normal setting of 65:35 was applied, than during 30 s 10:90 (~no milk removal) and than from 45 s after the start of the attachment the setting was switched to 65:35 again.

During phase 4 (overmilking), that starts when the quarter milk flow rate was fallen below 100 g per min the pulsation ratio was set back to 10:90. This prevented the liner from falling from the teat because the liner was mainly closed the impact of the vacuum on the teat was restricted.

In the experiment 16 dairy cows were used, 4 were in their first, 6 in their second and 6 in their third or higher parity. Thirteen cows had less than 100 lactation days. The daily milk yields varied between 19 and 42 kg. Each vacuum treatment was applied during 2 consecutive days. All treatments were repeated three times. The order of the treatments within a repetition was obtained by lot. The experimental period lasted 18 days (3 treatments x 2 days x 3 repetitions).

The cows were milked twice daily in a 2x3 open tandem-milking parlour of the former IMAG experimental farm "De Vijf Roeden". This parlour was equipped with devices for recording the milk removal process per quarter including the final milk yield. The cows entered the parlour one by one. The udder was cleaned and massaged during 5-10s with a dry clean towel. After this udder preparation the teat cups were immediately attached. The teat cups were detached when during a period of 12s the total milk flow of all four quarters together dropped below 300 g/min. The liners in the experiment had a small air inlet in the mouthpiece.

In the statistical analyses the effect of the vacuum treatments on several parameters were tested. Because of the chosen block structure it was possible to take into account the variance caused by individual cows or quarters and repetitions.

In table 1 the effects of the vacuum levels on milk yield and milk removal on udder basis are given.

Table 1 shows that the vacuum level did not affect the milk yield. The peak milk flow rate increased with 8.3% (3992 vs. 4324 g per min; $p < 0.05$) when the vacuum level was raised from 42 to 45 kPa. A further increase from 45 to 48 kPa showed an increase of the peak flow rate with 2.8% (4324 vs. 4445 g per min; $p < 0.05$). The mean milk flow rate increased with 5.6% (2411 vs. 2547 g per min; $p < 0.05$) when the vacuum level was raised from 42 to 45 kPa. When the vacuum level was raised from 45 to 48 kPa there was a smaller not significant increase. The machine-on duration decreased significantly (421 vs. 397s; $p < 0.05$) when the vacuum was raised from 42 to 45 kPa. A further vacuum increase to 48 kPa gave no significant decrease in the machine-on duration. The mean and peak milk flow rate and the milk yield in the 2nd min showed significant increases from 42 to 45 kPa as well as from 45 to 48 kPa.

In table 2 the effects of the vacuum levels on milk yield and milk removal on quarter basis are given.

The size of the effects on quarter basis (table 2) corresponds roughly with that on udder basis (table 1). The mean effective milk flow rate per quarter, at which the overmilking duration was excluded, increased with 42 to 45 kPa; a further increase from 45 to 48 kPa resulted in an increase of 1.6% (741 vs. 753 g per min; $p < 0.05$);

Results

The duration of phase 1 as well as phase 2 significantly ($p < 0.05$) decreased when the vacuum level was increased from 42 to 45 kPa, while the duration of phase 3 significantly ($p < 0.05$) increased. The effective milking duration, defined as the sum of the duration of the phases 1, 2 and 3, however, showed a significant decrease ($p < 0.05$) when the vacuum was increased from 42 to 45 kPa.

A further increase of the vacuum level from 45 to 48 kPa gave significant ($p < 0.05$) effects for the parameters mean effective milk flow rate, peak milk flow rate and milk yield in the 2nd min.

Discussion and conclusions

Increasing the vacuum level from 42 to 45 kPa gave an increase in the peak milk flow of about 8%. From 42 to 48 kPa the increase in the peak milk flow was about 11%. The increase of the mean milk flow was with respectively 6 and 8%, clearly smaller. This was mainly caused because the gain obtained in the 1st (increasing flow phase) and the 2nd phase (steady state phase) was partly lost again in the 3rd phase (descending flow phase). The gain of time in the 1st phase was reached because the steady state phase started 3 to 4s earlier. The steady state phase was shorter because of the higher milk flow rate in this phase. The descending phase, in which the milk flow rate falls from the steady state level to 100 g/min, lasted in the higher vacuum levels 5s longer, while the amount of milk that was removed in this phase was larger.

At the end resulted an increase of the vacuum level from 42 to 45 kPa in a decrease of the machine-on duration of about 6%. A further increase of the vacuum level to 48 kPa shortened the machine-on duration with another 1.5% (not significant). The relative small effect of the increase from 45 to 48 kPa was striking. Only the milk yield in the 2nd min was significantly larger at 48 kPa than at 45 kPa. In the 3rd min this difference was already of no importance.

We noticed that there are large differences in the responses of different cows to the tested vacuum levels. These differences were even larger on quarter basis. An increase of the vacuum level from 42 to 45 kPa resulted in an average increase of the peak flow rate on udder basis of 8.3%, ranging between 2.1 and 14.5% for the individual cows. On quarter basis the average peak flow rate increased also with 8.3%; the range was then between -1.1 and +23.6% for individual quarters. The increase of the vacuum level from 45 to 48 kPa gave on quarter basis an average peak flow rate increase of 2.8% with a range between -8.0 and +11.8%.

There are different phenomena that play a role in the differences in the responses. In principle a higher vacuum level will result in a larger pressure difference between the inner wall of the udder and the liner leading to a larger milk flow rate. However when there is not enough milk available in the teat cistern this larger milk flow rate will not be maintained during the full suction phase. Further it is known that higher

vacuum levels can lead to teat congestion (Gleeson & O'Callaghan, 1998, Neijenhuis et al., 2001). This can result in a higher flow resistance through the teat canal, which has a negative effect on the milk flow rate. Finally with higher vacuum levels climbing of the liners upon the teats will occur more easily. This might negatively effect the opening between teat and udder cistern so that the milk flow from the udder is somewhat diminished.

There is a large variation in the external and internal properties (dimensions, tissue types, structure) of individual teats and quarters. These properties together with the milk let down reflex determine the possibilities for milk removal. The milking machine will affect at least some of these properties and by that affect milk removal.

We conclude that:

- there are large differences in the responses between cows; these differences are even larger between teats/quarters. This often also counts for quarters within the udder of a cow.
- it might be worthwhile to look for possibilities to optimize the milking machine settings per quarter by analyzing the responses of certain milk removal parameters.
- a system for optimizing the milking machine settings per quarter should consist of hardware for measuring milk flow and vacuum levels, for adjusting vacuum levels, pulsation rates and ratios, for detaching teat cups and software for analyzing the measurements (milk flow rates, vacuum levels) and based on these analyses together with information about expected milk yields predict switch points for the milking machine settings.

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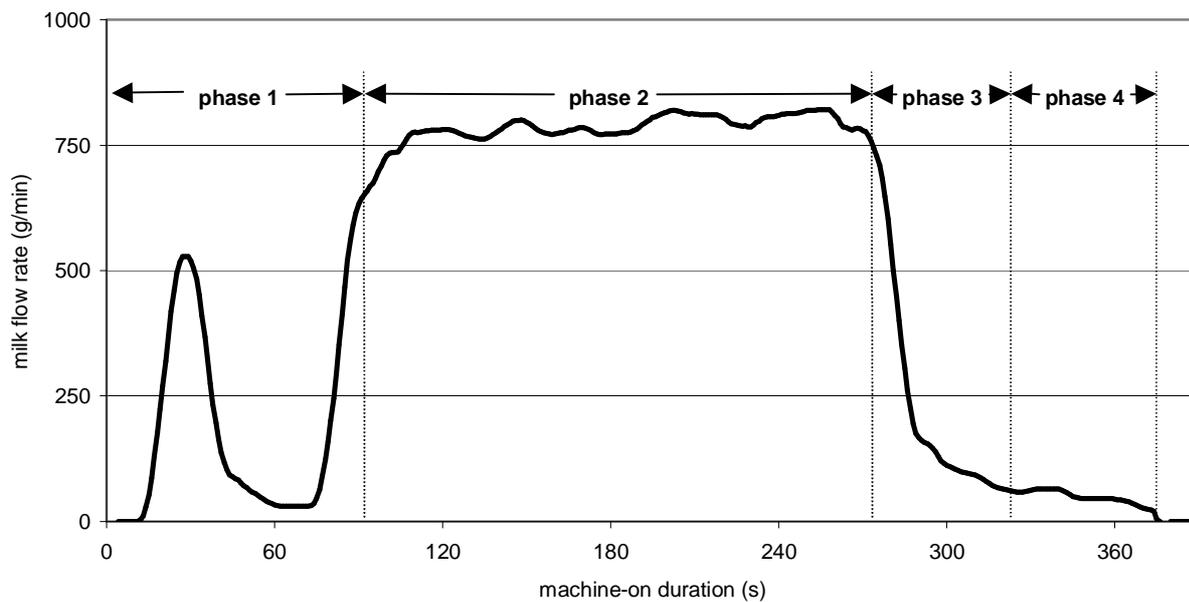


Figure 1. Phases of quarter milk removal curve.

Table 1. Results of three vacuum levels on milk yield and milk removal parameters on udder basis.

Parameter	Vacuum level (kPa)		
	42	45	48
Milk yield (g)	16491	16469	16616
Machine-on duration (s)	421 ^a	397 ^b	390 ^b
Mean milk flow rate (g/min)	2411 ^a	2547 ^b	2605 ^c
Peak milk flow rate (g/min)	3992 ^a	4324 ^b	4445 ^c
Milk yield in 1st min (g)	739 ^a	866 ^b	881 ^b
Milk yield in 2nd min (g)	3543 ^a	4012 ^b	4139 ^c
Milk yield in 3rd min (g)	3684 ^a	3951 ^b	3988 ^b

^{abc} Different letters in the same row mean a significant difference ($p < 0,05$).

Table 2. Results of three vacuum levels on milk yield and milk removal parameters on quarter basis.

Parameter	Vacuum level (kPa)		
	42	45	48
Milk yield (g)	4123	4117	4154
Effective machine-on duration (s)	360 ^a	338 ^b	333 ^b
Mean effective milk flow rate (g/min)	696 ^a	741 ^b	753 ^c
Peak milk flow rate (g/min)	1027 ^a	1110 ^b	1141 ^c
Milk yield in 1st min (g)	185 ^a	217 ^b	220 ^b
Milk yield in 2nd min (g)	886 ^a	1003 ^b	1035 ^c
Milk yield in 3rd min (g)	921 ^a	988 ^b	997 ^b
Duration phase 1 (s)	70 ^a	67 ^b	66 ^b
Duration phase 2 (s)	233 ^a	209 ^b	206 ^b
Duration phase 3 (s)	57 ^a	62 ^b	62 ^b
Duration phase 4 (s)	61	59	56
Milk yield phase 1 (g)	298	301	296
Milk yield phase 2 (g)	3380	3320	3349
Milk yield phase 3 (g)	408 ^a	456 ^b	468 ^b
Milk yield phase 4 (g)	36	40	40

^{abc} Different letters in the same row mean a significant difference ($p < 0,05$)

The impact of parity and lactation stage on initial milk flow

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In our previous studies it was established that milkings with low (<1 kg/min) initial flow, in average, are substantially less effective (in terms of milking time, peak flow etc.) in comparison to milkings of the same yield but with higher initial flow. The objective of this case study was to determine the proportion of “slow” and “fast-starters”, in terms of initial milk flow rate, in relation to cows’ parity and lactation stage. The study was performed at a commercial herd of 470 high productive Israeli Holstein cows milked trice daily. Milk flow parameters, including initial (0-15s) flow rate, have been monitored by Afiflo system (S.A.E Afikim, Israel). The data base comprised 5 consecutive days with about 7000 individual milkings. A cow was defined as slow-starter if it has 80% or more milkings with low initial flow. A cow with 20% or less milkings with low initial flow was defined as fast-starter. In first-calvers, in comparison to multiparous cows, the percent of slow-starters was significantly higher (51.2 vs. 31.1%), and percent of fast-starters – significantly lower (16.9 vs. 37.1%). The biggest difference in proportions of slow to fast start cows was recorded between first and second lactation. All fresh (DIM <30) primiparous cows, but only 31% from multiparous, were slow-starters. This proportion is declining for primiparous cows to 70.9% at 30-150 DIM and to 38.7% for cows later in lactation. In multiparous cows, the proportion of slow-starters was about the same for cows at different lactation stages.

We hypothesized that the higher percent of fast-starters in adult cows in comparison to first-calvers may be associated with age-related anatomical-physiological changes and also with better adaptation to milking procedure in adult cows. These results may contribute to definition of parity-related milk let-down traits. Substantial changes in proportions of slow- and fast-starters during lactation may alert on management- and equipment-related failures.

Key words: Dairy cows, milk flow rate

Summary

Introduction

There are only a few studies on effects of parity and lactation stage on particular parameters of milk let-down in dairy cows (e.g. Rothschild et al., 1980; Roth et al., 1998; Bagnato et al., 2003). Modern milk meters provide details on milk flow during each milking of each cow. For example, the Afiflo milk meter (S.A.E. Afikim, Israel) records flow rates in different time intervals, peak flow's rate and time, low flow time etc., leaving us with the problem how to exploit this data to improve management. This study deals with specific part of this information – initial (first 15s) milk flow rate. Previously it was established that milkings with low initial flow during the first 15 s are, in average, substantially less effective (in terms of milking time, peak flow etc.) in comparison to milkings of the same yield but with higher initial flow (Livshin et al. 2004, Maltz et al. 2004). We hypothesize that initial milk flow rate may be affected by cisternal milk yield increase and teat canal diameter enlargement with cow's aging, and also, in the long run, by harmful effect of machine milking on teat sphincters (Maltz et al., 2000, Devis et al., 2002). It was also supposed that at early lactation the initial milk flow rate in first-calvers may be inhibited because of incomplete adaptation to machine milking. Hence, the objective of this work was to study the possible effects of parity and lactation stage on initial milk flow rate.

Materials and methods

The study was performed in a commercial herd of 470 high productive (10500 kg per cow per lactation) Israeli Holstein cows, fed flat rate TMR. Cows were milked thrice daily in 2x14 herringbone parlor with standard prep routine (pre-dip and wipe). Milk flow parameters, including initial (0-15s) flow rate, have been monitored by Afiflo system (S.A.E Afikim, Israel). Data base comprised 5 consecutive days (15 milking sessions) in November 2003, with about 7000 individual milkings.

From the data base were excluded milkings: with multiple attachments, with yield less than 3 kg, of cows with less than 14 days in milk, and also milkings of cows that have less than 12 available milking data for this period. On the base of initial milk flow's level and stability, the cows were subdivided on slow-starters, fast starters, and intermediate group. A cow that had 80% or more milkings with low initial flow rate (less than 1 kg/min during first 15s) was defined as slow-starter. A cow that had 20% or less milkings with low initial flow rate was defined as fast-starter. The effects of lactation stage were determined for three periods: DIM <30, DIM 30-150, and DIM>150.

Results and discussion

The effects of parity.

During successive 15 milkings, about 70% of the cows were found to be either slow- or fast-starters (Table 1). This holds for primiparous, as well as multiparous cows, but in opposite proportions. In primiparous cows the slow-starters are the majority (51.2%) compare to 16.9% of fast starters, while among the multiparous cows were about equally distributed between slow- fasters, fast-starters and the intermediate group (Table 1).

Table 1. Proportion of slow-starters¹ and fast-starters² among primiparous and multiparous cows. Data for 15 milkings during 5 successive days.

Lactation	Total	Slow-starters		Fast-starters		Intermediate group ³	
	n	n	% of total	n	% of total	n	% of total
Primiparous	166	85	51.2	28	16.9	53	31.9
Multiparous	280	87	31.1	104	37.1	89	31.8

¹ Slow-starter - a cow that had 80% or more milkings with low initial flow rate (less than 1 kg/min during first 15s) in the 5d observation period.

² Fast-starter – a cow that had 20% or less milkings with low initial flow rate in the 5d observation period.

³ Intermediate group includes cows that did not qualify as slow- or fast-starters.

The percent of fast-starters increased and the percent of slow starters decreased as lactation number advanced (Fig. 1). The biggest changes were recorded between first and second lactation. Changes were more moderate, however persistent thereafter. The proportion of the intermediate group remains quite constant.

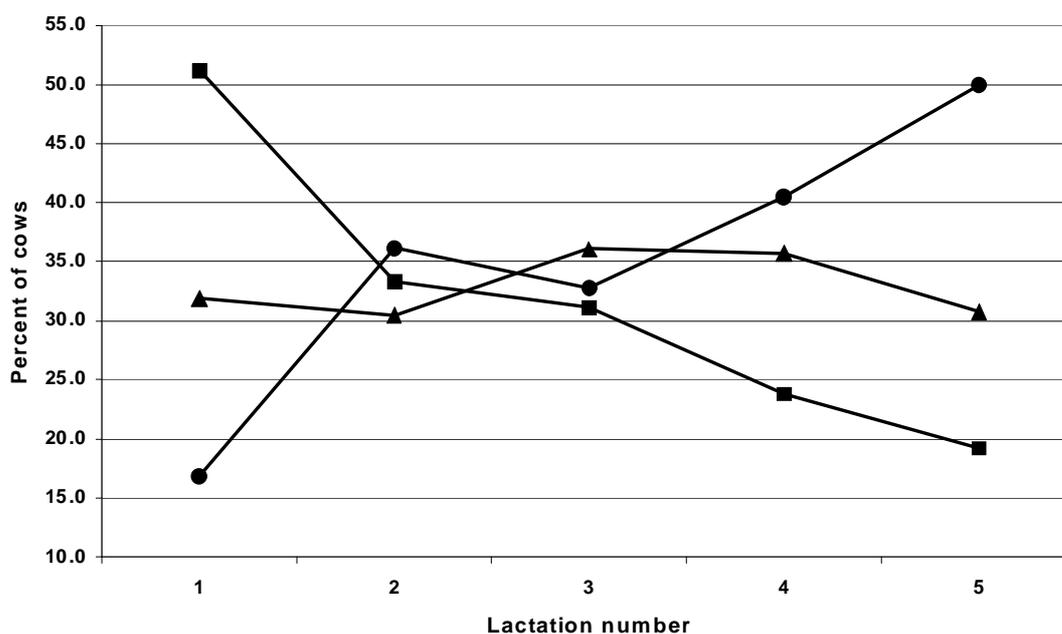


Figure 1. Proportion of slow starters (■ – cows with at least 80% of milkings with milk flow < 1 kg/min during 0-15 sec) and fast starters (● – cows with less 20% or less milkings with milk flow < 1 kg/min during 0-15 sec), and intermediate starters (▲ – cows not included in the other two categories) in different lactations. Number of cows in each lactation: first – 166, second – 141, third – 61, fourth – 42, fifth – 26.

We suggest that rapid increase in proportion of fast-starters in second lactation may be related to enlargement of the teat diameter due to continuing animal's growth and effects of machine milking. The subsequent increase in fast-starters proportion may be attributed to lasting effect of machine milking on the teats. Remarkably, the additional increase in fast-starters proportion in fifth lactation cows was accompanied by significant decrease in mean milk flow rate (Table 2). It indicates that initial flow rate may characterize teat condition more precisely than average milk flow rate.

Table 2. Average milk flow rates: lactations' means (\pm SD) for all cows, slow starters and fast starters.

Lactation number	All cows		Slow starters ¹			Fast starters ¹		
	n	Mean flow, kg/min	n	Mean flow rate kg/min	% to lactation mean	n	Mean flow rate kg/min	% to lactation mean
1	166	2.02 \pm 0.49	85	1.73 \pm 0.32	85.5	28	2.64 \pm 0.41	130.6
2	41	2.32 \pm 0.61	47	1.99 \pm 0.64	85.7	51	2.64 \pm 0.57	113.7
3	61	2.33 \pm 0.47	19	2.10 \pm 0.36	90.1	20	2.59 \pm 0.51	111.2
4	42	2.38 \pm 0.60	10	1.84 \pm 0.41	77.3	17	2.64 \pm 0.56	110.8
5	26	2.03 \pm 0.69	5	1.44 \pm 0.57	71.1	13	2.37 \pm 0.55	116.4

¹Slow-starter - a cow that had 80% or more milkings with low initial flow rate (less than 1 kg/min during first 15s) in the 5d observation period.

²Fast-starter - a cow that had 20% or less milkings with low initial flow rate in the 5d observation period.

The effects of lactation stage

During first lactation the proportion of slow and fast starters changes dramatically as lactation proceeds (Table 3). The later in lactation the more fast starters and less slow starters. In multiparous cows, the stage of lactation affected only the proportion of fast starters until 30 DIM. All fresh (DIM <30) primiparous cows, but only 31% from multiparous, were slow-starters. This proportion is declining for primiparous cows to 70.9% at 30-150 DIM and to 38.7% for cows later in lactation. In multiparous cows, the proportion of slow-starters was about the same for cows at different lactation stages. The proportion of fast-starters in primiparous cows increased from zero percent in fresh cows through 3.6% at DIM 30-150, to 24.5% afterward. The tendency of increased proportion of fast-start cows as lactation advances was found also in multiparous cows. These results apparently indicate that primiparous cows undergo rather prolonged adaptation to machine milking.

Table 3. Proportion of slow-, fast- and intermediate starters for primiparous and multiparous cows on different lactation stages. Data for 15 milkings during 5 successive days.

Cows' group	Period of lactation, days in milk					
	<30		30-150		>150	
	n	%	n	%	n	%
	Slow – starters ¹					
Primiparous	5	100	39	70.9	41	38.7
Multiparous	9	31.0	24	30.0	54	31.6
	Fast – starters ²					
Primiparous	0	0	2	3.6	26	24.5
Multiparous	8	27.6	30	37.5	66	38.6
	Intermediate group					
Primiparous	0	0	14	25.5	39	36.8
Multiparous	12	41.4	26	32.5	51	29.8
	Total					
Primiparous	5	100.0	55	100.0	106	100.0
Multiparous	29	100.0	80	100.0	171	100.0

¹ Slow-starter - a cow that had 80% or more milkings with low initial flow rate (less than 1 kg/min during first 15s) in the 5d observation period.

²Fast-starter – a cow that had 20% or less milkings with low initial flow rate in the 5d observation period.

³Intermediate group includes cows that did not qualify as slow- or fast-starters.

In the future, it may be useful to establish the “normal” proportions of slow-starters and fast-starters in relation to parity and lactation stage under proper dairy management. Exceptional deviations or changes in these proportions may alert on management – or equipment-related failures.

In this work we did not follow cows' aging process, but extracted a snapshot of a given situation in the dairy. However the analysis, similar to described above, was performed on the same 124 cows from that same dairy, once – as first-calvers and then after one year, in their second lactation. The proportions of slow- and fast-starters in these two lactations of the same cows were in accordance with this study results (unpublished data).

Cows can be characterized also by their initial milk flow rate. The proportion of slow-starters (cows with at least 80% of milkings with milk flow < 1 kg/min during 0-15 sec) decreases with each lactation number from 51.2% in first-calvers through 33.3% in second lactation and to 19.2% in 5 lactation. The proportion of fast starters (cows with less 20% or less milkings with milk flow < 1 kg/min during 0-15 sec) increases with lactation number, climbing from 16.9% in first lactation to 50% in the fifth. All fresh (DIM <30) primiparous cows, but only 31%

Conclusions

from multiparous, were slow-starters. This proportion is declining for primiparous cows to 70.9% at 30-150 DIM and to 38.7% for cows later in lactation. In multiparous cows, the proportion of slow-starters was about the same for cows at different lactation stages. The proportion of fast-starters in primiparous cows increased from zero percent in fresh cows through 3.6% at DIM 30-150, to 24.5% afterward. The tendency of increased proportion of fast-start cows as lactation advances was found also in multiparous cows.

The results obtained may contribute to understand parity- and lactation stage-related milk let-down traits. The anatomical, physiological and managerial factors behind the different levels of initial milk flow should be the subjects for future investigations. This variable (initial milk flow) may be incorporated in the future in selection programs.

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Udder cistern size and milkability of ewes of various genotypes

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A total of 263 Improved Valachian (IV), Tsigai (T), Lacaune (LC) and crossbred lactating ewes were used to study milk cistern anatomy in dairy sheep bred in Slovakia, to compare two methods of ultrasound udder scanning and to evaluate relations between cistern size and milkability. Milkability traits recording, external measurements, linear assessments and ultrasonic scanning of sheep udders were done. Sums of both cistern cross-section areas were computed on the basis of two methods of udder ultrasonography - from the side of udder (SCA) and from below in a water bath (BCA). Highest LSMs for cistern size (BCA=58.6 cm²; SCA=61.0 cm²) and the highest milk yield (MY=545 ml/milking) were detected in purebred LC ewes and also crossbreeds between IV or T and LC had higher cisterns and milk yield than purebred animals of IV (BCA=30.5 cm²; SCA=38.4 cm²; MY=412 ml/milking) and T (BCA=25.1 cm²; SCA=30.1 cm²; MY=293 ml/milking). On the other hand purebred LC had significantly higher average stripping milk percentage (40.9%) in comparison with other genotypes (22.8% to 28.2%). Between BCA and milk yield was found out slightly lower correlation (r=0.48) than between SCA and milk yield (r=0.53).

Key words: Sheep, udder, ultrasonography, mammary gland cistern

Sheep milking has long and plentiful tradition in Slovakia. Nevertheless machine milking have been introduced more widely into dairy sheep husbandry here in the last decade. The introduction of machine milking evokes the requirement to pay more attention on morphological and functional characteristics of sheep udders. One of the most interesting udder morphological characteristics from the machine milkability point of view is the size of glandular cistern (*Sinus lactiferus pars glandularis*),

Summary

Introduction

as the “cisternal milk” is available for milking before the oxytocine ejection, the large-cisterned animals being in general more efficient producers of milk and more tolerant to long milking intervals (Wilde et al., 1996). There are large differences in the proportion of total milk stored within the cistern among ruminant dairy species. Specialized dairy cows store less than 30% of the total milk yield volume in the mammary gland cisterns (Ayadi et al., 2003). Percentages of cisternal milk in sheep vary from 25% to 75% according to the breed but they are greater than 50% in most dairy sheep breeds (Caja et al., 1999, Rovai et al., 2000). *In vivo* scanning of the udder internal structures could be done by ultrasonography. Cisterns filled by milk are detectable very well as anechogenic structures in ultrasound scans. Different methods of sheep udder ultrasonography were proposed by Bruckmaier & Blum (1992) and Ruberte et al. (1994). The methods were used for cisternal measurements by Bruckmaier et al. (1997), Caja et al. (1999), Rovai et al. (2000), Nudda et al. (2000), Margetín et al. (2002) and others. This investigation was aimed on the study of milk cistern anatomy in dairy sheep breeds and crossbreeds in Slovakia, the comparison of two methods of ultrasound udder scanning and the evaluation of relations between cistern size and milkability traits in dairy sheep.

Material and methods

Investigations were performed in the experimental flock of Research Institute of Animal Production in Nitra, workplace Trenčianska Teplá. Totally 263 lactating ewes of Tsigai (T), Improved Valachian IV), Lacaune (LC) and crossbreeds between them were used. Six experiment batches were organized during the years 2002-2004 in different stages of lactation. Many animals were investigated repeatedly, so totally 590 individual measurements were done. Ewes were milked without udder prestimulation and milk flow was recorded in 10 s intervals. Then milk emission curves were constructed and total milk yield, machine milk yield, machine stripping milk yield and percentage of stripping yield were computed. 12 hours after milking the external measurements (6 traits), linear assessments (7 traits) and ultrasonic scanning of udders were done. Ultrasonography was carried out from the side of udder (figure 1) according to methodology of Ruberte et al. (1994) and from below in a water bath (figure 2) as described by Bruckmaier & Blum (1992). Scans were made with a digital ultrasound scanner Medison SonoVet2000 using a linear probe L2-5/170 CD. Acoustic coupling agent (Kerolan, Aveflor Kopidlno) was used to attach the probe to the skin in a case of scanning from the udder side. Images were recorded on memory card and later processed by the use of computer program Zodop32. Sums of cross-section areas of both cisterns measured from the side (SCA) and from below (BCA) were measured. The statistical analysis of variance in the dataset was performed using the GLM procedure of SAS. The model equation used for the data adjustment considered the effects of the experiment batch (fixed effect - 6 levels), breed or crossbreed combination (fixed effect - 7 levels), parity (fixed effect - 3 levels), interaction between breed and parity, days in milk (DIM) and square of DIM (both

covariables). The CORR procedure SAS was used for the computing of partial correlation coefficients on residuals after the data adjustment by the above mentioned model equation.

In table 1 the F-values of systematic effects obtained by analysis of variance of cistern areas are presented. Both measurements, from side (SCA) and from below (BCA), were significantly affected by all effects considered in model equation, anyway the effect of breed or crossbred combination was the strongest in both cases. Determination coefficients of used model equations of variance analysis were $R^2=0.531$ for BCA and $R^2=0.512$ for SCA. The least squares means and standard errors for the effect of breed or crossbred combination are listed in table 2. There were statistically significant differences in cistern size and milk yield between purebred Improved Valachians (IV), Tsigai (T) and Lacaune (LC). LC imported to Slovakia in order to improve milk production had the highest cistern size and the highest milk yield and also hybrids between IV or T and LC had higher cisterns and milk yield than purebred animals of native breeds. On the other hand purebred LC had significantly the highest stripping milk yield. Average percentage of stripping milk from total milk yield was 40.9% in LC while in other genotypes varied from 22.8% to 28.2%. The sums of both cistern cross-section areas were higher for measurements from side (30.08 cm²- 60.98 cm²) than from below (25.13 cm²- 58.55 cm²) in all genotypes. Higher relative differences in cistern areas between scanning from below and from side was detected in native breeds (IV-26.6%; T-19.7%) while in LC the difference was only 4.2%. Bruckmaier et al. (1997) refer about total cisternal cross sections obtained by udder ultrasonography from below $33\pm 7\text{cm}^2$ for LC. However in response to oxytocin injection alveolar milk was ejected causing enlargement of the cisternal area by $45\pm 8\%$. Caja et al. (1999) detected in Ripollés ewes 4 hours after milking average cistern area $5.6\pm 0.5\text{ cm}^2$ measured by ultrasonography from side of udder. Partial phenotypic correlations between BCA or SCA and other morphological and functional udder characteristics in purebred IV, T, LC and in all genotypes together are presented in table 3. Correlations between cistern areas and external udder size represented by udder height, udder width and udder length were moderate ($r=0.38-0.61$). Correlations between cistern areas and total milk yield were slightly higher in a case of measurements from side ($r=0.52-0.58$) than from below ($r=0.45-0.53$). Caja et al. (1999) found out similar correlation between SCA and milk yield $r=0.46$. For purebred LC was characteristic low correlation between machine milk yield and cistern size and on the contrary higher correlation between stripping yield and cistern size. These facts resulted in slightly positive correlations between cistern size and percentage of stripped milk in LC, while in IV and T these correlations were rather negative. Also correlations between cistern size and linear score for the udder shape from the point of view of machine milking were in LC much lower ($r=0.16-0.26$) than in IV ($r=0.46-0.47$) or T ($r=0.42-0.43$). Many LC ewes had baggy udders with big cisterns and horizontally placed teats. Big

Results and discussion

part of cistern volume was located below the orifice into the teat canal and therefore part of cisternal milk could be reached rather by stripping than by machine milking. Fernández et al. (1997) found out high positive genetic correlation between milk yield and udder depth ($r_g=0.82$) and negative genetic correlation between milk yield and linear assessment of udder shape ($r_g=-0.26$). These correlations showed that selection for milk yield could produce worse udder morphology.

Conclusions

The results show that the use of Lacaune sheep breed in Slovakia for genetic improvement of native dairy sheep breeds or for creation of synthetic line will lead to improving of milk production, but on the other hand could turn to the worse udder morphology with negative impact on some aspects of milkability. Taking this fact into account the use of udder morphology traits in breeding programs for dairy sheep would be reasonable. Ultrasonography of udders, both from below and from side, could be used for cistern size evaluation. Correlations between cistern size and milkability traits could be utilized in breeding. Nevertheless some breed specificities have to be considered.

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Table 1. Analysis of variance of sums of cistern cross-section areas measured from side (SCA) and from below (BCA).

Effects	BCA		SCA	
	F-value	P>F	F-value	P>F
Batch of experiment	5.02	0.0019	4.98	0.0020
Breed or crossbred combination	67.25	<0.0001	53.49	<0.0001
Parity	7.08	0.0009	3.91	0.0205
Breed-parity interaction	2.15	0.0086	2.10	0.0104
Days in milk (DIM)	5.71	0.0172	19.81	<0.0001
DIM ²	5.90	0.0154	15.85	<0.0001
	R ² =0.531		R ² =0.512	

Table 2. Effect of breed or crossbred combination on cistern size and milkability traits in sheep (LS-means±SE).

Breed	BCA cm ²	SCA cm ²	Milk yield ml/milking	Stripping yield ml/milking
Improved Valachian (IV)	30.52±1.27 ^b	38.35±1.29 ^b	412.3±13.8 ^b	105.5±8.4 ^a
Tsigai (T)	25.13±1.07 ^c	30.08±1.09 ^c	293.1±11.5 ^d	79.3±6.8 ^b
Lacaune (LC)	58.55±1.19 ^d	60.98±1.21 ^d	544.9±12.8 ^a	222.9±7.5 ^d
IV x LC	43.04±2.42 ^a	46.80±2.46 ^a	510.2±26.1 ^a	134.3±15.3 ^a
(IV x LC) x LC	38.22±1.61 ^a	44.43±1.63 ^a	502.8±17.3 ^a	130.4±10.1 ^a
T x LC	37.81±1.72 ^a	41.91±1.74 ^{ab}	424.1±18.4 ^{bc}	119.7±10.8 ^a
(T x LC) x LC	42.67±4.81 ^a	45.37±4.88 ^{ab}	468.8±51.8 ^{ac}	107.1±30.2 ^{ab}

^{a,b,c} : values with the same letters in the same column do not differ significantly (P<0.05)

Table 3. Correlations between cistern areas and other udder traits in sheep.

Breed	Improved Valachian		Tsigai		Lacaune		All genotypes	
	BCA	SCA	BCA	SCA	BCA	SCA	BCA	SCA
<i>Ultrasound measurements</i>								
SCA	0.71	-	0.76	-	0.84	-	0.79	-
<i>Linear scoring of udders</i>								
Udder depth	0.53	0.49	0.48	0.41	0.55	0.59	0.61	0.48
Cistern height	0.31	0.14	0.38	0.23	0.25	0.09	0.27	0.11
Teat placement	0.23	0.04	0.32	0.15	0.21	0.02	0.22	0.06
Teat length	-0.08	-0.06	0.21	0.12	0.26	0.17	0.13	0.09
Udder attachment	0.24	0.35	-0.06	0.11	0.12	0.16	0.11	0.18
Udder cleft	0.23	0.36	0.26	0.31	-0.04	0.06	0.10	0.18
Udder shape	0.47	0.46	0.42	0.43	0.16	0.26	0.27	0.32
<i>External udder measurements</i>								
Udder length	0.57	0.44	0.53	0.46	0.60	0.55	0.55	0.50
Udder width	0.43	0.50	0.40	0.38	0.40	0.47	0.41	0.45
Udder height	0.60	0.44	0.45	0.38	0.58	0.54	0.55	0.49
Cistern height	0.33	0.17	0.45	0.31	0.29	0.20	0.32	0.19
Teat length	-0.10	-0.09	0.04	0.03	0.21	0.06	0.03	0.00
Teat angle	0.14	0.01	0.24	0.05	0.15	0.06	0.17	0.03
<i>Milkability traits</i>								
Milk yield for 30 s	0.48	0.48	0.55	0.50	0.04	0.21	0.23	0.29
Machine milk yield	0.47	0.50	0.49	0.50	0.09	0.21	0.28	0.37
Total milk yield	0.53	0.58	0.49	0.52	0.45	0.53	0.48	0.53
Stripping yield	0.25	0.31	0.19	0.24	0.48	0.44	0.38	0.35
% of stripp. Yield	-0.07	-0.06	-0.15	-0.11	0.23	0.11	0.06	-0.02

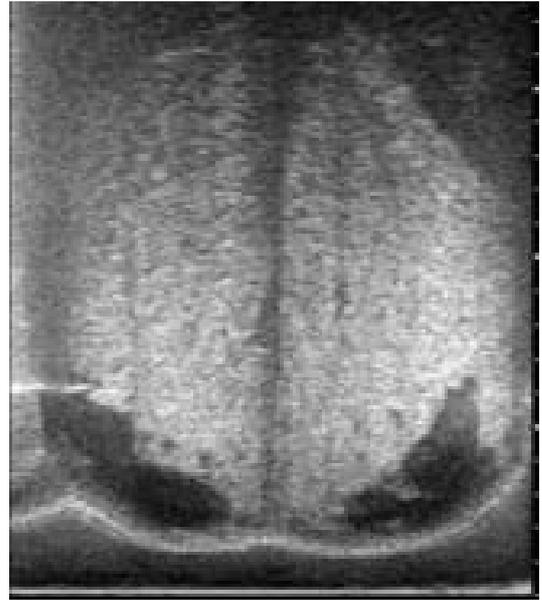
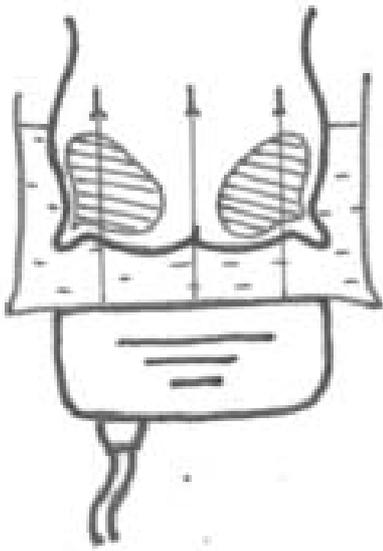


Figure 1. Ultrasonic scan of sheep udder from below (sum of cistern areas – BCA).

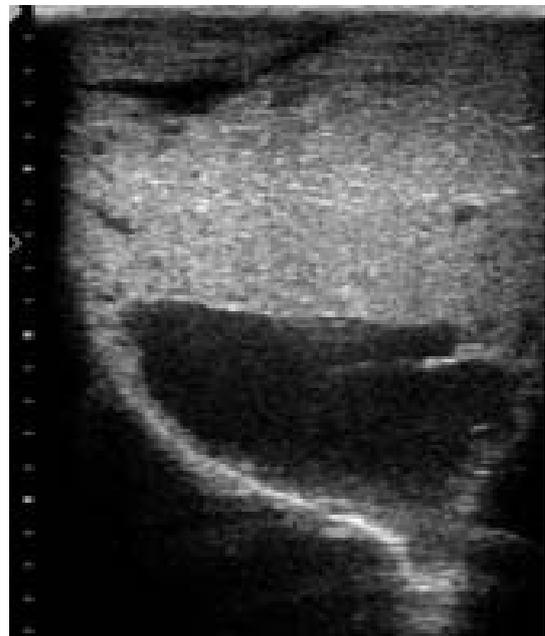
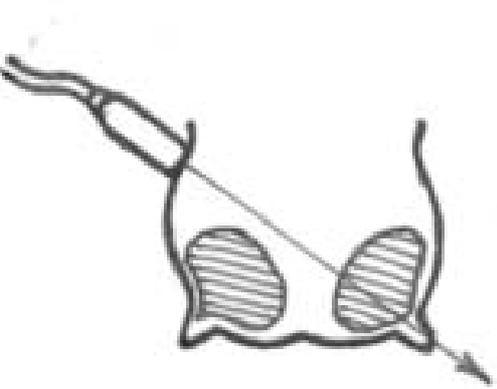


Figure 2. Ultrasonic scan of sheep udder from side (sum of both cistern areas –SCA).

Development of bulk milk quality from herds with automatic milking systems

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The objective of this paper was to analyse the changes in milk quality of AMS farms from the introduction in 1998 until the end of 2004. AMS companies reported the starting date of each new farm to the Danish Dairy Board and this information was merged with the bulk milk quality of each delivery. Bulk milk cell counts were higher on AMS farms in the first year, which led to the introduction of the Danish self-monitoring program. From that time bulk milk cell counts dropped until 2001, but then increased to slightly above the average of all Danish herds. It is not known if the increase in cell count can be ascribed to management or if AMS in general have a negative influence on the udder health. Total bacterial count is still higher than the average of all Danish herds, but has improved significantly over the years. A parallel trend was seen in spores of anaerobes. There were major problems with high freezing points in bulk milk during the first years with AMS, but these problems have now been solved. Overall quality of bulk milk from AMS herds has improved considerably over the years and the fact that some companies have reached the quality standard of all Danish herds makes us believe that general milk quality problems of AMS herds will disappear in the near future.

Key words: *Automatic milking systems, milk quality, cell count, bacterial count, freezing point*

Automatic milking systems (AMS) were introduced on commercial farms in Holland in 1992 and the first AMS came to Denmark in January 1998. AMS were well received in Denmark and the number of farms investing in AMS has been high since then. By the end of 2004, Denmark has close to 400 farms with AMS (Figure 1). In relation to a total of 6600 dairy farms, this corresponds to more than 6% which is the highest proportion of AMS in the World. The milk quality of Danish AMS farms did not reach the same average quality as that of all Danish herds during the introductory years (Rasmussen et al., 2002) and especially the bulk milk SCC was higher than in conventional herds, even compared with Dutch

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figures (Klungel et al., 2000). The objective of the present paper was to analyse the development in the milk quality during the years with AMS in Denmark.

Material and methods

The Danish distributors of AMS report the starting date of every new AMS farm to the Danish Dairy Board. Milk quality data of every delivery to the dairy factories were merged with the starting dates. Data were included as long as the AMS farms were delivering milk and 22 farms either stopped having dairy cows or invested in another milking system during the 7 years. Samples were analysed for somatic cell count (SCC) and total bacterial count once every week, freezing point once every four weeks, and spores of anaerobes once every four weeks from October to March. Averages of all Danish farms were included in the dataset to produce the figures and calculate differences to individual samples. SCC, TBC, and spores of anaerobes were log-transformed before statistical calculations to account for non-normal distributions. The procedure PROC MIXED (SAS, 1999) was used to test absolute values and differences from Danish averages. The statistical model included fixed effects of AMS model, year, month and the interaction between year and model. Herd number was included as the random variable and sampling date within herd was used as the repeated subject. Results are presented as LSMeans.

Cell count

The cell count of bulk milk was higher on AMS farms during 1998 and 1999 until the self-monitoring program was in place (Figure 2). Bulk milk SCC came very close to the average of all Danish herds in the year 2000 when only the peak seen during the summer months was higher than the average of all herds. Since then, the differences between the average of all herds and the average of AMS herds have increased steadily (Table 1), which mainly seems to be explained by a general drop in SCC of all Danish herds compared with AMS herds having a minor tendency to drop. Although the Danish self-monitoring program had good success in lowering the bulk milk SCC in its first years (Rasmussen et al., 2002), AMS herds have not reached the same SCC as other Danish herds. We can only speculate why this is so, but further statistical analysis did not reveal causation with starting year, which could have explained differences due to the efficiency of the Danish self-monitoring program or the technical mechanisms of the AMS in appointing cows with abnormal milk. Earlier studies have shown that the number of new infections in AMS herds increases during the first year of operation (Rasmussen et al., 2001) and the trend in AMS herds not to follow the country's average could indicate that udder health may be poorer in AMS herds than in conventional herds. If this is true, work is needed to explore and improve this to make AMS competitive compared to conventional milking.

Bulk milk total bacterial count was about doubled in milk from AMS herds during 1998, but has since declined steadily (Figure 3 and Table 1). The number of samples exceeding 30,000 cfu/ml has dropped from 21% in 1998 to 9% in 2004. A small increase was seen from 2003 to 2004 in both AMS and all herds. The geometric mean of AMS herds was 12,000 cfu/ml in 2004 compared with 7,000 cfu/ml of all herds. Although the quality in terms of total bacterial count has improved considerably since the introduction of the first AMS, there is still room for improvement compared to the high standard of Danish herds. We do not have conclusive material on the causes of the higher bacterial counts, but cleaning, cooling and hygiene may all play a role.

Total bacterial count

Anaerobic spores in bulk milk are an indicator of contamination with manure and as such of insufficient cleaning of teats before attachment of the teatcups. The anaerobic spores originate from poor quality silage, and perhaps farms with AMS do a poorer job in this respect, but this is not very likely. We probably have to ascribe a higher spore count in bulk milk of AMS herds to a poorer hygiene, including more cows with dirty teats and insufficient cleaning at time of milking. However, the number of anaerobic spores in milk from AMS herds have decreased steadily since 1998 and is coming close to the average of all Danish herds in 2004 (Table 1). There are differences between the AMS models on the market, and only one model has been able to keep the level of all herds in Denmark for all the years on the market whereas others have been significantly higher than the average of the country. The percentage of samples not reaching first class (400 spores/L) has dropped from >50% in the first years with AMS to 18% in 2004. This is a very positive trend indicating that management has improved over the years.

Anaerobic spores

A high freezing point in bulk milk was a major problem during the first years with AMS, but by the good efforts of the companies the freezing point has now been brought very close to the average of all Danish herds (Figure 4). The average for AMS herds was -0.524°C in 2004 whereas the national average was -0.525°C . The frequency of freezing points above -0.516°C was 23% in the first year with AMS, declining to 2.2% in 2004. Problems with high freezing points could mainly be ascribed to technical details, which has obviously been solved by now.

Freezing point

There were major problems with the milk quality of AMS herds during the first years in Denmark. Since then, the overall quality of bulk milk from AMS herds has improved considerably. This applies especially for freezing point, but also for spores of anaerobes and total bacterial count. Bulk milk cell count dropped during the first years with AMS, but has increased to slightly above the average of all Danish herds since then. It is not known if the increase in cell count can be ascribed to management or if AMS in general has a negative influence on the udder health.

Conclusions

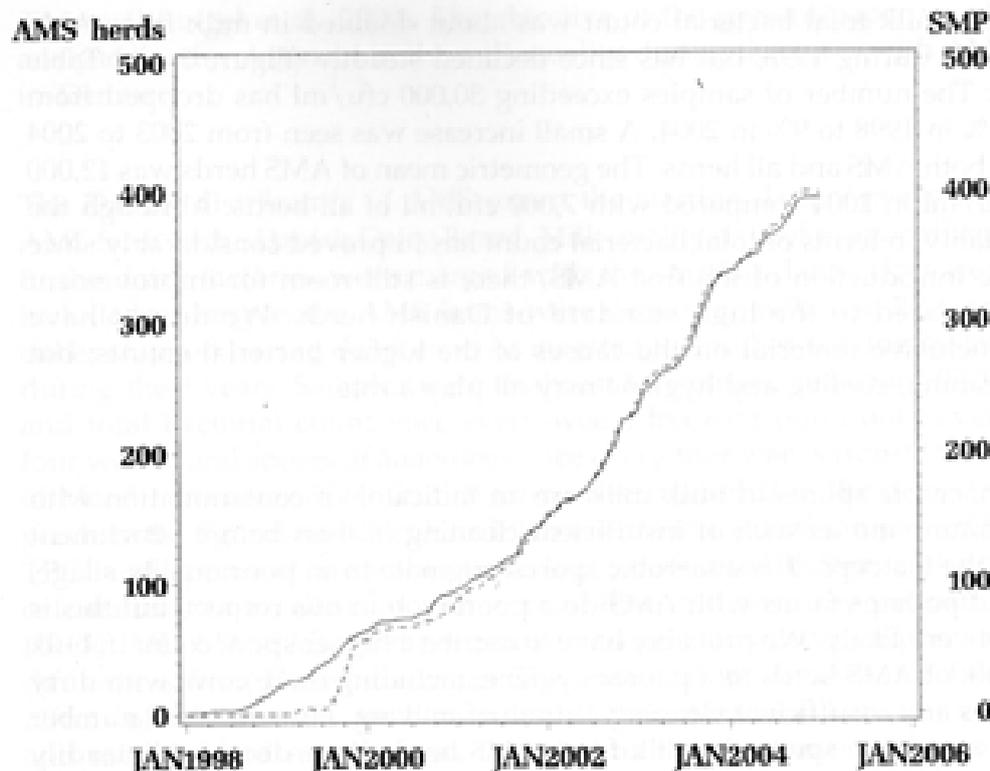


Figure 1. Number of AMS farms in Denmark (solid line) and farms included in the self-monitoring program (dashed line).

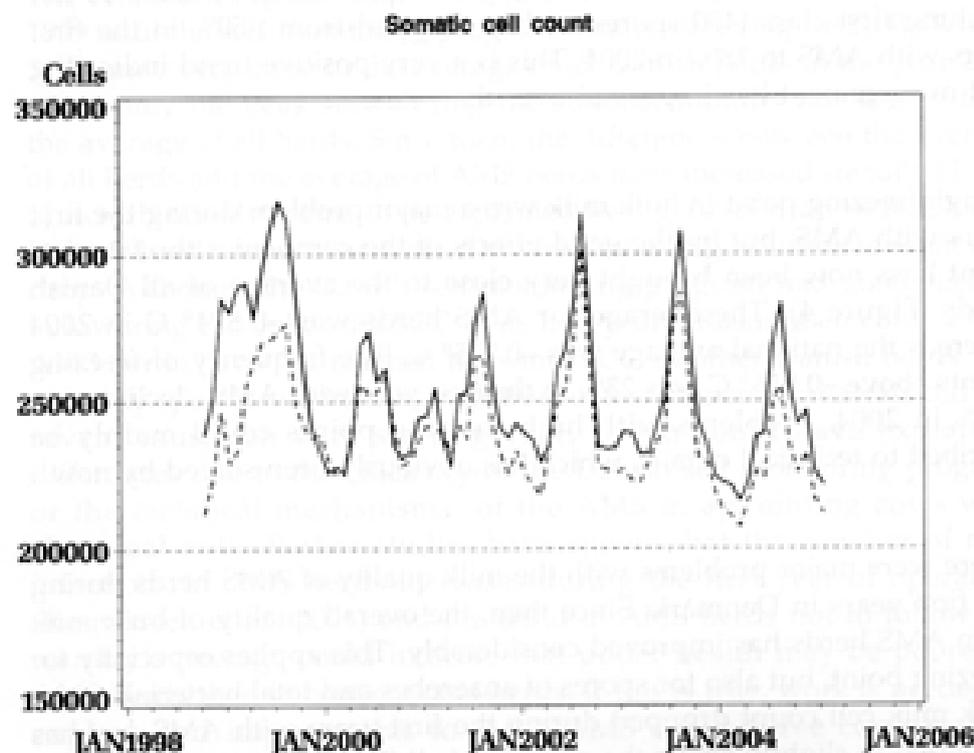


Figure 2. Bulk milk cell count of herds with AMS (solid line) and the average for all Danish herds (dashed line).

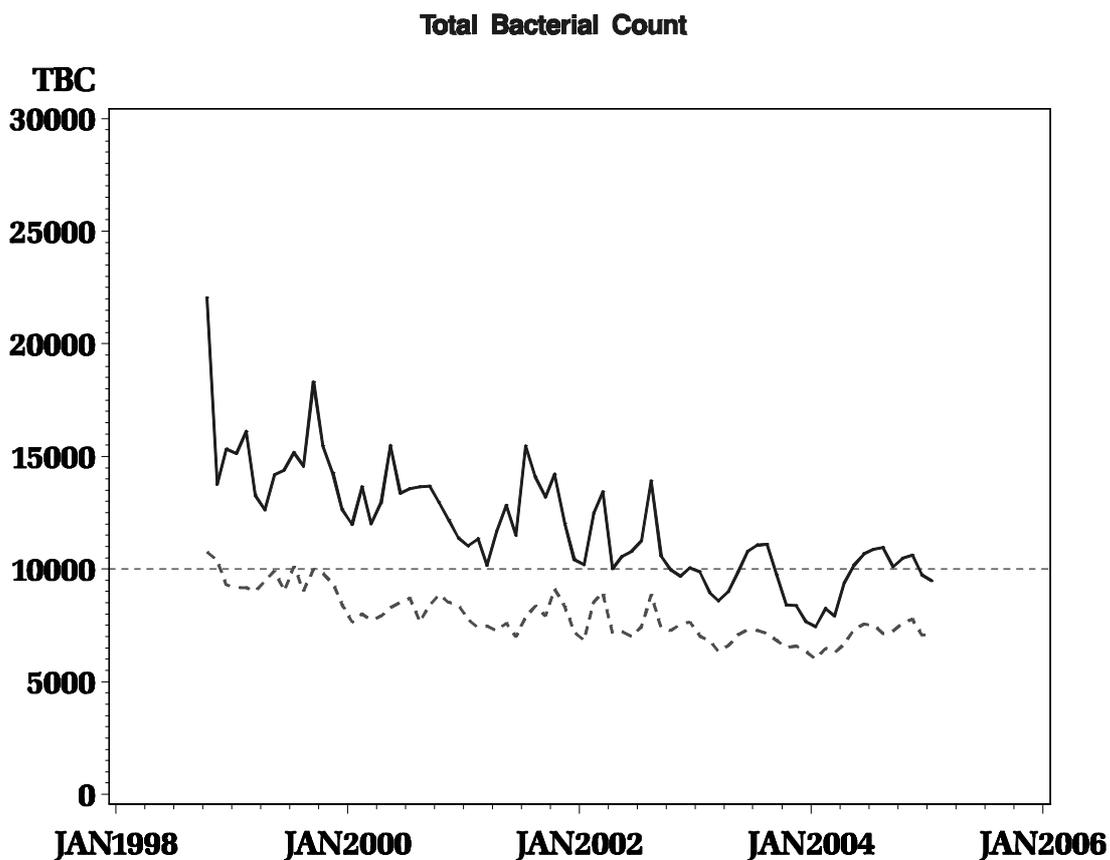


Figure 3. Bulk milk total bacterial count of herds with AMS (solid line) and the average for all Danish herds (dashed line).

Table 1. Development in the bulk milk quality of Danish AMS herds (log values) and the difference (dif) between AMS and the average of all Danish herds.

Year	Log cells	Dif cells	Log Bact	Dif Bact	Log Spores	Dif Spores
1998	5.47 ^d	0.129 ^f	4.27 ^f	0.28 ^c	2.99 ^e	0.53 ^e
1999	5.48 ^d	0.079 ^e	4.24 ^f	0.28 ^c	2.93 ^e	0.28 ^{de}
2000	5.41 ^a	0.036 ^a	4.17 ^e	0.26 ^{bc}	2.67 ^d	0.20 ^{bc}
2001	5.42 ^b	0.043 ^b	4.16 ^d	0.27 ^c	2.38 ^c	0.22 ^{cd}
2002	5.43 ^c	0.048 ^c	4.13 ^c	0.25 ^b	2.36 ^c	0.21 ^{bc}
2003	5.43 ^c	0.050 ^c	4.07 ^a	0.23 ^a	2.19 ^b	0.19 ^b
2004	5.41 ^a	0.056 ^d	4.08 ^b	0.23 ^a	2.12 ^a	0.12 ^a

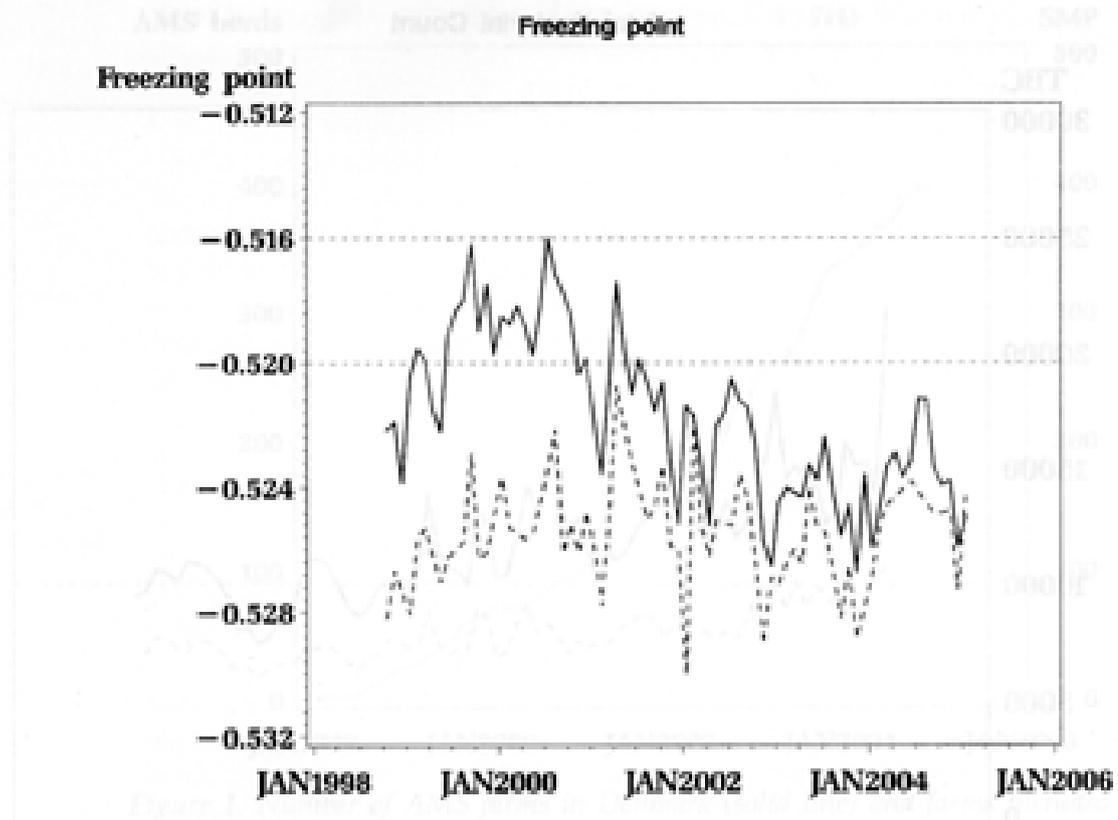


Figure 4. Freezing point of bulk milk from herds with AMS (solid line) and the average for all Danish herds (dashed line).

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Aspects on quarter milking in automated milking systems

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The bovine udder consists of four separate quarters, with equal milk yield and milk composition in front and rear quarters, which leads to the conclusion that quarter milking (Q-m) ought to be optimal for the cows. In a series of experiments, Q-m was tested and it was found that Q-m gave better teat condition, higher milk flow and shorter milking time compared to conventional milking. Furthermore, it was observed that Q-m could be used as a diagnostic tool for detecting affected udder quarters. Deviating milk composition, mainly lactose content, indicated quarters with udder disturbances.

Key words: Quarter milking, milking characteristic, SCC, lactose

Whether quarter milking (Q-m) is a beneficial milking concept has been discussed and during the past decade Q-m was made possible with the introduction of automated milking (AM) systems to the market. The difference between conventional and Q-m is the detachment of the teat cups from the udder. In conventional milking systems the teat cups are attached and detached simultaneously, manually or automatically. With Q-m the teat cups are detached individually, i. e. when the separate udder quarter is emptied or when the milk flow has reached a predetermined level for take off.

There are biological reasons for practicing Q-m. The udder consists of four separate quarters. Under normal circumstances milk that is produced in one quarter never passes over to the other quarters. The distribution of milk yield is, in general, 40 % and 60 % in the front and rear quarters, respectively. The protein and lactose content is almost equal in front and rear quarters while the fat content is higher in front quarters (Table 1). In conventional milking, the uneven distribution of milk yield results in

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a shorter milking time for the front quarters compared to the rear ones, which can cause over-milking of the front quarters. Since the milk composition is the same for the front and rear quarters, deviations in composition could be used as a diagnostic tool to detect udder quarters with disturbances caused by bacterial infection or some kind of trauma. At our department, a series of studies have been initiated to evaluate if Q-m is preferable to conventional whole-udder milking, and if deviations in comparative milk composition can be used as a diagnostic tool.

Table 1. Somatic cell count (SCC), milk production gram/hour, fat-, protein- and lactose content in different udder quarters when SCC is below 100 000 cells/ml milk. 22 cows. (LS means \pm SE).

	SCC (x 1000 cells/ml) ¹	Milk prod. (gram/h)	Fat (%)	Protein (%)	Lactose (%)
RR ²	18	388 \pm 52	4.63 \pm 0.63	3.33 \pm 0.09	4.95 \pm 0.06
LR	14	399 \pm 44	4.60 \pm 0.67	3.33 \pm 0.12	4.95 \pm 0.07
RF	18	265 \pm 28	4.85 \pm 0.67	3.33 \pm 0.11	4.91 \pm 0.07
LF	16	265 \pm 29	4.81 \pm 0.62	3.33 \pm 0.09	4.91 \pm 0.07

¹Antilogarithmical value, ² RR=right rear, LR=left rear, RF=right front, LF=left front. (Berglund et al., 2004b).

Q-m and its effects on milking characteristics and milk somatic cell count (SCC)

The aim with the first study was to test whether there were differences in milking characteristics between Q-m and conventional milking when the cows were milked in a conventional parlour (Seeman, 1997). The study included 14 cows and was carried out at Hamra Farm, DeLaval, Tumba, Sweden. It was a change-over design with two treatments and three periods, where the third period was designed to test for carry-over effects.

Milking characteristics such as milking time and milk flow were positively influenced by Q-m (Table 2). The change in teat-end thickness before and after milking was -2 % and +3.8 % for Q-m and conventional milking, respectively. These results indicated that the Q-m improved the milking procedure.

Since AM enables Q-m, a study was done in order to compare conventional milking in a herringbone parlour with Q-m in an AM system. The 25-week study was divided into three periods, and included 66 cows, which were allotted in two groups of comparable pairs, matched on the basis of milk yield, milk somatic cell count (SCC) and lactation stage before assigning them to either Q-m in the AM system or conventional parlour milking (Berglund et al., 2002).

Table 2. Comparison between quarter milking and conventional milking. 14 cows. (LS means).

	Quarter milking	Conventional milking	Sign Level ¹
Time to milk flow (min)	0.19	0.22	*
Milking time (min)	5.34	5.42	**
Peak flow (kg/min)	3.96	3.82	**
Average flow (kg/min)	2.64	2.55	**

¹Statistically significant differences between treatments *=p<0.05, **=p<0.01 (Seeman, 1997)

That teat-end thickness was reduced with Q-m, especially in the front teats, compared to conventional milking was observed also in this study (Berglund et al., 2002). Furthermore, the SCC was lower in strip-quarter milk in cows exposed to Q-m compared to conventional milking (Table 3). This effect was however not detected in composite milk.

Table 3. Log SCC in quarter-strip milk milked in AM quarter milking or by conventional parlour milking. 66 cows (LS means)

Period	AM quarter milking	Conventional milking	Sign level
I	3.84 ^a (46)	4.02 ^a (56)	ns
II	3.89 ^a (49)	4.17 ^b (65)	*
III	4.11 ^b (61)	4.84 ^c (126)	***

The anti-logarithmic geometric means are shown within brackets (x 1000 cells/ml). Significant difference *=p<0.05, ***=p<0.001.

^{abc} Means within column with different superscripts differ significantly p<0.05. (Berglund et al., 2002)

The farmer is informed monthly about individual cow's composite milk SCC content from the official milk recording scheme and the dairy provides analytical results regarding SCC in the tank milk. The farmers base management decisions on these figures. However, a more efficient way for detection of udder disturbances would be to analyse the milk at each separate udder quarter, whereby the dilution effect from healthy quarters is prevented. Indeed in our studies we have observed that in as much as 12 % of the composite milk samples with SCC below 200 000 cells/ml contained one or more udder quarters with CMT 3 and above (Berglund et al., 2004a). Those results indicate the importance of udder quarter sampling. When evaluating mastitis detection with an electronic nose it was also observed that the measurements must be taken at udder quarter level (Eriksson et al., 2005).

Milk composition is the same in healthy quarters but is altered in disturbed quarters, thus deviations in milk composition at the udder-quarter level could be used as a diagnostic tool. In order to further test this hypothesis a 13-week long study was initiated that included 68 cows. In total 4158

**Quarter milking –
a diagnostic tool?**

quarter-milk samples were analysed (Berglund et al., 2004b). Depending on the obtained milk SCC results the cows were divided in three groups; a) cows with all four quarters below 100 000 cells/ml, b) cows with moderately increased SCC in one udder quarter (> 100 000 cells/ml and > 1.5-fold higher than the opposite quarter) at one occasion, and c) cows with moderately increased SCC in one quarter at more than one occasion. Composition differences within pairs of udder quarters (unaffected – affected) were calculated and tested if the difference was separated from 0.

In b group cows only lactose content differed significantly ($p < 0.05$) following increased SCC. In group c the fat and protein content also deviated significantly (Table 4). The results indicated that deviations in milk composition can be used as a tool for detection of udder disturbances and lactose seems to be a promising indicator.

Table 4. Milk composition (fat, protein and lactose content (%)) in affected (A) and unaffected (N) udder quarter when SCC increased at more than one sampling occasion. 12 cows (LS means).

Variable	Sampling occasion ¹					
	-3	-2	-1	0	+1	+2
Fat (%)						
N	4.69	5.39	4.95	4.92	5.27	5.01
A	4.80	5.34	4.95	4.75	5.23	4.94
Diff N-A	.10	.01	.03	.20	.08	.07
Sign level	ns	ns	ns	*	ns	ns
Protein (%)						
N	3.41	3.44	3.37	3.37	3.4	3.32
A	3.41	3.42	3.33	3.43	3.43	3.33
Diff N-A	.01	.02	.05	-.06	-.04	-.03
Sign level	ns	ns	*	***	(*)	ns
Lactose						
N	4.87	4.86	4.88	4.86	4.87	4.89
A	4.81	4.83	4.86	4.69	4.73	4.71
Diff N-A	.05	.02	.04	.17	.14	.17
Sign level	ns	ns	ns	***	***	***

¹ Sampling occasion -3 = 10 or 11 days before sampling occasion 0; - 2 = 7 days before 0; - 1 = 3 or 4 days before 0. +1 = 3 or 4 days after 0; +2 = 7 days after 0. 0 = sampling occasion when milk SCC was elevated.

² ns=not statistically significant, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (Berglund et al 2004b)

Since we observed that quarters with a moderate increase in SCC influenced milk composition it can be questioned if it is worthwhile to separate milk from quarters with elevated SCC. In a study where the protein composition in relation to SCC was studied, we found that both the casein content and casein number were significantly decreased in affected quarters (Table 5) (Åkerstedt, 2003). Whether or not this will be of importance for the dairy industry as such has to be further evaluated.

**Further
applications with
Q-m**

Table 5. Protein, casein, whey, casein number and lactose (%) in udder quarter with low SCC and adjacent udder quarter with elevated SCC. 36 cows.

	Low SCC mean	High SCC mean	Diff mean	Sign level ¹
Protein (%)	3.54	3.58	0.04	ns
Casein (%)	2.68	2.64	-0.04	*
Weigh (%)	0.86	0.94	0.08	***
Casein no. (%)	76	74	-2	***
Lactose (%)	4.8	4.59	-0.21	***

(Åkerstedt, 2003) ¹ns=not statistically significant, * p<0.05; ***p<0.001

It can be concluded that there are benefits with quarter milking. It improves the milking procedure and it can be used as a diagnostic tool. However, it has to be mentioned that individual treatment of quarters, giving different types/degree of teat stimulation during milking can influence the milk synthesis (Svennersten et al., 1990). In a fully automated milking system provided with Q-m there are many possibilities for improving the milking procedure. The physiological possibilities and applications exist – we just need to learn how to take advantage of the potential opportunities with Q-m.

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Automatic milking: lessons from an EU project

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Since the first commercial systems appeared in 1992, automatic milking systems (AM-systems) have been installed increasingly. No other new technology since the introduction of the milking machine, has aroused so much interest and expectations among dairy farmers and the periphery. Reduced labour, a better social life for dairy farm families and increased milk yields due to more frequent milking are among the important benefits of automatic milking.

Automatic milking changes many aspects of farm management since both the nature and organisation of labour is altered. Manual labour is partly replaced by management and control, and the presence of the operator at regular milking times is no longer required. Visual control on cow and udder health at milking is, at least partly, automated. Facilities for teat cleaning and separation of abnormal milk are incorporated into the automatic system and adaptation of conventional cleaning schemes and cooling systems is needed to accommodate continuous milking. Cow management including routing within the barn and opportunities to apply grazing is altered. A high quality of management together with realistic expectations are essential for a successful implementation of automatic milking. Automatic milking systems require a higher investment than conventional milking systems. However increased milk yield and labour reduction may lead to a decrease in the fixed costs per kg milk. Automatic milking is gaining widespread acceptance and is now estimated to be in use on more than 2500 farms in over 20 countries worldwide.

Key words: Automatic milking, AM-systems, management, milk quality, animal health, labour

Interest in fully automated milking began in the mid-seventies. It was initially driven by a sound technological curiosity with the growing costs of labour in Europe in mind. Since automatic cluster detachment and teat spraying had become common practise in machine milking,

Abstract

Introduction

automatic cluster attachment became the challenge of European research and development work. Although various prototypes demonstrated its feasibility in the initial state of development, it took a decade before fully integrated and reliable automatic milking became a reality and another five years before adoption by farmers had reached a level worth mentioning. After the first introduction of AM-systems on commercial farms in The Netherlands, adoption went slowly, until 1998 (figure 1).

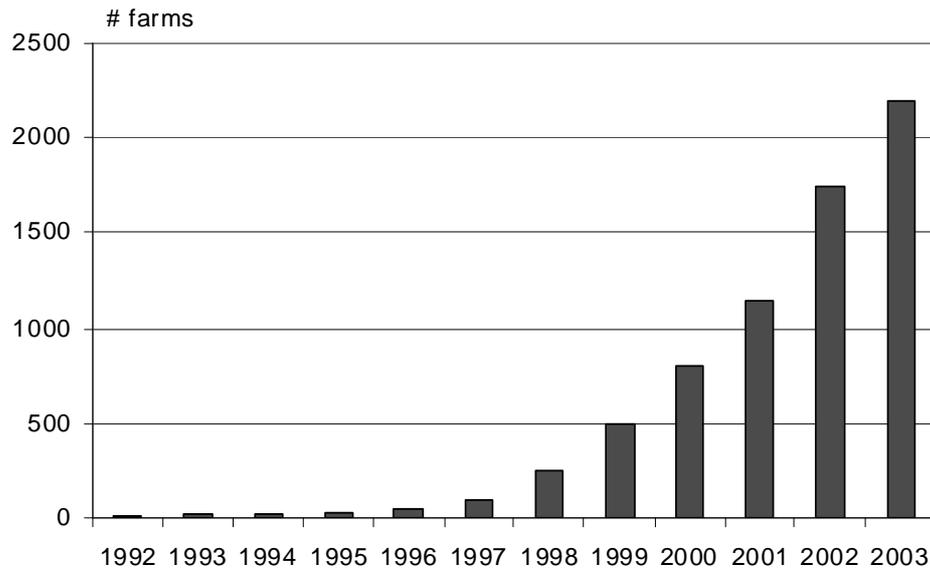


Figure 1. Number of farms using an automatic milking system upto the end of 2003 (De Koning & Rodenburg (2004)).

From that year on automatic milking gradually became an accepted technology in the Netherlands and a number of other countries in the North-west of Europe. Later, farmers in central and south Europe followed, as well as in North America and Japan. Recently a few automatic milking systems have been installed in Australia and New-Zealand. By the end of 2003, worldwide some 2200 commercial farms used one or more AM-systems to milk their cows (figure 1). Over 85 % of the world's automatic milking farms are located in north-western Europe. The largest group of present adopters in Europe are middle-sized enterprises with a relatively high numbers of cows (50-100), high herd yields per hand (>700.000 kg) and consequently labour under stress (Mathijs, 2004).

**Management
Aspects**

Switching from a milking parlour to automatic milking results in big changes for both the herdsman and the cows and can cause stress to both. Although with AM-systems immediate supervision of milking is eliminated, new labour tasks include control and cleaning of the AM-system, twice or three times a day checking of attention lists including

visual control of the cows and fetching cows that exceeded maximum milking intervals. Field data on labour savings is limited. On average a 10% reduction in total labour compared with the conventional twice daily milking is assumed, but large variations between farms can be found. In the study on 107 AM-farms in Belgium, Denmark, Germany and The Netherlands (Mathijs, 2004), labour savings recorded were around 20% on average. Averages per country varied between around 11% in Denmark and almost 30% in Belgium.

However, the biggest change is the nature of labour. The physical work of machine milking, is replaced with management tasks such as frequent checking of attention lists from the computer and appropriate follow up. This work is less time bound than parlour milking, the input of labour is more flexible, which is particularly attractive on family farms. But because milking is continuous, and system failures can occur anytime there must be a person “on call” at all times. System failures and associated alarms typically occur about once in two weeks although this varies with the level of maintenance and management. For the sake of a better management support, the industry is challenged to realize improvements in the integration between milking system and herd management software, in the presentation of attentions and in the control functions of the milking system (Ouweltjes, 2004). A further improvement and development of sensor techniques for an accurate detection of abnormalities or for in-line measurements of milk composition is on the wish-list as well.

In terms of the impact on cows, the AM-system is not suitable for all cows. Poor udder shape and teat position may make attachment difficult and some cows may not be trainable to attend for milking voluntarily. In new installations, the number of cows found to be unsuitable is generally reported to be less than 5-10% at maximum. In the transition from conventional to automatic milking, cows must learn to visit the AM-system at other than traditional milking times. Training and assistance in the first weeks should involve quiet and consistent handling, so they adapt to the new surroundings and milking system.

One important factor in successful implementation of an AM-system is the attitude and expectation of the dairy farmer (Hogeveen et al, 2001, De Koning et al, 2002, Ouweltjes, 2004). While there is considerable variation in level of satisfaction with different types of systems, an estimated 5-10% of owners have switched back to conventional technology. In some cases expectations were not realistic, in others farmers were unable to adapt to the different management style, and in some cases a high rate of failures of the AMS discouraged the farmer to continue.

Attitude and expectations

During the start up period, automatic milking requires a high input of labour and management. Key factors of a successful implementation of AM-systems are:

- Realistic expectations
- Good support by skilled consultants before, during and after implementation
- Flexibility and discipline to control the system and the cows
- Ability to work with computers
- A well-adapted barn layout supporting a smooth cow traffic
- Good technical functioning of the AM-system and regular maintenance
- Healthy cows with good feet and an eager eating behaviour

Milk quality

Milk quality is a critical concern on modern dairy farms because milk payment systems are based on milk quality and consumers expect a high level of quality and safety from the milk products they buy. Although automatic milking uses the same milking principles as conventional milking, there are major differences. Results from commercial farms in Europe (Klungel et al, 2000, Van der Vorst & Hogeveen, 2000, Pomies et Bony, 2001, Van der Vorst et al, 2002, De Koning et al, 2004) and North America (Rodenburg and Kelton 2001) indicate, that milk quality is somewhat negatively effected after introduction of automatic milking. In general data show an increase in bacteria counts, although the levels are still relatively low and well within the penalty limits. A recent study (Helgren and Reinemann, 2003) determined that SCC and bacteria counts in the US were similar to conventional milked herds. Both the cleaning of the milking equipment and milk cooling are critical factors in controlling bacteria counts. Also cell counts are not reduced after the change to automatic milking, despite the increased milking frequency. With increasing milking frequency a small decrease in fat and protein percentage and an increase in the free fatty acids levels has been reported (Ipema and Schuiling, 1992, Jellema, 1986, Klei et al, 1997 and De Koning et al, 2004).

De Koning et al (2004) conclude that, although milk quality requires attention during the transition period from conventional to automatic milking, in general no serious problems are encountered afterwards (Figure 2). The observed increase in level of free fatty acids demands more research however. An increased milking frequency is not the only explanation of increased free fatty acid levels as can be seen from table 1.

The general conditions of hygiene in milk production in the EU are currently defined by the Commission Directive 89/362/EEC (1989) but not all elements apply to automatic milking (Rasmussen, 2004). The following text is proposed to be included in the coming EU Hygiene Directive: "Milking must be carried out hygienically ensuring in particular, that milk from an animal is checked for abnormalities by the

milker or by a method achieving similar results and that only normal milk is used for human consumption and that abnormal, contaminated, and undesirable milk is excluded”.

AM-systems have accurate cow identification and this also means less chance of human errors than in conventional milking, which might have a positive effect on lowering the presence of inhibitors in milk, as reported from North America. In this way automatic milking also potentially enhances food safety and quality.

Table 1. Initial FFA level (meq/100 g fat) and increase after passing through a conventional or an AM system (De Koning et al, 2004).

Milking system	mean initial FFA (mmol/100 g fat)	increase FFA (mmol/100 g fat)
Test 1		
Conventional	0.36	+0.04 ^a
AM brand 1		+0.07 ^a
Test 2		
Conventional	0.52	+0.07 ^a
AM brand 2		+0.21 ^b

TPC (*1000)

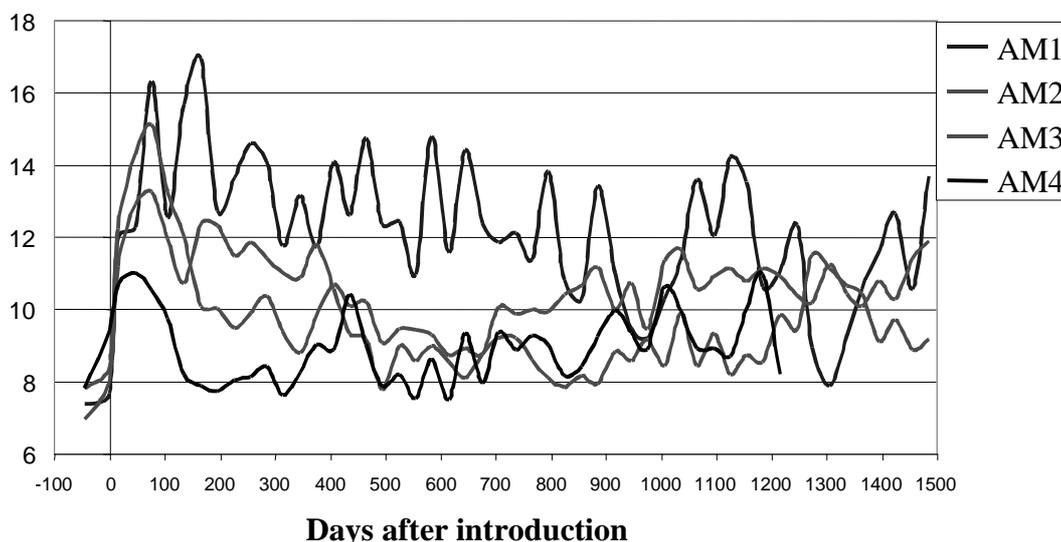


Figure 2. Course of TPC after introduction of the AM-system on Dutch farms (De Koning et al, 2004).

Animal Health

Within the EU project Automatic Milking, special attention was paid to animal health. In Denmark, The Netherlands, and the UK, 15 herds each were recruited for monitoring the impact of transition to automated milking on animal health. The herds recruited represented the types of AMS marketed in each country. Each farm was visited at least twice before installation of the AMS and a minimum of twice, but often up to six times, after installation. On these visits assessments were made of at least half of the cows or fifty animals on body condition and locomotion, and forty cows for teat condition (on some farms in the Netherlands and UK only). Farm data including milk production, milk quality, animal records on individual cow cell count, fertility, animal treatments, animal movements, veterinary purchases were collected.

The body conditions varied more between countries than in response to the introduction of AM (Hillerton et al, 2004). In Denmark and the UK there was no change in body condition between 3-6 months prior to AM installation and 6 months post installation. A slight but not significant drop occurred with the Dutch cows (Dearing et al, 2004). On the Dutch farms the range of body condition narrowed significantly from 1.35 to 0.98 points score suggesting that the farms are managing body condition better.

No change in locomotion was seen one month after AM installation. The scores in Denmark and UK increased slightly by 3 months after installation, but not significant. In the UK the average score increased on seven farms whilst unchanged on 6 farms. Scoring was continued on 12 of the UK farms. Twelve months after installation of AMS the lameness has increased significantly. Prior to installation eleven of fourteen UK herds were grazed but only six after installation. The poorer locomotion may reflect the increase in constant housing (Hillerton et al, 2004).

The overall impact of conversion to AM was assessed by comparing how each individual farm handled the main indicators of animal health during and after the transition to automatic milking. Comparing 12 Dutch farms only one farm improved in locomotion, body condition as well as cell counts. Overall, little change was apparent. Locomotion improved in five herds and deteriorated in five herds. Body condition score decreased in eight herds but only by a small amount. It increased in two herds but not making the cows any fatter, just more typical (Hillerton et al, 2004). The only major deterioration was in average milk cell count and the proportion of cows with a cell count above a threshold, where only two of the herds produced better quality milk. Average milk yield in the Dutch herds decreased in continuation of a trend starting up to 12-months prior to installation of the AMS and the cows became thinner with only a small reduction in DIM. Overall there is little evidence of major changes occurring in the common measures of fertility. None of the changes were statistically significant but all suggestive of poorer fertility, at least in the transition period from conventional milking to AM.

Hillerton et al (2004) conclude that no major problems in converting from conventional milking to AM have been identified but equally none of the 44 farms has been found to achieve a substantial improvement in any aspect of cow health. The transition period to AMS comprises a period of higher risk to health that extends from weeks before installation when resources start to be diverted from cow management.

In most European countries, grazing during summer time is routine (Van Dooren et al, 2002); in some Scandinavian countries even compulsory. Moreover, from an ethological point of view, many consumers in North Western Europe believe grazing is essential for cows and one Dutch dairy pays a premium for milk from grazed herds. In the Netherlands grazing is common practice (>80%). However, only about 52% of the farms with an AM-system apply grazing, showing on one hand that grazing in combination with AM is less common, but on the other that it is still possible (Van der Vorst & Ouweltjes, 2003; Mathijs, 2004). In respect of capacity use of the milking system and percentage of cows to be fetched, restricted grazing systems perform better than unrestricted (Van Dooren et al., 2004). Walking distances of up to 500 meters seem to be of little influence on the frequency of robot visits.

Investment required for AM-systems are much higher than for conventional milking systems and thus the fixed costs of milking are higher. However more milk with less labour means that the costs of milking per kg of milk will decrease. Theoretically, with an AM-system more cows can be kept with the same labour force than with conventional milking, but this may involve additional investments in buildings, land or feed and perhaps in milk quota. On a farm with more than one full time worker the possibility exists to reduce labour input and thus costs. Quite often that does not happen and the time saved as a result of lower labour requirement is used for personal activities. Meskens and Mathijs (2002) found that two third of AM-farmers state social reasons for investing in automatic milking, such as increased labour flexibility, improved social life and health concerns. In parts of North America, with large-size herds and numerous milkers, it may turn out that savings on labour costs may become a decisive motive to implement automatic milking.

Several simulation models have been developed to calculate the pure economic effect of investment in automated milking. The "Room for Investment" model computes the amount of money that can be invested in an AMS, without a decrease in net return compared with conventional milking (Arendzen & van Scheppingen, 2000). The RFI-value calculates the annual accumulated return from increased milk yield, savings in labour, and savings in not investing in a milking parlour and divides this by the annual costs of the AM-system. The model can use farm specific factors and circumstances to calculate the RFI-value. Figure 3 shows the

Grazing

Economical aspects

results of a combined sensitivity analysis illustrating that increased milk yield and labour savings are essential factors regarding the economy of automatic milking. The RFI-value for the basic farm (700.000 kg milk, 8500 kg milk per cow per lactation, 82 cows, 75 hrs of labour per week) with 500 kg per cow yield increase, 0,75 hour net labour saving per day (~10% labour saving), compared with a automated milking parlour and 25% annual costs of the AM-system amounts 137.000 Euro. Both labour saving and yield increase have a large effect on the RFI value. Since capital costs tend to decrease while labour costs tend to increase, more widespread adoption of automatic milking in nearly all areas of the developed world would appear to be only a matter of time.

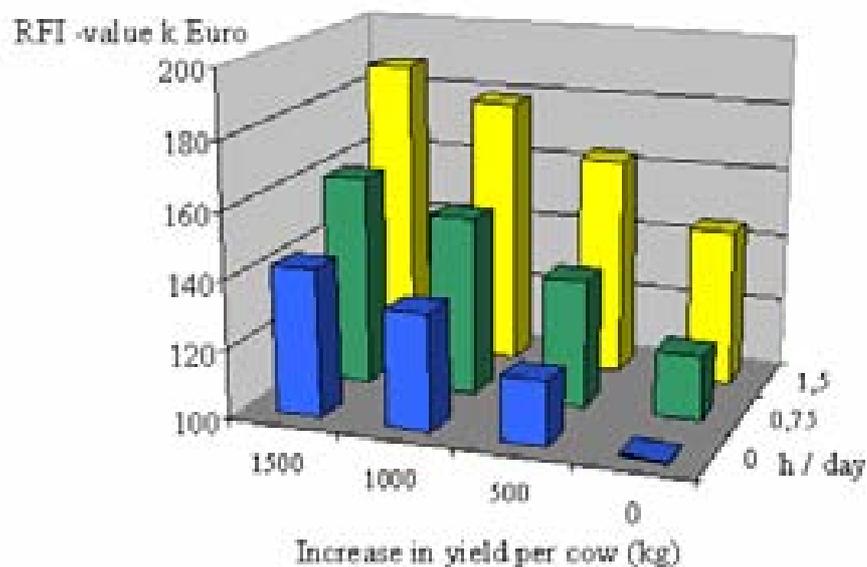


Figure 3. Room for Investment (RFI) due to labour saving and milk yield increase with annual costs for AM-system of 25% of investment. Comparison made with an highly automated milking parlour (De Koning & Rodenburg, 2004).

Conclusion

The number of farms milking with automatic milking has increased significantly since 1998. In areas where labour is expensive or in short supply, automatic milking is a promising alternative for traditional parlour milking. However if (cheap) labour is available, and particularly where herd sizes are large conventional milking, often with rotary or rapid exit parlours equipped with features to increase throughput per man- hour will be competitive.

The introduction of automatic milking has a large impact on the farm and affects all aspects of dairy farming. Because milking is voluntarily there is large variation in milking intervals. Both farm management and the lifestyle of the farmer is altered by automatic milking. AM-systems require a higher investment than conventional milking systems but increased milk yields and reduced labour may lead to lower fixed costs per kg milk. Successful adoption of automatic milking depends on the management skills of the farmer and the barn layout and farming conditions. Both conventional and automatic milking will be used on dairy farms in modern dairy countries in the foreseeable future.

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Comparison of teat tissue changes after milking with conventional or automated milking units

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For this trial, 32 German Holstein Frisian cows were milked conventionally (CON, 2 x 4 tandem parlour with low pipe lines; DeLaval; vacuum: 43 kPa) and 33 cows robotically (VMS, voluntary milking system; DeLaval; vacuum: 43 kPa; mean milking frequency (MF): 2.7 per day). With 21-day intervals, the CON group was sampled 5 times (twice a day) and the VMS group 13 times (during 24 hours at every milking). Parameters included the cytobacteriological status of quarter foremilk (QFM), the changes in thickness (cutimeter technique) prior to and after milking in teat end and teat barrel, and the corresponding changes in teat length. The overall cell count (SCC) mean in QFM in both groups was $< 4.5 \lg$ cells/ml (< 32.000 cells/ml), but differed significantly ($p < 0.0001$). The mean teat end thickness before milking was 11.2 mm, the mean teat length 5.1 cm, displaying the physiological level of teat dimensions. All thickness changes were significantly ($p < 0.05$) lower in the VMS group than in CON. While for VMS, the most significant factor influencing the changes in teat was the variation in milking intervals, in the CON group the quarter position represented the only significant influence on machine-induced teat tissue changes.

Key words: Milking systems, VMS, CON, teat tissue changes

As the majority of pathogens gain access to the gland via the teat canal and local defence may be impaired due to technopathies, the interaction between machine milking and teat tissue is one of the key factors to identify machine-induced influences on the new infection risk of the bovine udder. This study was performed with the main goal of comparing the influences of the two different milking procedures – conventional (CON) and automatic (VMS) - on machine-induced changes in teat characteristics such as teat end thickness, teat barrel thickness and teat length.

Summary

Introduction

Material and methods

The trial cows (German Holstein Frisian) at different lactation stages and numbers were randomly distributed to the milking systems CON (32 cows) and VMS (33 cows). The milking systems were operating with 43 kPa vacuum, 60 cycles/min and a pulsation ratio of 65 %. Sampling pattern included 5 (sampling twice a day) and 13 (sampling every milking during 24 h) sessions in CON and VMS, resp., observing 21-day intervals in both groups. In every session, quarter foremilk (QFM) samples were taken for posterior cytobacteriological analysis (incl. somatic cell count, SCC) and determination of NAGase (NAG) activity. The machine-induced thickness changes at teat end (TEC) and teat barrel (TBC) were determined by applying a cutimeter just before and immediately after milking (Hamann, 1985). Changes in teat length (TLC) were assessed by using a rigid, open-ended transparent tube (internal Ø = 30 mm) marked with a graduated scale from the upper end (Hamann et al., 1993).

Results

Table 1 compares the teat conformation before milking for the CON and the VMS group. It should be stressed that the identical cows could not be included in all sampling days.

Teat conformation

Table 1. Level of absolute values for teat characteristics before milking in both cow groups (CON, VMS).

Parameter	CON	VMS	Significance
Measurements (n =)	1270	4520	(T-test)
Teat end thickness [mm]	11.15 ± 1.31	11.18 ± 1.30	p < 0.3889
Teat barrel thickness [mm]	12.64 ± 1.67	12.14 ± 1.95	p < 0.0001
Teat length [cm]	4.98 ± 0.75	5.24 ± 0.82	p < 0.0001

Significant (p < 0.05) differences between CON and VMS groups regarding TBC and TLC occurred, while corresponding TEC value differences were not significant.

Udder health

Table 2 details the means of SCC and NAG in QFM. Statistically significant differences (p < 0.05) were encountered, but they ranged within the physiological levels.

Table 2. Comparison of SCC and NAG in QFM between CON and VMS cows.

Parameter	CON	VMS	Significance
SCC [lg]	4.43 ± 0.78	4.33 ± 0.81	p < 0.0001
NAG [lg]	0.26 ± 0.28	0.21 ± 0.34	p < 0.0001

As shown in Table 3, the distribution of percentage changes in teat tissue parameters expressed as values indicating an increase (+) or decrease (-) is not homogenous for changes in teat barrel and length (chi-square test) between CON and VMS.

Machine-induced changes in teat characteristics

Table 3. Distribution of percentage changes (PC) in different teat parameters as increase (+), decrease (-) and zero changes (0) after application of CON or VMS.

Parameter Changes	Distribution of changes in percentages (chi-square test)					
	PC (+)		PC (-)		PC (0)	
System	CON	VMS	CON	VMS	CON	VMS
Teat end	41.6	38.8	52.0	55.3	6.4	5.9
Teat barrel	65.2	52.4	31.3	43.4	3.5	4.2
Teat length	69.4	53.0	21.6	36.9	9.0	10.1

Therefore, it is difficult to interpret the mean values of machine-induced changes for the two milking systems adequately. In general and for the milking intervals (MI) between 8 and > 14 h, the mean values for all percentage changes (TEC, TBC, TLC) were significantly ($p < 0.001$; Ryan-Einot-Gabriel-Welsch-multiple-range test) lower in the VMS group than in the CON group.

Table 4. Comparison of percentage changes (+, -) in teat parameters related to different milking intervals (MI) and milking systems (CON, VMS).

Parameter	Teat end		Teat barrel		Teat length	
	CON	VMS	CON	VMS	CON	VMS
System	CON	VMS	CON	VMS	CON	VMS
MI 8-10h	-0.47	-1.19	5.47	0.74	5.50	1.53
MI 10-12h	-0.57	-0.97	5.85	-0.02	6.44	1.87
MI 12-14h	-0.43	-2.12	4.70	-1.57	5.90	3.54
MI > 14h	-0.35	-3.14	3.42	-3.00	5.75	3.03

All differences between CON and VMS significant different, except teat end changes MI 8-10h and 10-12h (Ryan-Einot-Gabriel-Welch-multiple-range test ($p < 0.05$)).

The application of a two-factorial analysis of variance (separately for CON and VMS) pointed out the quarter position as the main factor of influence for CON, but the MI for the VMS.

Table 5. Results ($p < 0.05$) of two factorial analyses of variance (CON or VMS) of percentage changes (+, - or absolute) in teat parameters (TEC, TBC, TLC) related to MI and quarter positions.

Parameter	Milking interval		Quarter position		Interactions	
	CON	VMS	CON	VMS	CON	VMS
TEC (+/-)	n.s.	0.041	<0.001	n.s.	n.s.	n.s.
TEC (abs.)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
TBC (+/-)	0.003	<0.001	<0.001	n.s.	n.s.	n.s.
TBC (abs.)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
TLC (+/-)	n.s.	0.013	n.s.	n.s.	n.s.	n.s.
TLC (abs.)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Discussion

Despite varying durations of the trial (85 days in CON, 253 days in VMS), the general physiological condition during lactation was nearly identical in both groups (not shown here). Teat conformation, mean SCC and NAG in both groups were in a physiological range. Tables 3 and 4 show that the application of VMS always resulted in lower teat parameters values. In so far, these values indicate that the application of automated milking systems *per se* does not lead to greater changes in teat morphology (i.e. a higher risk for new infections) than a conventional system does. Teat thickness changes up to $\pm 5\%$ have been postulated as threshold for an increased mastitis risk (Zecconi et al., 1992). During the present study, this level was not reached in VMS at all and rarely in CON.

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Automatic Milking Systems (AMS) and their influence on the fat content of milk

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The influence of irregular milking intervals (MI) on the fat content of milk was investigated on two farms with 85 cows, each milked with one automatic milking system (Lely). In addition to the influence of the „actual“ MI, the influence of the MI „before“ was also analysed. The difference in milk secretion rates between short (<6h) and long (>12h) actual MI was about 12% and as expected. The fat content of the milk was significantly influenced by both the actual MI and the MI before. Long MI before raised the fat content (<6h → >12h / 3.94% → 4.70%) almost as high as long actual MI lowered it (<6h → >12h / 4.80% → 3.77%). The conclusion is that fat from long MI (with high fat percentage in the residual milk) is transferred into the following shorter MI.

Key words: Milk, secretion, interval, fat, irregular milking interval

It is well known that milk fat is not evenly distributed in milk during milking with highest values towards the end of the milking process. Experiments with regular milking intervals (MI) show that the percentage of fat in different milk fractions is not constant, but after long MI will be lower in foremilk and higher in strippings or residual milk, compared to shorter MI (Grimm, 1984). More confusing results can be seen in milking with irregular MI: milk after long MI will have lower fat content than milk from the corresponding (shorter) MI (Nuber, 1989). This will also occur with automatic milking and thus will confuse calculations of breeding data. So the aim of the present study is to elaborate possible reasons for these findings.

Two farms with automatic milking systems (LELY) were evaluated; farm I with 58 cows (Deutsche Schwarzbunte, 29.8 kg/day) and farm II with 36 cows (Fleckvieh, 19.8 kg/day). Milk samples were collected over a period of 72 hours on each farm and all samples were analysed separately. Additional data was extracted from information during milking: time of milking, duration of milking, milk yield. Not only were the time and length of the actual MI recorded, but also time and length

Abstract

Introduction

Material and methods

of the preceding MI. Here MI „actual“ is the MI from the last milking until the actual milking – where the milk samples were taken – and MI „before“ is the MI before MI actual. For the present evaluation, only data from cows with at least one MI <<9h and one >>12h was used, and if the relation of the calculated milk secretion rates (actual : before) was > 2:3 and < 3:2. In this way, data from incomplete milkings were excluded. The MI were divided in four steps (≤ 6; >6-9; >9-12; >12 [h]). Although data from 94 cows and over 1000 milkings were recorded, only 450 complete data sets from 85 cows could be used. This was due to the necessity of including complete data from two consecutive milkings: both MI actual and MI before. The results were calculated with SPSS (Version 11.5 for Windows). The influence of MI actual and that of MI before (Least Squares Analysis) was calculated according to the following model:

$$y_{ijkl} = \text{cow}_i + \text{MI actual}_j + \text{MI before}_k + (\text{MI actual} * \text{MI before})_{jk} + 0_{ijkl}$$

were

- | | |
|--|--|
| y_{ijkl} | = trait value |
| cow_i | = random effect of cow (i = 1..85) |
| $\text{MI}'\text{actual}'_j$ | = fix effect of the actual interval (j=1..4) |
| $\text{MI}'\text{before}'_k$ | = fix effect of the interval before (k=1..4) |
| $(\text{MI}'\text{actual}' * \text{MI}'\text{before}')_{jk}$ | = interaction MI actual*MI before |
| 0_{ijkl} | = error of estimate |

Results and discussion

Figures 1a – c show the relations between consecutive milkings for the recorded traits. Relations between secretion rates and between protein contents are very close, whereas those for fat are almost undetectable.

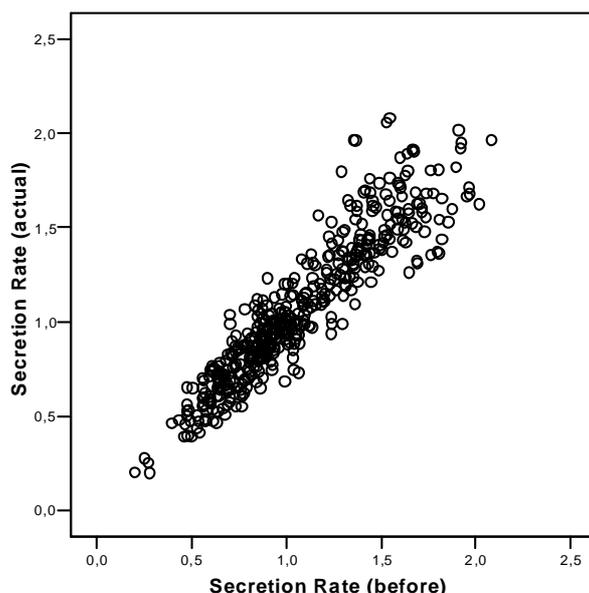


Figure 1a. Actual secretion rates [kg/h] in relation to secretion rates before.

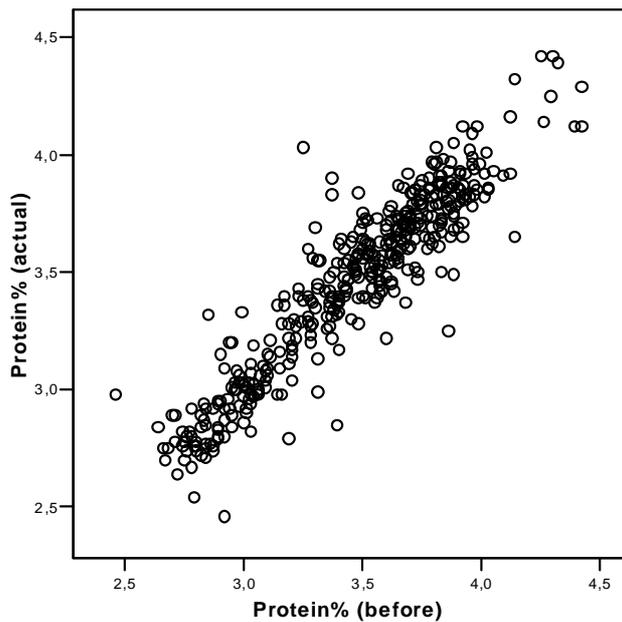


Figure 1b. Actual protein content in relation to protein content before.

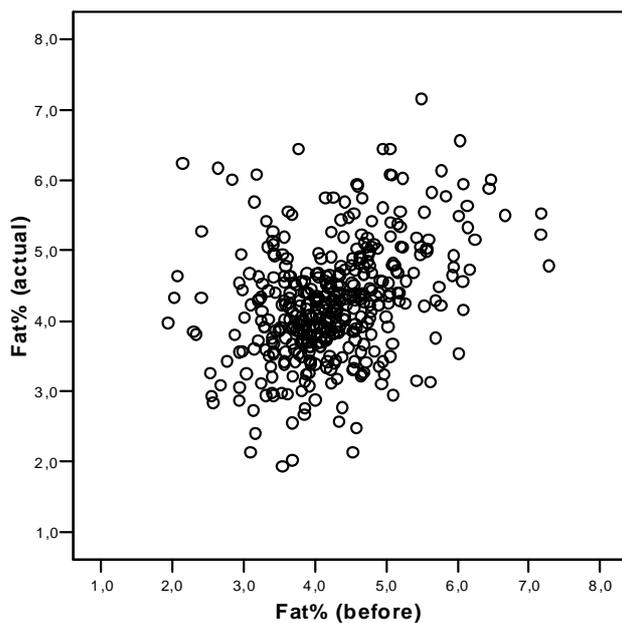


Figure 1c. Actual fat content in relation to fat content before.

The results for protein content ($r^2 = 0.86$) and secretion rate ($r^2 = 0.58$) are as expected. It is astonishing, however, to see almost no correlation between the fat content of milk from two consecutive milkings ($r^2 = 0.1$). These differences can be explained by the results of the least squares analysis according to the statistical model mentioned above: the closest relation between values of two consecutive milkings is found with a parameter that is entirely uninfluenced by milking interval (protein

content), followed by parameters that are (physiologically) influenced by the length of the actual milking interval only (secretion rate, milk yield [$r^2 = 0.22$ – graph not shown]) and almost no relation can be found when the parameter is influenced by both intervals - actual milking and milking before (Table 1).

The lower secretion rate after milking intervals longer than 12 h, compared to short milking intervals of less than 6 h, is as expected (~12%). The fat content of the milk, however, is influenced by both the actual milking interval and the milking interval before. The higher fat content after short actual milking intervals is as expected. The influence of short milking intervals before the actual milking interval is quite the opposite – they will lower the fat content of the milk.

The results from Grimm (1984) may help to explain these findings. He found that the fat content of the milk from a complete milking is neither influenced by the length of the milking interval (6 or 12h) nor by a diurnal rhythm. There are big differences, however, within the milkings: the fat content of the milk after long milking intervals is lower at the beginning of the milking and higher towards the end of the milking (strippings, residual milk) compared with short milking intervals. This means that no differences in fat secretion can be found with regard to any diurnal rhythm, but there are big differences in the stratification of milk fat in the udder. As a consequence, differences in the fat content of the milk – when milking with uneven intervals during day and night, respectively – are not due to different secretion rates of fat. It seems reasonable that in „evening milk“ more fat can be found from the residual milk from the morning (longer interval at night and consequently higher fat content of this residual milk) and *vice versa*.

Table 1. Estimated least squares means for actual milking interval (MI actual) and milking interval before (MI before).

Milking Interval	Milk Yield [kg]	Secretion Rate [kg/h]	Protein [%]	Fat [%]
MI actual	***	***	-	***
1 (< 6h)	5.19	1.12	3.43	4.80
2 (6 – 9h)	7.71	1.03	3.45	4.54
3 (9 – 12h)	10.44	1.00	3.47	4.14
4 (> 12h)	12.59	0.97	3.44	3.77
MI before	-	-	-	***
1 (< 6h)	9.06	1.03	3.44	3.94
2 (6 – 9h)	9.14	1.06	3.43	4.17
3 (9 – 12h)	8.77	1.02	3.45	4.43
4 (> 12h)	8.96	1.00	3.48	4.70

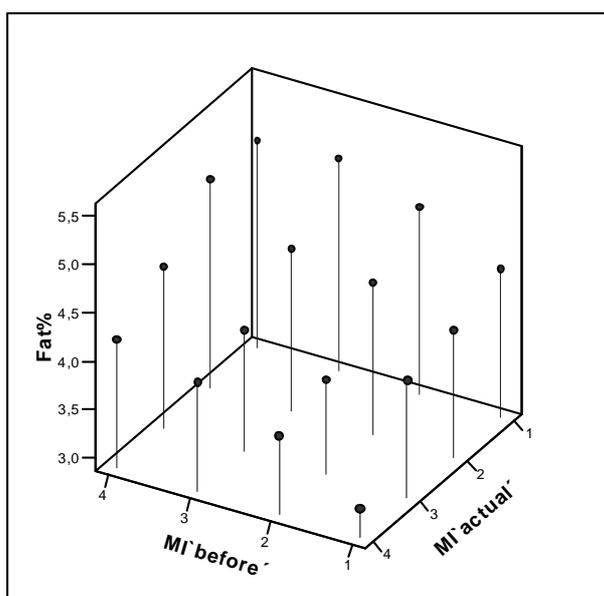


Figure 2. Fat content per cell of (MI actual x MI before)

Earlier results (Ludri, 1984; Nuber, 1989) showed lower fat contents of the milk after longer milking intervals – when the corresponding milking interval was shorter. In those studies the effect of the actual milking interval was investigated, but not that of the milking interval preceding the current milking interval. The present observations, however, show increasing fat contents with longer MI before.

- No difference in fat content during even milking intervals
- Higher fat content in strippings and residual milk after long milking intervals
- Higher fat content after short milking intervals and lower fat content after long milking intervals – when consecutive milking intervals are uneven lead to the following interpretation:

Long milking intervals increase the fat content in the residual milk and cause transfer of milk fat to a following, under practical milking conditions shorter, milking interval – resulting in higher fat contents of milk after these short intervals.

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Conclusions

Results

References

Effect of two milking systems on the milking performance of dairy cows over a complete lactation

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Dairy cows were milked with either of two milking systems over a complete lactation. Milking system 1 (WB) had of a heavy cluster weight and wide-bore tapered liners. Milking system 2 (NB) used a light cluster weight and narrow-bore liners. There was no significant difference between milking systems for milking time, milk-flow rate, gross milk composition or new infection rate. Milk yield was ($P<0.08$) higher at the morning milking for WB than for the NB milking system. There was a significant ($P<0.001$) interaction for all parameters with lactation stage and a system x stage interaction ($P<0.01$) for somatic cell count (SCC), with NB tending to have higher SCC during lactation than the WB milking system. Both systems gave satisfactory milking performance.

Key words: Dairy cows, milking systems, teat tissue

In Ireland cows are milked with milking machines using heavy clusters, and wide-bore tapered liners or with an alternative milking system, which incorporates a light cluster weight and narrow-bore tapered liners. Vacuum at the teat-end, was shown to be 7kPa higher for wide-bore liners with simultaneous pulsation patterns as compared to narrow-bore liners using an alternate pulsation pattern (O' Callaghan, 1998). This increased vacuum may affect milking time (Gleeson *et al.*, 2003) and changes in teat thickness (Hamann *et al.*, 1993), which is associated with higher infection rates (Zecconi *et al.*, 1992). The objective of this study was to compare the affect of two milking systems on milking characteristics, SCC and teat tissue over a complete lactation.

Fifty-six Holstein-Friesian dairy cows were assigned to either of two milking systems at calving. Milking system 1 (WB) consisted of a heavy cluster weight (3.2kg) with a claw volume of 150ml, wide-bore tapered liners (31.6-21.0mm) and a simultaneous pulsation pattern. System 2

Summary

Introduction

Material and methods

(NB) used a light cluster weight (1.65kg) with a claw volume of 275ml, narrow-bore tapered liners (25.0–21.0mm) and an alternate pulsation pattern. All cows were milked in a 14-unit, 80-degree side-by-side milking parlour, using id-13.5mm long milk tubes, with a milk lift of 1.5m above the cow standing. Cows were milked at intervals of 16h and 8h. Milk yield (kg), milking time (sec) and peak milk flow-rate (l/min) was recorded daily. The pulsation rate was 60 cycles/min and pulsator ratio was 65.1 and 68.4 % for NB and WB milking systems, respectively. The system vacuum level was 48kPa and system vacuum reserve was 870-l/min. Milk samples were measured weekly for fat, protein and lactose percentage and biweekly for SCC. Changes in teat tissue after machine milking were measured during mid and late lactation using ultrasonography. The measurements recorded were teat canal length, teat diameter thickness, cistern diameter, teat wall thickness and teat length. Measurements of teat tissue (mm) are presented as the mean changes in values per teat directly after milking as compared to pre-milking values.

Results and discussion

There was no significant difference in lactation milk yield between milking systems. However, morning milk yield tended to be higher ($P < 0.08$) for the WB system as compared to the NB system. There were no differences between milking systems for milking time, milk butterfat, protein, lactose percentages and SCC. There was a significant ($P < 0.001$) interaction for all measurements with lactation stage. This interaction could be expected as milk yield per cow is reduced as the lactation progresses. There was a system x stage interaction for SCC ($P < 0.01$) and peak milk-flow-rate ($P < 0.08$). NB tending to have higher SCC during the lactation than the WB milking system and a higher peak flow-rate during the latter part of lactation. Increased changes in the cistern diameter ($P < 0.001$) and teat wall thickness ($P < 0.01$) were shown with WB as compared to the NB milking system at the mid lactation stage. While changes in teat diameter tended to be higher with the WB system as compared to the NB system, these changes did not result in higher infection rates. There was no difference in the incidence of clinical mastitis or sub-clinical mastitis between systems. The number of cows with clinical mastitis was 9 (15 cases) and 13 (16 cases) for WB and NB milking systems, respectively.

Table 1. Mean daily milk yield, milking time, peak milk flow-rate, and somatic cell count for WB and NB milking systems for the complete lactation.

	WB	NB	SED	Lactation Stage (P)	System (P)	Lactation Stage x System (P)
Milk yield AM (kg/c/)	13.40	12.73	0.42	0.001	0.08	NS
Daily milk yield (kg/c)	20.19	19.47	0.70	0.001	NS	NS
Daily milking time*	0.054	0.055	0.003	0.001	NS	NS
Daily peak flow-rate (l/min)	3.22	3.31	0.18	0.001	NS	0.08
SCC (Log ₁₀)	4.76	4.89	0.11	0.001	NS	0.01

*Milking time= (yield/time*100) SED: standard error of differences

Table 2. Effect of milking system on mean teat-tissue changes (mm.)

	Mid lactation				Late lactation			
	WB	NB	s.e.d	Sig	WB	NB	s.e.d	Sig
Canal length	2.11	1.89	.52	NS	1.86	1.54	0.63	NS
Teat diameter	1.16	0.84	.34	NS	1.08	0.43	0.39	NS
Cistern diameter	-5.85 ^a	-4.31 ^b	.46	0.001	-7.23	-6.23	0.63	NS
Wall thickness	2.21 ^a	1.26 ^b	.32	0.01	2.67	2.59	0.32	NS
Teat length	7.7	5.5	2.85	NS	7.34	4.89	1.84	NS

^{ab} Means, within rows, with different superscripts differ significantly P<0.05 for milking system

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Comparison between conventional and automated milking systems – udder health, milk secretion and milk yield

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Approximately 80 German Holstein Frisian cows were milked robotically (VMS®, DeLaval) and 40 cows conventionally (CON) throughout 400 days. During 20 session days at 20-days intervals, samples (quarter foremilk [QFM], quarter composite milk [QCM] and cow composite milk [CCM]) were drawn during the two milkings (CON) or during the session day (24 hours; VMS). QFM were examined cytobacteriologically. Somatic cell count (SCC) was also determined in QCM and CCM. Milk NAGase activity, lactate, fat, protein and lactose were analysed in QCM. Mean daily yield per cow was 26 kg for both groups despite different milking intervals (VMS: 2.7 and CON: 2 milkings/d). Data analysis (SAS, PROC GLM) evaluated SCC, milk secretion and milk composition in relation to milking intervals (MI).

The overall SCC in QCM in both groups (VMS and CON) with < 4.8 lg cells/ml shows clearly that an automated milking system is not causing an increase in SCC *per se*. Milk secretion rate showed significant (p < 0.05) differences between all five MI as higher secretion rates occurred for shorter MI (i.e. MI = 6 h: 356 g/h; MI > 12 h: 232 g/h), amounting this difference to 35 %. Moreover, a non-linear secretion pattern was observed at all MI.

Keywords: Milking systems VMS, CON, udder health, milk secretion, milk yield

Besides genetics, feeding and management, the udder health status is also strongly determined by the milking system and, possibly, the corresponding milking interval (MI). It is assumed furthermore that factors like the variation of MI as well as the frequency and the degree of

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incomplete milkings may cause marked reductions in milk secretion and therefore reduced milk yields. Also, very little information is available on milk constituents in relation to different MI. Therefore, this study was performed to detail the influences of CON and VMS milking systems on udder health, milk secretion and milk yield as the most important economic factors determining the efficacy of dairying.

Material and methods

The 120 German Holstein Frisian cows at different lactation stages and numbers were randomly distributed to the milking systems. Study 1 (S1) was conducted mainly to compare udder health and milking performance of CON and VMS, while study 2 (S2), performed 1 year later than S1, included 40 cows using the same VMS system and focused on a detailed analysis of the milk components. The milking systems were operating with 43 kPa and 42 kPa vacuum (CON and VMS, resp.), 60 cycles/min and a pulsation ratio of 65 %. The milk yield was assessed on cow (CON) or quarter (VMS) level. The different milk constituents were measured by corresponding systems, i.e. Fossomatic (somatic cell count, SCC), Fluorometer (NAGase activity), AutoAnalyser (lactate) and Milkoscan (fat, protein, lactose).

Results

Table 1 compares the SCC and NAG values in QFM between the CON and VMS groups (S1) regarding four udder health categories (20 session days; ~30 cows/group).

Udder health

Table 1. Comparison of SCC and NAG in QFM between CON and VMS.

Health status	Normal secretion		Latent infection		Unspecific mastitis		Mastitis	
	CON	VMS	CON	VMS	CON	VMS	CON	VMS
System	CON	VMS	CON	VMS	CON	VMS	CON	VMS
n =	2124	1780	369	415	512	391	382	267
SCC [lg]	4.21	4.28	4.46	4.50	5.48	5.39	5.43	5.48
NAG-U [lg]	0.18	0.15	0.23	0.20	0.71	0.62	0.53	0.56

The mean SCC and NAGase values showed no significant ($p < 0.05$) differences between CON and VMS, ranging the overall SCC mean for the two groups below 40,000 cells/ml.

Table 2 details the SCC in different milk fractions for S2 (VMS) in order to evaluate the repeatability of results in different milk fractions (QFM, QCM and CCM) considering the udder health category.

Table 2. Comparison of SCC in different milk fractions (VMS; 33 cows, 400 days).

Health status	Normal secretion	Latent infection	Unspecific mastitis	Mastitis
Quarters: n=	3212	1592	703	687
QFM: SCC [lg]	4.24 ^c	4.41 ^b	5.31 ^a	5.34 ^a
QCM:SCC [lg]	4.49 ^c	4.63 ^b	5.46 ^a	5.49 ^a
CCM: n=	312	499	309	562
CCM:SCC [lg]	4.39 ^d	4.46 ^c	5.17 ^b	5.23 ^a

*) different letters within lines indicate significant differences ($p < 0.05$)

In both studies, the mean milking frequency was significantly ($p < 0.05$) higher (2.7 milkings/day) in the VMS group (CON: 2 milkings/d). The secretory activity means (i.e. g/h and cow) in relation to lactation stage (days in milk; DIM) and milking system (CON, VMS) are summarized in Table 3.

Milk secretion

Table 3. Comparison of secretory activity [g/h and cow] in relation to lactation stage (days in milk; DIM) for study 1 (S1) and study 2 (S2).

Study	MF/24 h	1 - 100 d	101 - 200 d	201 - 300 d	> 300 d	Total
S1: CON	2.00	1332 ^a	1190	910	708	1098 ^a
S1: VMS	2.74	1444 ^b	1222	938	706	1142 ^b
S2: VMS	2.86	1485 ^c	1237	926	736	1136 ^c

*) different letters indicate significant differences ($p < 0.05$) within columns

Significant differences ($p < 0.05$) between studies and milking systems were observed merely for the early lactation (DIM 1-100) and the complete lactation. The secretory activity was reduced by approx. 50 % from DIM 1 - 100 to DIM > 300 in all milking systems.

The influence of different MI on milk secretion and milk components (QCM) under VMS conditions is summarized in Table 4.

Table 4. Comparison of secretory activity [g/h and quarter] and milk components related to different milking intervals (QCM; VMS).

Interval	< 6 h	6 – 8 h	8 -10 h	10 – 12 h	> 12 h
Milkings: n =	490	1880	1859	1081	884
g/h/quarter	356 ^{a*}	310 ^b	286 ^c	260 ^d	232 ^e
SCC [lg]	4.77 ^a	4.72 ^b	4.73 ^b	4.78 ^a	4.79 ^a
NAGase [lg]	0.19 ^e	0.22 ^d	0.26 ^c	0.33 ^b	0.37 ^a
Lactate [lg]	1.43 ^a	1.43 ^a	1.43 ^a	1.42 ^a	1.48 ^a
Lactose [%]	4.83 ^a	4.81 ^b	4.79 ^b	4.74 ^c	4.73 ^c

*) different letters within lines indicate significant differences (p < 0.05)

Significant (p < 0.05) differences occurred between the quarter secretion rates at all MI. Regarding milk constituents, a basically non-linear pattern of secretion in relation to the different MI was observed for all parameters but lactate.

Milk yield

Milk secretion rates were significantly (p < 0.05) different between healthy and diseased udder quarters (347 vs. 266 g/h). Despite this, the milk yield of the two systems were rated, under practical aspects, as comparable.

Discussion

Based on these two studies, each lasting 400 days, the tendential udder health, milk secretion and milk yield was compared between CON and VMS milking systems (Reinecke, 2003; Halm, 2003), and while udder health was the same, secretion rate increased significantly in the VMS group for the first 100 DIM. Yet, the lactational yield was practically identical in both systems. Since higher yields were one reason for the implementation of VMS, this data should incite to further improve this innovative system. Against common assumption, the secretion pattern was not time-linear, neither for yield nor for milk composition. More study is needed to investigate this phenomenon.

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Usefulness of standard milk components for monitoring udder health

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With respect to upcoming devices for on-farm analysis of milk it was evaluated, whether milk components, being object of standard milk analysis, could be used as indicators of udder health. As to be deduced from several publications it was found that variations of lactose content were corresponding in a rather stable way with variations of somatic cell count. It therefore can be concluded that this component, beyond electrical conductivity of milk, could be useful for monitoring udder health at on-farm level.

Key words: Milk components, udder health, on-farm milk analysis

Data about milk components, to be found in every protocol of standard milk analyses, mainly are related to fat, protein and lactose. All these components are useful for herd management purposes, e.g. optimisation of cow feeding. Lactose, originating from the synthetic activity of the mammary gland, as mentioned e.g. by SCHLIMME and BUCHHEIM (1995), is one of the osmotic relevant components of milk. When, due to an infection by pathogens (LERCHE, 1966; TOLLE, in: GRAVERT, 1983), its production is inhibited, mineral substrates, mainly containing sodium and chloride, are entering the milk, stabilising the osmotic pressure of the mammary gland, but also increasing the electrical conductivity of milk. It therefore is obvious that, beyond somatic cell count, not only electrical conductivity but also lactose may be an indicator for detecting disturbances in the mammary gland (TOLLE, in: GRAVERT, 1983), if data are available with short delay.

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In recent years at least one research project (France Contrôle Laitier, France) was indicating upcoming facilities for on-farm-milk analysis, which not only would reduce the amount of samples to be stabilised and transported to central laboratories, but also would produce a rapid feedback to the farmer, improving the efficiency of herd management. That system, prototypes of which were tested for some time at several departments in France, is using near infrared parameters for milk analysis. So it is able to evaluate with good accuracy standard milk components, like fat, protein and lactose, but it does not provide direct information on somatic cell counts of milk samples.

It therefore was investigated to what extent standard milk components would be useful for monitoring udder health. Furthermore, spectroscopic parameters of samples were evaluated according to the standard CIE- $l^*a^*b^*$. Electrical conductivity, commonly used as an indicator of udder health, also was recorded.

Experiments

At the experimental station of FAL, Braunschweig, from a group of 15 cows over a whole lactation about 2200 foremilk samples were taken by quarter. Standard milk analyses were done in the central laboratory of the local milk recording organisation.

Analytical results were classified according to three levels of somatic cell count (SCC), representing < 200 000 cells/ml (1666 samples), 200 000 – 500 000 cells/ml (296 samples), > 500 000 cells/ml (209 samples). For each parameter, included into the experiments, the coefficient of correlation to SCC was calculated.

Results

The average milk yield per cow over the whole lactation varied between 15,1 and 15,3 kg at various SCC levels (Tab. 1). As to be expected, there was an obvious negative correlation between milk yield and week of lactation, but no influence of this parameter on level of SCC was to be found.

Average electrical conductivity increased from 5,6 mS/cm at a SCC of <200 000/ml to 5,9 mS/cm at 200 000-500 000 somatic cells/ml up to 6,4 mS/cm at >500 000 somatic cells/ml. Significant positive correlation to SCC was found for this parameter at all levels of SCC.

As to be deduced from earlier investigations, a standard milk component, clearly interacting with SCC at all three levels, was lactose. The average concentration varied from 4,9% at the SCC-level <200 000/ml to 4,6% at 200 000/ml to 500 000/ml and down to 4,3% at the level >500 000/ml.

Table 1. Survey of monitored parameters at foremilk samples.

Parameter	SCC (* 1000/ml)					
	< 200		200 - 500		> 500	
	Average	SD	Average	SD	Average	SD
Yield (kg)	15,1	4,0	15,3	4,4	15,2	4,4
SCC (* 1000/ml)	45,0	48,0	320,9	82,2	1440,4	2102,2
Cond. (mS/cm)	5,6	0,3	5,9	0,5	6,4	0,7
Fat (%)	1,5	0,7	1,7	0,7	1,9	0,9
Protein (%)	3,4	0,3	3,4	0,3	3,4	0,3
Lactose (%)	4,9	0,2	4,6	0,3	4,3	0,5
Luminance	69,3	2,4	67,8	2,6	67,3	2,7
Red/green	-2,6	0,4	-2,7	0,5	-2,5	0,5
Yellow/blue	-1,0	1,4	-1,7	1,7	-1,4	1,8

Table 2 gives a survey of the correlation of evaluated parameters to SCC. It can be seen that for all classes of SCC there was found an interaction between SCC and lactose which in all classes is beyond the limit of $p < 1\%$ ($> 0,08$ for SCC below 200 000/ml, $> 0,18$ for the other classes).

Data included into table 2 indicate that also other parameters were affected by SCC. As to be expected, electrical conductivity in average behaved in a rather constant way. In the class > 500 000 cells/ml protein was also reacting rather clearly on variation of SCC. Spectroscopic parameters, however, did not behave in a uniform way. While luminance was negatively correlated with SCC, especially at lower classes, the parameters red/green and yellow/blue were shifting in a clear direction, towards red and yellow, only above 500 000 somatic cells/ml.

An additional cow specific evaluation of data has shown that, especially at cell counts below 200 000/ml, lactose was correlated to SCC at least at a level comparable with electrical conductivity. The behaviour of spectroscopic parameters in cow specific samples was less constant. They produced most sensitive reaction at the lowest and the highest classes of SCC. Of course it should be suspected that colour of milk also may be affected by species of pathogens being present in the mammary gland.

Table 2. Survey of correlation of monitored parameters with SCC.

Parameter	SCC (* 1000/ml)		
	< 200	200 - 500	> 500
Yield (kg)	0,001	0,021	-0,097
Cond. (mS/cm)	0,227	0,245	0,223
Fat (%)	0,062	0,072	0,192
Protein (%)	0,044	-0,116	0,478
Lactose (%)	-0,318	-0,265	-0,329
Luminance	-0,158	-0,124	-0,066
Red/green	-0,128	-0,006	0,283
Yellow/blue	-0,087	-0,033	0,344

Conclusions

Besides direct counting of somatic cells, which already is possible at on-farm conditions, and monitoring electrical conductivity of milk, to be regarded as an indirect parameter, also lactose can be useful for evaluating udder health. It will not require additional technical input as soon as on-farm analysis of milk components will be available. The sensitivity of that milk component at low cell counts may be of special interest for herd management.

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Detection of clinical mastitis in automatic milking systems

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The objective of this paper was to determine state-of-the-art ability of AMS to detect abnormal milk or clinical mastitis. Five different models of AMS were tested in six herds and sampled for 13 to 48 hours to find at least 10 cow milkings with abnormal milk and 50 cow milkings with normal milk. Due to the short sampling periods, the CMT-score of the foremilk was used to identify and support classification of abnormal and normal milk. Cows and quarters with a CMT-score >3 and no clots on a 0.1 mm filter were omitted from the calculations.

The current AMS models have systems to produce alarm lists of cows whose milk should be checked for abnormalities, but these systems are not intended for automatic diversion of milk at present. This should be taken into account when evaluating the current systems. The sensitivity of the detection for the six herds varied from 13 to 50% when calculated for the actual milking, from 22 to 100% for the test days, and from 43 to 100% when calculated for the previous week. Specificities for the same time periods were found to be 87-100%, 85-100%, and 35-100%, respectively. At present, the sensitivities and specificities are generally too low for automatic diversion of abnormal milk, and it seems that most of the models could benefit from application of more sophisticated algorithms.

Key words: Automatic milking systems, clinical mastitis, sensitivity, specificity

Automatic milking systems (AMS) mainly base detection of cows with mastitis on the measurement of milk conductivity. The conductivity of the milk increases in quarters with subclinical and clinical mastitis and comparisons between the four quarters and maybe inclusion of historical data make it possible to detect mastitic quarters. However, being mastitic is not a steady condition because infected quarters may have high and fluctuating SCC and a varying excretion of bacteria. The foremilk may occasionally or never show clinical signs and the milk yield of the infected quarter may be reduced. The automatic detection systems do not divert abnormal milk automatically at present but produce an alarm list, which

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herds with more than 100 cows we expected to be able to find at least 10 cow milkings with abnormal milk from at least five different cows. One herd was selected for each of the AMS models 1 to 4 and two herds for no. 5. The models are kept anonymous in the tables. Only one of the AMS models was equipped with a colour sensor to automatically divert milk with blood.

Data were collected from the five AMS models present in Denmark, i.e. DeLaval VMS, Fullwood Merlin, Gascoigne Melotte, Insentec Galaxy, and Lely Astronaut. The six selected herds were sampled for various numbers of hours from 13 to 48 and at least 50 cows with normal milk were sampled twice in each herd. Cows were foremilked in the milking box just before the automatic milking. Foremilking was done into a four-chambered strip cup with 0.1 mm filters mounted at the outlet, a CMT-scoring plate collecting the foremilk from each quarter. Visual scoring was done during foremilking. A small amount of water was run through the filters to remove foam before the visual inspection of the filters. CMT-scoring was also done immediately after foremilking. Two consecutive milkings without clots on the filter, no visual abnormality, and low CMT-score were needed to classify cows and quarters as normal whereas any milking with clots on the filter and a CMT-score >3 was rated as abnormal. The remaining unclassified cows and quarters were either omitted (first milking but otherwise normal) or discarded (CMT-score >3 or visually changed in colour but no clots on the filter).

Sampling was carried out in the six herds for a time period of 13 to 48 hours and resulted in collection of foremilk scorings of 169 to 623 cow milkings (Table 1). A large percentage of the samples were omitted, especially in the herds with a short sampling time. About 5 to 15% of the cow milkings were discarded because the CMT-score was 4 or 5 or they were visually changed in colour but with no clots on the filter. The number of cow milkings with normal milk was from 47 and up and the number of cow milkings with abnormal milk was from 4 to 18.

All herds had an alarm list based on conductivity and the results are presented in Table 2. The number of discarded samples that appeared on the alarm lists varied. One to five cow milkings with abnormal milk matched directly the alarm based on conductivity and 2 to 13 did not.

Table 3 presents the sensitivities and specificities calculated for the actual milkings, the test days, and the previous week (including the test day). Sensitivities were generally low for the actual milking and increased when looking at a longer time span. Specificities were generally high at the actual milking and dropped when looking at a full week. Herd 5 had the lowest specificity for the actual milking but it turned out that sensors were not calibrated sufficiently. Consequently, the specificity was very low when looking at the alarm list for a week. It could be speculated that the relatively high numbers of abnormal cow milkings found in Herd

as the main source of information for mastitis detection (de Mol and Woldt, 2001). Some of the systems may obviously benefit from adopting and implementing such calculation models.

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Table 1. Number of cows and milkings in the tested herds.

Model	Herd	AMU	Cows	Hours of		No. of cow milkings				Quarters	
				AMU	Hours of sampling	Total	Drop	Discard	Normal	Abn.	Normal
1	1	2	79	48	350	89	46	206	9	936	9
2	2	3	145	13	222	113	35	56	18	256	22
3	3	4	116	13	178	90	21	61	6	243	6
4	4	2	100	14	192	104	26	47	15	227	15
5	5	2	105	16	169	102	7	54	6	223	6
5	6	3	184	36	623	184	69	366	4	1526	7

Differences in milk conductivity on quarter level induced by milking machine

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Measurement of electrical conductivity (EC) of milk to detect mastitis is now common in most of the milking systems. EC indicates changes of tissue permeability, but does not reveal the causes of these changes. A monitoring of udder health in a herd milked in a rotary parlour showed significant higher EC readings for the right front quarter. The analysis of the data indicated a systematic influence by twisted milking clusters. To review this hypothesis, EC of quarter foremilk was measured monthly in a herd (120 cows) where the milking cluster is usually attached with the long milk tube right angled to the cow. Quarter strippings were gained in the middle and at the end of lactation (n = 19 cows). The forces applied to the teats were measured by a device developed by Deutsche Landwirtschaftsgesellschaft (DLG). 84 cows (55 %) were measured at least 6 times during the investigation. 56 % of them were always milked at the same parlour side: on 21 (25 %) and 26 (31 %) cows the cluster was attached on the left and on the right side of the body, respectively. The preference of one parlour side influenced the EC readings of the quarter. EC of the left front quarter was higher when the cow was always milked from the left side and vice versa. No cases of clinical mastitis on the left front quarter were observed in cows which were milked from the right side and vice versa. The manually gained quarter strippings did not significantly differ. The results indicated a monotonous strain of the teat tissue. A continuous measurement of EC on quarter level might be used for the detection of unequal forces applied to the teats by the milking machine. However, the results also indicated a possible bias of EC readings used for the monitoring of subclinical mastitis.

Keywords: *Electrical conductivity, machine milking, udder health*

To monitor the udder health, EC of foremilk was measured monthly in a herd of 330 cows milked 3 times per day in a rotary parlour. The right front quarters showed significant higher EC readings but not necessarily higher somatic cell counts (SCC) and the incidence of clinical mastitis

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cases was doubled compared to the left front quarter (BARTH & WORSTORFF, 2003). The observation of the milking routine revealed an unilateral influence: the cup of the right front teat was always slightly twisted. SUTTER (1988) showed, that different cluster positions might cause changed tensile forces on the teats and lead to unequal yields of machine stripping per quarter.

The present study aimed to investigate the influence of a twisted milking cluster on the EC readings in foremilk.

Materials and methods

The herd of the research station consisted of 120 cows, which were milked two times per day in a 2x5 tandem parlour. The milking cluster was always attached with the long milk tube right angled to the cow (figure 1).

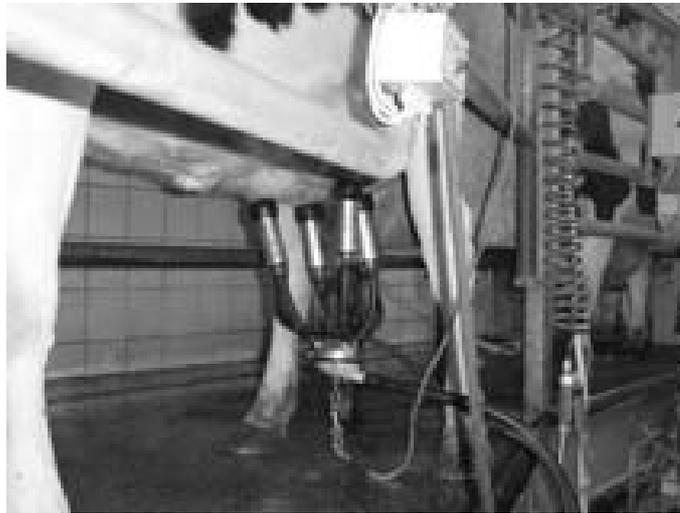


Figure 1. Cluster position with the long milk tube right angled to the cow.

From October 2002 to July 2003, EC was measured monthly with a hand-held conductometer on foremilk prior to udder cleaning to avoid alveolar milk ejection. The cow's position in the milking parlour (right or left side) was registered. In the middle and at the end of lactation strippings were gained after the automatic remove of the cluster. Cows were not used to be stripped manually after machine milking and sampling was difficult. Thus, only a part of the herd (n = 19 cows) was sampled. Teat positions of 41 cows were measured in mid lactation.

The forces applied to the teats were measured by a device, which was developed by the Deutsche Landwirtschaftsgesellschaft (Rose & Klimetschek, 2004). A test stand simulates different udder shapes (normal, unequal teat positions etc.) and data of different forces (torsion, horizontal, vertical, tilt) caused by the cluster were recorded (figure 2).



Figure 2. Test device to measure forces applied to teats developed by Deutsche Landwirtschaftsgesellschaft.

Due to other experiments carried out during the investigation period and due to culling of cows, the number of animals in the herd was not stable. 84 cows (55 %) were recorded at least six times during the experiment. 56 % were always milked at the same parlour side. On 25 % (n = 21) of the cows the cluster was attached on the left side, and 31 % (n = 26) were milked from the right side of the body.

The preference of the parlour side influenced the EC readings of the quarter. EC of the left front quarter was higher when the cow was always milked from the left side and vice versa (figure 3). Torsional forces applied to the teats might offer an explanation. When the cluster was attached from the left, the torsional force measured at the front left position was the highest (figure 4). The shape of the udder might contribute to the strain: the mean distance between the two front and the two rear quarters was 20 and 10 cm, respectively. Thus, the cluster puts more stress on the front quarter of the outside position. The gentler treatment of the inner front quarters might be the reason that no case of clinical mastitis was observed in these quarters. Another explanation would be that the quarters which are better to reach by the milker are healthier (Bothur *et al.*, 1977).

Results and discussion

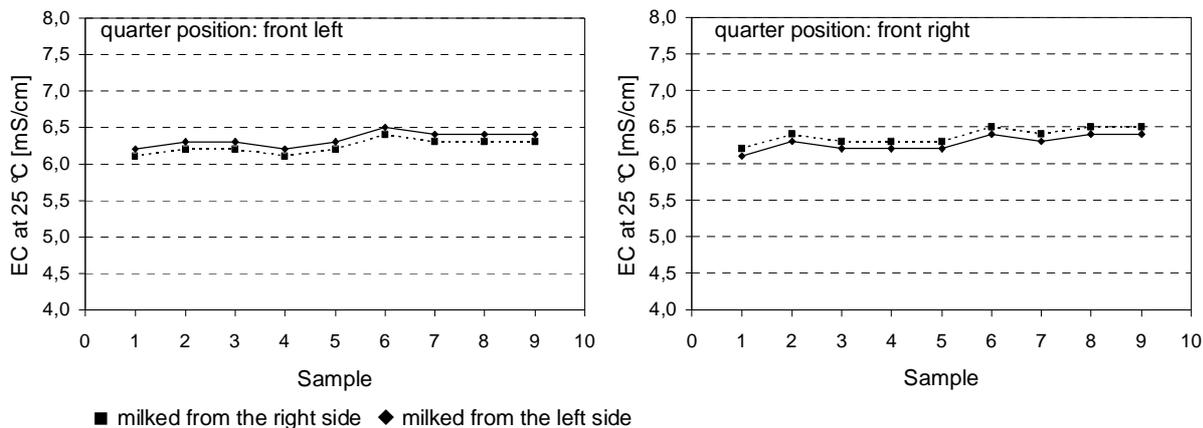


Figure 3. Mean electrical conductivity (EC) of foremilk gained from left and right front quarter of cows milked always from the left or right side of the body.

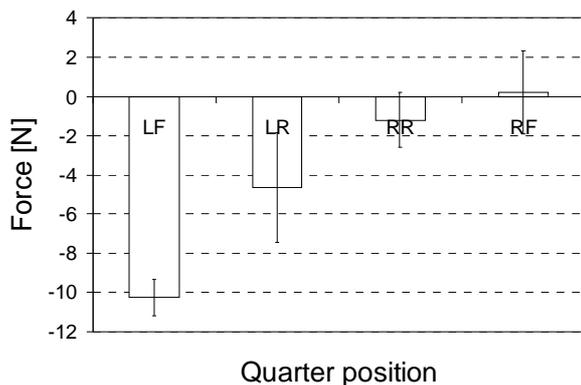


Figure 4. Mean and standard deviation of torsional forces on teats (cluster attached from the left).

Stripping yield per quarter differed only slightly but not significantly at the front left position (figure 5). The results are certainly biased by the method of hand milking. A better solution might be the use of quarter specific milk flow curves.

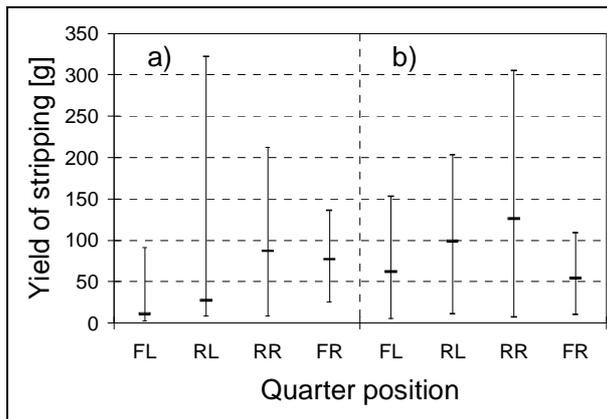


Figure 5. Median and range of stripping yield from cows milked always from the left (a, n= 8) and the right (b, n = 11) side.

In cases when cows are milked permanently in the same position (i. e. preference of one parlour side, rotary parlour, automatic milking systems) a monotonous stress might be put on some of the teats. EC is an indicator of a changed permeability of the udder tissue and thus might be used to detect tissue damages caused by the milking machine. On the other hand, these damages might not be accompanied by a bacterial infection or an increase of SCC in milk. This would be another explanation for the often observed low sensitivity of EC to detect subclinical mastitis. However, further investigations should focus on the effect and the relevance of forces applied to the teats by machine milking.

Conclusions

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Do Automatic Milking Systems affect the shape of the lactation curve?

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In the automatic milking systems (AMS) milking frequency is variable among cows and between days within cows. Since milking frequency is related to many factors associated with secretion rate and udder evolution and involution, we may expect that the AMS can affect curve of lactation. Measures of milk yield persistency were made in two experiments comparing Italian Friesian primiparous cows reared in an automatic milking system or in a conventional 8+8 herringbone milking parlour system. In the first experiment 10 cows per group were used. In the second experiment 5 pairs of twins were compared. In our experimental conditions, variability of results obtained didn't give sufficient evidence of a different persistency caused by the milking systems. In the AMS group, persistency was found to be correlated with milking frequency, milking interval, and with their variability. These correlations let to suppose that cows with higher and more regular milking frequency could have higher persistency.

Key words: Dairy cow, automatic milking system, lactation curve, persistency, milking frequency

Measuring the effect of AMS on milk yield (MY) is a complex challenge because of many methodological and technical aspects. Surveys performed to investigate the changes in farms that adopted AMS evidenced a variable improvement of milk yield associated with milking frequencies ranging between 2.3 and 2.8 milking/day. Pre-planned experiments comparing conventional systems (CS) and AMS showed contradictory results. However the extent of MY increase obtained with the AMS seems currently to be lower than early expectations. This is probably due to difficulties to adapt management to such new system. Most of early studies on AMS were conducted in the North of Europe, where the AMS was first adopted. In Italy, Ministry of Agricultural Politics and Regione Lombardia granted research projects in order to evaluate effect of AMS on the peculiar aspects of Italian dairy farms. Here, we present some results regarding the shape of lactation curve from two experiments comparing AMS and CS. Effect of AMS on persistency of lactation is a still open question and few data are currently

Summary

Introduction

available; however some considerations can be argued from the more known relations between milking frequency (MF) and milk secretion in CS. Since MF is related to many factors associated with secretion rate and udder evolution and involution, we may expect that the AMS can affect curve of lactation. Long intervals produce the increase of the endomammary pressure that limiting secretion rate. Moreover, long intervals allow a more effective action of chemical factors limiting milk secretion that are otherwise removed more frequently when cows are milked with shorter intervals. The critical interval is not the same for all cows because it depends on the udder capacity. Also nutrient uptake in the udder is affected by interval milking, raising until 8h and decreasing after. Even short intervals can result in an immediate MY reduction because of the lack of availability of cisternal milk. In CS, frequent milking (4 or 6 times per day) at the beginning of lactation showed an effect on MY that persisted even after frequent milking end (Bar-Peled *et al* 1995, Hale *et al*, 2003, Dahl *et al*. 2004). These effects were related with the increase in mammary growth during early lactation and with a delay of the involution process in late lactation (Capuco *et al*. 2003). Moreover, MF affects permeability of tight junctions (TJ). Increased TJ permeability was associated with MY shortage when cows were milked once daily. Stelwagen *et al*. (1994) showed a temporary disruption of TJ when cows were milked once a day. Low MF was also demonstrated to increase the activity of plasminogen, plasmin and plasmin activator in milk (Stelwagen *et al* 1994). Since plasmin–plasminogen system was related to the involution of mammary tissue in late lactation, increasing MF was expected to maintain persistency of lactation. However, in the AMS, MF is variable and irregular; there are cows milked more than thrice and cows milked less than once a day; an herd average of 3 milking per day (that could be considered an optimal goal) can be obtained with regular intervals (about 8 hours each) o with irregular intervals (i.e. two short intervals and one long interval). During the first two years of AMS usage at the Porcellasco Farm, the average MF of 2.56 was obtained with 50% of cows ranging between 2.5 and 3.0 milkings per day; more than 30% of cows had an average of 2.0-2.5 milkings per day ; 2% of cows were milked less than twice and 6.6% of cows were milked more than thrice daily. The 9604 considered milkings were performed after an average interval of 9 h 23 min 50 s, with the 12.5% of milkings occurring after an interval shorter than 6 h, the 19% of milkings occurring after intervals longer than 12 h; 4.5% of intervals were longer than 16 h. (Speroni *et al* 2003). In CS it was demonstrated that regularity in milking improves MY. Bach *et al*.(2004) showed that also in the AMS irregular intervals may have detrimental effect on MY.

Material and methods

The two trials were carried out in the experimental barn of the Animal Production Research Institute, at the Porcellasco Research Farm. The barn was a free stall house with cubicles. Two similar herd of 45-50 Italian Friesian cows were housed on the opposite side of the barn. On one side, the cows were milked twice a day in a conventional 8+8 herringbone

milking parlour (CS), on the other side there was a single box AMS (DeLaval VMS™). Both groups were fed with the same TMR distributed once daily in the morning. Cows in AMS received also a concentrate supply in the milking stall. Guided cow traffic was adopted in the AMS so that animals were forced to pass the milking area before entering the feeding area. A pre-selection gate prevented cows which had recently been milked to pass the milking stall and deviated them directly to the feeding area. In the AMS, the set minimum milking interval was 5h and it was the same for all cows in the herd and for all stage of lactation. Cows in the CS had milking intervals of 11 h and 13h. In the CS, MY was recorded weekly (for two consecutive milkings); in the AMS, MY and MF were recorded continuatively. Daily MY means of the AMS were calculated on four consecutive days as representative of a week. BCS were scored before and after calving regularly.

Experiment 1. Before calving, 20 heifers, were assigned to the two experimental groups which resulted comparable for average breeding value, expected age at first calving, expected calving date. At the beginning of lactation, the primiparous were introduced in the two herds (AMS or CS). The following repeated mixed model was tested to evaluate the effect of milking system on MY from 1 to 41 weeks in milking (WIM): $(1) Y_{ijk} = \mu + \alpha_i + d_{ij} + \tau_k + (\alpha\tau)_{ik} + e_{ijk}$, where Y_{ijk} and e_{ijk} were respectively the daily MY and the error for the cow j in the milking system i , at WIM k ; μ , α , τ ($\alpha\tau$) were fixed factors: μ = mean effect; α = milking system effect (i =AMS, MP); τ = WIM effect (k =1 to 41); ($\alpha\tau$) = interaction between milking system and WIM; d_{ij} was the random effect associated to j^{th} cow in the i^{th} milking system. Resulting least square means were fitted by a regression with the log linear form of Wood function ($\ln MY = \log_e a + b \log_e WIM + c WIM$). Persistency was calculated as $-(b+1)/c$; distance between calving and peak was calculated as b/c ; e MY at peak was calculated as $a(b/c)^{b-1}$. The following mixed model, in which WIM was introduced as covariate together with interaction between milking system and WIM, was tested to estimate if a common slope model would be adequate to describe the data from the 11th to the 41 week and from the 22nd to the 41st week for both AMS and CS: $(2) Y_i = \alpha_{cs} + (\alpha_i - \alpha_{cs}) + \beta_{cs} x_{ij} + (\beta_i - \beta_{cs}) x_{ij} + b_j + e_{ij}$, where i = AMS, CS; 11-41 or 22-41; α_i and β_i are respectively the intercept and the slope for the i^{th} milking system model; b_j is the effect of WIM; e_{ij} is the random experimental unit error.

Experiment 2. Five pair of twins were used to compare milk production in CS vs AMS. After calving each heifer was introduced in the herd. One of the six pair was eliminated from the analysis because the twin assigned to the AMS had trouble in the training with the milking system. Three couple were examined until 24 weeks. Only two could be analysed until 38 week and later. Model (1) was used to test the effect of milking system on MY 1 to 24 WIM (5 pairs) and from 1 to 40 WIM (two pairs). Model (2) was tested the slope from 11WIM to 21WIM. Udder morphology was scored around 10 WIM.

In both experiment persistency was also calculated by the ratios between MY in different stage of lactation and correlated with individual traits.

Results

Experiment 1. The pattern of least square means for MY was reported in Figure 1 together with the Wood's curves. Average correlations among MY measures within cows calculated as the ratio between the animal variance component (σ_c) and the sum of animal variance plus the random residual variance ($\sigma_c + \sigma_r$) was 45%. Although their MF averaged 3.00 ± 0.53 milkings/day, AMS heifers produced the same as the MP heifers on average and at each week, except at the 27th week when AMS group produced less than CS group ($P=0,022$). Parameters for Wood's curves are reported in table 1; R^2 were 0.93 and 0.83 for AMS and CS respectively. Analysis of curves slopes in the late lactation (>21 WIM) didn't provide sufficient evidence to conclude the slopes were unequal, but when the middle lactation data (>11 WIM) were also considered the AMS curve had a significantly lower slope ($P=0.01$) than the CS one. Other measures of persistency are reported in table 2. They tend to be lower in the AMS were some of them resulted positively correlate with MF and negatively correlated with milking interval (MI) and variability of MY, MF and MI (table 3.). BCS and BCS variations were equal for the two groups and they didn't result significantly correlated with persistency.

Experiment 2. Average MF from week 0 to week 21 for the five heifers in the AMS was 2.59 ± 0.50 . There was not a significant effect of milking system on MY. However, when comparison was made within pairs, two pairs resulted in higher MY ($P < 0.01$) in the AMS and three pairs in the CS. The average pattern of MY was reported in figure 2. Slopes of curves between 12 to 22 WIM were equal. Also persistencies, measured as 12-22 WIM/1-11 WIM, were very similar (1.08 and 1.05 for the AMS and CS respectively). Pattern of the pairs of twins that had complete lactation data are reported in figure 3 -5. In one case persistency of AMS measured as the ratio between MY in late lactation and in early lactation heifer was higher (0.92 vs. 0.62) but in the other case persistency of the two curves are very similar (1.00 and 1.03 for AMS and CS heifer respectively). BCS and BCS variations were equal for the two groups. Persistency didn't result significantly correlated neither with BCS and BCS variations nor with udder morphology traits.

Conclusions

A higher individual variability was observed in our experiments. On average, we didn't get sufficient evidence of the improvement in MY persistency that we could expected as a consequence of a higher MF. On the contrary, in most of cases, MY persistency tended to be higher in CS. Poorer persistency in the middle lactation of AMS group could be explained by an underfeeding of energy or nutrient deficiency due to an higher requirement of heifer in the AMS but our data do not provide enough information to support any of these hypothesis. However, between persistency and MF and MI traits were found correlations that let to suppose that cows with higher and more regular MF could have

higher persistency. Further investigations are needed about the nutritional aspects and the individual traits that can influence effect of AMS on the MY. Promising fields are cistern capacity measurement and consistency of individual feeding and moving behaviour.

Table 1. Experiment 1. Parameter of Wood's curves.

	a	b	c	(b+1)lnc	b/c	a(b/c) ^b e ^{-b}
AMS	25.3	0.2	-0.025	4.579	9.63	34.296
CS	24.1	0.2	-0.018	4.922	12.54	34.125

Table 2. Experiment 2. Measures of persistency of lactation curve.

	Persistency measured as ratios between MY at different stage of lactation				
	41 WIM/ at peak	12 - 22 WIM/ 1-11 WIM	22 - 41 WIM/ 1 - 11 WIM	12 - 41 WIM/ 1-11 WIM	average/ max
AMS	0.615±0.043	0.956±0.050	0.806±0.037	0.906±0.033	0.724±0.027
CS	0.735±0.043	1.042±0.050	0.892±0.035	0.967±0.033	0.826±0.027*

*P< 0.05

Table 3. Experiment 2. Correlations between persistency and MY, MF and MI in the AMS.

	Persistency measured as ratios between MY at different stage of lactation				
	41 WIM/ at peak	12 - 22 WIM/ 1-11 WIM	22 - 41 WIM/ 1 - 11 WIM	12 - 41 WIM/ 1-11 WIM	average/ max
CV of MY	-0.75*	-0.40	-0.73	-0.47	-0.96*
Average MF	0.61	0.47	0.54	0.47	0.76*
CV of MF	-0.51	-0.45	-0.42	-0.50	-0.70*
Maximum MI	-0.50	-0.44	-0.67*	-0.53	-0.67*
Average MI	-0.66*	-0.54	-0.69*	-0.41	-0.70*
CV of average MI	-0.66*	0.03	-0.76*	-0.33	-0.29

*P< 0.05

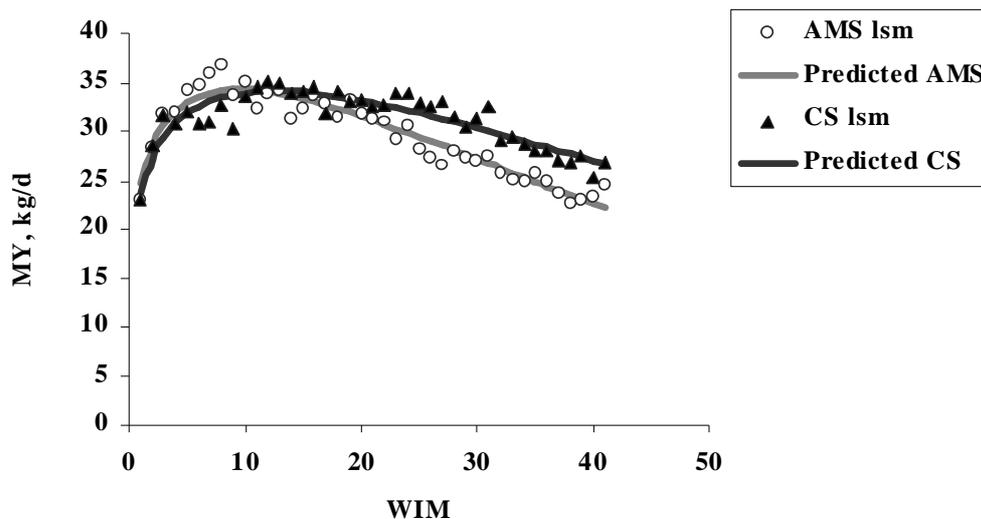


Figure 1. Experiment 1. MY pattern: Least Square Means and Wood functions.

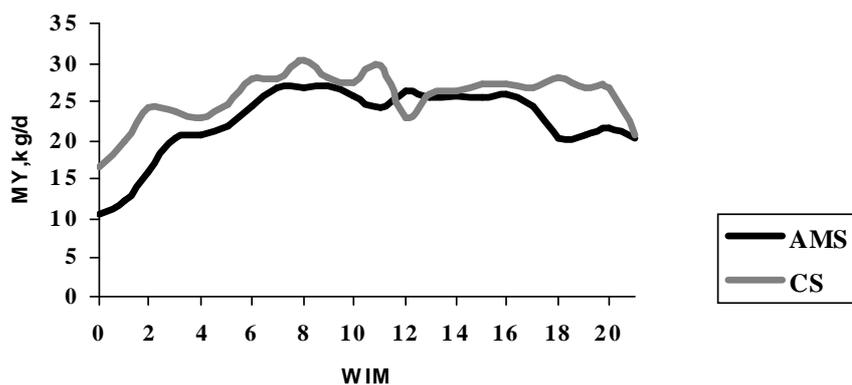


Figure 2. Experiment 2. MY pattern: least square means (5 twin pairs).

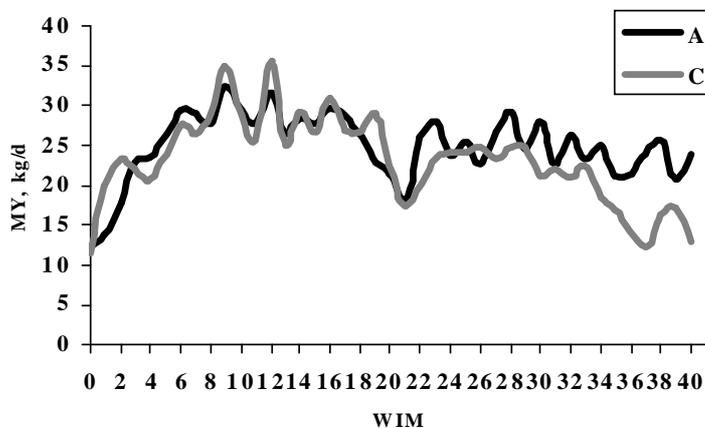


Figure 3. Experiment 3. MY pattern: least square means (2 twin pairs)

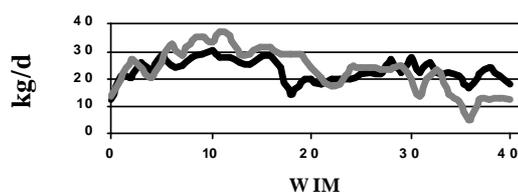


Figure 4. Experiment2. MY pattern: — AMS
least square means of pair n° 1. — CS

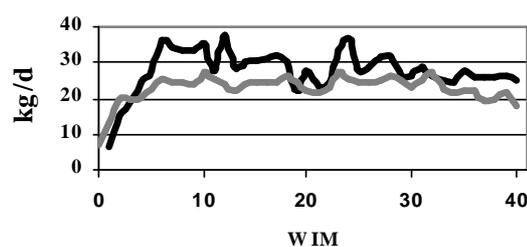


Figure 5. Experiment2. MY pattern: — AMS
least square means of pair n° 2 — CS

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Influence of pulsation parameters on milking and udder health of dairy goats

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Two experiments were carried out on 24 goats each (6 groups of 4 goats) of the two main breeds kept in France : Alpine and Saanen breeds.

In two distinct Latin Square designs, they compared three pulsation frequencies (60, 90 et 120 cycles per minutes) combined with 2 pulsator ratios 50 and 60%. Each period lasted on week.

At each period, milk yield, milking times, average and peak milk flow rates were recorded during two morning and evening milkings consecutively, milk samples were taken for analyse of fat and protein content and SCC and teat end thickness was also recorded once with the cutimeter method and level of oxytocin in blood, before, during and after milking was recorded.

In both breeds, no statistical difference was found on milk yield and composition between de six treatments. The highest pulsation frequencies (90 and 120 cycles/min) combined with the larger pulsator ratio (60%) statistically lead to shorter milking times, shorter lag times, higher average and peak flow rates. On the contrary, every combinations with small frequency and short ratio lead to longer milking times and lower flow rates. Results at the highest pulsation rates could be explained by a better udder stimulation due to a higher level of oxytocin release into blood during the whole milking.

Summary

Because SCC and teat end thickness and conditions were not statistically different between the 6 treatments within the two studied breeds, we can conclude that increasing pulsation frequency up to 120 cycles/min with a 60% pulsator ratio would be a good mean in order to decrease individual milking time for dairy goats in Alpine and Saanen breeds.

Key words: Goats, milking, pulsation, udder health

Introduction

French goat farmers have two main objectives: a quick milking in order to get more efficiency and less labour time, and in the meantime to secure udder health and especially Somatic Cell Count (SCC). Pulsation characteristics are among numerous parameters able to lead to a quicker milking by improving stimulation of the udder as clearly demonstrated by Marnet et al (2000) on dairy ewes. Nevertheless, oxytocin release due to the stimulation of the udder is surely less crucial for goats than for cows or ewes because around 70 % of the total milk yield is cisternal milk which flows from alveoli to the cistern between milking. Obviously oxytocin is needed in order to get the 30% remaining milk within the acini.

Le Du (1989) thought that it is possible to milk goats at a low frequency similar to the one used for cows (60 cycles/min), but higher frequencies might be useful in order to strengthen the needed endocrinal reflex. However, Lu et al. (1990) showed that the best pulsation characteristics for the Alpine breed seemed to be a pulsation rate of 90 cycles/min with a 60% pulsator ratio. However, these authors advised a 45-52 kPa vacuum level for milking which is very high compared to those used especially used in France.

The main goal of the experiments was to study effects of different pulsation rates combined with different pulsators ratios on milking characteristics and on udder health of dairy Alpine and Saanen goats.

Materials and methods

Two different experiments were carried out at the experimental herd of the National Institute for Agronomical research (INRA) (Le Rheu, France) with two different breeds usually kept in France; the first one in January and February 2000 on Saanen goats and the second one in June and July 2003 on Alpine goats.

In each experiment 24 goats were used and milked on one side of the double 12, 12 units side by side parlour with a low milk line of the experimental farm. The vacuum level was 38 kPa and the cluster used during the two experiments was the Delaval SG 10 with automatic teatcup valves.

Three pulsation rates: 60, 90 and 120 cycles/min combined with 2 pulsator ratios: 50 and 60% were studied as shown in table 1.

Table 1. The different studied pulsation parameters.

Treatment	Pulsation rate (cycles/min.)	Pulsator ratio (%)
1	60	60
2	60	50
3	90	60
4	90	50
5	120	60
6	120	50

6 groups of 4 goats were alternatively milked during 6 weeks at the different studied pulsation rates and pulsator ratios in a specific Latin square design such as it was possible to figure effect of the previous experimental period. Thus, average results presented in the following paragraph will be adjusted means from this calculated effect.

Milking was done twice a day at 6h45 am and 4h30 pm. Clusters were attached immediately without any udder washing or pre-dipping and immediately removed after milk flow stopped.

Milking kinetics were recorded during two morning and evening milkings for the 24 goats. Milk yield was measured every 1.5 seconds and recorded every 3 seconds. The following parameters were directly recorded or figured from the milking curves: total milk yield (TMY), total milking time (without overmilking) (TMT), lag time (between attachment and beginning of milk flow) (LAG), milk flow rate during the first minute of milking without overmilking and lag time (MF1), real average flow rate (without lag time and overmilking) (RFR), peak flow rate (PFR), plateau of peak flow rate (average maximum peak flow rate during at least 9 seconds) (MAXPLAT), time during attachment of cluster and the beginning of the plateau (TPLAT) and duration of the plateau (DUR). Milk samples from each goats were taken as usually during one evening and one morning milking and milk analysed for fat and protein content and Somatic cells count. Teat end thickness was also recorded with a cutimeter (Hamann and Mein, 1990). During the first experiment with the Saanen goats, oxytocin level in blood was measured during two consecutive milkings (one morning and one evening) on 12 goats among 24 (2 by group of 4) (Marnet et al., 1994). Oxytocin was recorder 5 minutes before milking, at the attachment of cluster, after 30, 60, 90 and 180 seconds of milking and 6 and 12 minutes later.

In addition, after the last experiment on Alpine breed, the milking machine was adjusted with the 120 cycles/min pulsation rate and the 60% pulsator ratio during 2.5 months. Somatic cells cont and teat end condition were recorded at the beginning and at the end of this period.

Results

During both experiments, neither during morning milking nor during evening milking, any statistical difference on TMY was found. TMY was in average within the range of 1.74-1.82 litres at morning milking and 1.20-1.28 litres at evening milking in Saanen breed and in average within the range of 1.35-1.41 litres at morning milking and 1.03-1.08 litres at evening milking in Alpine breed. No difference where noticed on milk composition (fat and protein contents). Fat content was within the range of 3.25-3.41% for Alpine and 3.66-3.81% for Saanen breed. Protein content was within the range of 3.17-3.24. for Alpine and 3.12-3.23% for Saanen breed.

Statistical differences were found on TMT between the studied pulsation parameters (table 2). Except during evening milking for Alpine breed (no statistical difference between each treatment), milking time was the lowest when pulsation rates and pulsators ratios were the highest (treatment 5 and 3 with pulsation rate respectively 120 and 90 cycles/min with 60% pulsator ratio). Pulsation rates of 60 and 90 cycles/min with a 50% pulsator ratio led to the highest TMT.

Table 2. Influence of pulsation parameters on TMT (time in seconds).

Milking	Breed	Treatments					
Morning	Alpine	3	5	6	1	2	4
		166 ^a	171 ^{ab}	177 ^{abc}	180 ^{abc}	185 ^{bc}	189 ^c
	Saanen	5	3	6	1	4	2
		172 ^a	190 ^a	196 ^{ab}	198 ^{ab}	205 ^{bc}	215 ^c
Evening	Alpine	5	4	1	3	6	2
		135 ^a	139 ^a	139 ^a	142 ^a	145 ^a	153 ^a
	Saanen	5	3	6	1	2	4
		138 ^a	144 ^{ab}	146 ^{ab}	147 ^{ab}	160 ^b	161 ^b

Values with different letters within the same line indicate significant differences ($P < 0.05$)

The lag time (LAG) elapsed between attachment of cluster and the beginning of milk flow is a typical characteristic of small ruminants. When significant statistical differences were found (both breeds in morning milking and only in Alpine breed in the evening milking), the shortest lag time was noticed for treatment 5 firstly and treatment 3 secondly. LAG with treatment 5 lasted around 15 seconds and with treatment 3 around 17 seconds (table 3). Furthermore, highest LAG were noticed for treatment 1 and 2 (60 cycles/min) but also for treatment 4 and 6 (90-120 cycles/min and 50% pulsator ratio).

Table 3. Influence of pulsation parameters on LAG time (in seconds).

Milking	Breed	Treatments					
Morning	Alpine	3 166 ^a	5 171 ^{ab}	6 177 ^{abc}	1 180 ^{abc}	2 185 ^{bc}	4 189 ^c
	Saanen	5 172 ^a	3 190 ^a	6 196 ^{ab}	1 198 ^{ab}	4 205 ^{bc}	2 215 ^c
Evening	Alpine	5 135 ^a	4 139 ^a	1 139 ^a	3 142 ^a	6 145 ^a	2 153 ^a
	Saanen	5 138 ^a	3 144 ^{ab}	6 146 ^{ab}	1 147 ^{ab}	2 160 ^b	4 161 ^b

Values with different letters within the same line indicate significant differences ($P < 0.05$).

Milk flow rate during the first effective minute of milking (without overmilking and lag time) (MF1) was similar to the lag time: the highest flow rates were noticed when milking with the highest frequencies (90 and 120 cycles/min) and the widest ratio (60%). Treatment 5 could lead to the highest flow rate in Alpine breed (morning milking) and in Saanen breed (evening milking). Treatment 3 was equivalent to treatment 5 in Alpine breed (evening milking) and in Saanen breed (morning milking) (table 4). For example at the morning milking, MF1 raised of 21.5 % from treatment 2 to treatment 5 (opposite results) and of 16.7 % from treatment 6 to treatment 5 (same pulsation rate but two different ratios in Alpine breed). Treatment 2 (60 cycles/min and 50% ratio) always led to the lowest flow rate.

Table 4. Influence of pulsation parameters on MF1 (l/min).

Milking	Breed	Treatments					
Morning	Alpine	2 0.712 ^a	6 0.741 ^{ab}	4 0.746 ^b	1 0.746 ^b	3 0.816 ^c	5 0.865 ^d
	Saanen	2 0.620 ^a	4 0.625 ^a	1 0.655 ^{ab}	6 0.691 ^{ab}	5 0.703 ^b	3 0.727 ^b
Evening	Alpine	2 0.700 ^a	4 0.755 ^{ab}	6 0.760 ^{ab}	1 0.800 ^b	5 0.857 ^{bc}	3 0.897 ^c
	Saanen	2 0.635 ^a	4 0.690 ^{ab}	1 0.711 ^{bc}	6 0.733 ^{bcd}	3 0.773 ^{cd}	5 0.797 ^d

Values with different letters within the same line indicate significant differences ($P < 0.05$).

The peak flow (PFR) was measured as the highest flow recorded during 3 seconds. Tables 5 shows the same response to the different treatments as previously seen for LAG and for MF1 of milking. In addition, treatment 5 led to the highest peak flow except for Saanen breed at the evening milking where it was similar to the one noticed for treatment 3.

Table 5. Influence of pulsation parameters on PFR (l/min).

Milking	Breed	Treatments					
Morning	Alpine	2 0.907 ^a	6 0.941 ^a	4 0.958 ^{ab}	1 0.998 ^{bc}	3 1.025 ^{cd}	5 1.069 ^d
	Saanen	2 0.881 ^a	4 0.907 ^{ab}	1 0.948 ^{bc}	6 0.964 ^{bc}	3 1.002 ^c	5 1.057 ^d
Evening	Alpine	2 0.922 ^a	4 0.941 ^a	6 0.967 ^{ab}	1 1.004 ^b	3 1.016 ^b	5 1.094 ^c
	Saanen	2 0.809 ^a	4 0.856 ^a	1 0.929 ^b	6 0.946 ^b	5 0.965 ^b	3 0.980 ^b

Values with different letters within the same line indicate significant differences (P<0.05)

From treatment 2 (the lowest peak flow) to treatment 5 (the highest peak flow), PFR raised approximately from 18% up to 20% in both breeds at morning and evening milking respectively. In the meanwhile, PFR raised from 10 up to 21 % from treatment 2 to treatment 3.

The level of the plateau (MAXPLAT) was also figured as the highest flow rate between at least 3 consecutive recordings representing 9 seconds. A very similar classification of the studied treatments was obtained.

Time elapsed between the attachment of cluster and the beginning of the plateau (TPLAT) showed also the same classification: the shortest time was noticed for treatments 5 and 3. Duration of the plateau (DUR) was inverse of MAXPLAT; DUR was the shortest when using treatments 3 and 5 which led to the highest MAXPLAT.

SCC in milk samples hand taken at each period for each goats were analysed and the difference of teat end thickness between after and before milking was calculated in order to investigate possible effects of one or several treatments on udder and teats health. SCC were transformed into logarithms for statistical analysis but no difference were found between the six studied treatments.

Difference in teat end thickness shown in table 6 is related to the morning milking. No statistical difference was found especially because of the high variability of results as a consequence of the great differences in teat morphology and of response of animals. In addition, table 6 shows a different classification and different results for both right and left udder

halves and within the two breeds. These results show that there was no marked effect of the different treatments on teat end thickness. However, it can be noticed that every values are positive. That indicates that teat end after milking is, in average, always thicker than before milking. This is a specific characteristic of goats which can be explained by more or less congestion due to a bigger sensitivity to milking than cows and ewes.

Table 6. Influence of pulsation parameters on teat end thickness (difference after-before morning milking in mm).

Udder half	Breed	Milking	Treatments					
Right	Alpine	morning	4	5	6	1	2	3
			0.19 ^a	0.26 ^a	0.28 ^a	0.38 ^a	0.38 ^a	0.39 ^a
		evening	5	4	3	1	2	6
			0.24 ^a	0.30 ^a	0.30 ^a	0.35 ^a	0.35 ^a	0.43 ^a
Left	Saanen	morning	4	6	1	2	3	5
			0.10 ^a	0.19 ^a	0.21 ^a	0.23 ^a	0.31 ^a	0.32 ^a
		evening	6	2	1	4	5	3
			0.09 ^a	0.15 ^a	0.19 ^a	0.20 ^a	0.37 ^a	0.49 ^a

Values with different letters within the same line indicate significant differences ($P < 0.05$)

Average data of this study related to milk yield, milking time, lag time and flow rates (during the first minute of milking, peak flow and plateau level) are very similar to those mentioned by Billon et al. (2000) in a general study of milk ability of goats for the two studied breeds.

There is no particular influence of the pulsation characteristics on milk production and composition which indicates that stimulation of the udder by the milking machine seems to be sufficient even when using small pulsation rate to get the 30% alveolar milk still remaining in the acini before milking. No stripping was done during the two experiments and contrary to ewes, there is no tendency for a more complete milking when using high pulsation rates (Casu and Carta, 1974; Le Du and Benmederbel, 1985).

Milking times and flow rates are greatly influenced by the pulsation characteristics. The highest pulsation rates combined with the largest studied pulsator ratio lead to the shortest machine on time, lag time and the highest milk flow rates (average milk flow rate and flow rate during the first minute of milking, peak flow and plateau level).

Shorter milking time can be explained by the highest milk flow rates noticed during the study. Influence of the pulsator ratio is very high since most of the studied flow rates were the lowest when using treatments 2, 4 and 6 with the smaller ratio (50%). It seems obvious that

Discussion

because the ratio is more important, time when the liner is open and milk is flowing is greater leading to a higher flow rate. Our results are in accordance with Ricordeau and Labussière (1970) who showed that the average milk flow rate raised to 23% when moving from the 50% ratio to 60%.

When using a 60% pulsator ratio, machine on time and lag time were the lowest and milk flow rates the highest with the highest pulsation rates. Additional measurements of liner movements were recorded with a flow simulator with artificial teats at 1 and 1.5 l/min milk flow rates respectively with 90 and 120 cycles/min pulsation rates. Results showed that within 1 second milking, time when the liner is fully open is higher at 90 cycles/min than at 120 cycles/min (respectively 410 and 360 ms at 1 l/min milk flow rate and 415 and 380 ms at 1.5l/min milk flow rate). In addition, if we consider that milk approximately begins flowing when the liner is half open and flow stops when the liner is half closed, time during which milk effectively flows respectively lasts 528 and 522 ms at 90 and 120 cycles/min with a 1l/min milk flow rate and 522 and 516 ms at 90 and 120 cycles/min with a 1.5 l/min milk flow rate. That indicates that milk flows during a nearly similar time (difference not more than 10 ms) when using 120 cycles/min compared with 90 cycles/min.

These results may explain why no large difference were noticed in results with 90 and 120 cycles/min. However, oxytocin concentration in blood was always higher after stimulation and during the whole milking when using 120 cycles/min pulsation rate. That may indicate that the highest pulsation rates could lead to a more intensive and persistent stimulation of the udder inducing a higher intra mammary. Long-term experiments should be undertaken in order to investigate the effects of the highest level of oxytocin in blood noticed with the 120 cycles/min pulsation rate during several consecutive lactations.

If milking with higher pulsation rate and pulsator ratio seems to have a great interest for farmers who want to get a better efficiency in their milking parlour, we have to ensure that these new adjustments do not lead to worst teat end conditions, more clinical mastitis and more SCC. Results of the two experiments showed no difference between treatments in teat end thickness and SCC. However, the Latin square design with 6 period of one week was not a good enough experimental plan to investigate results related to udder health.

After the second experiment with Alpine breed, the milking machine was adjusted with a pulsation rate of 120 cycles/min with a 60% pulsators ratio and the whole herd (around 90 goats) was milked with these adjustments during the rest of the lactation (2.5 months). Milk samples were analysed for SCC and teat end conditions for the 24 Alpine goats involved in the previous study were recorded .

No particular evolution of SCC was noticed and most teat ends were similar to the one shown on figure 1 with a black spot which looks like hyperkeratosis but which is very common on goats at the end of their lactation. This cannot be considered as a particular trouble due to the pulsator adjustments.

However, duration of the experiment was too short (2.5 months) and period no adequate (end of lactation); so longer observations should be undertaken in order to ensure that high pulsation rate and wide pulsator ratio do not lead to udder health troubles.

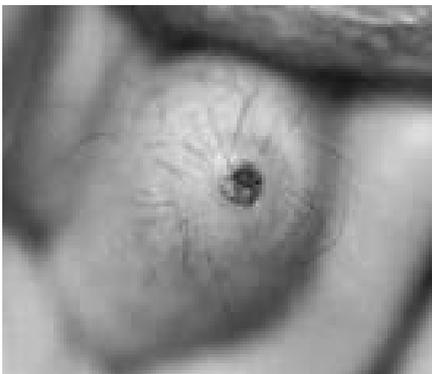


Figure 1. Teat end of goats at the end of lactation.

Pulsation characteristics have a great influence on dairy goats milking, especially regarding milking times and flow rates.

Low pulsation rate (60%) and short ratio (50%) are not adequate for milking Alpine and Saanen goats. On the contrary, the wider 60% ratio is strongly recommended combined with a pulsation rate of 90 or 120 cycles/min. 120 cycles/min pulsation rate can be advised in order to milk quicker and to improve efficiency of labour.

However, further researches are needed in order to ensure that high pulsation rates do not lead to udder health troubles.

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Conclusion

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Electricity and water consumption by milking

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Large milking parlours with more techniques and the introduction of automatic milking systems (AMS) in Denmark have brought an increase in the consumption of electricity and water in connection with milking. It is important to optimise all subcomponents to get the most out of the investment in a milking system. By regular monitoring of the consumption, one can react quickly if it deviates from the normal consumption.

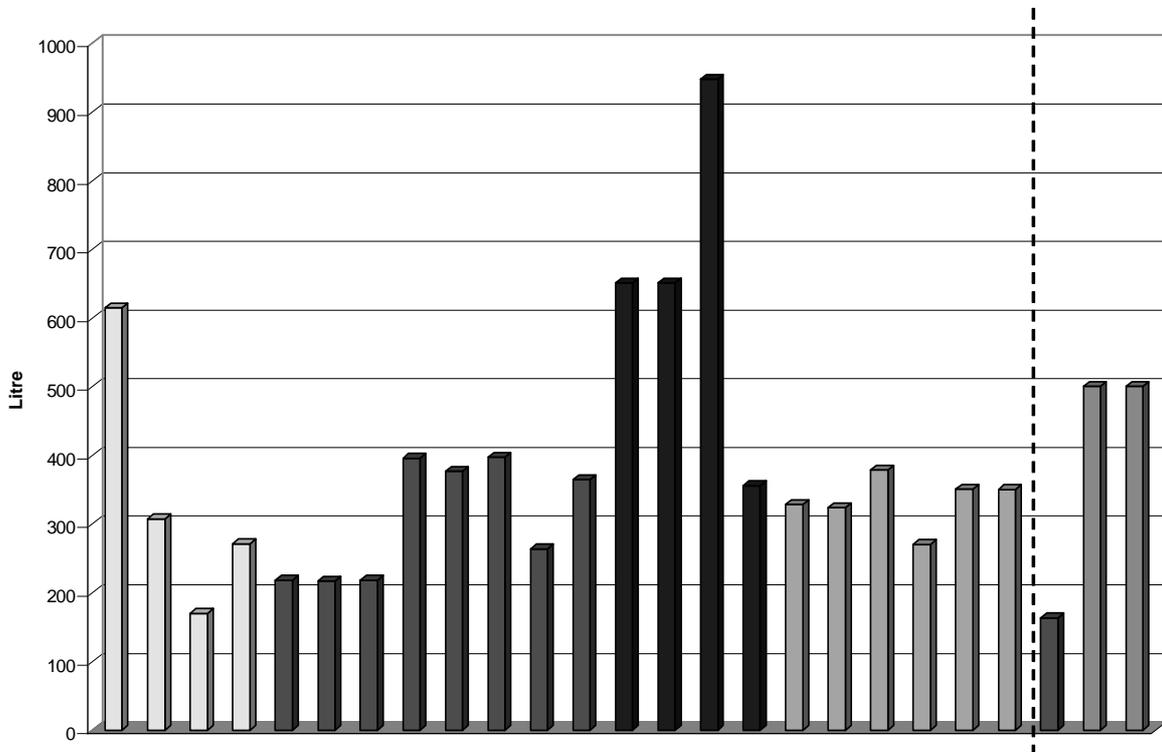
High electricity consumption leads to high electricity costs. High water consumption results in high costs of water, waste water storage and subsequent application to fields. Waste water storage costs amount to app. 2 Euro per m³, and field application costs amount to app. 2 Euro per m³.

Previous Danish measurements of electricity and water consumption in connection with AMS have shown a high electricity consumption. Especially, the electricity consumption of DeLaval VMS was at a very high level. Moreover, the 24-hour water consumption varied considerably.

The milk quality depends on many different factors. One of these factors is hygiene including washing of the milking system. It is important to wash the milking system thoroughly by means of water and chemicals in appropriate quantities, neither too little nor too much. The use of CIP washing systems (CIP = clean in place) can reduce the washing costs considerably. The CIP washing system reuses some of the wash water, and hence it is possible to reduce the consumption of water among others. However, the CIP washing system cannot yet be used to clean AMS. This is a future development task for the companies.

The purpose of this FarmTest was to determine the electricity and water consumption at milking. It was primarily interesting to monitor the consumption in connection with AMS as this type of milking takes place day and night and hence water and electricity are used continuously.

of the AMS with the lowest energy consumption. The electricity consumption of the 40-stall rotary milking parlour was at 37.7 kWh per ton of milk.



- Farm 1-4: Galaxy Automatic milking system
- Farm 5-12: Lely Astronaut Automatic milking system
- Farm 13-16: DeLaval VMS Automatic milking system
- Farm 17-22: Gascoigne Melotte Automatic milking system
- Farm 23: 2x12 herringbone milking parlor
- Farm 24: Rotary milking parlour, internal, 26 stalls
- Farm 25: Rotary milking parlour, external, 40 stalls

Figure 1. Water consumption per ton of milk.

The water consumption should be optimised and kept at as low a level as possible. A high water consumption results in high costs of water storage and application to fields and costs of water if it is from public water supply.

Water consumption

The number of system cleanings and unit flushes has a great influence on the water consumption. The system is typically cleaned three times every 24 hours, i.e. every eight hour. However, some chooses only to wash the milking system two times every 24 hours. Fewer system

System cleaning and unit flushing

Automatic washing of milking box floors can be necessary to maintain a good hygiene. However, it also requires a great deal of water. This FarmTest has shown an average 24-hour consumption of 278 litres per milking box with automatic floor washing.

Floor cleaning

It is important to fine-tune the system to wash the floor when necessary only. Typically, the floor washing frequency depends on the number of milkings. An example could be floor washing every fifth milking.

The greatest "consumers"

The greatest „electricity consumers“ in connection with milking is the vacuum pump, compressor, electric water heater and automatic washing system (in the mentioned order).

Electricity consumption

Frequency-controlled vacuum pumps

The FarmTest showed that the use of frequency-controlled vacuum pumps reduces the energy consumption considerably. For example, the test of DeLaval VMS showed a 20 kWh difference per 24 hours between frequency-controlled and non-frequency-controlled vacuum pumps.

At a 24-hour electricity reduction of 20 kWh, a frequency control price of DKK 15,000 and a seven per cent interest rate, it takes app. 4.8 years to repay the frequency control.

Compressor

Leaks in the air system and too high working pressure can be some of the reasons for a high electricity consumption on the compressor. It is important to monitor the electricity consumption continuously by means of manometer and hour meter mounted on the compressor. These should be supplemented with a measuring of the leaks in the system.

Electric water heater

Heating of water is energy consuming, and hence the system should be adjusted. Firstly, the water should not be heated more than necessary, and, secondly, the amount of water heated should be adjusted to the consumption. Preheated water from heat recovery systems can also contribute to reducing the electricity consumption.

Automatic washing system

Some of the automatic washing systems are provided with an integrated water heater. Thus a good deal of energy is used for heating the water prior to cleaning the milking system.

In the FarmTest, defects on milking units of all AMS brands were found. When installing a milking system, electricity and water meters should be installed on all supplies to be able to monitor the consumption from the outset.

Defects of new systems

The Dutch quality system for milking machine maintenance in 2003 and 2004

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In the eighties and nineties ISO and ICAR standards were developed for milking machines and milk recording devices. In the Netherlands these standards were implemented in a Quality System for the maintenance of milking machines and the accuracy check on milk recording equipment managed by an independent organisation KOM. This organisation is controlled by national farmers union, the milking machine manufacturers union and the national breeding and milk recording organisation. KOM has set up several actions and procedures to supervise and to control the quality system, like registration and evaluation of all test reports made by the technicians including reports on the accuracy of milk meters and jars, annual control and calibration of the test equipment used by technicians, performing random checks on the 'quality of work' of the technician and education and certification of (new) technicians. Moreover studies on the relation between milking machine settings and milk quality are carried out and guidelines for new areas like automatic milking systems are developed. The system guarantees the farmer that the maintenance of his milking machine and the necessary accuracy checks of milk meters and jars are performed well against minimal costs. The system has been incorporated in the total quality management system for dairy producers (KKM) of the Dutch dairy industry.

Key words: *Quality system, maintenance, milking machines, milk meters, recorder jars, accuracy, calibration*

With the introduction of milking parlours in the early seventies, it became clear that milking machines need regular testing and maintenance for good milking. Testing was done by advisors from the dairy industry, animal health services or governmental extension services on request of the farmer or when problems with milk quality or udder health occurred

Abstract

Introduction

on the farm. In the case of malfunctioning, a technician of the milking machine dealer was asked to perform the necessary repairs, and the dairy advisor or extension officer checked the milking machine again. In the early eighties the Dutch farmers union, governmental extension service and the milking machine manufacturers developed a national maintenance system. The basic idea behind this system was that all regular testing and maintenance should be integrated and performed by the technicians employed by dealers of the manufacturers to reduce the costs for the farmer and to improve the quality of maintenance. The national extension service became responsible for the training and evaluation of the technicians to guarantee their quality of work. The testing method was described in a national guideline for technicians. From that time on, all manufacturers used the same testing method, a uniform test report (Maintenance and Advice Report - MAR) and farmers paid a fixed price for the yearly test. At the end of the eighties over 80% of the Dutch farmers participated in this voluntarily maintenance system.

International Standards

In the seventies and early eighties manufacturers and experts from various countries, prepared the first international standards for milking machines. ISO 3918 describes the vocabulary, ISO 5707 describes the standards for construction and performance of milking machines and ISO 6690 deals with the testing methods. These standards are under revision at the moment. The standards apply to both new installations, and machines in use, to check the performance of operation periodically. In the same time ICAR developed guidelines for the approval and the use of milk meters and jars for milk recording purposes (ICAR, 1995).

Quality control system

In the mid nineties plans were developed with the Dutch farmers union, the national milk recording organisation and the Dutch organisation of milking machine manufacturers, to establish a quality control system for milking machine maintenance including milk recording devices (KOM). The quality system was expanded with certification programs for the technicians, calibration of test equipment and training and education courses. The ultimate goal of course was to guarantee the farmer that the milking machine is working properly, without having a negative effect on milk quality or udder health. Another prerequisite was that such a system should fit in the Total Quality Management system for dairy farms (KKM, 2002) as developed by the Dutch dairy industry and the national farmers union. The KKM system is permissive to the national and EU legislation aspects, and joining such a system is obligatory for all Dutch dairy farmers since 2000. In 2005 this national program will be transferred to individual dairy industry quality programs, however the main objective will remain the same. Farmers, who want to deliver milk to one of the dairies, have to meet the requirements of the Quality Control Programs. Current modules of the Quality Programs are Medicines, Animal health

and welfare, Foodstuff and water, Milking and milk storage and Cleaning and disinfection. The module Milking specifies that the milking machine should be tested yearly by a KOM-certified technician.

The institution KOM was founded in 1998. The KOM organisation is responsible for the entire quality system focussing on milking machines and milk recording devices. The supervision on the annual routine accuracy check of electronic milk meters and recorder jars is part of the KOM responsibilities. The check is necessary for meters used for the official milk recording system as stated by the ICAR rules. The technicians from the manufacturers combine the annual service on the milking machine with the routine tests on the functioning and accuracy of electronic milk meters and jars. The reason to do so was to reduce the costs for the farmer by combining the annual accuracy checks and the maintenance.

Institution KOM

KOM has developed several activities within the KOM quality system. These activities and the procedures are recorded in the KOM guidelines (KOM, 1999):

The KOM Quality System

- Registration and evaluation of all test reports made by the technicians including reports on the accuracy of milk meters and jars,
- Yearly control and calibration of the test equipment used by technicians,
- Performing random checks on the 'quality of work' of the technician including milk meters and jars,
- Certification of (new) technicians,
- Development of standard reports (MAR) and tests (based on ISO),
- Studies on the relation between milking machines and milk quality,
- Development of guidelines for new areas, like automatic milking systems.

During the yearly check on the milking machine, all components are checked and tested. If necessary, repairs are made or devices like pulsators are adjusted to the right value. Vacuum level, reserve capacity, air inlet, air consumption, air leakage and pulsation curves, are measured by using test equipment like airflow meters, vacuum testers and pulsation testers. The test results are recorded in a standard test report, which is equal for all manufacturers. The technician can also write down his comments. A copy of the report is handed over to the farmer, another copy is sent to KOM. The reports are registered per technician and evaluated at random using an evaluation protocol. The evaluation report is discussed with each technician once a year.

Registration of all test reports

Control and calibration of the test equipment in use

At Waiboerhoeve experimental station, the research facility of the Animal Sciences Group of Wageningen UR, a training and test centre was established. This centre has a special test installation suited to test and calibrate vacuum gauges, air flow meters and pulsator test devices (De Koning & Huijsmans, 2001).

Random checks

The KOM institution performs random checks on farms to evaluate the quality of work by the technicians, both for milking machine maintenance and for the routine test of milk meters. Each technician will get at least one random check per year by one of the KOM-officers. This re-test is carried out as soon as possible after the technician has performed the annual test. The random check test consists of a check on vacuum level, reserve capacity, regulator leakage, and the pulsation system partially, cleaning temperature and the presence of the test report. If necessary a complete test procedure will be carried out. If the technician is not doing a good job, KOM may decide to withdraw his certificate, so that he is not longer allowed to test milking machines.

Certification of the technicians

According to the requirements of KOM, technicians should be well qualified. Because there is no general education for this type of work, KOM together with the Animal Sciences Group of Wageningen UR, has set up a special education program for milking machine technicians. The course consists of several modules varying from udder physiology, milking routines, milk quality, mastitis, machine milking and testing, milk meter routine testing to dialogue techniques with the farmer. For more skilled technicians a modified course was developed. Over 350 technicians joined these courses and approximately 85% succeeded and obtained a certificate, so they are allowed to test milking machines within the KOM system. Joining an annual retraining course including the accuracy check of the test equipment, is a prerequisite for keeping the certificate. Moreover special courses were developed for technicians of automatic milking systems and technicians dealing with the maintenance of milk cooling tanks.

Results of evaluation and test equipment calibration

One of the first activities of the KOM -project was to evaluate the technicians by reviewing an at random selection of ten Maintenance and Advice Reports (MAR) for each technician. The reports were evaluated on several aspects, like completeness of the report, measurements, interpretations and remarks and advise. The results were discussed with the technicians. The number and type of milking machine installations and the number of received test reports has changed in the past 20 years as presented in table 1.

Table 1. Number of farms and type of milking installation in The Netherlands.

Milking System	1983	1993	2003
Bucket milking machines	26.3%	5.3%	0.8%
Pipe line milking machines	27.3%	21.1%	14.4%
Herringbone parlours	40.4%	62.7%	68.6%
Side by Side / tandem parlours	5.6%	10.1%	12.5%
Rotary parlours	0.4%	0.6%	1.3%
Automatic Milking Systems	0.0%	0.04%	2.4%
Total number of farms	49500	35540	23595
Number of MAR test reports	21000	32000	25000

Technicians use different types of test instruments. These devices have to comply with the relevant ISO and ICAR Standards. The equipment used by technicians vary from Bourdon gauges and digital vacuum meters, air flow meters (metering tube and a floating device, orifice air flow meters and electronic air flow devices), pulsation testers, balances and angle measurement instruments to check the position of recorder jars.

Accuracy requirements

The test results are shown in figure 1. In the year 2003 85% of the vacuum meters, air flow meters and pulsation testers was approved immediately, compared to 83% according to De Koning (1994). About 14% was approved after adjustment and 1% was rejected.

Results

For the other test devices like balances and temperature meters, the results were well within the acceptable limits, although over 22% of all angle measuring instruments had to be readjusted. The results clearly show that calibration is necessary to guarantee accurate testing in practice to prevent wrong interpretations on the functioning of milking machines and or milk meter devices. Therefore it was decided to calibrate the test equipment of the technicians at least once a year (KOM, 1999). Each approved device will get an approval sticker of KOM, so farmers can check whether the technician is using calibrated equipment.

Table 2 presents the results for the random checks performed by KOM in 2002 and 2003. The objective is to check 2% of all MAR test reports and 5% of the milk meter routine tests. The figures show an improvement from 2002 to 2003. Around 11% of the random checks in 2003 resulted in a remark concerning one or more aspects. Most remarks concerned completeness of data entry, assessments, and test procedures. In a few cases the technician was ordered to repair some things, like pulsation system or air leakages. About 13% of the farms with milk meters had a deviation on the accuracy of one or more milk meters.

Random checks

Milking Machine Maintenance

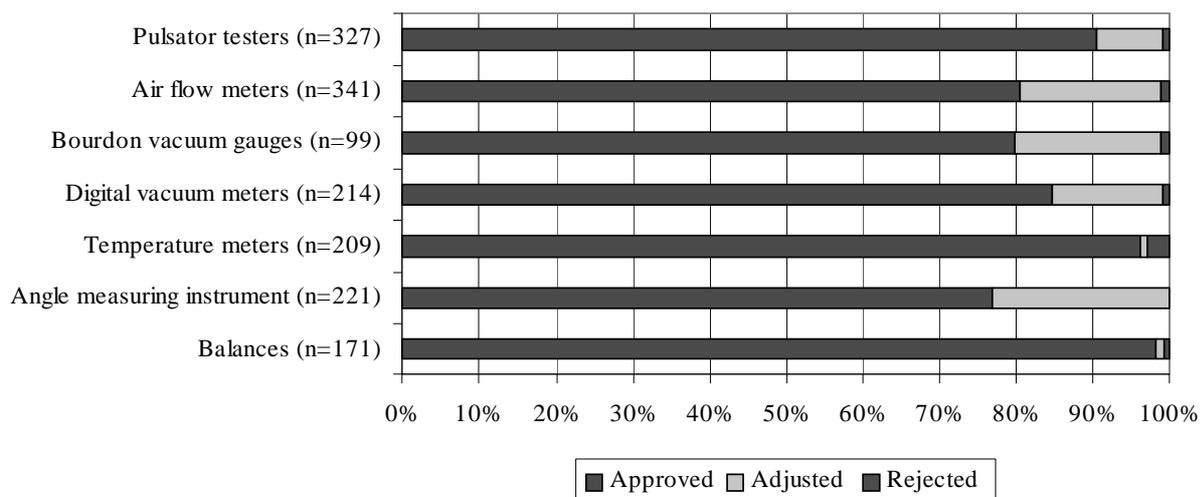


Figure 1. Results of the calibration tests in 2003 for different devices.

Table 2. The number of random checks (farms and meters) in 2002 and 2003.

2002	Milking parlours	Milk meters		Recorder Jars	
		Farms	Meters	Farms	Meters
Random checks	364	79	788	122	1082
Number with comments ¹⁾	41	14	29	39	94
% Deviation with comments	11,3%	17,7%	3,7%	32,0%	8,7%
2003					
Random checks	443	128	1222	135	1273
Number with comments ¹⁾	48	17	37	9	23
% Deviation with comments	10,8%	13,4%	3,0%	6,7%	1,8%

¹⁾ Type of comment not specified (there has been a comment due to deviation in the test results, or over the procedure used, or on the report itself).

Studies on the relationship between milking machines and milk quality

A study was performed on the relationship between technical parameters and milk quality parameters. MAR reports received in March 2002 were used for this study. Technical parameters like reserve capacity, vacuum level and pulsation characteristics were analysed for the relation with somatic cell counts and total plate count. In 9% of the reports from milking parlours with a known installation date, reserve capacity was below the ISO standards. For installations installed after 1996 this was 3%, for installations installed before 1996 11% did not meet the standards. Somatic cell counts and TPC (total plate counts) on farms with insufficient reserve capacity were slightly higher, however the differences were very small and not significant.

Conference on "Physiological and technical aspects of machine milking"

The fast development and introduction of portable PC's, e-mail services and Internet offer interesting perspectives to improve the quality system. Improving the speed, for example by using digital MAR reports which are send electronically to KOM using Internet, can make a further step. Another interesting aspect is the expected integration of test equipment; so one device is able to measure the different functions of the milking machine and to fill the data into a digital MAR report. New data could be checked for mistakes but could also be compared automatically with the historical data. Moreover working procedures and regulations will be standardized between the neighbour countries.

Annual tests for milk recording devices are quite time consuming due to the fact that most milk meters have to tested in routine test procedures using water. When milk meters are connected to a PC system, statistical data analysis might offer time and money saving alternatives to the current procedures. For farmers using electronic milk meters connected to a PC system, such an alternative might save costs and will improve the quality of measured data.

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Future developments

References

Association of milking practices with DHI somatic cell counts in large Brandenburg dairy herds

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Summary

The association of milking practices with DHI somatic cell counts (DHI-SCC) was studied on 80 large dairy farms in Brandenburg, Germany, in 2002 and 2003. All farms were visited by the same veterinarian and milking practices were recorded using a standardized record sheet. To reduce the number of individual items in the analysis compound variables were extracted using factor analysis. The association of the milking practices with DHI-SCC was analysed for the current month and the average DHI-SCC of the last year.

Factor analysis for variables associated with milking management and routines derived three compound factors that combined two or three variables each. The first component was “use of water in the milking parlor” for udder and teat cleaning and cleaning of the parlor between cows. The second was “attention of the milkers” (detection of mastitis, reliability of teat dipping, use of cluster disinfection) and the third was “udder preparation” (material used for teat cleaning, forestripping). The range of values derived from the factor analysis was categorized into three classes, representing one third of the range each with low values being good and high values being bad.

Good values for use of water in the parlor were associated with lower DHI-SCC both for the current month and the last year than bad values ($P=0.019$ and 0.003 , respectively). Attentive, keen milkers were associated with lower DHI-SCC than milkers that were less attentive ($P=0.014$ and 0.012 for the current month and the last year, respectively). In contrast, the component including material used for teat cleaning and method of forestripping was not significantly associated with SCC.

Results of the study indicate that it is crucial to sensitize milkers for the importance of proper milking routines and to remind them of their vital role for the udder health of a dairy herd.

Key words: Mastitis, milking practices, hygiene

Introduction

Average bulk tank somatic cell counts (BMSCC) in Brandenburg were 241,000 per ml milk in 2003 (LKV Brandenburg, 2003) and did not differ much from recent years and other east German states. This is much higher than what is estimated as a healthy herd. However, BMSCC are not the whole story. Their relationship to udder health is fairly weak and a true estimate of the udder health in large herds is not possible. Average SCC from DHI data (DHI-SCC) varied between 297,000 and 341,000 in 2003 with an average of 308,000 cells / ml (LKV Brandenburg 2003).

The association of milking practices with udder health has been extensively studied in various countries. However, most of the studies are based on BMSCC data and a lot of the research was carried out on small or medium scale dairy farms in western Europe, or the north eastern states of the US. Hence it was doubtful if their results could be transferred to the situation of large scale east German dairy herds.

In a cross sectional study we therefore tried to estimate udder health and to identify factors that contribute to the high somatic cell counts of dairy cows in Brandenburg.

Material and methods

We included 80 of the approximately 850 dairy farms registered by the Brandenburg DHI service (Landeskontrollverband Brandenburg, Waldsiedersdorf, Germany) in the study. Farms were chosen by convenience from the respondents of a questionnaire survey that we had carried out to collect preliminary data. Herd sizes were between 100 and 1100 cows per herd. Farms were visited once between July 2001 and October 2002. Information on housing conditions and management was collected using standardized recording sheets and entered into an MS Access database. DHI data on all cows on the farms were obtained from the LKV Brandenburg for the month when the visit took place and the year before the visit.

The multitude of single management items was reduced using factor analysis (Varimax – method) as provided by the SPSS package. Factor analysis aims at identifying the relationship between factors and at reducing the complexity of models by combining factors to compound variables. In the part of the study that is described here we included 8 variables that were combined to 3 compound variables. The association of the compound variables with the geometric mean of the DHI-SCC was analysed using univariate analysis of variance (UNIANOVA, SPSS Inc. Chicago).

Results

Average herd size was 300 cows with 56 % of the herds between 100 and 299 cows and 2 herds with more than 900 cows. Most herds were kept in loose housing systems with cubicles (80 %). A loose housing system with straw bedding was used in 6 herds and a combination of cubicle

and non cubicle loose housing systems was used by another 6 herds. 2 herds were kept in tie stall barns. Most of the cubicle systems (53 %) used straw as bedding material. Herringbone parlors were the predominant type of parlor used (65%), followed by rotary parlors (18%) and parallel parlors (9 %). Forestripping was common with most milkers using a strip cup (74%) or milking on the floor of the parlor (18%). Automatic cluster removal was common (97.5%). Automatic stimulation (41.3%) and automatic machine stripping (38.8%) were widespread. Most machines worked with a vacuum of 41 to 43 kPa (47.5%) or below (38.8%).

Postmilking teat disinfection was common (97.5%) and mostly applied with a dip cup (58/80, 72.5%) or a hand held sprayer (18/80, 22.5%). An automatic spraying system was used by 2 herds (2.5%). Cluster disinfection was also widespread. Two thirds of the herds (65.1%) used it consistently, another 3 herds used it after mastitis cows. An automatic disinfection system was used by 5 herds. However, in 4 of the 5 herds the system did not work properly.

The mean SCC (*1000 cells/ml) of the cows per herd was 372 with a range from 158 to 754 in the current month and 366 (203 to 659) for the past year. 42 % of the cows had DHI-SCC of below 10^5 , while 7 % had DHI-SCC higher than 10^6 .

Good values for use of water in the parlor were associated with lower DHI-SCC both for the current month ($P=0.019$) and the last year ($P=0.003$) than bad values. The average category did not differ significantly from the other two categories.

Attentive, keen milkers were associated with lower DHI-SCC than milkers that were less attentive ($P=0.014$ and 0.012 for the current month and the last year, respectively). The worst category did not differ from the other categories. However, there were only 6 herds in that category, therefore the statistical power was low.

The component including material used for teat cleaning and method of forestripping was not significantly associated with SCC.

Overall, udder health was not satisfactory in most of the study farms. Target values are > 60 % of cows below 10^5 cells/ml (Wendt et al. 1998) or less than 15 % of cows with more than 2.5×10^5 cells/ml (Ruegg, 2003). In the herds studied, only 42 % of cows were below 10^5 cells/ml and about 25 % were above 3×10^5 cells.

The factors included in the analysis were combined to three major compound variables. These were characterized by use of water in the parlor, attention of milkers and preparation routines.

Discussion

The compound variable “use of water in the parlor” combined udder cleaning procedures on the one hand and use of water for cleaning the parlor during milking. Use of water to clean the udders before milking has been associated with high somatic cell counts in other studies (Moxley et al. 1978, Bartlett et al. 1992, Spohr 1998). Wet teats have a negative impact on machine milking and water dripping along the udder tends to carry bacteria to the tip of the teat, hence increasing the risk of mastitis.

Table 1. Results of the factor analysis on milking practices.

Compound	Variables	Categories
Use of water in parlor	Use of a hose to clean udders	1. never
		2. rarely
		3. frequently
		4. always
	Cleaning of floor during milking	1. after each cow
		2. after each group
		3. from time to time
		4. never
	Cleaning of teats	1. dry
2. humid		
3. wet		
Attention of milkers	Detection of clinical mastitis by foremilk screening	1. always
		2. not always
	Consistency of post milking teat dipping	1. consistent
		2. inconsistent
		3. no teat dipping
	Cluster disinfection	1. always
		2. after mastitis cows
		3. from time to time
Preparation routines	Method of udder cleaning	4. never
		1. paper towels
		2. clothes and paper towels
		3. more than 1 cow / towel
	Foremilk stripping	4. no cleaning
		1. strip cup
		2. floor of parlor
		3. plastic shield

Table 2. Geometric mean of SCC (GM SCC) and 95 % CI for month of visit and year before visit for the different compound categories.

Compound	Category	N	Month of visit		Year before visit	
			GM SCC	95% CI	GM SCC	95%CI
Use of water	Good	22	125 ^a	110-144	123 ^a	110-139
	Average	41	149	135-164	152	139-164
	Bad	17	168 ^b	144-195	164 ^b	144-187
Attention of milkers	Good	54	135 ^a	124-147	136 ^a	127-147
	Average	20	168 ^b	146-193	166 ^b	147-187
	Bad	6	175	135-224	168	135-209
Routines of preparation	Good	52	143	131-156	143	132-155
	Average	19	156	135-182	153	135-175
	Bad	9	137	110-171	140	116-169

^a vs ^b: values within compounds and columns differ significantly ($p < 0.05$)

The crucial role of attentive and accurate milkers has been pointed out in recent studies (Barkema et al. 1999, Barnouin et al. 2004). While it was common on the farms to do foremilk stripping and post milking teat disinfection there was a great variation in the consistency of the procedures. Teat dipping as such is rarely associated with good udder health because it is performed on most farms especially if a mastitis problem is recognized by the farmer. Therefore, there is no true control group of farms not using the measure. However, on several farms, teat dipping was officially applied but not consistently performed. The farm management thinks it is using a method to control mastitis but in fact it does not do so.

In line with that the compound variable combining the two procedures of udder preparation had no significant relation to DHI-SCC. About 80 % of the farms used single cow towels and on most other farms single cow towels were combined with wet towels in a bucket to clean the most dirty udders. Forestripping was performed by all farms. However, the differences between farms were in the accuracy of detecting mastitis which was not sufficient in 32 % of the farms.

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Evaluation of the opportunities for continuous monitoring of milking installations

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An overview of possibilities of continuous monitoring of milking installations is made, based on a literature review and a market survey of possible sensors. The importance of some measuring points (vacuum, air consumption, vacuum pump, pulsation, attachment of clusters, liner slips, milk transport, abnormal milk, cleaning, operator faults, cow behaviour, milk cooling and electric supply stray voltage) and possibilities of monitoring are evaluated.

Key words: Milking machine, monitoring system, sensors

Today, commercial monitoring systems can already detect malfunctions in an early stage and prevent serious problems (e.g. bad teat conditions, mastitis, etc.). The availability of reasonably priced and reliable sensors and processing devices might make continuous monitoring (CM) of milking installations in the future cost-effective.

For an optimal milking process, the installation should maintain the desired vacuum at the teats. Checking this requires many sensors, difficult to build in and inappropriate for CM. A solution is to check the vacuum in the receiver, the milking line and the airline at the vacuum pump inlet and at the regulator. The measurements have to comply with ISO 5707. Literature mentions several vacuum sensors for on-line measurement. In wet locations, milk residues can block the connections of sensors with a small internal measuring chamber. This affects not only the measurements (Rasmussen et al. 2003), but is not hygienic either. A flush mounted sensor can be hygienic, but the diaphragm can be sensitive and break quickly. There are besides research systems (e.g. Bray et al., 1998; Spencer, 2000), some commercial systems which include functional checks for vacuum (e.g. vacuum gauge from A/S S.A. Christensen & co, "DairyDaq" from Viper Technology, "DairyTest Monitor" from InnovAg).

Summary

Introduction

Possibilities of CM

A pulsation stop affects the milking and causes harm to teats. A CM system should check if the pulsators are operating. The DeLaval EP70 Pulsators have such a control. Pulsator characteristics can change with time and faults in pipes and tubes can change the pulsation chamber vacuum record. A CM system can detect such faults before udder health is affected. Some research systems (e.g. Bray et al., 1998; Spencer, 2000) and commercial systems (e.g. "Pulse-O-Rater" from Bou-Matic, "DairyDaq" from Viper Technology) which monitor pulsators already exist.

During a liner slip, air enters the clusters, resulting in an unstable vacuum. Spencer (1990) describes an in-line liner slip counter. This system is however not yet suitable for CM. On-line measuring vacuum in the mouthpiece chamber is namely technically difficult.

The most frequent reason for defect with oil-sealed pumps is lack of lubrication. An alarm for low oil level could prevent this. A water ring vacuum pump requires a certain amount of seal liquid to operate at the design pressure. Insufficient liquid may result in reduced capacity or cavitations in the pump. A flow switch can alert if seal liquid flow is low. A temperature sensor in the pump body can indicate problems, including increased exhaust pressure. For water ring pumps, the temperature of the seal fluid affects the vacuum at which the pump operates. Several vacuum pumps nowadays have a temperature security device, which can make the pump turn slower or can switch it off.

The amount of air admitted by the regulator during normal milking indicates the ability of the system to cope with irregularities of air admission. Another monitoring point is to discover and to locate air leakages, allowing a quick repair of malfunctions. Existing flow sensors cannot fulfil the ISO 5707 requirements, due to creating a too high a vacuum drop. Moreover, pulsations and fluctuations from irregularities cause inaccurate measurements. A solution is to detect air leaks by interpreting the vacuum variations.

Milk meters, individual cow identification and timing allow monitoring of the milking dynamics, as well as parlour performance (Maltz et al., 2004, Eicker et al. 2000). This is possible as milk flow curves per cow are to a high degree repeatable. They change however with an increasing lactation period and the same errors in handling and in milking equipment among the individual cows may have different effects (Steidle et al., 2000). The data captured by milk meters, vary moreover widely between different manufacturers (Eicker and Stewart, 1998). Some milk meters only measure the total amount of milk per cow. A milk meter as the Lactocorder (Steidle et al., 2000) can register further useful parameters. A rare bimodality in milk flow curves is an expression of milking readiness whereas frequent occurrence signals stimulation deficits. A short plateau with reduced flow signals defects in vacuum and/or milk delivery. A long decline is due to milking out and then overmilking individual

quarters. The milking gear position influences the ratio between plateau and decline. The Lactocorder also determines the time of overmilking by the machine and it registers abrupt air leakages.

At present, there are no standards defining abnormal milk or describing how to detect abnormal milk. At Lelystad (2004), Rasmussen presented proposals for such standards. There is much research on this topic. Several on-line sensors are being developed, but as far as known, none of them is commercially available yet in a suitable version.

The cleaning procedure comprises many elements, which can fail and cause contamination of the milk (interruption in heating, water or detergent supply). CM of the cleaning process can be more or less comprehensive as such monitoring systems already exist.

Milk cooling is essential to prevent contamination of the milk. A monitoring system could be more or less comprehensive, as monitoring systems for a milk bulk tank exist. In some countries (e.g. Belgium) such a system is even obligatory.

Leakage currents can disturb the milking process. Cows are more susceptible to stray voltages compared to humans due to the cows' relatively lower body resistance (Lefcourt, 1991). The sources of relatively small electrical currents passing through animals are often difficult to locate and it is often unclear how to calculate the current through the animal. Therefore, monitoring of the electric supply stray voltage is a task of specialists.

A CM system could today contain monitoring of vacuum levels at several points in the milking installation, of pulsators, of the proper working of vacuum pumps, a basic monitoring of the milk transport, the milker and the cow with milk meters and monitoring of the cleaning of the installation as well as the cooling of milk. Research promises to add further monitoring possibilities with vacuum meters, with milk meters and monitoring of abnormal milk in the future. Monitoring of air consumption or electric supply stray voltage is not ready for CM.

Thanks go to the members of the Action Team "Continuous monitoring of milking systems" from International Dairy Federation for their advice.

Conclusion

Acknowledgement

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Development of microbiological colonisation in a newly installed milking system

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A field trial was conducted to characterize the development of microbiological colonization in a newly installed milking parlor regarding to seasonal influences and time that the liners were un use. The milking equipment was a 2x34 Side-by-Side milking parlor in a commercial dairy herd in Germany. We examined 2 charges of samples. The 1st charge of samples was taken before beginning of milking and in weekly intervals for a period of two months under climate conditions of winter (10th October – 18th December 02). The 2nd charge of samples was collected in summer 2003 (24th July – 11th September 03). Sterilized swabs were used to collect the samples. After sampling the diagnostic material was kept in Amies medium at 4°C until analysis.

Samples were analyzed from the mouthpiece of the liner, the shank of the liner, and the flushing adapter. The samples were collected immediately after disinfection of the milking equipment. They were analyzed qualitatively and quantitatively according to the official German guidelines (Amtliche Sammlung von Untersuchungsverfahren, §35, LMBG).

We considered mesophil aerobe total plate count, *S. aureus*, *E. coli*, *Coliforms*, *Streptococci*, *Yeast* and *Lactobacilli*. Results indicate a dependence of microbiological colonisation of the surface of the milking technique on season and position of sampling ($p < 0,05$).

Key words: *Milking technique, hygiene, microbiological colonization, swabs, seasonal influence*

Summary

Materials and methods

Experimental Design

A field observation trial was conducted to characterize the development of microbiological colonisation in a 2x34 Side-by-Side milking parlor of a commercial dairy herd in Germany housing 1400 lactating dairy cows. We examined 2 charges of samples. The 1st charge of samples was taken before beginning of milking and in weekly intervals for a period of two months under climate conditions of Winter (10th October – 18th December 02). The 2nd charge of samples was collected in summer 2003 (24th July – 11th September 03). After sampling the diagnostic material was kept in Amies medium at 4°C until analysis.

Samples were analysed from: mouthpiece of the liner, the shank of the liner, and the flushing adapter. On the left hand of the milking parlor (milking unit 1 and 17) the right front and the left hind liner were sampled, respectively. On the right side of the parlor (milking units 51 and 68) sampling was conducted at left front and right hind liner. From each milking unit one flushing adapter (unit 1: left front adapter, unit 17: right front adapter, unit 51: right hind adapter, unit 68: left hind adapter) was sampled immediately after disinfection of milking equipment.

Before Milking the teats were cleaned with udder paper wetted with a disinfecting dilution (Wofasteril®, Peressigsäure, 0,25%). Cleaning and disinfection of the milking technique was performed between the milkings with alkaline (two times) and acidic (one time) disinfectants.

Bacteriological Analysis

The samples were analyzed qualitatively and quantitatively according to the official German guidelines (Amtliche Sammlung von Untersuchungsverfahren, §35, LMBG). Mesophile aerobe total plate count, *S. aureus*, *E. coli*, Coliforms, Streptococci, Yeast and Lactobacilli were considered.

Statistical analysis

The effect of season, milking unit, position of sampling (mouth of the liner, shank, flushing adapter) cow (fixed factors) on mesophile aerobe total plate count (MTPC) was analysed using the UNIANOVA procedure of SPSS. The level of significance was set at $\alpha = .05$. (ln x)

Results and discussion

Results indicate a proper hygienic status of the mouthpiece and shank of the liner and flushing adapter at the start of the milking process. Jasper (1976) described an increasing count of coliforme pathogens on the surface of milking technique as an indicator for an inadequate cleaning and disinfection of milking technique. We did not any coliforms in our study. Mastitis associated pathogens (*S. aureus* or Streptococci) were not detected and in only 20% of samples mesophile aerobe pathogens organisms could be cultured. This observation points out that milking technique was only a vector and not a resource of contagious mastitis pathogens. Various investigators describe teat skin as a source of contagious and environmental pathogens. For this reason the teat preparation before milking should result in a dry teat surface because of a reduction of detectable pathogens (Galton et al, 1982 and 1984, Mc Kinnon, 1990). In our investigation the teat skin was wet and therefore a

source for contamination of the milking technique with associated pathogens. Because of the absence of *E. coli*, coliforme pathogens, streptococci and Staphylococci in our swabs any time of examination we conclude that cleaning and disinfection of the milking machine is efficient.

Statistical analysis with a general linear model (GLM) regarding to mesophile aerobe total plate count (ln) showed season and position of sampling as important factors on concentration of pathogens of the sample ($p < 0,05$). Number of sampling and the number of the milking unit did not influence the concentration of the pathogen in the swab ($p > 0,05$). Less pathogens regarding to mesophile aerobe plate count and yeast colonize on the surface of the milking technique in winter compared to summer (figure 1 and 2). The number of detected pathogens did not cumulate over the two study periods (figure 3 and 4). The application of the GLM on the count of detectable yeast in the samples reflects season as an important factor ($p < 0, 05$). Position of sampling, milking unit and number of sampling did not influence the number of detected pathogens. Yeasts were detected in summer in a higher percentage of swabs and the concentration of the pathogens was higher than in winter. This could be caused by the high temperature and thus the better growth condition of the organisms. Even though the concentration of yeast on the surface of milking technique was higher in summer the incidence of clinical mastitis in summer did not differ from winter.

In accordance to our results seasonal influences on bacterial colonization regarding to mesophil aerobe plate count are described in literature (Mc Kinnon, 1990). However, these investigators did not described this seasonal coherences for yeast.

In the international literature quality of liner material is discussed controversy. Some investigators describe quality of liner material as a risk factor for bacterial colonization (Jasper 76, Grindal 88, Wendt, 1994, Mc Donald and Packer, 1968, Noorlander and Heckmann, 1980). Others reported that there is no correlation between quality of rubber and bacterial colonisation (Zimmermann 2003). Our results indicated no accumulation of detected pathogens over the study period. Between the charges of samples the liners were about 130 hours in use. That's why no accumulation of pathogens is estimated as an advice for no influence of time that the liner is in use.

Further research is required on the importance of detected pathogens on mastitis in cows.

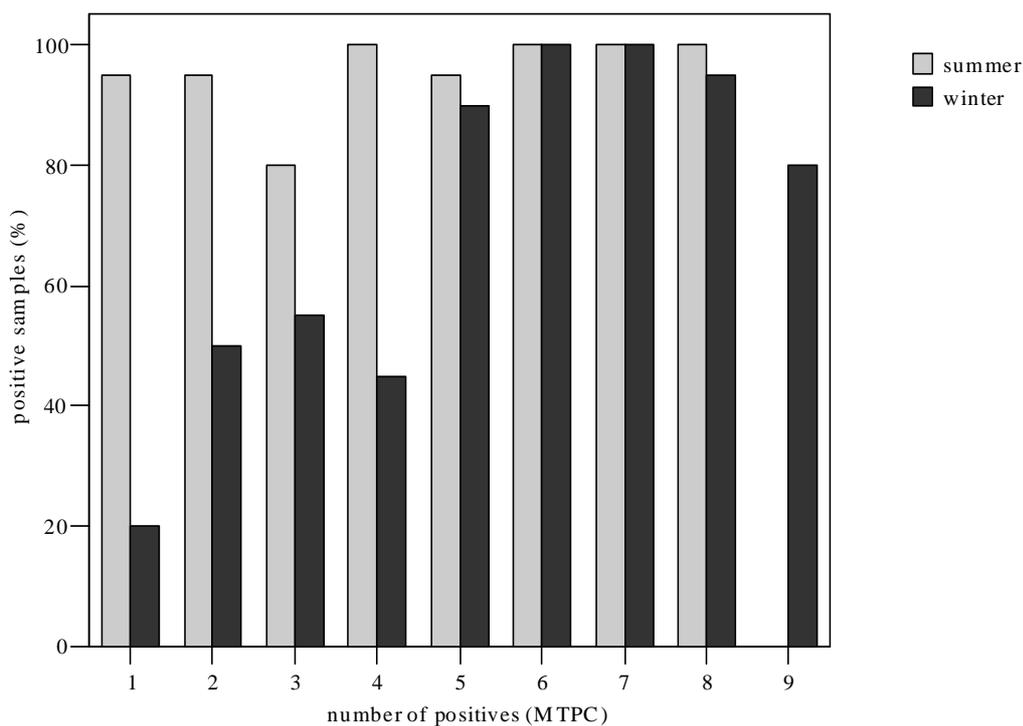


Figure 1. Number of positive samples regarding to mesophil aerobic total plate count.

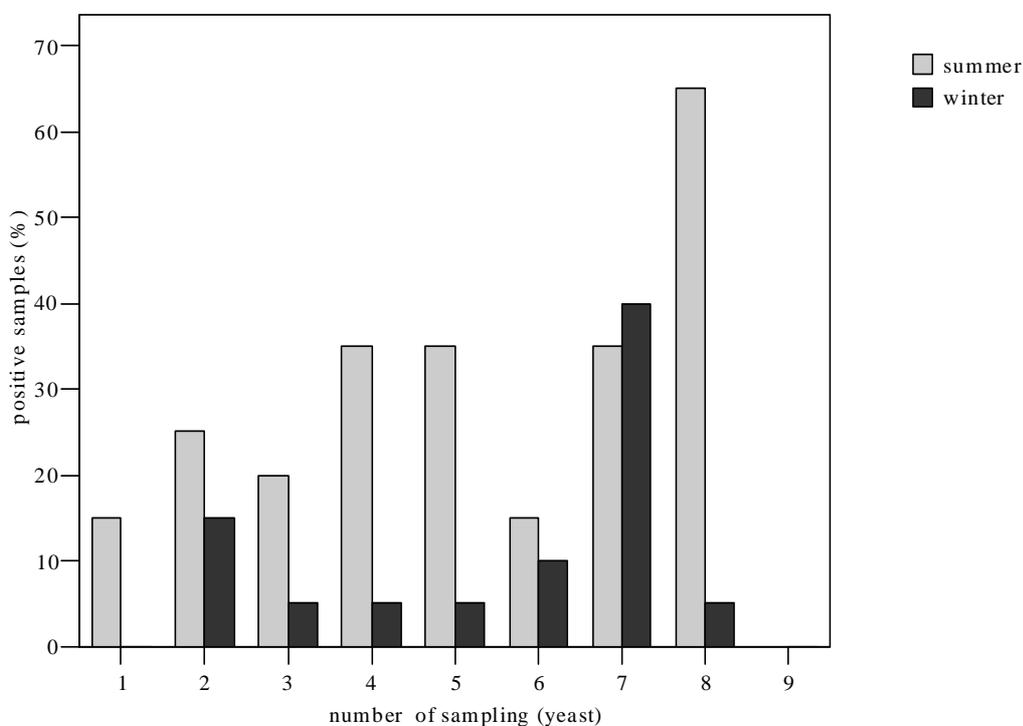


Figure 2. Number of positive samples regarding to yeast.

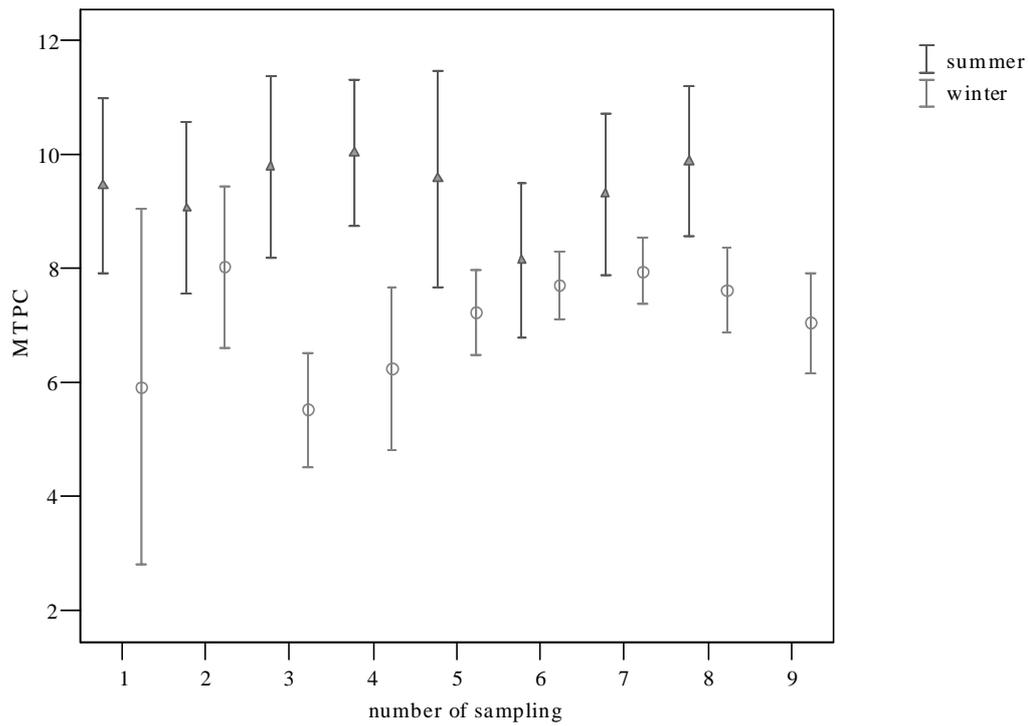


Figure 3. Mean and standard deviation of positive samples (mesophilic aerobic total plate count).

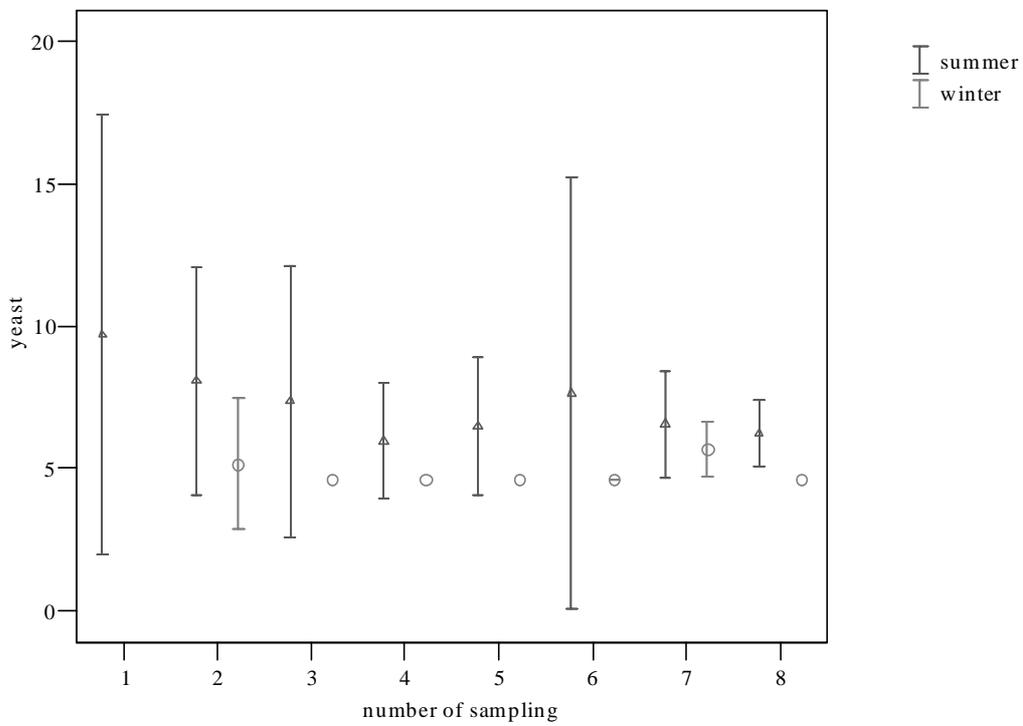


Figure 4. Mean and standard deviation of positive samples (yeast).

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Noise and vibration as stress factors in milking: causes, effects and possible solutions

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As our research shows, design and installation faults occur in practice that not only completely wipe out the advantages of the new developments but also adversely affect udder health and the welfare and performance of both cow and milker.

Anyone wishing to install a milking parlour and his or her architect should contact the milking machine manufacturer as early as the planning phase. This will allow many assembly and installation errors to be avoided and will save on assembly and annual maintenance costs. The desired values of $< 0,3 \text{ m/s}^2$ for vibration and $< 70 \text{ dB (A)}$ for noise are achievable and the farmer should ensure that they are stipulated in the purchase contract. The manufacturers of AMS should also take steps to ensure that their equipment achieves these values.

Key words: *Milking, stress, milking machine, air-borne noise, structure-borne noise, vacuum stability*

A cow can realise its full performance potential only in an environment in which it feels comfortable. The milking parlour is part of this environment. Having purchased a new milking parlour, farmers often become aware that the advantages are accompanied by signs of unfavourable conditions:

- The cows do not enter the milking parlour of their own accord.
- They defecate before entering the milking parlour or during milking.
- They are restless during milking and pull the milking units (MU) off.

Summary

Introduction

- There is a dramatic change in milking behaviour (decline in milk yield, longer milking time, the cows do not allow their udders to be stripped).
- The milker feels uncomfortable and under stress both during and after milking.

Measurements and studies show that a phenomenon to which little attention has been paid to date, that of airborne noise ("noise") and structure-borne noise ("vibration"), may be the cause of this change in behaviour.

Such phenomena can be a source of discomfort for both people and animals and can have a negative impact on the vacuum stability of the milking machine and the performance and general well-being of the animals.

Measurements taken at 38 farms classified as good, at 12 problem farms and at 9 farms equipped with AMS make it clear that the design, installation and quality of assembly significantly affect noise and vibration levels. At good farms noise of up to 70 dB (A) and vibration of between 0.1 and 0.2 m/s² were measured. Problem farms have noise levels of over 70 dB (A) and vibration in excess of 0.3 m/s². Statistical analyses show that the majority of farms with fewer than 200,000 cells/ml have vibration levels of up to 0.3 ms² and noise levels of up to 72 dB (A).

Material and methods

In choosing the farms to be investigated, we tried to take account of all the makes available on the Swiss market and the various types of milking parlour (side by side, herringbone, tandem). We also measured noise and vibration in nine farms equipped with AMS.

Using specially adapted sound meters (real time analysis), the individual values were recorded at various frequencies, generally between 1 Hz and 20 kHz, in the airborne noise and structure-borne noise range.

As we are particularly interested in the comfort of the milker and the animals in our study, our measurements and evaluations therefore focus on the values at the points of impact. Airborne noise was measured in the milking pit and milking stalls 1.2 m above the floor, while structure-borne noise was measured at the level of the manure splash guards and on the structure of the milking parlour.

We were interested in the levels of vibration and noise in these AMS farms. For our measurements we selected three farms for each make of AMS. Fig. 5 shows the points at which vibration and noise were measured. Vibration was measured at the places where the cows came into contact with the structure of the milking robot (point 1: fixing point, point 2: robot arm, point 3: concentrated feed distribution point). Noise was measured in the holding area directly in front of the entrance to the

milking stall (No. 1), near the robot arm (No. 2) and at head height in the feed distribution point (No. 3). At each of these three measurement points for vibration and noise, measurements were taken during various work processes: entrance of the animal, premilking (to clean the teats), attaching the milking unit, milking and removal of the milking cup.

In order to understand the effects of noise on the vacuum conditions of the milking machine, we measured the vacuum stability and frequencies in the air pipe, the milk pipe and the end unit using a measuring technique specially developed for this purpose.

As well as measuring airborne noise and structure-borne noise, we also noted the cell count, milking problems and any installation errors.

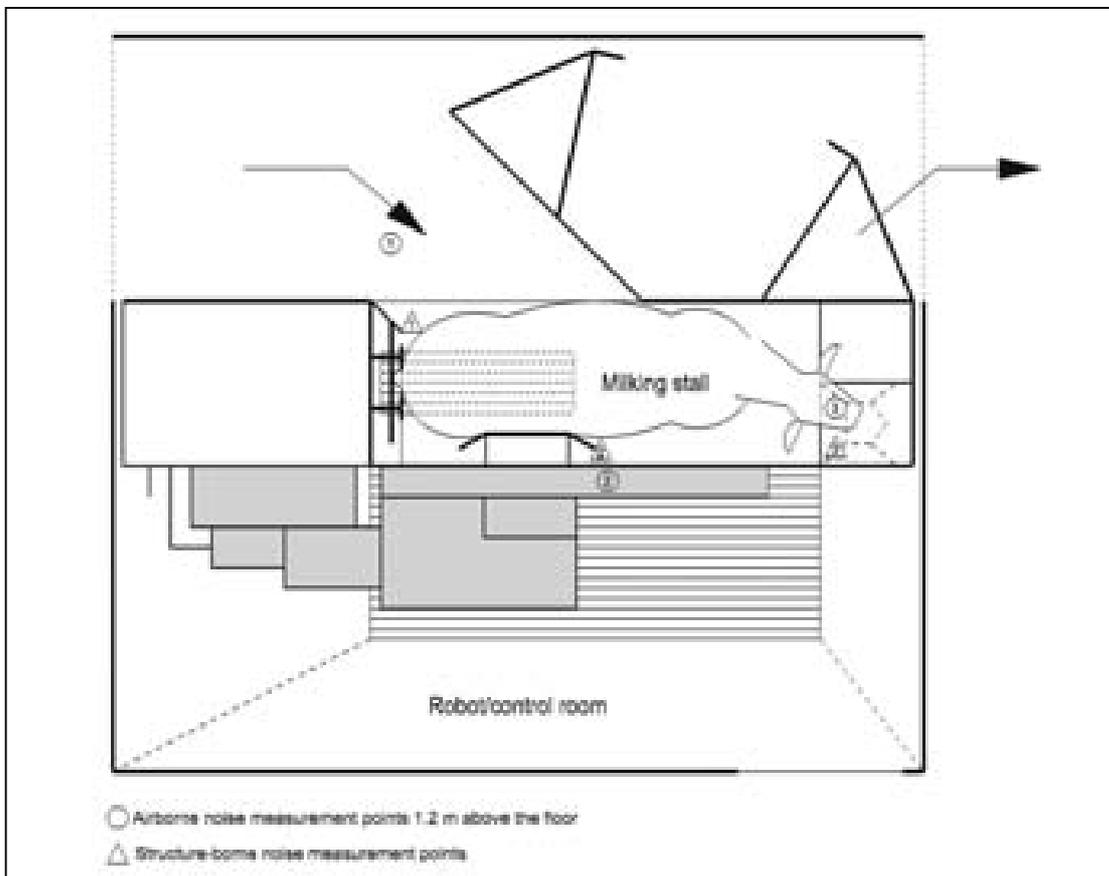


Figure 5. Measurements of vibration and noise in AMS farms taken during various operations.

Results

The statistical evaluation of all the farms shows that vibration has twelve times more impact on the cell count than noise. This is also clearly illustrated by a comparison of the trendlines for vibration (Fig. 1) and noise (Fig. 2). These two figures also show that the majority of farms with a cell count of fewer than 200,000 cells/ml experience vibration levels of up to 0.3 m/s² and noise levels of up to 72 dB (A).

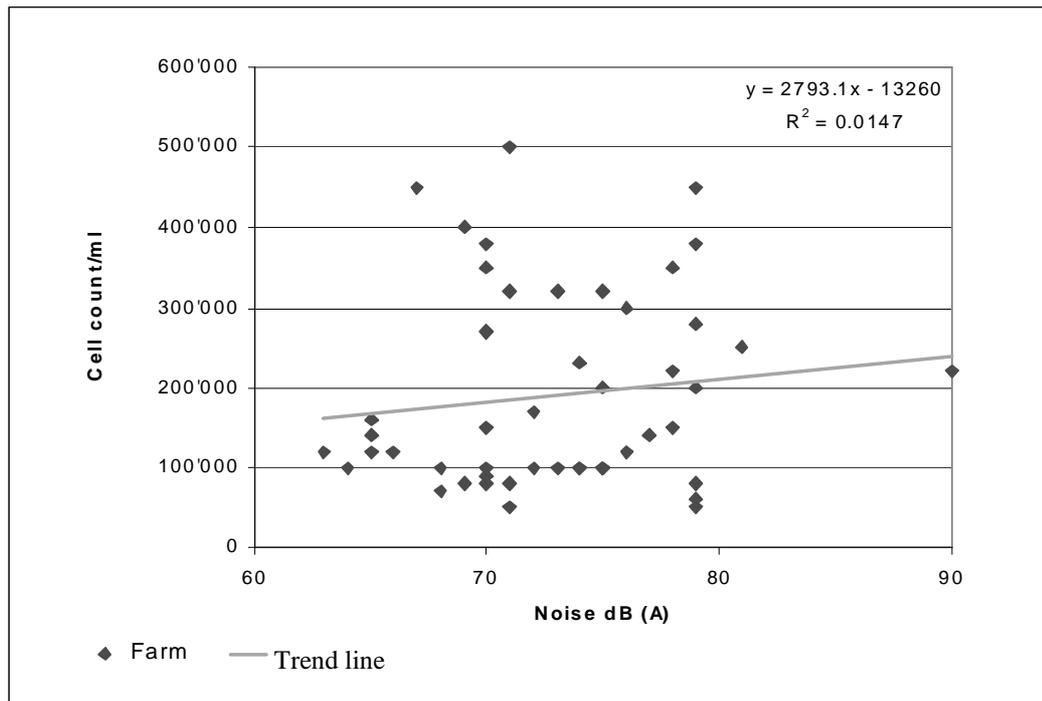


Figure 1. Relationship between vibration and cell count in the farms investigated.

In collaboration with the farmers and milking machine companies we were able to introduce changes in the installations of twelve farms and modify the milking machine.

The modifications significantly reduced the noise and vibration levels. The impact of these reductions in noise and vibration levels on the cell count (udder health) is shown in Figures 3 and 4 respectively. Statistical evaluations show that the reduction of vibration is three times more effective than the reduction of noise in decreasing the cell count per ml. There is a positive correlation between the reduction of vibration and reduction of the cell count.

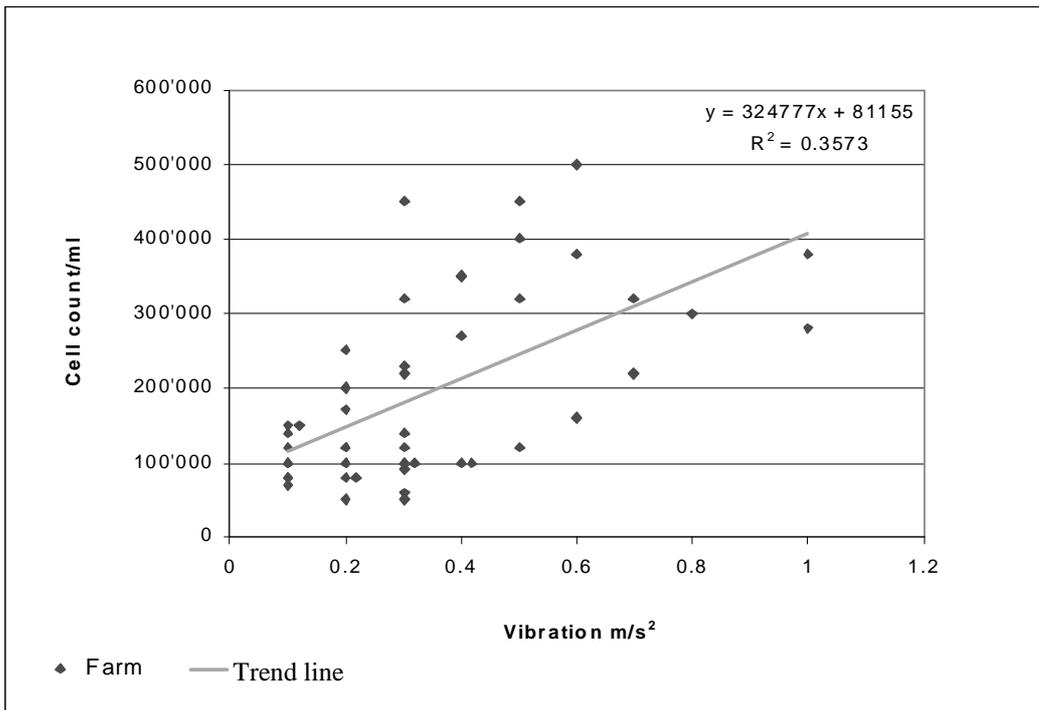


Figure 2. Relationship between noise and cell count in the farms investigated.

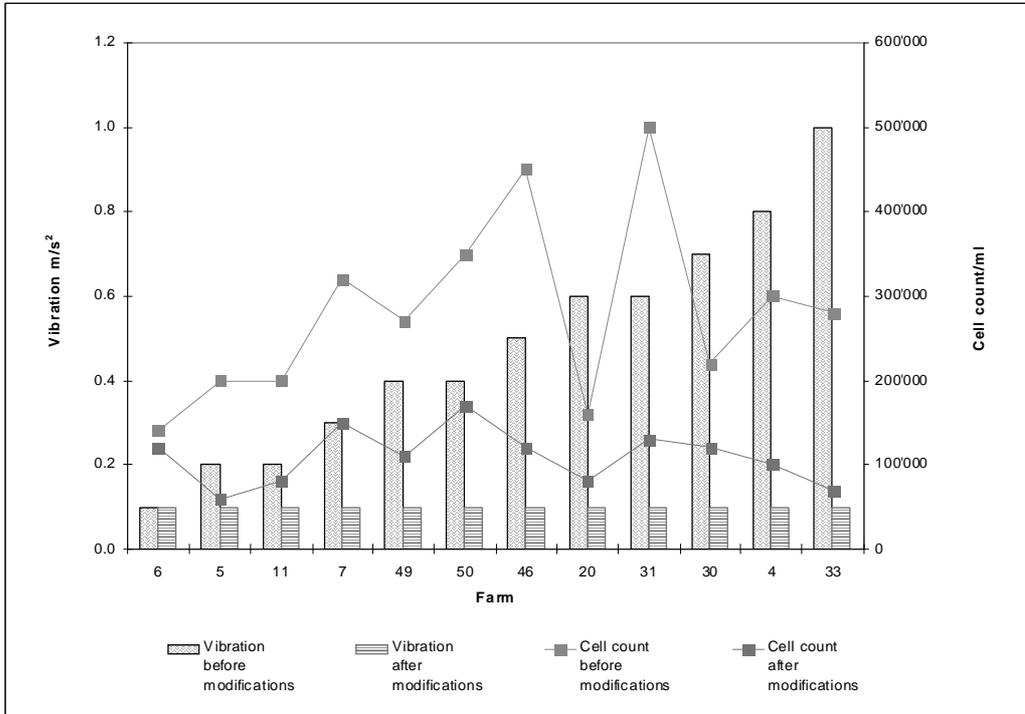


Figure 3. Relationship between vibration and cell count in the individual farms before and after the modifications.

For example, in farm No. 31 the vibration decreased from 0.6 to 0.1 m/s² and the cell count fell from 500,000 to 130,000 (Fig. 3). Noise reduction also produced striking results in terms of reduced cell count in certain farms. In farm No. 46 noise fell from 79 to 55 dB (A) and the cell count decreased from 450,000 to 120,000 (Fig. 4). The reduction of cell numbers also had a positive effect on the cows' performance (a healthy udder produces more milk). With the same feed and same farm management, the yield per cow per lactation rose from 7400 to 8100 litres.

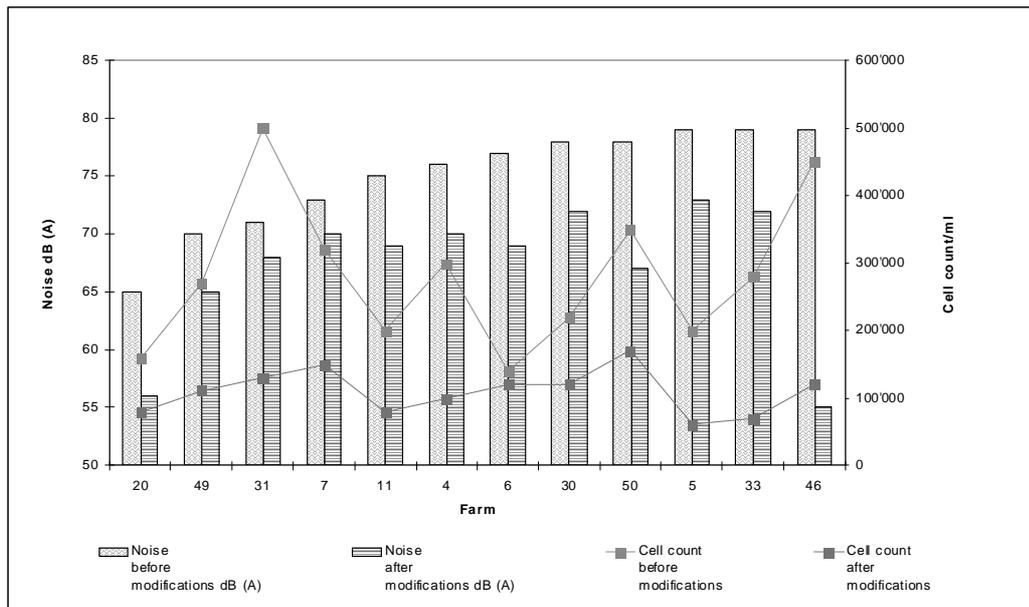


Figure 4. Relationship between noise and cell count in the individual farms before and after the modifications.

Today, around 30 farms in Switzerland are equipped with milking robots (AMS – automatic milking systems) made by DeLaval, Lely and ProLion. The results revealed no direct link between the level of vibration and noise and the measurement point, the work process or the make of AMS. The results for vibration and noise during the milking process (entrance of the animal, premilking, attaching the milking unit, milking and removal of the milking cup) show values that are too high for the individual work processes. In the case of vibration, the average value lies between 0.22 and 0.62 m/s², depending on the work process concerned. Maximum values of up to 1.50 m/s² were also reached in certain cases. In the case of noise, the average lies between 70.3 and 78.3 dB, (A) with maximum values of up to 88 dB (A).

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Perfection of methods and testing means of milking systems

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Regarding to requirements of international standards the comparative analysis of interaction of milking units with teats of animal udder allows to receive time parameter diagrams which describes operation of milking units in dynamics. Besides phases of pulsation cycle for them are as follows: the beginning and the end of milk letdown moments; contact points of liner walls; the beginning and the end of massage of teat by liner; periods of full milk letdown and teat of liner massage; vacuum of balance (if vacuum becomes lower than this level, it will act as „over-pressure“) or effective massing influence of teat on teat tip operates; integrated influence of liner on animal udder teat.

Control of the specified parameters is carried out with help of microprocessor measuring parameter instrument of the milking equipment EXITEST-2.1, supplied with complete set of gauges. The device includes electronic unit with display and printer, removed vacuum pressure gauges, multi-purpose artificial teat-sensor, air flowmeter, external charge device, adapters-fittings and tubes for connection. The device allows controlling vacuum modes of the milking and vacuum systems of the milking equipment in dynamics.

The artificial teat-sensor is equipped with the following: gauge measuring vacuum pressure in teatcup liner; hydrodynamic pressure gauge, perceiving through artificial teat cover of the integrated influence of liner and liner vacuum on teat. It's also stipulated: transformer controlled a vacuum mode in a mouthpiece chamber, imitation of milk letdown and regulation of penetration depth of artificial teat-sensor in a teatcup.

Key words: *Artificial teat sensor, integrated influence on teat, generalized rigidity of liner*

Summary

Introduction

The studies of L.P. Kartashov, S.A.Soloviov, D.I. Reinemann, M.A. Davis, G.A. Mein, K. Muthukumarappan, M.D. Rasmussen [2,3,5], E. Harty, P.M.Grace, E.J.O' Callaghan, J.Szlachta, K. Aleksander, M.C. Butler, H. Worstorff, E. Bilgery [6] and others are dedicated to improvement of systems and facilities for analysis of interaction between suspended part of milking units with teacups of particular liners (L) with udder teats of animals. The aim of the above-mentioned studies was to find out the way of impact of teacup liner both on the very teat as a whole, and on the tip of cow's teat, as well as on its hyperkeratosis reaction.

Moreover, many researchers supplement the requirements to testing methods of milking systems stated in ISO standard specifications [1].

Materials and methods

Analysis of interaction nature of milking units (MU) with animal's udder teats, processes occurring in a claw, long milk tube MU and milk line and vacuum system of milk installation, as well as taking into account the requirements to milking units testing stated in the standards ISO 5707 and 6690, standards ASAE EP 445 and S 518, results obtained by key researchers [2,3,5,6] and our own researches [4] allow to combine the above-mentioned statements and to present time diagrams of parameters which describes an overall performance of milking units (see fig. 1).

Pulsing vacuum pressure transmitted by pulsator to teacup pulsation chamber (PC) is shown on fig.1 in form of diagram $P_{v.1}$. Vacuum pressure in liner vacuum (LV) chamber of teacup (TC) - in form of diagram $P_{v.2}$. Its characteristic sections are vacuum surge in LV while liner opening and milk flow just starting (JS ○) of a teat and vacuum fall in LV while liner closing and milk flow stopping (StM●) of a teat. Shape of curve $P_{v.2}$ significantly depends on parameters of suspending part MU (volume of milk chamber and type of claw, parameters and condition of liner and a short milk tube, form and overall dimensions of an udder teat, milk flow rate intensity, etc.).

Let's allocate standard breakpoints with help of which we can define phases *a, b, c, d*, sucking times (milking) – t_{milk} and massage (rest) – t_{mas} on diagram $P_{v.1}$, minus 4 kPa as respects to the upper and lower level in accordance with standard ISO 3918.

Let's allocate characteristic points on diagram $P_{v.1}$ on the base of research results of Mein G. [2]:

- SM (◇) – start of teat massage by liner and start of teat channel opening;
- StM (●) - end of milk flow rate, due to the teat channel is pinched by line. This moment corresponds to touch point (TP) of liner walls;
- JS (○) – just start of milk flowing owing to start of teat channel opening while liner disconnecting;
- EM (◆) - end of teat massage by liner (at full stop of its non axisymmetric deformation), that corresponds to full opening of the teat channel.

Thus, in contrast to distinguished phases of pulsation cycle (*a*, *b*, *c*, *d*) according to ISO 3918, we can assume that the following sections of $P_{v,1}$ are characteristic zones and we mark them out as: JS - EM - phase *a'*; EM - SM - phase *b'*, which characterizes the process of „clear“ milk flow rate with duration $t_{b'} = t_m''$; SM - StM - *c'*; StM - JS - phase *d'*, which characterizes the process of influence of compressive liner load on teats, usually designated in science literature as over-pressure (OP) with duration $t_{d'} = t'_{mas}$;

Then milking time duration (time of total milk flow rate) is equal $t'_m = t_{a'} + t_{b'} + t_{c'}$, and time of massage (period of full massage) - $t''_{mas} = t_{c'} + t_{d'} + t_{a'}$ (according to, approximately $t'_m : t'_{mas} \approx 65:35$ and $t''_m : t''_{mas} \approx 50:50$).

The periods of total milk flow rate and massage marked out in the diagram are overlapped in phases *a'* and *c'*.

Curve RV passes through characteristic points EM and SM. The curve describes residual vacuum for massage (vacuum necessary for liner closure). Vacuum pressure in the milk chamber of claw $P_{v,c'}$ measured at the moment of sensor connection is 38-42 or 44-48 kPa, depending on type MU.

After vacuum has reached the level called equilibrium vacuum $P_{v,eq}$ [2], in the pulsation chamber of a teatcup, JS - milk flow just starts and StM - milk flow stops. Compressive force (force of liner influence on teats) is balanced by «fanning force» on vacuum level $P_{v,eq}$, as a result of higher vacuum level $P_{v,2}$ in LV, within closed liner. It was shown, that the optimal value of $P_{v,eq}$ is 8-12 kPa [2].

Below this vacuum level the liner carries out one of the major functions - the teat effects on a tip (massages it) while liner bending around it is being compressed with force, defined by so-called over-pressure (OP), or « compressive load »[2].

Efficiency of milking from an udder (without dropsied, stagnation and hyperkeratosis – which is damage of teat tips), and, therefore, health of cows depends on efficiency of OP influence.

There is a problem of control of level of integrated interaction of teats with a teatcup while researching and testing parameters MU. To solve this problem we are developing a device for measuring parameters of milking equipment with an artificial teat-sensor (ATS), schematically shown on fig. 2 while interacting with TC. In case of similar developments [2,3], the following problem was set: estimation of complex influence of teatcups of suspended part MU on a whole teat body in dynamic, from base, mouthpiece, central part to tip, as well as from insertion depth into TC. We think it will allow to estimate character of impact of massing procedure of teatcups liners both on a whole teat, and on its tip in details.

Results and discussion

ATS is made in form of an average cow's udder teat and is an elastic membrane 1 filled with a special liquid 2. There is channel 3 along ATS axis. It is for milk simulator run and it is for damp testing. An elastic tube 4 for simulation of milk flow rate dynamics is inserted in the lower end of the membrane in the channel 3. Membrane 1 is attached to body 5 in its upper part with help of sleeve 6 and washers 7. Device 8 for regulation of teat elasticity is mounted into sleeve 6. Sensitive element 9 of the sensor is mounted in the lower part of the teat. The sensor is intended for recording of vacuum gauge pressure $P_{v,2}$ in the liner vacuum chamber under teat tip. An additional ring 10 is mounted on membrane 1 for better contact between ATS and liner and for improvement of its sensitivity. Vacuum pressure sensor 14 connected to mouthpiece chamber (C.Mth) by channel 15 is built into body 5 of mouthpiece chamber of liner 11 TC 12 (Fig. 2) put on ATS 13 in order to carry out vacuum pressure $P_{v,Mth}$ control.

Integrated dynamic liner impact, teatcup liner vacuum $P_{v,2}$ and suspended part MU on ATS through membrane 1 is registered by the built-in hydrodynamic pressure (PHD) sensor 16 installed in body 5 and is marked out as a characteristic **Re**.

Re is an integrated resulting pressure inside of the working hollow of membrane 1 as a result of interaction between ATS and teatcup liner 11 and suspended part of milking unit

$$R_e = f(P_{v,1}; P_{v,2}; P_{v,Mth}; T; H; E; B; L_s / L; \delta; \psi; \xi), \text{ kPa}$$

where: **T**-liner tension, N; **H**- liner hardness, on Shore A; **L_s**-shell length, mm; **L**-liner length, mm; **B**- liner bore, mm; **E**-modulus of elasticity of liner material, N/m²; **δ** - walls thickness of liner, mm; **ψ** and **ξ**-coefficients depending on ATS design features and suspended part of MU.

To control ATS insertion depth in a teatcup, ring nozzles 17 are put on teat 13. In order to carry out dynamic (damp) test MU and simulation of milk flow rate, in accordance with requirements of ISO 5707, ATS is equipped with feeding system 18 of milk simulator $Q_{m,i}$.

We made a device for measuring parameters of milking equipment „EXITEST“ in 1993 and equipped it with reduced version of ATS [4]. The latest version of microprocessor device EXITEST-2.1 is equipped with sophisticated ATS. It contains two remote vacuum gauges pressure sensors, artificial teat-sensor, gauge –flowmeter of air stream, complete set of tees and nozzle-adapters providing connection to any point of testing milking equipment.

Diagram **Re** (fig. 1) was obtained with help of ATS of the above-mentioned device while carrying out control of parameters MU at the same time with measurement of vacuum pressure pulsations. According to results of preliminary researches [4] the inverted diagram **Re** corresponds to diagram $P_{v,1}$ with approximately 2 % time delay in terms of phases of pulsation cycle that is a result of inertia of liner motion relative to vacuum oscillations in PC.

Idealizing interaction process (Fig. 1), lets copy characteristic points JS (○), EM (◆), SM (◇) and StM (●) down from diagram $P_{v,1}$ on diagram **Re** and obtain points JS' (□), EM' (▲), SM' (Δ) and StM' (■) there. After that we can allocate series of characteristic levels on time diagram **Re(t)**:

Level of points JS' and StM', where **Re(t) = Re.cr** corresponds to integral impact of suspended part MU at equilibrium vacuum $P_{v,eq}$ on a teatcup teat (i.e. liner and liner vacuum).

Below this level the diagram section (from **Re.eq** to **Re.max**) characterizes a value range of „compressive load» or an over-pressure occurred while massaging and swaging a teat tip by close liner. The maximum overpressure value is **Re.op = Re.max - Re.eq**. As appears from the above, over-pressure value (compressive load) **Re.op**, defined with help of diagram **Re** as area of its section **Sop** which lays below **Re.eq** within StM'-JS' (phase **d'**) can serve as a method of estimation of efficiency of massing impact of liner on a teat tip. Preliminary researches showed that **Sop** is lower in case of rigid liners, even within allowable phase duration $d > 15\%$. In order to simplify, let's obtain **Re.eq** copying point StM of level **Pv.eq** to diagram **Re**. With help of obtained point StM' we draw a horizontal line. Intersections of this line give us point StM' and JS', which define level **Re.eq**. Furthermore we determine area **Sop** of diagram segment starting from t'_3 to t'_4 below level **Re.eq**, between points StM' , and JS' according to amplitude **Re.op**. Efficiency of massing procedure liner on dummy tip can be estimated with help of value Sop.

Point EM' corresponds to the moment of completion of teat massage by liner, and the corresponding level can be called critical. It is characterized by minimal force impact, at that pressure in cavity ATS marked out as **Re.cr**. Therefore, reaction **Re** ATS indicating pressure of full strain of liner is **Re.def = Re.max - Re.cr**. The upper glow iris section **Re** corresponds to reduction of absolute pressure, in cavity ATS filled with liquid, down to minimum level **Re.o**. The whole pressure range indicating integral impact **Re.i** on environment ATS and its strain, lays within **Re.o < Re.i < Re.max** and depends on many parameters. Namely the following: surface condition, rigidity and stress level (owing to a tension) liner, underteat vacuum condition, rigidity of ATS cover, initial pressure of liquid into its cavities, ratio of overall dimensions of ATS and liner and others. Its strict mathematical description is pretty difficult and such a description isn't cited in the present paper. Integral impact of a teatcup on an udder teat (or ATS) can be estimated with help of amplitude value **Re.i = Re.max - Re.o**.

We have offered a sophisticated ATS version which allows to change rigidity of its elastic part. In case of proper metrology calibration of microprocessor measuring device EXITEST against magnitude **Re** it is possible to simulate and to estimate impact of TC liner on natural cow's teats.

In order to immediately determine impact of liner on teats only, without taking into account impact of underteat vacuum while dry testing, ATS is installed in a teatcup with disconnected collecting channel and other teatcups with removed plugs. As a result we obtain „pure“ (without impact of vacuum) value **Re.cl**, which allows to estimate (generalized) rigidity and tension condition of liner directly in a teatcups. Comparative calibration **Re.cl** according to standard technique of estimation of liner rigidity at elongation, will allow to receive the corresponding parameter which we called parameter of “generalized rigidity” of liners and which can be estimated with help of ATS—a component of the microprocessor measuring device EXITEST 2.1.

Conclusion

Equipment of microprocessor meter of parameters of milking systems EXITEST-2.1 with proposed ATS, along with other sensors, will provide expansion of its capability. Later on it will allow carrying out the following:

- Registration and estimation of milking system parameters **Pv.1**; **Pv.2**; **Re**, phases of pulsation cycle and vacuum in a milk chamber of claw **Pv.c** in dynamics;
- Monitoring of vacuum condition $P_{v,2}$ directly under teat, during influence of liner on teat’s tip;
- Opportunity to record parameters of milking systems while simulating their interaction with teats of different elasticity and lengths;
- Estimation of tension, rigidity, generalized rigidity and extent of wearing off of liners without disassemblies of teatcups with help of **Re.cl**;
- Tension regulation and selection according to rigidity of liners in teatcups, depending on properties (parameters) of udder and teats of milk cow herds.;
- Determination of „over-pressure“ value OP, or compressing load of liner on teat tip, according to value of integrated reaction **Re.op** ATS within the range of phase d' .
- Determination of integral impact of teatcups on teats $R_{e,i}$.

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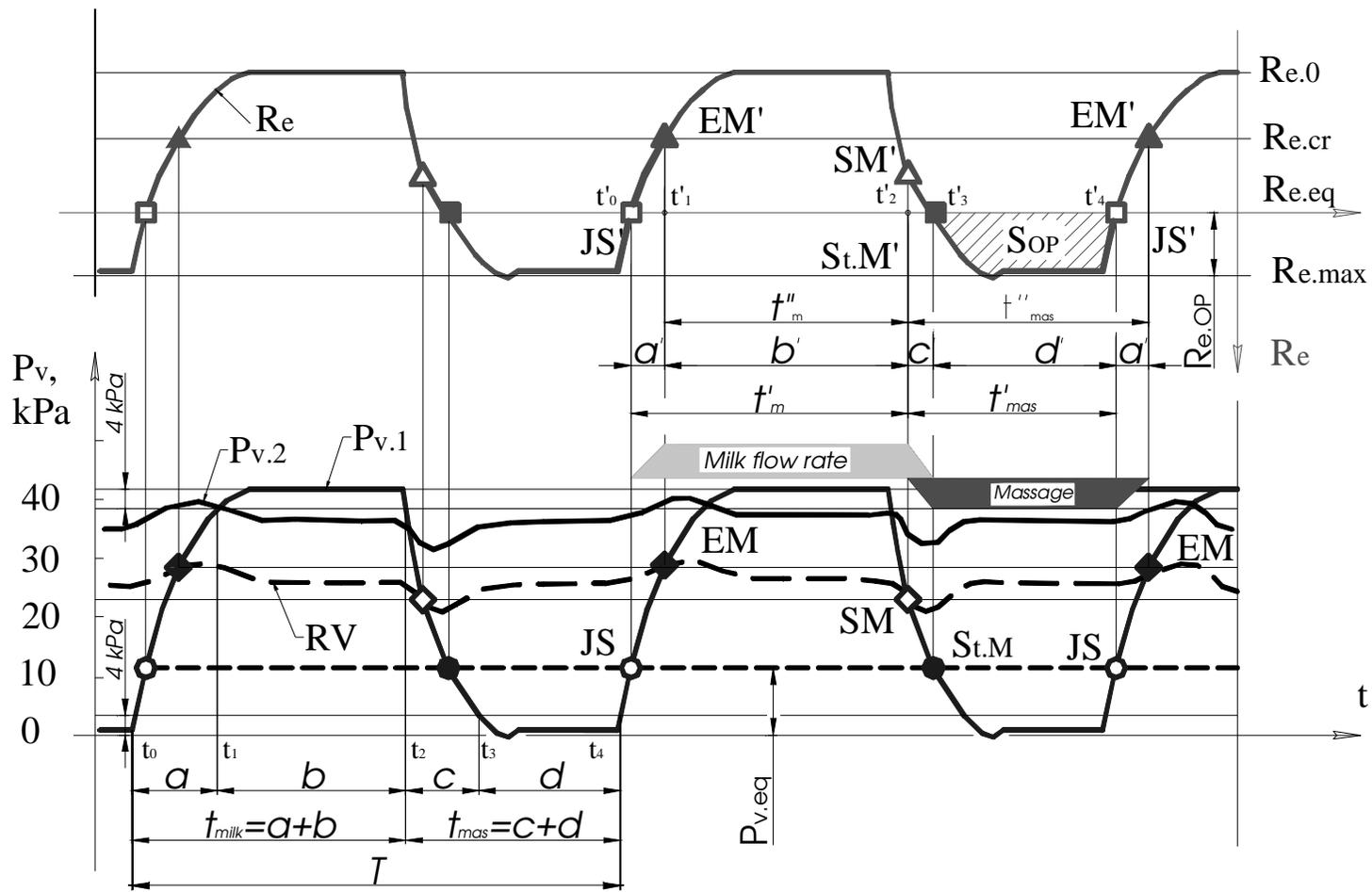


Figure 1. Characteristic diagrams of pressure and parameters of milking units.

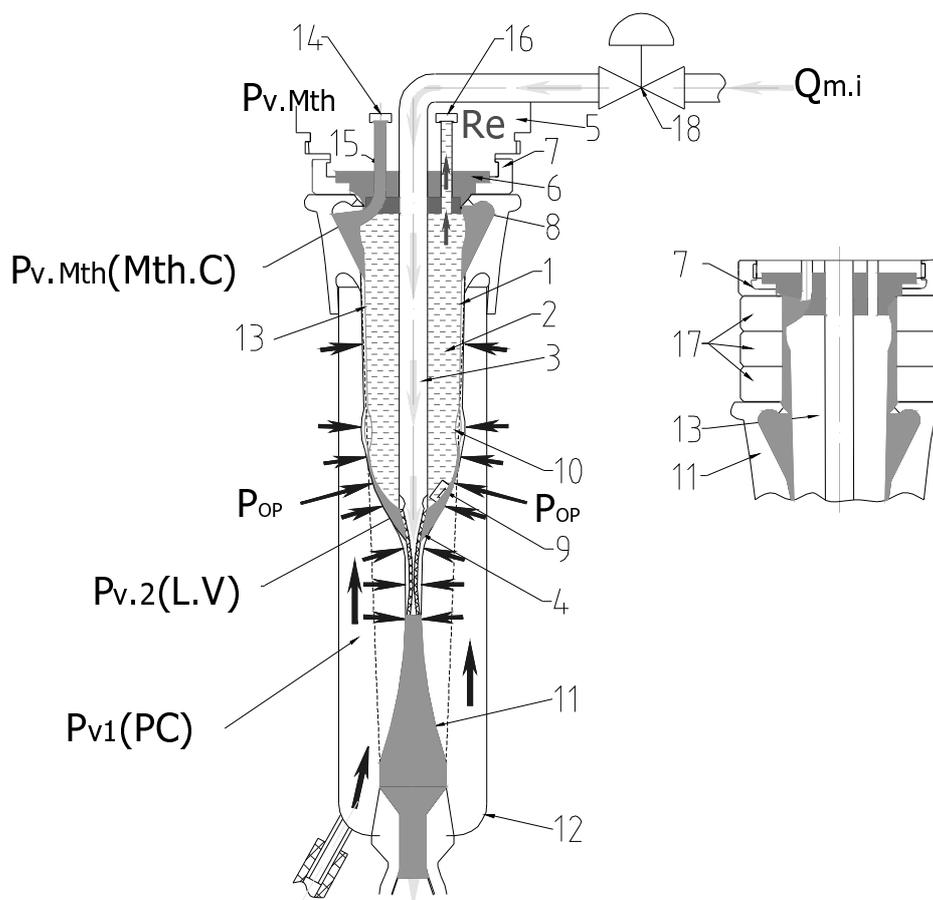


Figure 2. Interaction between artificial teat sensor and teatcup.

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Specificity and sensitivity of a mastitis diagnostic method based on the electrical conductivity for single quarter and punctual data elaboration

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Clinical and sub-clinical mastitis have a strong impact on dairy cow breedings, because they cause big economical losses. The monitoring of the electrical conductivity (EC) of milk is the most diffused diagnostic method for mastitis. The aim of this project was to measure the sensitivity and the specificity of a method based on the measure of the EC for quarters and on a relative and punctual data elaboration. The study involved 55 cows in lactation.

The results of this study confirm that the EC is a little sensitive indicator, but that, at the same time, can be a valid aid.

Key words: Milk quality, mastitis, electrical conductivity

On the market two different types of system can be used for the on-line detection of EC of milk: with measurement on the mass milk for single cow or quarter by quarter. The former has problems principally due to the dilution of the milk that comes from the mastitic quarter in the rest of the mass milk. The latter, if it works on the basis of limit value, shows problems connected to the choice of this value, although specific for each

Summary

Introduction

animal. If it works on the basis of values that are connected to the previous milking, it may highlight some limits when used for the first time on pluriparous cows without suitable previous data.

The aim of this project was to measure the sensitivity and the specificity of a method based on the measure of the EC for quarters and on a relative and punctual data elaboration.

Material and methods

The study involved 55 cows in lactation for a total of 214 mammary quarters. For each cow, after the identification of the quarter with inferior medium value of EC (considered healthy) the relationship with the other electrical conductivities was calculated. Every quarter with relationship >1,1 was considered indicative of mammary infection, subsequently verified using as gold standards, bacteriological analysis and the somatic cells count (SCC).

Results

The sensibility and specificity values of the EC parameter, obtained through different gold-standards, were the following: SCC, sensibility 46% and specificity 82%; bacteriological analysis, sensibility 41% and specificity 81%; SCC + bacteriological analysis, sensibility 58% and specificity 78%.

Conclusion

The results of this study confirm that the electrical conductivity is a little sensitive indicator of the presence of mastitis in the mammary quarters (the maximum sensibility was 58%) but that, at the same time, the monitoring of this parameter, through devices of low cost that implements similar method of elaboration and analysis, can however be a valid aid.

Factors affecting the results of CMT in a Tunisian dairy herd

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Variations of CMT scores were studied on a sample of 31 dairy cows from a herd of 182 Holstein-Friesian cows milked three equally spaced times a day by an automatic machine. Scores were determined three times a week and during 60 days in the midday milking. Scores were determined for the whole mammary system and for each quarter on every cow. Associations of udder cleft, udder balance, teat placement, front teat distance, side teat distance, teat length, teat implantation, end teat diameter, rank of lactation, DIM, and disinfecting before milking with infection status were detected using logistic regression. Up to 35% of cows were infected, of which 4.5% were severely infected. The rate of infection varied only between rear and front quarters. The CMT scores varied with the rank ($p < 0.01$) and stage of lactation ($p < 0.05$). Older cows showed higher infection rates than first lactation cows and middle of lactations were associated with lower infection rates than other lactation phases. The odds of infection increased with teat length ($p < 0.01$) and foot angle ($p < 0.01$) and decreased with teat end diameter ($p < 0.01$) side teat distance ($p < 0.05$), and udder to knee distance ($p < 0.05$). Older cows producing at the end of lactation with pendulous udders and long and thick teats are more likely to get infected with mastitis than other cows.

Key Words: Dairy cows, CMT, infection, logistic regression

Mastitis constitutes a major cause of losses to the dairy industry by increasing involuntary culling and deteriorating chemical and bacteriological qualities of milk (Strandberg and Shook, 1989). Mastitis occurs in different forms in herds (Obey, 1999). Detection of mastitis at early stages may reduce costs. CMT is an effective and quick means to identify infected animals. Milk production level, rank of lactation, days in milk, and udder traits were found to affect rates of infection (Rupp and Boichard, 2000). The objective of this study was to link variations of CMT scores to udder traits, rank of lactation, days in milk, and management.

Summary

Introduction

Material and methods

A sample of 31 cows were randomly chosen from a herd of 182 Holstein-Friesian cows milked three equally spaced times a day by an automatic machine. The sample was chosen to represent first (15 cows) and later lactations and various days in milk (<60, 60-200, and > 200 days). CMT scores were determined three times a week and during 60 days at the midday milking. Scores on a scale of 0 to 4 were determined for the mammary system and for each quarter on every cow. A cow that has a score greater than 1 was considered infected and was assigned a code of 1 and 0 otherwise. The probability of being infected was then linked to udder cleft, udder balance, teat placement, front teat distance, side teat distance, teat length, teat implantation, end teat diameter, rank of lactation, DIM, and disinfecting. The search for explanatory variables associated with infection status was done with the stepwise selection technique in SAS (1989) for logistic regression.

Results

Infection status of sampled cows

Up to 35% of cows were infected of which 4.5% were severely infected (Figure 1). Around 17% of the quarters were infected. Few cows had all quarters infected (<1%). Left and right quarters were similarly infected while posterior quarters were more susceptible to mastitis infection than anterior ones (23% vs 11%). Multiparous cows (79%) seemed to catch infection more than primiparous cows (21%) and those in the end of lactation (7.4%) were more likely to get infected than those in the beginning (6.5) and in the in middle of lactation (3.1%). Disinfecting the udder before milking seemed to reduce infection incidence by the 7th week of the experimental period (Figure 2).

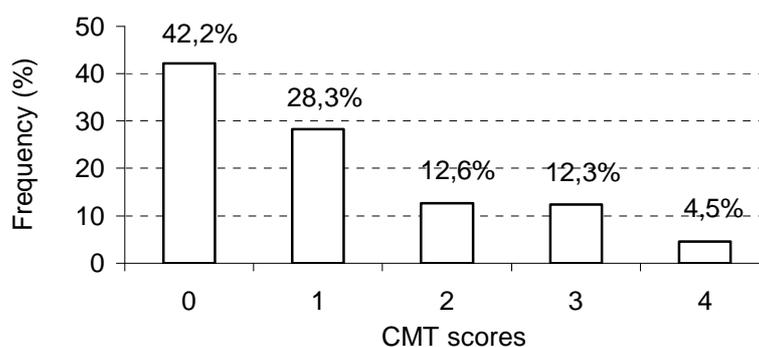


Figure 1. Distribution of CMT scores of sampled cows.

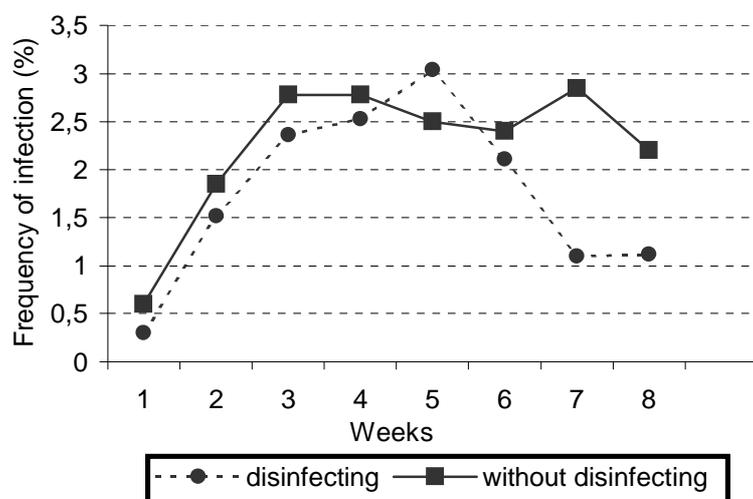


Figure 2. Evolution of mastitis infection rate with and without disinfecting the udder.

Factors levels associated with the incidence of infection by mastitis at the 5% significance level are given in Table 1. Most of teat measures and udder conformation traits seemed to affect infection rates of sampled cows. Long teats with large end diameter and an unsatisfactory implantation increased the odds of infection of milking cows (Table 1). A balanced udder with optimal fore and rear attachments and rear, side, and front teat distances decreased the probability of infection by pathogens. Furthermore, older cows at the end of lactation are more likely to get infected than first lactation cows during the whole lactation.

Associations of somatic cell scores with studied factors of variation

Table 1. Factor levels and variables associated with mastitis occurrence ($p < 0.05$)

Factor	Parameter estimate (β)	Standard error	Standardised estimate	Odds Ratio
Primiparous	-0,97	0,19	-0,267	0,38
Beginning of lactation	0,33	0,15	0,086	1,39
Left rear quarter	-1,01	0,14	-0,244	0,37
Right rear quarter	-1,02	0,15	-0,245	0,36
Front teat distance ≤ 3	-1,73	0,28	-0,2980	0,18
$4 \leq$ Front teat distance ≤ 6	-2,36	0,30	-0,524	0,09
$1 \leq$ side teat distance < 5	1,59	0,28	0,439	4,92
Udder to knee distance < 4	1,07	0,22	0,255	2,92
$4 \leq$ udder to knee distance ≤ 6	-0,29	0,13	-0,081	0,74
Teat length > 55	0,39	0,13	-0,108	1,48
Teat end diameter < 20	-0,71	0,16	-0,192	0,49

Conclusion

An udder with optimal conformation is easier to milking by an automatic machine. Putting more emphasis on udder conformation when selecting replacement cows and disinfecting the mammary system before milking would substantially reduce risks of mastitis infection in Tunisian dairy herds.

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Does housing and feeding during milk-feeding period affect the milk production of primiparous dairy cows?

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Calves are usually removed from their mother immediately after calving and fed by milk replacer (MR). Only a few calves, particularly from small herds, are fed with native milk until weaning. Majority of calves used individual housing (IH) during the milk-feeding period, about 10 % of calves are kept in loose housing (LH) with bucket feeding and very small part is housed in LH with the computer-controlled feeder (CCF).

IH could be stressed for calves. However, heifers reared in isolation until weaning milked significantly more milk than heifers from loose housing (Arave *et al.*, 1985). Arave *et al.* (1992) found that pre-weaning isolation affected growth, but did not affect milk yield (MY) during the first lactation.

The early separation of the calf from the cow is of course important for maximum production, but this system can be disadvantage for calves. On the other side, uncontrolled access to the mother by the calf can reduce MY of the mother, but daily weight gains (DWG) of nursed calves are higher than the separated calves (Metz-Stefanowska, 1987).

The purpose of this paper was to find whether milk production of primiparous cows is affected by their housing to weaning and the feeding method of milk or milk replacer. We tested hypotheses that the milk efficiency are impacted by the housing of heifers from the second to seventh day of life, the method of feeding milk from the second week of life to weaning, and the sire lineage.

32 Holstein heifer-calves were randomly divided in two housings on the second day of life: into the hutches (IH, n=19), or loose housing in the pen with the mother (LH, n=13). Calves from IH received colostrum and mothers milk in free choice three times a day from a bucket with nipple from the second to seventh day. Calves of the group LH were allowed to suck their dams ad libitum, but mother was milked from the second day after calving.

Introduction

Materials and methods

Ten heifers were randomly moved out from IH on the seventh day to a group pen with the CCF and received MR through an artificial nipple of this equipment (AF). The remaining nine heifers stayed in individual hutches and were fed by sucking MR from an artificial nipple of the bucket (BF). Heifers, which were with the mother until the seventh day (LH), were moved to a group pen with nursing cows and sucked native milk from udder (UF).

Heifers of the treatment AF received 6 kg of MR per day divided into 4 portions in 6 h intervals. Calves of the treatment BF got the same amounts of MR divided into 2 portions in 12 h intervals. From the second day until weaning the calves could eat starter mixtures and alfalfa hay in free choice. The number of calves of group UF per one nursing cow was determined according to their milk yield (6 kg milk per each calf). Calves were allowed to suck ad libitum and they also had free access to starter mixture and feeds of cows.

All animals were weaned at the age of 8 weeks. Heifers of all groups were kept in common group pens in loose housing with bedding in age-balanced groups after weaning. Equal conditions of nutrition were ensured in all groups.

Primiparous dairy cows were kept in free-stall housing and fed by total mixed ration according to the stages of lactation. Cows originated from four sires: S₁ (n=8), S₂ (n=6), S₃ (n=9) and S₄ (n=9). Milking occurred twice daily with a milking interval of 12 hours in a 2x5 stall herringbone parlor, and individual MY was recorded once weekly by Tru-tests. Milk samples were collected every 2 weeks. The data were analysed with a statistical package STATISTIX (Analytical Software, Tallahassee, USA).

Results

The MY in the 305 days lactation was higher in LH cows than in the IH group (6894.1 ± 879.8 kg vs. 6202.1 ± 923.9 kg; P<0.05). A significant differences were found also in the productions of FCM (6541.9 ± 649.2 kg vs. 5986.4 ± 669.2 kg, P<0.05) and protein (215.3 ± 23.9 kg vs. 193.2 ± 27.3 kg; P<0.05).

The UF cows reached the highest MY (6894.1 ± 879.8 kg) and AF cows the lowest (5757.5 ± 865.5 kg; P<0.01) for 305 days lactation. A similar trend was recorded also in FCM (6541.9 ± 649.2 kg vs. 5820.9 ± 797.3 kg, P<0.05). The contents of fat and total solids (TS) were the highest in the group AF (4,10 %; 13.14 %).

Effects of the sire lineage were very significantly showed in the fat content (P<0.001), very significantly in the production of the lactose and content of TS (P<0.01) in 305 days lactation. Statistical significancies (P<0.05) were showed in MY, contents of protein and lactose, as well as in the content and production of non-fat solids (NFS).

We found that productions of milk, FCM and protein were significantly higher in the LH group than in the group of IH. It is however possible that an effect of housing from the second to seventh day of life was suppressed by the method of milk feeding to weaning. That had a decisive effect on growth and subsequently milk production.

How could we explain the highest production of milk, FCM, protein, lactose, NFS and TS of the UF group? Basically by a higher live body weight (LBW) at calving. According to results of Khalili *et al.* (1992), calves given a high level of milk or MR in early life have a LBW advantage over similar calves given a lower level of milk. Differences in LBW due to increased DWG in the early life of a calf may be retained subsequently or, in certain situations, the difference in LBW may increase later in life. UF group had just this advantage, difference were significant in comparison to AF and BF group (35.7 kg and 18.6 kg).

The calves fed by nursing cows grew faster than the conventionally fed calves before weaning, probably as a result of the higher intake of milk. And that even when we limited the amount of milk by the number of calves per one cow. In suckling calves, postnatal growth rates ad libitum-fed calves were greater than in calves fed with limited intake (Egli and Blum, 1998).

Differences among rearing groups (factor R) can be also explained by nutrition during milk-feeding period of these first-calf heifers. Animals of group UF received obviously more valuable nutrition from udder than animals from groups AF and BF. In the experiment of Bar-Peled *et al.* (1997), heifer calves that suckled milk had higher DWG, an earlier age at calving, and a tendency for greater MY than did calves fed MR.

Another reason why dairy cows fed by the milk automat machine produced the lowest amount of milk can be their worse health condition by weaning. According to Plath *et al.* (1998) a higher proportion of calves reared in groups with CCF were affected by diarrhoea and bronchopneumonia and showed less DWG than calves reared in groups with bucket feeding. The risk of developing respiratory disease was 2.8 times higher in LH with CCF than in calves kept in IH (Svensson *et al.*, 2000).

We can conclude that the milk and its composition of primiparous cows is affected by their housing to weaning, the feeding method of milk or milk replacer, and the sire line.

Discussion

Conclusions

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The economic aspects of dairy heifer management

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Increasing productivity of dairy cattle has long been the goal of farm development. During recent decades, the productivity of dairy cows has increased as a result of advances in animal breeding and modern technology. Modern methods of dairy cattle husbandry are based on effective herd management. Breeders want to know the definition of optimum size are mostly based on live weight and some body measures because they are relatively easy to be determined. But recommended values should reflect much more complicated relationships, they should take into account body condition, reproductive performance, feed consumption, etc. The objective of rearing dairy heifers is to produce high-quality dairy replacements at low costs. A basic approach in reducing period by lowering the age at parturition. In Slovakia the rearing period lasts 23 – 26 months.

However, because of various biological interactions with growth rate, the ultimate economic outcome of such a reduction in rearing time will depend on the balance between the possible advantages (such as decreased feed costs and lower overhead costs) and disadvantages (such as lower conception rates and reduced milk production per lactation).

The objective of this paper is to describe the general outline of a stochastic dynamic programming model developed to optimize the rearing strategy of individual heifers. The parameters (age, season, body weight, reproductive state and maximum prepubertal growth rate) of the heifer model have been chosen to represent the Holstein population in the Slovakia. However these input factors can easily be modified and adapted to reflect the conditions of a different production system.

The basic rule of replacement heifer rearing optimization is a shortening of nonproductive period by earlier mating and lower age at first calving. Advantages of this approach are a decrease in fed costs, increase in production calculated per age and decrease in costs per animal.

Sampling of raw cow milk by a conventional method and autosampler

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The creation of a unified European market with raw materials and foodstuffs of animal origin requires also to unify the rules, procedures and legislation, mainly the criteria of hygiene and quality. We may say that this development has been very dynamic in the Slovak Republic.

This related to processing of a complex standard for judging, classifying and evaluating raw cow milk for the purposes of its dairy treatment and processing.

The standard valid in this sense is STN 57 0529 Raw Cow Milk, which became effective on 1st December 1999. By its last amendment the conformity with the standards valid in the member states of the European Community has been reached.

The objective of this work was to:

- (1) Carry out the research of suitability of autosampler use in sampling raw cow milk in relation to its classification to individual classes of quality;
- (2) Analyse the number of somatic cells (NSC), content of proteins (P), content of fat (F) and total number of microorganisms (TNM) in taken samples;
- (3) To compare the results of sampling of raw cow milk between the conventional method and autosampler and

Introduction

- (4) To propose the next procedure.

Material and methods

In order to carry out determined objectives we have selected the Senica dairy (Senická mliekareň a.s., Senica) and its hinterland (24 suppliers with maximum distance of 35 kilometres from the dairy plant).

The above-mentioned dairy meets the criteria prescribed by EU legislation and is an export plant for EU member states (Edam cheese and butter). In addition to it, this dairy exports milk products also to Hungary and Croatia.

Sampling of raw cow milk was carried out

- by a conventional method / manually (STN 57 0530 and STN 56 080), immediately before sampling by a transporting tank vehicle equipped with the automatic device for sampling by a flow method
- by an automatic sampler (STN 57 005/Z1) – autosampler of the German company Schwarte & Werk GmbH.

Totally in four samplings 96 samples were taken, 24 samples in one sampling.

In laboratory analyses the following methods and analytical devices were used for the determination of

- the number of somatic cells (STN 57 0532, Fossomatia 90)
- the content of proteins (STN 57 0536, Milko Scan FT 120)
- the content of fat (STN 57 0536, Milko Scan FT 120)
- the total number of microorganisms (STN 57 0537, Minipetross).

Results and discussion

- (1) the number of somatic cells
Judging this criterion the number of somatic cells according to valid standard was as follows: 43 samples taken manually, irrespective of the moving average, would conform to Q class of quality and 41 samples taken by autosampler would conform to Q class of quality.
- (2) the content of proteins
The results were similar as in the number of somatic cells. But autosampler showed higher values than manual sampling in 58 samples.
- (3) the content of fat
The content of fat was different in the samples taken manually and in the samples taken by autosampler. A higher content of fat was found in 23 samples taken manually. The highest difference in the content of fat was 0.5 %. 4 samples taken manually were very close to this result. On the contrary, one sample taken by autosampler showed the content of fat by 0.65 % higher than in case of the sample taken manually.

- (4) the total number of microorganisms
With respect to dynamic development of individual indicators a notable development was recorded. Out of 96 samples, 84 samples showed a higher number of microorganisms than in case of samples taken manually. The maximum percentual difference of this indicator was in third sampling (Klátov), where the sampling by autosampler was higher by 188 %.
- (5) differences between the sample taken manually (100 %) and the sample taken by autosampler were the following:
- number of somatic cells (101.8 %)
 - proteins (102.2 %)
 - fat (104.7 %)
 - total number of microorganisms (110.9 %).
- (6) the research was made
on the basis of the requirements of primary producers, who, in suppliers-customers relations in monetizing the milk, refused to use the results obtained in sampling by autosampler referring to present unpreparedness and inaccuracy of these results.
- (7) autosampler system for raw cow milk sampling
corresponds to the most advanced level of technology. By means of cooperation with national and foreign institutions it offers the solution, which exactly corresponds to operating conditions and takes into account also the requirements resulting from law and special characteristics of milk transport in Slovakia.

On the basis of the comparison of results reached when sampling manually (according to STN 57 530 and STN 56 0080) and sampling by autosampler (according to STN 57 0005) we recommend to carry out the following procedures:

- (1) also for the future period to leave in validity the exception from the use of sampler in the purchase of milk, granted by the Ministry of Land Management of the Slovak Republic
- (2) to use sampling by autosampler for the determination of:
 - the number of somatic cells / NSC (results are comparable)
 - the content of proteins (results are comparable)
 - the quantity of fat only in case the difference between a conventional and automatic sampling is not more than 0.05 weight % of fat (results are provable)
- (3) not to use sampling by autosampler for the determination of:
 - the total number of microorganisms / TNM . ml⁻¹ of raw cow milk (higher values in sampling by autosampler than when using a conventional method)
- (4) for practical application by autosampler
 - to ensure the necessary quantity of raw cow milk for washing out the whole system before next sampling.

Conclusion

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Psychrotrophic microflora as one of the criteria microbiological quality of milk

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Psychrotrophic bacteria (PBC) in raw milk are regarded as a frequent cause of the current unexplained problems in milk processing. It is becoming increasingly dangerous to the dairy industry due to their production of extracellular heat-resistant lipases and proteases (Shah, 1994).

Cempírková (2002) confirmed the effect of housing and milking technology on microbial milk quality. The differences between TBC (total count) and PBC between herds using different housing and milking technologies were significant ($P < 0,05$). The correlation coefficient for bulk milk samples was $r = 0,69$ ($P < 0,01$).

Nearly 90% of contamination is caused by insufficient sanitation of milking and cooling equipments (Vyletelová et al, 1998). Some Gram-negative representatives of psychrotrophic microorganisms have a higher resistance to any types of detergent (Ruzicková, Majeríková, 1999).

The objective of this study was to establish how certain factors, act in basic production of milk, influenced changes of TBC and PBC and to test the efficiency of alkaline and acid detergents to psychrotrophic microorganisms, isolated from raw cow's milk, in model experiments.

Milk sample were collected during 1 year period on 2 farms with different milking systems (1- milking parlour, $n=40$; 2- pipeline milking machines; $n=31$). Samples were taken after morning milking and after evening milking (morning and evening milk mixed in cooling tank).

Bulk tanker samples ($n=10$) were taken off the vehicle, to which milk of 5 suppliers was collected. Pool samples ($n=50$) were taken on each farm of these 5 suppliers.

TBC was determined according to STN ISO 4833 (1997) and PBC according to STN ISO 6730 (2000) in laboratory of the Department of Evaluation and Processing of Animal Products of SAU.

Introduction

Material and methods

The effectiveness of alkaline and acid detergents was tested in pattern experiments. 13 psychrotrophic microorganisms originally isolated from raw cow's milk, in suspension of growing medium, were used for testing. The effectiveness of detergents was tested by standard suspension method in 3 repetitions. Detergents were tested as 0,75% solutions at the temperature 60°C resp. 40°C and action of 10 minutes in condition with increasing concentration of organic impurities. Bouillon was used as an organic impurity.

Results and discussion

It was found out that the effect of milk obtaining (housing and milking) has high significant influence ($P < 0,01$) on TBC and significant influence on ($P < 0,05$) PBC. These results correspond with findings of Cempirkova (2002).

Statistically significant correlation between TBC and PBC in bulk milk samples ($r = 0,702$; $P < 0,001$) was observed. The correlation was calculated from the regression line ($y = 0,923x - 0,203$).

Transport of milk from the farm to dairies was contributed to growth of TBC as well as PBC. TBC increased 2,59-times and PBC 1,38-times. Reduction of number of the dairies contributes to changes of milk collection frequency from the farms. Pre-processing prolongation of milk storage in dairies negatively reflects in microbiological milk quality.

The high correlation between TBC and PBC was observed in milk samples stored in cooling tanks ($r = 0,800$; $P < 0,001$). The regression line was defined by the equations $y = 0,571x + 0,937$ (x -TBC, y -PBC). It is possible to use the equation for assessment of probable PBC in milk, whose determination is time-consuming.

The results of correlation corroborate with findings of Cempirkova (2002) ($r = 0,69$) and they are higher than published by Vyletelova et al. (1999) ($r = 0,61$).

There was not found out the growth of psychrotrophic microorganisms after application of alkaline and acid detergents in conditions prescribed by their producers (temperature 60°C) in water environment or in environment with organic impurities. These results correspond to findings of Ruzicková, Majerikova (1999). Microbicidal effect was achieved by high temperature of solution.

In pattern experiments lowering temperature of alkaline solution to 40°C inhibited the growth of microorganisms only in environment without impurities or with their concentration up to $0,6 \text{ g} \cdot 100\text{ml}^{-1}$. Proportion of surviving psychrotrophic bacteria was increased by gradually increasing concentration of organic impurities in solution. The effect of fall in temperature to surviving of microorganisms was even more marked at application of acid detergent. Microorganisms survived in water

environment (without organic impurities). Lower disinfection effect on psychrotrophic bacteria corroborates our earlier findings (Canigova et al, 2001).

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Microbiological value of the ewe's milk sample as the criterion for GMP and HACCP on the farms with machine milking

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According to the Slovak legislation, sheep farm producing milk for the human consumption, must keep to the rules of good manufacturing practice (GMP) and HACCP system (Hazard analysis critical control point). The critical points during machine milking of ewes are described in this article.

In Slovakia, ewe's milk is produced from a herd of animal that have been subjected to periodical veterinary inspections.

The adoption of EC Directive 92/46 to the Slovak legislation emphasized the role of hygiene in milk production. In addition to the bacteriological standard for the raw ewe's milk, the milk must be produced in herds having proper good status of hygiene, equipment cleaning and animal health. Beside this, sufficient hygienic conditions for milking, milk treatment and processing must be done in each ewe's farm. Nowadays, in Slovakia also machine milking of sheep is used. Thus is minimized the risk for the consumers, mainly if the unpasteurised ewe's milk is used for the cheese making. Low microbiological value of ewe's bulk milk sample (total bacteria count is less than 500 000 and 1 500 000 in 1 ml milk, respectively) sets up one of the basic assumption for the effective economical selling of milk and milk products. Worst milk quality will hard reflect milk economy. That is why it is important find the all critical points in machine milking of ewe's which may negative influenced the consequent milk quality.

The prerequisite to producing hygienic milk is udder health (Ariznabaretta et al., 2002). Mastitis, particularly subclinical and chronic is the most persistent and widely spread group of diseases of importance to milk hygiene in dairy animals. Previous study have confirmed that

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bacteriological examination of milk and milk somatic count (SCC) are reliable methods for detecting subclinical mastitis in dairy ewes (González-Rodríguez et al., 1995), and inverse relationship between SCC and milk yield has been proved (Gonzalo et al., 1994). Traditionally, the most common mastitis – causing agents have been classified as minor or major pathogens according to the degree of inflammation they produce in the mammary gland. The most prevalent etiological group is represented by staphylococci and particularly by coagulase – negative staphylococci, considered to be minor pathogens or commensals by many authors. Changes in the udder health are characterized by physical, chemical and usually bacteriological changes in the glandular tissue. The most important changes in the milk include discoloration, the presence of clots and the presence of large numbers of leucocytes. Although there is swelling, heat, pain and induration in the mammary gland in many cases, a large proportion of mastitic glands are not readily detectable by manual palpation nor by visual examination of the milk using a strip cup. Because of very large numbers of such subclinical cases the diagnosis of mastitis have come to depend largely on indirect tests which depend, in turn, on the leukocyte content of the milk.

In the Slovak ewe's milk producers, there are seldom problems with herd mastitis in sheep. This is because each change of the udder indicates separation of the animal. The affected animal is discarded from the sheep flock. Because the antibiotic therapy is very expensive, it is not common to use it in the sheep flock.

According to the Slovak legislation, sheep farm producing milk for the human consumption, must keep to the rules of good manufacturing practice (GMP) and HACCP system (Hazard analysis critical control point). Following critical points should be observed on the sheep farm with machine milking to receive high quality raw milk (only as example):

1. Health of the mammary gland:
a) good; b) satisfactory; c) bad
2. Cleaning of the mammary gland:
a) none; b) dry; c) a damp cloth; d) a wet cloth; e) shower
3. Teat dipping:
a) yes – after each milking; b) yes – only in the case of some visual abnormalities on the udder; c) none
4. Cleanliness of the pipe line milking system:
a) automatic control of the sanitation; b) hand control of the sanitation
5. The speed of milk flow in pipes:
a) the length of a pipe line system; b) a backwards milk flow
6. The speed of milk cooling:
a) precooler of milk; b) modern type cooler; c) old type cooler
7. Temperature of milk in cooler:
a) from + 4 °C to + 6 up to 8 °C; b) below + 4 °C; c) above 4 °C
8. Milk filtration:
a) under pressure; b) descent, above the cooler; c) none

Except these examples, also temperature and concentration of cleaning and disinfection solutions, visual control of the equipment, personal hygiene, etc, should be included.

Bad hygienic conditions on the farm, low hygienic level of the workers as well as not sufficient milk standard for the buying and selling and processing of the raw ewe's milk result in milk rejection. The presence of these shortcomings may require a change in flock management practices to minimize the risk factors that contribute to bad quality of milk.

Poor flock hygiene increases the risk of bacteria entering the ewe's udder. Dirty teats and udders increase the chance of bacteria entering the teat canal. This increases the risk of ewe ending up with a subclinical or clinical udder infection. Improper milking machine function can result in uneven milk out, liner slips and damaged teat ends. These factors can all have a negative impact on udder health.

It is very good that ewe's milk producers in Slovakia start to use machine milking. Thus is the quality of the raw milk increasing and total bacteria count not exceed the stated maximum values. The following microorganisms were isolated from the individual milk samples of the raw ewe's milk: coliforms, *Staphylococcus capitis*, *St. caprae*, *St. cohnii cohnii*, *St. epidermidis*, *St. Haemolyticus*, *St. xylosus*, *St. aureus*, as well as *Escherichia coli*, *Klebsiella* spp., *Pantotea* spp., *Micrococcus luteus* were detected only in rare cases. From the hygienic point of view, the following shortcomings on the sheep farms were observed: presence of insects, mainly flies, dirty walls and floors, insufficient cleanliness of the back body of ewes, insufficient personal hygiene, insufficient padding of doors and windows, exceed temperature in the ripening rooms, spider webs in parlours, milk rooms, etc. Despite these negatives, the Slovak producers of ewe's milk have their important position in dairy industry, because they understand the basic fact, that they are producing safety milk products not only for the Slovak consumers but also for all consumers in also European union.

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Evaluation and comparison of sanitation control in primary production with different milking technology

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Investigations were carried out concerning the testing of commercial and classical disinfectants and cleaning agents used in primary milk production. The testing of disinfectants was performed under laboratory and operation conditions.

The results obtained during the testing of the disinfectants as well as the results obtained in critical points refer to the suitability of their application under operation conditions.

The paper describes some relationships between milk CPM (total plate count of microorganisms) and additive hygienic qualitative traits and specified effective methods of special advisory service related to nonstandard values of CPM and coliform microbes (additive microbiologic characteristics).

In Slovak Republic extensive monitoring of coliform bacteria frequency (upper threshold value 1 000 CFU/ml) is used as a complementary hygienic trait of milk. In EU countries this control is used only selectively in cheese production sphere.

The following complementary hygienic parameters are controlled according to the Slovak standard No. 57 0529 :

- count of psychrotrophic microorganisms (<50 ths. CFU/ml);
- count of thermoresistant (heat-resistant) microorganisms (<2 ths. CFU/ml);
- spore – forming anaerobic bacteria (negative in 0.1 ml milk).

Relations CPM – total count of psychrotrophic elements (CPP) were studied in RIAP Nitra. According to local investigations approx. 96 % delivered in Slovak Republic comply with the standardized level of psychrotrophic microorganismus. Significant CPM-CPP correlations (0.61 – 0.96) were determined in three sets of bulk milk samples. Relatively high correlations demonstrate adequate efficiency of CPM as a hygienic parameter included in fresh milk CPM control (marketability parameter).

Preliminary estimates of distribution rates (CPM and psychrotrophic elements) had been made in a less standard set (longer sample transport). These estimates were precised later and relative CPP proportion in CPM was established in three standard sets. Calculatin utilizing the weighted mean of the mentioned values (24 %) indicate that the standard limits for CPM £ 100 ths. and £ 50 ths. CFU/ml can correspond to CPP£ 24 ths. and £ 12 ths CFU/ml. The metioned facts substantiate non-acceptance of the proposed revision of CPP limit (£5 ths. CFU/ml) as a complementary qualitative parameter included in the Slovak standard No. 57 0529. As for confrontation of relative frequencies (29 % >24 %), longer transport periods and longer storage – analysis intervals characterizing the firstly mentioned sample demonstrate increasing proportion of psychrotrophic elements from milkint to milk processing. Therefore, milk sampling in the terminal phase of the transport line as well as longer milking – sampling intervals impair some producers (not even effective cooling procedure does stop increase of pychrotrophic elements).

Relatively close relationship between mean microbiologic quality of milk and its variability (i.e. technologic repeatability) – 0.5 – 0.7 – was envisaged. Much more close relationship ($r = 0,94$) was found in case of 6 analyses at minimum realized ones during 3 – 6 months in most cases, but also in 12 month – period.

Consulting activity is aimed at hygienic problems associated with coliform microorganisms incidence. Prompt and efficient solution of problems was conditioned by milk sampling (phase samples and other additive ones) for specification of the objective principal causes of problems :

- cleaning and sanitation regimes included in the mentioned „economical modification“ were classified as inadequate ones;
- they did not prevent trace incrustation in receiver units (collectors) of milking apparatuses. Incrustation was detectable only by touch after dismounting of the apparatus; simple visual control was ineffective. Besides of this principal defect a circular adipose sediment of waxy character (removable with difficulty) was found in milkmeters;
- efficient and repeated manual cleaning of all receiver units and milkmeters with acidic cleaning agent was followed by a circuit acid cleaning (1 % nitric acid) for 20 min (inlet temperature 75°C; outlet temperature 45°C). The sanitary regimen was modified according to the standards declared by the International Dairy Federation.

The following principles guarantee success of advisory service:

- proper complex analysis of the actual situation, its objectivization, specification of effective acceptable and realizable measures,
- responsible approach of the personal staff management board and service staff to realization of the proposed corrective measures and intervations will (process itself will result from the professional educational activity).

Methods to measure teat condition in relation to machine milking with two different liners

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The aim of the present study was to test different methods to measure teat condition in relation to machine milking. 12 cows were included in an experiment where two liners were tested. The teat condition was measured by infrared thermography, teat-end thickness, visual inspection of the teats, milk somatic cell count and cow behaviour during milking. Teat-end thickness and teat-end temperature were the methods that indicated milking-related changes in teat condition when different liners were tested.

Key words: *Machine milking, teat condition, teat thickness, teat temperature*

The function of the milking equipment is one of the most important factors to keep high-producing cows free from udder-health problems. The performance of the liner is critical because it is the only part of the milking unit that is in direct contact with the udder during milking. Therefore safe and reliable tests of teat condition are needed when evaluating new liners. The aim of the present study was to test different methods for measurement of teat condition when the cows were milked with two different liners.

The experiment was carried out at Harma Research Farm, DeLaval, Tumba Sweden. It was a change-over design with two periods and two treatments [a normal-bore liner (article no. 960016) (A), and a wide-bore liner article (no. 999295) (B), both from DeLaval]. The study lasted for 12 days and included 12 cows milked three times a day. The methods tested were teat temperature measured with an infrared camera (four milkings/cow and period), cutimeter measurements of teat-end thickness

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(two milkings/cow and period), visual inspection of teat condition (three registrations during the experiment), milk somatic cell count (two milkings/cow and period) and cow behaviour during milking (each milking; shuffling, kicking, rumination, urination and defecation).

Results

The front teats showed a significantly ($p < 0.05$) increased teat-end thickness (0.51 mm) with liner B after milking compared to before milking. Teat-end temperature increased after milking compared to before milking both at the teat end and middle of the teat (from 30 to 35° C). One of the cows showed deviating results compared to the others in temperature measurements and when this cow was excluded from the calculations there was a significant difference ($p < 0.01$) in the increase of teat-end temperature with 3.61 and 4.37 ° C for liner A and B, respectively. There was no difference between treatments for the other measurements

Discussion and conclusion

The finding that a wide-bore liner gave increased teat-end thickness is in agreement with earlier studies (Hamann et al., 1994). Increased teat-end thickness after milking indicates a disturbed circulation in the teat end. In this study, measuring teat-end thickness was the method that indicated a significant difference between treatments. Teat-end temperature was also measured. According to Paulrud and Rasmussen (2003) it is likely to find milking-related changes in temperature at the teat end. However, since not all cows in the experiment reacted to teat-end temperature, the method teat-end thickness measured with a cutimeter turned out to be the most useful tool for evaluating teat condition in the present study.

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Measurement of some studied parameters of liners and its statistical evaluation

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The aim of the work was to evaluate, by mathematical-statistical methods, the mutual relation between the operation time and some physical-mechanic properties of the liners. Theoretically, optimal operation time in relation to the thickness and hardness of the liner ranged from 942.2 to 1263.9 hours.

Key words: Teat-cup liner, physical-mechanical properties, regression analysis

In the previous experiment several physical – mechanical qualities of the selected liners were observed (Galik et al., 2003). This paper brings results of the test's evaluation carried out by means of multiple and simple regression analysis methods. A more extensive scope of literature on the problem of liners is given in further published works (Galik et al., 2003, Galik et al., 2002, Karas, 1996).

The method of multiple regression was used for the purposes of mathematical – statistical procession of the test's results. Basic form of the statistical model through which we evaluated causal relation between the values of the dependent variable (time of activity) simultaneously on several non-dependent variables (hardness, firmness at break, protraction at break, liner's thickness) was as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 \quad (1)$$

where: y – dependent variable value, b_0 – allocation invariable, $b_1...b_4$ – regression coefficient expressing the influence of the unit change of non-dependent variable on the value of the observed dependent variable, $x_1...x_4$ – non-dependent variable value.

To assess the intensity of regression relationship between the dependent variable and non-dependent variables, as well as to assess suitability of the used regression model (equation 1), the determination index R^2 was

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calculated. To assess the characteristics and intensity of relation between the selected sets more profoundly, we applied a simple non-linear regression method, using the parabolic function ($y = a + bx + cx^2$), with the assessment of its suitability based on determination index (R^2). A detailed methodology for determining individual indicators of the performed test of liner is given in the previous paper (Galik et al., 2003).

Results and discussion

For sample 2, regression model equation reached the following form:

$$y = 6156,038 + 18,134x_1 - 204,999x_2 - 1,573x_3 - 1509,436x_4 \quad (2)$$

Determination index (R^2) as a general measure for the expression of suitability of the above regression model reached the value of 0.467. Applying regression coefficients, it is possible to express, from the equation, a theoretically expected change of dependent variable (y). If, for example, the firmness of liner increases by 1 MPa, time of its activity would theoretically decrease by 204.999 hours. If liner's thickness increased by 0.1 mm, its operation time would decrease by 150.946 hours. Both regression coefficients for x_2 and x_4 reached conclusive values ($P < 0,05$). To assess characteristics and intensity of relation between selected sets with the highest determination index value (R^2), we bring also results of simple non-linear regression. Dependence of the time of the liner's operation on its thickness (sample 1), or hardness (sample 2) may be most suitably theoretically expressed through a parabolic function of the following type:

$$y = - 114976 + 121124x - 31639x^2 \quad (3)$$

$$\text{resp. } y = - 83204 + 3437,3x - 34,969x^2 \quad (4)$$

Graphical illustration of the relation (sample 3) is given in Fig. 1. It shows that the time of a liner's operation is influenced by its thickness expressed by the used function at 61.37 % (sample 1). As for sample 2, the operation time is influenced by its thickness expressed by the used function at 95.93 %. From regression function characterising relation between liner's thickness and time of its operation may be derived optimal value for the liner's thickness, namely, using the following equation:

$$\frac{dy}{dx} = 121124 - 63278x = 0 \quad (5)$$

For optimal liner's thickness, this relation will give the value of $x = 1,914$ mm. If analysing regression function expressing dependency of the liner's thickness on the time of its operation, the liner's thickness optimal value is $x = 49,147$ Sh A. A reverse incorporation of optimal values of the liner's thickness and hardness into parabolic functions will give theoretical optimal value of operation time in relation to the liner's thickness (for sample 1) $y = 942,2$ hours, and in relation to its hardness (for sample 2) $y = 1263,9$ hours. The acquired results show that an unequivocal determining of the optimal value of operation time for both observed indicators is not possible, because it fluctuates in the given range.

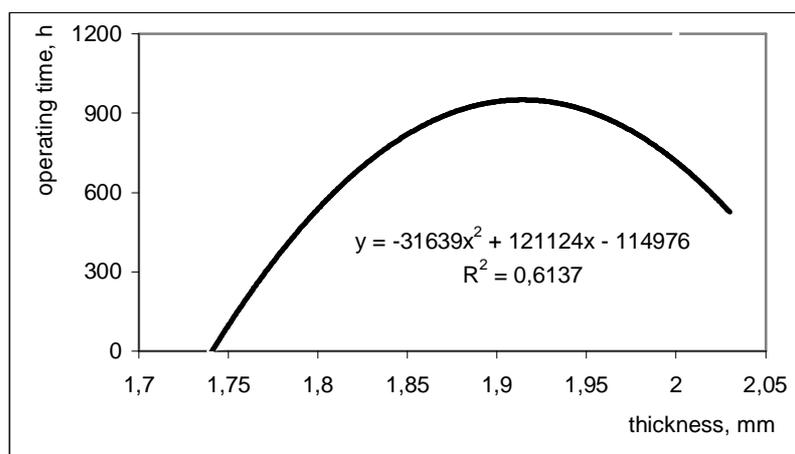


Figure 1. Regression relationship of dependency of operating time on thickness.

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Effect of post-milking teat disinfectant on the relationship between teat hyperkeratosis, somatic cell count and the incidence of mastitis

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Fifty-six Holstein-Friesian dairy cows were milked twice daily over a complete lactation. Right-sided teats were disinfected after milking (TD) by submersing teats in a disinfectant solution containing 4250-ppm chlorohexidine gluconate, which contained a fly repellent, and emollients. Left-sided teats were not disinfected (NTD). Milk samples were taken from individual quarters to measure somatic cell count (SCC) and teats were classified for hyperkeratosis (HK) on eleven occasions during the lactation. The mean SCC was lower ($P < 0.01$) and the mean score for HK was significantly higher ($P < 0.001$) for TD compared to NTD teats. There was a significant correlation ($P < 0.01$) for teat scores = 2 and SCC in NTD teats and no effect when post-milking teat disinfectant was practiced. The number of clinical infections was significantly higher ($P < 0.001$) in NTD teats compared to TD teats. NTD teats had a higher ($P < 0.01$) number of non-haemolytic staphylococci and *Staphylococcus aureus* pathogens in quarters compared to TD teats. Teat texture was improved ($P < 0.001$) with TD compared to NDT. Results from this study suggest post milking teat disinfectant will improve teat texture, SCC and mastitis, but may increase teat HK.

Key words: Post milking disinfectant, dairy cows, teat hyperkeratosis, somatic cell count

Teat hyperkeratosis is used to describe a thickened smooth keratin ring or extending fronds of keratin around the teat orifice. Damage to the teat end allows colonisation by pathogenic organisms and may reduce the defence mechanism of the teat canal. Colonization of the teat end with bacteria may be greater in the absence of post-milking disinfectant (Fox, 1991). Little or no correlation has been shown between teat HK and the development of intramammary infection (IMI), however a greater degree of TK and roughness is associated with an increased

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probability of new infection (Neijenhuis F, *et al.*, 2000). Increased teat colonization in association with a high degree of HK may increase the risk of mastitis. The objective of this study was to establish the effect of omitting teat disinfectant post milking on SCC, IMI, and teat HK

Materials and methods

Fifty-six Autumn calving Holstein-Friesian dairy cows were milked in a 14-unit, 80-degree side-by-side milking parlour, using 13.5mm long milk tubes, with a milk lift of 1.5m above the cow standing for a complete lactation. Pre-milking teat preparation consisted of washing with warm running water and drying with individual paper towels. Right-sided teats were disinfected post milking by submerging teats in a chlorohexidine solution containing 4250-ppm chlorohexidine gluconate (solution 20% Ph Eur), which contained a fly repellent, and emollients. Left-sided teats were not disinfected. Teats were classified for HK using a scale of zero to four, on thirteen occasions, at the morning milking, immediately after cluster removal. In addition individual quarter foremilk samples were taken on consecutive days for SCC and to identify pathogens. Milk samples were analyzed for SCC using the Bentley Somacount 300. Teat barrels were classified once for texture, by manual palpation in mid-lactation and scored as 1=normal (soft), 2=firm (swollen or hard).

Results and discussion

The SCC over the full lactation was lower ($P < 0.01$) for disinfected teats (153k) than for teats where disinfectant was omitted (261k). HK was higher ($P < 0.001$) where teats were disinfected compared to teats where disinfectant was omitted. The immersion of teats in disinfectant and the subsequent exposure of teats to cold weather conditions may explain the higher TK score with disinfected teats. A significant correlation ($P < 0.01$) was shown between TK and SCC with untreated teats however this correlation was not evident where teat disinfection was practiced. Teat scores =1 had no effect on SCC, however teat scores =2 had higher ($P < 0.01$) levels of SCC when teat disinfection was omitted. The number of cases of clinical mastitis was significantly higher ($P < 0.001$) for NTD teats compared to TD teats. There was no difference between treatments for sub-clinical infection. NTD had a higher ($P < 0.01$) number of non-haemolytic staphylococci and *Staphylococcus aureus* and a higher percentage of quarters ($P < 0.001$) with pathogens than TD teats. NTD had a higher ($P < 0.001$) teat texture score, indicating fewer smooth teats compared to TD.

Table 1. Effect of omitting teat disinfectant on IMI and teat texture score.

	TD	NTD	Significance
Clinical mastitis	6	22	***
Sub-clinical mastitis	5	7	NS
Mean teat texture score	0.85	0.93	***

TD: teats disinfected post milking; NTD: teats not disinfected

Table 2. Effect of omitting teat disinfectant, on the relationship between HK and SCC.

Teat HK score	Treatment	Teats	SCC '000	Significance
≤1	TD	537	126	NS
≤1	NTD	605	178	NS
2	TD	518	142	NS
2	NTD	485	306	***
≥3	TD	174	157	NS
≥3	NTD	138	412	**

Teat disinfectant post-milking improved teat texture and reduced SCC and IMI. However, an increase in HK developed which may be associated with weather conditions and/or method of applying disinfectant. Where post milking teat disinfectant was omitted higher levels of SCC occurred with teat scores =2.

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Conclusion

References

Long-term effects of different pulsation characteristics on teat thickness, teat skin moisture and teat skin pH of dairy cows

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Summary

Ten identical twin sets, located at the research station of Dexcel Ltd., Hamilton, (New Zealand), were submitted to two different pulsation modes in a long-term trial, in split twin set design. The group, treated with the 'fast' milking mode, with a dynamic [b] phase, exhibited significantly higher teat thickness changes than the group treated with 'slow' pulsation mode. The pulsation treatment had no significant effect on teat skin moisture or pH.

Key words: Teat thickness, teat skin moisture, teat skin pH, pulsation

The pulsation rate is of importance for cow comfort, teat condition and new infection risk. If pulsation is faulty or ineffective, congestion and oedema of the tissues surrounding the teat canal is resulting. The purpose of this study was to determine the long-term effect of different pulsation modes on teat tissue and teat skin moisture and pH.

The pulsation effect on teat tissue change is demonstrated in Figure 1. The analysis of variance with repeated measurements showed significant differences between the treatment groups 'fast' and 'slow' ($P = 0.001$).

The duration of the open phase of the liner influences the teat thickness change significantly. Yet this was the first study to demonstrate this over a whole lactation. Bigger teat end thickness is known to be a sign of increased congestion or oedema in the teat tissue. The lactational changes in teat skin pH and moisture (data not shown) were interesting findings, but a more complicated trial design will be required to determine the delicate effects of pulsation on teat skin parameters.

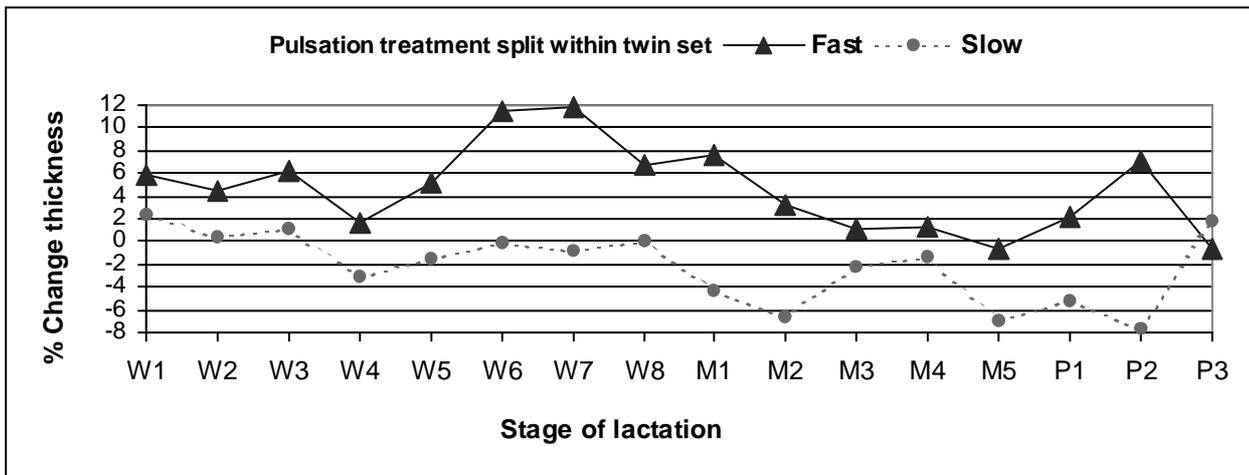


Figure 1. Mean teat thickness change (%) of 5 twin sets, during an entire lactation (W1 – 8 and P1 – 3 weekly, M1 – 5 monthly determinations).

Data for Figure 1: Per cent teat thickness change

Treatment	W1	W2	W3	W4	W5	W6	W7	W8	M1	M2	M3	M4	M5	P1	P2	P3
Fast	5.9	4.4	6.3	1.6	5.2	11.5	11.7	6.8	7.6	3.3	1.1	1.2	-0.6	2.2	7.0	-0.6
Slow	2.3	0.4	1.1	-3.1	-1.5	-0.1	-0.8	0.1	-4.3	-6.6	-2.2	-1.3	-6.9	-5.2	-7.7	1.9

Reference

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Non contact thermometry in the milk removal process

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The temperatures of mammary glands of tested dairy cows were evaluated by a multifactor analysis of variance. The time and place of measuring were statistically significant on the significance level 0.05. The F-test value for the factor of time was 12.342, with probability 0,0007. The F-test value for the place of temperature measuring was 1061.979, probability 0.0000. Among the equations of curves of the dependences of teat end temperature on the milking time, the closest seemed to be the logarithmic function with determination index $R^2 = 0.7404$.

Key words: *Temperatures, non-contact thermometer, mammary gland, milking house*

The milking of cows in milking houses is carried out under different conditions than in stables. Recent research shows that milking was improved especially by the influence of construction elements, which was verified under laboratory and operational conditions by many researches (Karas, 1996; Galik, 2001; Tancin et al., 2001; Fryc, 2002).

Kejik and Maskova (1989) pointed out that one of the possibilities how to determine the response of the organism to milking conditions is to use thermovision, measuring surface temperatures of the udder during milking.

The following parameters were monitored in the milking house during 24 hours in one-hour intervals, using a non-contact thermometer RAYNGER ST-6 with laser:

- temperature of udders before and after milking (°C)
- temperature of teats at the base before and after milking (°C)
- temperature of teats in the middle part before and after milking (°C)
- temperature of teats at the end before and after milking (°C)
- time of milking of the experimental cow group (min)

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Basic statistical processing of measured temperature values of mammary gland before and after milking is shown in table 1. The highest average temperature before milking was measured on udders (30.14 °C), at the base (29.55 °C) and in the middle part (28.59 °C); the lowest one was measured at teat ends (7.1 °C). After milking, the temperature on the udder increased on average by 0.31 °C, at the base by 0.82 °C, in the middle part of the teat by 1.47 °C and at teat ends by 2.68 °C.

Table 1. Basic statistical assessment of measured temperatures of mammary gland.

Place of measurement	Winter season - temperatures (°C)										
	Before milking - statistical value					After milking - statistical value					
	\bar{x}	max.	min.	s	v	\bar{x}	max.	min.	s	V	
UDDER	30.1	31.3	28.6	0.919	3.048	30.4	32.1	28.7	1.302	4.276	
T E A T S	at base	29.5	30.8	28.3	0.903	3.055	30.3	31.3	28.8	0.806	2.656
	in the middle part	27.1	29.8	27.3	0.889	3.112	28.5	30.6	27.6	1.047	3.564
	at teat end	7.1	8.8	4.9	1.426	20.089	9.7	15.6	5.1	3.397	34.730
	Milking time of twelve tested cows (min)					8.7	12.1	5.2	2.114	24.453	

\bar{x} = arithmetic mean max - maximal value in the set
s = decisive aberration min - minimal value in the set
v = coefficient of variation

It is very difficult to determine immediate responses of cows to the environmental conditions. One of the possibilities how to monitor changes in mammary gland temperatures is to use thermovision. Thermovision AGA 782 uses an inbuilt display system to create a „temperature“ picture of the object. The developed picture - a thermogram distinguishes isothermal areas by means of colours. The paper of Kejík and Mašková (1989) investigated the influence of teat liners made of various materials on the udder and teats as well as the influence of washing, drying and first milk on the temperature of mammary gland and its monitoring by means of thermovision.

The authors of thermograms further claimed that the field of udder and teat temperatures before milking was different for individual cows; the udder temperature before milking reached approximately the value of 33 °C, the teat temperature was lower, reaching approximately 27.5 °C in the summer season.

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Microclimatic conditions in milking parlour during winter period

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The aim of this study was to find out and to compare microclimatic conditions in milking parlours built in dairy stable (B) and in milking parlours detached out of stable (A) and exterior (E) in winter period. Air temperature showed statistically significant differences ($P < 0.05$) between milking parlours A vs. B and A vs. E and B vs. E. Air flow showed significant differences ($P < 0.05$) between A vs. E and B vs. E. The differences in relative humidity were not found out to be significant. The higher air temperature in milking parlour A was caused by heating all day long. This heating was not invoked in milking parlours B and air temperature was found out to be lower than recommended value (minimum 10°C) for milking parlours in winter period. It is concluded that milking parlours built in stable do not provide adequate thermal comfort for milkers in winter period and can worsen the milking process.

Key words: Milking parlours, air temperature, relative humidity, air flow

Milking parlours are an integral part of dairy farms. A quality of working environment in milking parlour significantly affects a comfort of milkers and procedure of milking (Dolezal, 2000). The microclimatic conditions are a very important element of working environment and significantly influence of thermal comfort of milkers (Mathauserová, 2003).

Six milking parlours detached out of stable (A) and seven milking parlours built in dairy stable (B) and exterior (E) were tested. During three winter months (January – March), air temperature, relative humidity (by digital

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thermometer TESTO 615) and air flow (by digital anemometer TESTO 415) were measured in operating zone of milkers. The measurements were provided monthly three times during day in every tested milking parlour. The obtained values were processed by Statistica.cz (ANOVA).

Results and discussion

Results are showed in Table 1.

Table 1. The average air temperature, relative humidity and air flow of milking parlours A,B and exterior E in winter period.

	Air temperature (°C)	Relative humidity (%)	Air flow (m.s ⁻¹)
Milking parlours A	10,51 ± 2,74 ^{a,A}	79,79 ± 13,68	0,1 ± 0,07 ^A
Milking parlours B	8,37 ± 4,29 ^{a,B}	77,88 ± 10,65	0,09 ± 0,06 ^B
Exterior E	-1,20 ± 6,21 ^{A,B}	73,84 ± 16,03	1,58 ± 1,18 ^{A,B}

Air temperature showed statistically significant differences ($P < 0.05$) between milking parlours A vs. B and A vs. E and B vs. E. Air flow showed significant differences ($P < 0.05$) between A vs. E and B vs. E. The differences in relative humidity were not found out to be significant. Air temperature in milking parlours B did not accord with recommended air temperatures. Luymes (1990) recommends minimal air temperature 10°C but Romaniuk, Overby (2003) mention minimal air temperature 14°C in milking parlours. The higher air temperature in milking parlour A was caused by heating all day long. This heating was not invoked in milking parlours B and air temperature was found out to be lower than recommended value in winter period. The values of air flow were found out according to recommended values (Mathauserová, 2000; Tuure 2003). It is concluded that milking parlours built in stable do not provide adequate thermal comfort for milkers in winter period and can worsen the milking process.

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The effect of calf suckling and machine milking on bovine teats

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The aim was to test hypotheses that the suckling of calves is more stressful for teats than machine milking and that the injurious impact of suckling is depended on the age of calves and time of their suckling. The effect of machine milking and calf suckling on teats was observed by means of thermographic method. Generally, machine milking and calf suckling evoked an increase ($P < 0.05$) of teat temperature (TT). The highest increase of TT was caused by suckling of calves in milk period, the lowest teat stress ($P < 0.05$) was find out by after suckling of calves in colostrum period. The shortest time of suckling was recorded in the oldest calves. On the basis of results it is concluded that teat stress depends on age of calves and time of suckling. Machine milking with vacuum 42.6 kPa cannot be considered as significantly injurious.

Key words: teats, calf suckling, machine milking, thermography

The teats are the most stressed part of the udder. Repeated teat compressions may cause mechanical and circulatory changes in teat tissue and hyperaemia in the teat wall (Isaksson and Lind, 1992; Burmeister *et al.*, 1998; Zecconi *et al.*, 2000). There are a number of factors in machine milking that may influence the teat condition but calf suckling is regarded as more “friendly” to the teats (Kubíček, Novak, 1995).

The aim was to test hypotheses that the suckling of calves is more stressful for teats than machine milking and that the injurious impact of suckling is depended on the age of calves and time of their suckling.

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Four groups of animals were used in the experiment: the group A (machine milking, 42.6 kPa) – 10 dairy cows; the group B (calves, colostrum period, age 5 days) – 6 dairy cows + 6 calves; the group C (calves, milk period, age 20 days) – 4 dairy cows + 12 calves; the group D (calves, weaning, age 60 days) – 3 dairy cows + 7 calves. The teat stress was evaluated by means of the changes of teat temperature (TT). The TT was measured by thermographic method (camera AGA 570) at the following intervals: immediately before suckling (milking), immediately after suckling (milking), 1 – 5 minutes after suckling (milking) for 2 days in every group. The time of suckling (milking) was recorded. The thermograms of the teats were evaluated by program Irwin 5.3.1., the obtained values by ANOVA.

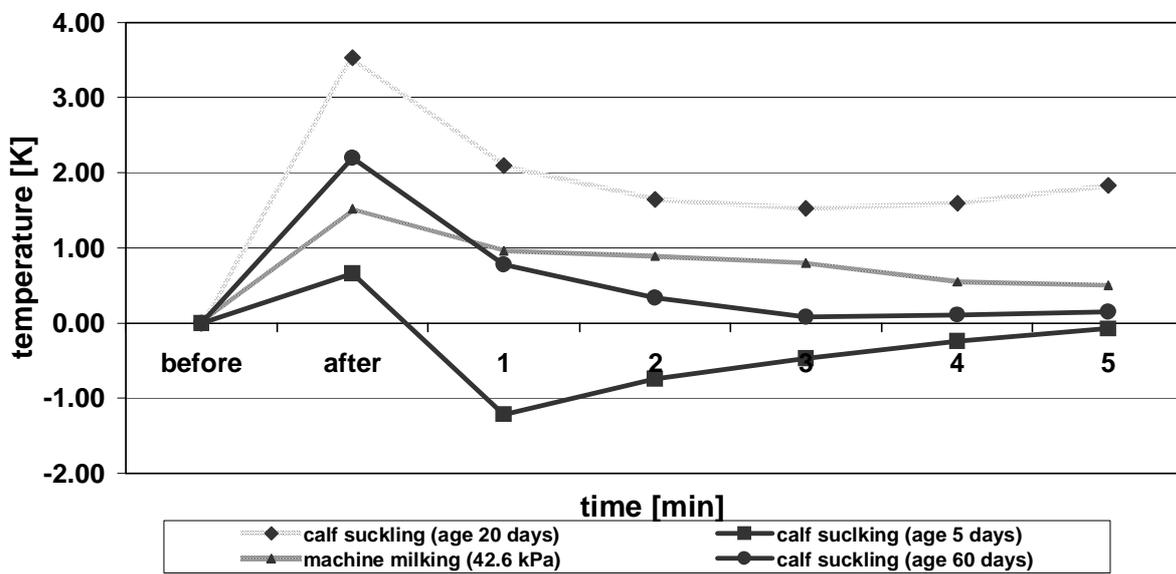


Figure 1. The course of temperature changes in teats depending on calf suckling and machine milking.

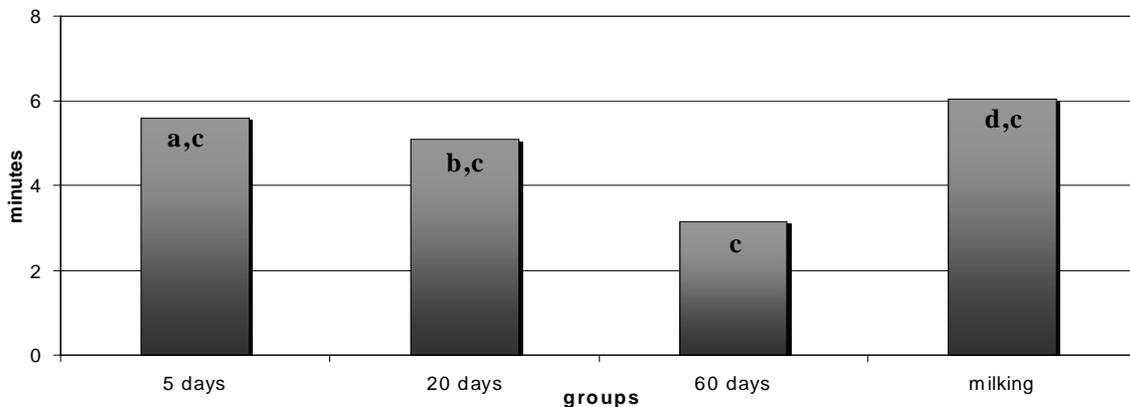


Figure 2. The average time of suckling and machine milking.

Results are showed in Figure 1 and Figure 2.

Generally, machine milking and calf suckling evoked an increase ($P < 0.05$) of TT. The highest increase of TT was caused by suckling of calves in milk period (group C; difference 3.53 K) compared with groups A (1.52 K), B (0.66 K), D (2.19 K) ($P < 0.05$). The lowest teat stress ($P < 0.05$) was find out by after suckling of calves in colostrum period (B). The shortest time of suckling (3.14 min) was recorded in D compared with B, C and A ($P < 0.05$). After 5 minutes the TT did not reinstate to the initial values in groups A and C.

The effect of suckling on the teats has not been explored as the effect of machine milking, and thermographic measurements have not been published. Our results show that the suckling of calves in the milk period induces the significantly highest temperature in teats. On the basis of results it is concluded that teat stress depends on age of calves and time of suckling. This supports the findings of Krohn (2001). This author recommended only short-term suckling. Flower and Wear (2001) reported similar results. Machine milking with vacuum 42.6 kPa cannot be considered as significantly injurious.

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Results and discussion

Acknowledgements

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Knowledge of a milking robot operation

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In the field of milking technology there is a continued and systematic development of automatic milking systems (AMS). The present-day conceptual solutions of automatic milking systems (AMS) differ in the number of milking boxes being attended by a single equipment, by technical solution of setting on teat cups, by solving management systems.

New items of knowledge and experiences gained from operating two dairy robots, make LELY ASTRONAUT, are presented in this paper. About 120 cows were milked by means of milking robots. Investment costs to purchase milking robots represented nine million Czech crowns. Building costs amounted to fifteen million Czech crowns.

LELY – ASTRONAUT consists of the following components:

The milking box - with a pneumatic control, a door, a feed components feeder, electronic equipment for recognising cows, guiding frame for the robot arm, the robot arm with laser system to determine position of teats, the system for cleaning teats and the equipment for setting on teat cups and discharge equipment.

The milking equipment - consists of a vacuum pump, teat cups and cups with an independent milk pipe liner for each quarter, automatic pre-milking equipment with milk separation, a vessel with measuring instrument to measure the total quantity of milk drawn, sensors to measure vacuum height, electric conductivity of milk, milk flow for particular quarters of the teats, device for automatic scanning of teat cups, a milk pump, a device for milk separation, a device for taking milk samples and a system for teats disinfection.

The electronic process management system – subsystem for conducting all the moves of the robot arm of the system of milking, udder cleaning system and the system for taking a milk sample, subsystem for electronic recognising of cows and feeding of feed components, subsystem for

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determination of milk quantity drawn, electric conductivity and milk flow, personal computer with a printing machine with management programme and alert system.

Other components – cleaning equipment to clean the parts through which the milk had flown and a pneumatic system to control doors.

Results

The evaluated milking robots were introduced into operation in November 2003. No serious defects occurred since they were introduced into operation.

About 50% of costs expected to be imposed on veterinary care have been saved as a result of implementing milking robots into this technological system.

An important contribution of this system is that dairy cows efficiency has increased by about 15% compared to classical milking. In the first operation year efficiency reached 28 litres of milk per day and head. Selekta Pacov joint-stock company paid a high attention to its running in. After putting milking robots into operation, when entered, the dairy cows had to accustom themselves to a milking box. After one week of operation as many as 50% of cows entered the milking box by themselves and approximately after one month nearly all the cows entered the milking boxes without any problems.

From the experiences obtained it is convenient for dairy cows to be transferred from other method of milking to a milking robot immediately after calving. To milk, mainly primiparas, by means of robots proved to be good. Milk is acquired from each quarter independently. After individual quarters have been stripped, the teat cups are disconnected automatically by which mammary gland is not burdened for a longer time than it is necessary. After taking the last teat cup away, the disinfection of teats by a special nozzle is carried out. The disinfection preparation is atomized by whirling effect. Milk quality is controlled by sensors. If the colour does not correspond with the normal, it is separated. In case of any change or unusual matter being occurred, the operation is warned by the computer monitor. The milking robot was visited 2.5 times by dairy cows throughout the day.

Conclusions

By introducing robotized milking (AMS) in the evaluated dairy cow farm was decreased the need for human work, it was possible for the dairy cows to chose the proper time of milking, the number of milking. The quality of milk obtained increased and performance of dairy cows increased by 15%. Health condition of the mammary gland improved, with veterinary costs being decreased by one half.

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Teat traumatization by milking in side by side milking parlour and tandem parlour

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The aim of this study was to find out and compare the stress of fore teats and hind teats during milking in side by side milking parlour (attaching the milking unit from behind) and tandem milking parlour (attaching the milking unit abeam). The stress was evaluated by means of the changes of teat temperature. The measurements were provided by thermographic method in field conditions. Milking in side by side milking parlour showed statistically ($P < 0.05$) higher stress hind teats and especially fore teats compared with milking in tandem milking parlour. Milking in tandem milking parlour can consider to be „friendly“ to udder.

Key words: Teats, machine milking, attaching, milking parlour, thermography

First of all milking in side by side milking parlour was used in sheep and goats, now this system is expanded in dairy cattle (Kubina, 1999). But mammary gland anatomy of dairy cow is very different compared with ewe or goat (Reece, 1997). Further, weighting of milking machine significantly influences milking process (Dolezal, 2000; Gleeson et al., 2003). Suspension of machine milking induces the moment, which influences teat tissue stress. First of all this moment is influenced by torsion of tubes. The aim of this study was to find out and compare the stress of fore teats and hind teats during milking in side by side milking parlour (attaching the milking unit from behind) and tandem milking parlour (attaching the milking unit abeam).

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The traumatization was evaluated by means of the changes of teat temperature before and after machine milking (morning + evening milking). The measurements were provided by thermographic method in field conditions (thermographic camera AGA 570). Three side by side milking parlours and three tandem parlours were investigated (milking vacuum 42.6 kPa). Twenty high-yielding dairy cows (udders) in every parlour were measured. The thermograms of teats were evaluated by special computer program Irwin 5.3.1., the obtained values by Statistica.cz (non parametric test).

Results and discussion

Results are showed in Figure 1.

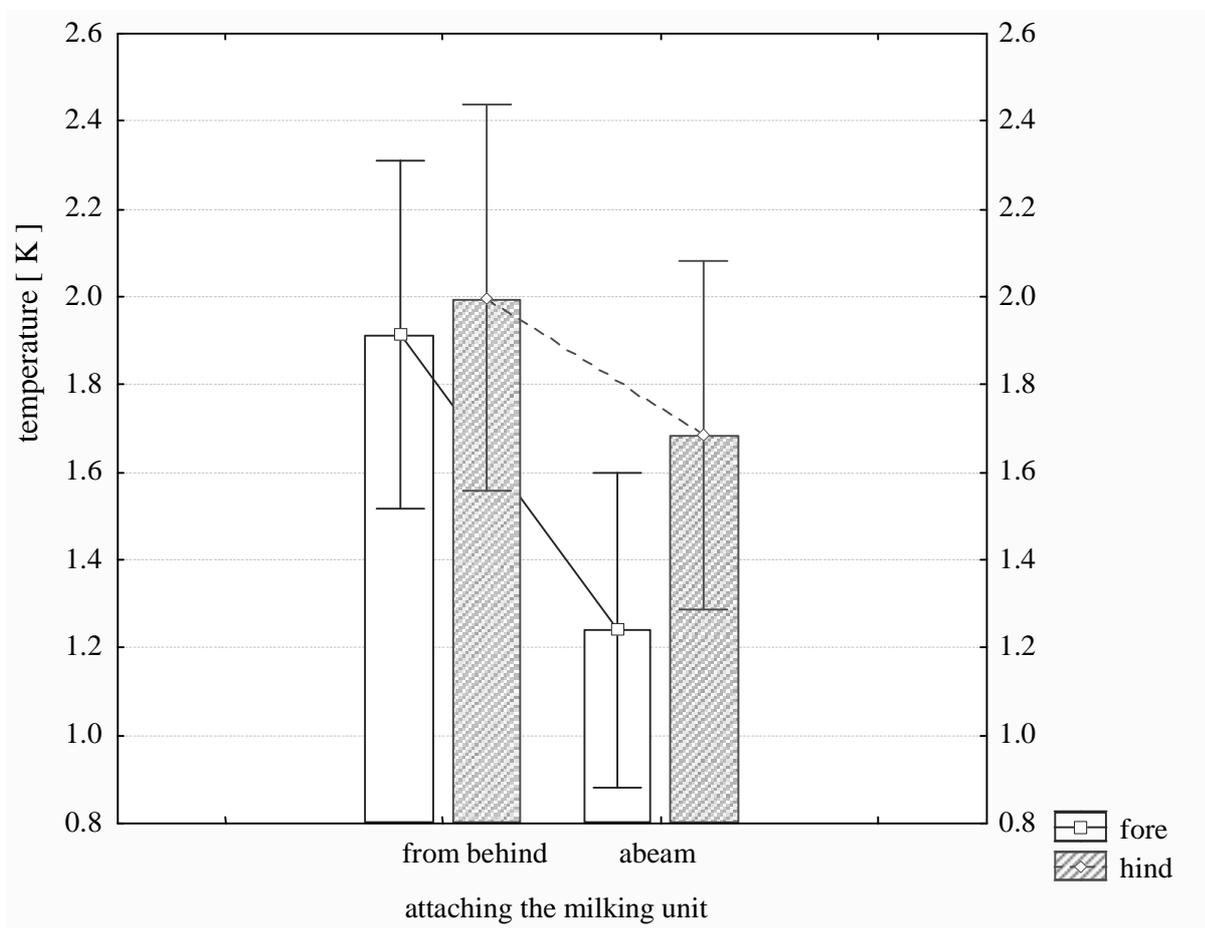


Figure 1. The changes in teat temperature by attaching the milking unit from behind and abeam.

Milking in side by side milking parlour showed statistically higher stress of hind teats and especially fore teats compared with milking in tandem milking parlour. The temperature of fore teats in side by side parlour increased by an average of 1.92 K, in tandem parlour by the average of 1.24 K immediately after milking, the difference 0.68 K was statistically significant ($P < 0.05$). The temperature of hind teats in side by side parlour increased by the average of 1.99 K, in tandem parlour by the average of 1.68 K after milking, the difference 0.31 K was statistically significant ($P < 0.05$). This fact is caused by anatomic conformation of dairy cow udder and distribution of force of gravity of milking unit in side by side milking parlour. These findings agree with Dolezal (2000). It is concluded that milking in tandem milking parlour can consider to be „friendly „to dairy cow udder.

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Safety and health protection in milking process

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The modern milking equipment is a complicated agricultural machine, in which there comes to interaction man – machine – animal – milk. In the past, the milking equipments were assessed from the view of safety, efficiency, technical characteristics, durability, quality, hygiene, price, etc. The equipment had to fulfil mandatory technical regulations and mandatory standards. After the Slovak Republic became a member state of EU, most of requirements were transformed into relation producer – customer. As a public interest, there remained only the safety of equipment.

The milking equipment consists of mechanical parts, electrical parts and control parts (often anthers), therefore it has to fulfil the requirements of EU directives now – Machinery Directive, Low voltage Directive, Directive about Electromagnetic compatibility, Sound power level Directive. These directives have their equivalents in the Slovak Government Orders. Producer, which brings milking equipment to Slovak market (which is part of UE market), has to issue, in written form, the Conformity declaration before. Conformity declaration is a legal document, by which the producer confirms that the product fulfils requirements of mentioned directives and standards. If the producer is not from UE countries, than the distributor, which brings the product to the UE market, has to issue the Conformity declaration.

Having declared the conformity, producer takes responsibility for equipment's safety in the moment of its bringing to the market. After installation of the milking equipment, customer has to do the tests in accordance with regulations of the Slovak Republic, before it starts to operate. Inspections and revisions shall take place in regular intervals during equipment's operation. The milking equipment usually works in humid environment with a high corrosion activity. From our experiences, it results that besides some damages of protective parts there can be also increasing of transference resistance of connected lifeless parts, or connection breaks. When there is accidentally created voltage on lifeless parts or when there are some floating currents, there the operators and animals are endangered, therefore it is necessary to make regular

measurements and remove the breaks. The operators have the complete instruction handbook in their state language, what also contributes to maintaining on the reached level of safety. Operators are regularly trained. There is also regular control of fulfilling the safety regulations and of the use of protection means. These requirements come out from the Laws and regulations about the work protection in SR.

It is only up to the customer – farmer to choose the proper milking equipment from the market. Today there are no state mandatory recommendations and restrictions. The customer has to choose himself the suitable equipment according to its efficiency, quality, price, services, etc. When he decides between comparative equipments, he has to rely on company materials, or published results of independent organizations. Certainly, he should not to make decision only on the base of purchasing price. The milking equipment contains many parts that have to be regularly removed and changed and the price of these parts and the work in its changing can expressive influence the total costs on operation. As to the influence of milking equipment on the milk quality, on the health of milk cow, etc., he can be oriented only according to referencies. The aim is to buy such milking equipment that enable gaining the milk in the suitable quality.

Our Institute provides the experts services to producers or distributors in elaborating of the technical documentation necessary to Conformity declaration in accordance with the Directives mentioned above. We provide detailed information about regulations and about the Conformity declaration at our Institute.

Effects of vacuum level and teat cup weight on milk removal in an automatic milking system

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Milkability is an important functional trait in dairy cattle with respect to milking performance, udder health and is therefore considered in selecting and breeding of animals. The rate of milk flow is one of the critical parameters causing variation in milking time. Besides anatomical traits of the cow (teat canal length, diameter of the teat canal and the tension of the teat sphincter) and management of the milking routine also physical properties of the milking machine can affect milking performance. The aim of this study was to test the effects of different vacuum levels (44 and 48 kPa) and teat cup weights (standard teat cups (400 g/cup) and heavy teat cups (800 g/cup)) on quarter and udder milking parameters (average milk flow and machine-on time) and the efficiency of udder emptying during milking in an automatic milking system (AMS) (Merlin®, Lemmer-Fullwood, Germany). Therefore, quarter milk flow was recorded during four days by an especially rebuilt set of four Lactocorders® while vacuum level and teat cup weight changed in 2 × 2 design. To test the efficiency of udder emptying, residual milk was removed after 10 IU of oxytocin injected i.v. at the end of milkings. To exclude possible effects of teat cup reattachment on milking parameters and efficiency of udder emptying, only milkings with attachment of all teat cups at first attempt were evaluated. Altogether quarter milk flow was recorded and residual milk was removed during 83 milkings (20 milkings with low vacuum and standard teat cups, 23 milkings with low vacuum and heavy teat cup, 12 milkings with higher vacuum and standard teat cups and 28 milkings with increased vacuum and heavy teat cups). During automatic milking, intervals between milkings differ individually. Moreover, cows in different parity and lactational stage at different production levels were used for the experiment. Therefore, besides effects of treatments (different vacuum levels and teat cups weights) on quarter and udder milking parameters also the effects of parity, lactational stage, milking interval, quarter (resp. udder) milk yield were tested. Moreover, on a quarter level also effects of quarter position (front right, front left, rear right and rear left) and on an udder level effects of duration of teat cup attachment were tested.

Average quarter milk flow was significantly ($P < 0.05$) affected by treatments, milking interval and quarter milk yield. Higher average quarter milk flow was observed during milkings at a higher vacuum level, but without an effect of teat cup weight. With increasing milking interval average quarter milk flow decreased. In quarters with higher average quarter milk flow was observed. Parity, lactational stage and quarter position did not influence average milk flow. Quarter machine-on time was significantly ($P < 0.05$) influenced by treatments, milking interval, quarter milk yield and quarter position. Shorter quarter machine-on time was observed at higher vacuum level, but without difference in machine-on time between teat cup weights. Quarter machine-on time increased also with increasing milking interval and quarter milk yield. Quarter machine-on time was longer in rear quarters than in front quarters. On an udder level, machine-on time was significantly influenced only by the milk yield and just tended to be influence by treatments ($P = 0.22$) and milking interval ($P = 0.21$). With increasing milk yield and milking interval udder machine-on time was prolonged. Numerically longer udder machine-on time was observed during milking at low vacuum. However, average udder milk flow was not significantly influenced by any of tested parameters. Only a tendencial effect was observed by treatments ($P = 0.12$) and milk yield ($P = 0.24$).

The amount of residual milk was 1.33 ± 0.11 kg (11.5 \pm 0.8 %) by applying low vacuum and standard teat cups, 1.53 ± 0.14 kg (11.9 \pm 1.2 %) by a low vacuum and heavy teat cups, 1.83 ± 0.25 kg (13.3 \pm 1.8 %) by higher vacuum and standard teat cups and 1.88 ± 0.15 kg (13.5 \pm 0.9 %) by higher vacuum and heavy teat cups. From tested parameters (treatments, parity, lactational stage, milking interval and total milk yield (milk yield removed during milking in AMS including residual milk)) amount of residual milk was significantly influenced only by total milk yield. The amount of residual milk increased with increasing total milk yield. Lactational stage tended ($P = 0.16$) to have a effect on the amount of residual milk. Percentage of residual milk was affected by none of tested parameters. This was not surprising, because the percentage of residual milk is typical for individual animals. Moreover, the percentage of residual milk did not change in the course of lactation, i.e. it was not depended on actual milk yield or milking interval.

In summary, higher vacuum level increased average quarter milk flow and decreased duration of quarter machine-on time. However, on the udder level no effect of vacuum level on milkability was found. The udder emptying during milking in AMS was in the normal range and was not influenced by vacuum level or teat cup weight. In conclusion, neither vacuum level nor teat cup weight influences amount of residual milk.

Relationships between morphological and functional udder traits and somatic cell count in milk of ewes

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On the basis of analysis of 20 parameters studied during the milking period in ewes of 8 genotypes we found positive phenotypic and residual correlations between teat position ($r = 0.163$; $P < 0.001$ and/or 0.102 ; $P < 0.05$) and teat size ($r = 0.141$; $P < 0.001$ and/or 0.133 ; $P < 0.01$) (1st to 3rd lactation, years 2002 – 2004) and by means of logarithm transformed SCC (LOGSCC or SCS). Ewes with more horizontal teat position and larger teats had higher LOGSCC. We found no significant residual correlations between the areas of both udder cisterns and LOGSCC. Residual correlations between parameters of milkability and LOGSCC varied from -0.173 to -0.175 ($P < 0.001$). Ewes with quicker milk ejection (they produced more milk during 30 and 60 s) and higher amount of machine milk had lower LOGSCC. On the contrary, higher LOGSCC was in ewes with higher machine stripping. We found highly significant phenotypic and residual correlation between LOGSCC and proportion of machine stripping ($r = 0.199$ and/or 0.165 ; $P < 0.01$).

Key words: Ewe, linear description of udder, udder cisterns, milkability, somatic cells

Breeding programmes in milk sheep are more and more aimed at the so-called functional traits that influence their longevity. New selection criteria are being looked for to be used in milk sheep breeding for better milkability and good udder health condition (Sanna et al., 2002; Margetin et al., 2003). It is necessary to find the genetic and phenotypic relations among somatic cells (indicator of udder health), udder morphology and milk ejection (Rupp et al., 2003) for us to be able to define the global milk index in milk sheep that provides good health condition in udder and milkability in ewes. The objective of this work was to find the degree of

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dependence between the somatic cell count on one hand and linear evaluation of udder, udder cistern size and milkability of ewes on the other by means of phenotypic and residual correlations.

Material and methods

During the years 2002 – 2004 we performed linear evaluation of udder in ewes (tab. 1) of 8 genotypes created on the basis of purebred Tsigai (T), Valachian (IV) sheep and sheep of Lacaune breed (LC) within a milking period. We used ultrasonographic method to detect udder cistern size, and we recorded selected traits that characterize milkability in ewes (tab. 1). We sampled milk from the same ewes and we assessed somatic cell count (SCC) by means of Bentley apparatus 500. Because of irregular SCC distribution we analyse in this work the decimal logarithm SCC (LOGSCC) as well as the somatic cell score trait – SCS ($SCS = \log_2 (SCC / 100000 + 3)$). To analyse primary data of all variables ($n = 517 - 571$) we used linear model with fixed effects and we took into consideration the effect genotype (8 levels), parity (3 levels), control year (3 levels), and milking period (2 levels). We calculated the residual correlations from estimates of residua detected on the basis of mentioned linear model of analysis of variance. We used the mathematical and statistical package of programmes SAS – ver. 8.2 (SAS/STAT, 1999-2001), GLM and CORR procedure, for calculations.

Results and discussion

Mean estimates of selected morphological and functional characteristics of udder and somatic cells in milk of ewes are given in tab. 1. Analysed traits of linear evaluation of udder were in 2 cases (position and size of teats) in statistically significant relation with LOGSCC and/or SCS irrespective of whether we started from phenotypic or residual correlations (tab. 2). Ewes with more horizontal teat position and larger teats had higher somatic cell count ($r = 0.102$ to 0.163 ; $P < 0.05$ to $P < 0.001$). Ewes with more horizontal teat position (linear evaluation 7,8,9) have greater problems with milk output, greater probability of subclinical mastitis inception. Therefore it is necessary to put greater attention to udders with more horizontal teat position at machine stripping. We found no statistically significant residual correlation coefficients (tab. 2) between the size of udder cisterns detected by ultrasonographic method and LOGSCC. In two cases we found significant phenotypic correlations between udder cistern size and LOGSCC ($r = 0.149$ and/or 0.174 ; $P < 0.001$) that are presumably related to the effect of LC breed, having the largest cisterns as well as the highest SCC. Milk amount milked during 30 seconds, 60 seconds and machine stripping were in significant negative correlation with LOGSCC or SCS ($P < 0.001$) in our observations. Ewes with worse milk ejection have higher somatic cell counts at machine milking without the help of milker and there is greater probability of subclinical mastitis occurrence. Remarkable is the detection of positive phenotypic and residual correlation between LOGSCC ($r = 0.217$ and/or 0.175 ; $P < 0.001$) and portion of machine stripping. Somatic cell counts

rose with rising portion of machine stripping. Subclinical mastitis connected with increased SCC is one of the factors influencing portion of machine stripping. Selection of sheep for lower portion of machine stripping could therefore manifest itself in better state of udder health.

Table 1. Least square means (LSM) of chosen morphological and functional characteristics of udder and somatic cell count in milk.

Trait	Number of obser.	LSM	Root MSE	Variation coefficient	Minimal value	Maximal value
Udder depth (points)*	564	4,84	1,194	24,70	1	9
Cistern height (points)	564	4,94	1,701	34,43	1	9
Teat position (points)	564	5,12	1,554	30,33	1	9
Teat size (points)	564	4,46	1,156	25,89	1	9
Udder cleft (points)	564	4,82	1,490	30,90	1	9
Udder attachment (points)	564	5,39	1,135	21,05	2	9
Udder shape (points)	564	5,22	1,351	25,90	2	9
Area of left udder cistern (method 1, mm ²)	552	1853,1	735,51	39,69	137	6598
Area of right udder cistern (method 1, mm ²)	552	1875,7	689,99	36,79	188	5552
Area of left udder cistern (method 2, mm ²)	554	2104,7	750,15	35,64	166	6731
Area of right udder cistern (method 2, mm ²)	554	2133,5	725,29	33,99	178	4832
Machine milk milked per 30 s (MM30s, ml)	517	217,5	82,68	38,01	0	560
Machine milk milked per 60 s (MM60s, ml)	517	284,3	114,54	40,29	0	780
Machine milk (MM, ml)	517	293,0	120,17	41,01	0	780
Machine stripping (MS, ml)	517	110,0	68,94	62,65	0	720
Total machine milk (TMM, ml)	517	403,0	129,65	32,17	30	1020
Portion MS/TMM (PMS, %)	517	28,4	15,04	52,94	0	100
Somatic cell count (SCC)x1000	571	421,6	1138,1	269,93	13	15328
Log ₁₀ SCC	571	5,16	0,518	10,04	4,114	7,185
Somatic cell score (SCS)	571	3,54	1,721	48,64	0,057	10,260

*Median and modus for traits of linear evaluation = 5

Table 2. Phenotypic and residual correlations between LOGSCC (SCS) and linear evaluation traits, udder cistern size and milkability of ewes.

Trait	Udder depth	Cistern height	Teat position	Teat size	Udder cleft	Udder attachment
Phenotypic correlations	0,242+++	0,136++	0,163+++	0,141+++	0,003ns	-0,025ns
Residual correlations	0,069ns	0,050ns	0,102+	0,133++	0,038ns	-0,053ns
Trait	Area of left udder cistern	Area of right udder cistern	Area of left udder cistern	Area of right udder cistern		
	Method 1 (ultrasonography from below)		Method 2 (ultrasonography from side)			
Phenotypic correlations	0,149+++	0,174+++	0,077ns	0,068ns		
Residual correlations	0,005ns	0,009ns	-0,060ns	-0,066ns		
Trait	MM30s	MM60s	Machine milk	Machine stripping	TMM	PMS
Phenotypic correlations	-0,071ns	-0,045ns	-0,046ns	0,204+++	0,048ns	0,217+++
Residual correlations	-0,173+++	-0,175+++	-0,175+++	0,100+	-0,110+	0,175+++

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Morphology of udder and milkability of ewes of Tsigai, Improved Valachian, Lacaune breeds and their crosses

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During the milking period 2002 - 2004 we evaluated morphology of udder and milkability of ewes (583 observations with each trait) in ewes of 8 genotypes (286 ewes) created on the basis of Tsigai (T), Improved Valachian (IV) and Lacaune (LC) breeds. All studied parameters were influenced by the genotype ($P < 0.001$), many of them also by the effect of parity. Linear assessment (9 points scale) and exact measures of udder showed that ewes of T and IV breeds had smaller udder, with smaller cisterns and better teat position than ewes of LC breed. Portion of machine stripping (PMS) was the best in IV ewes (26.0 %) out of the purebred breeds, then in T ewes (27.2 %) and the highest with purebred IV ewes (36.3 %). The highest portion of milk milked within 30 and 60 seconds out of total milk yield was in ewes of T, then with machine milk ($r = 0.296$ and/or 0.314) as well as with total milk yield ($r = 0.465$ and/or 0.518 ; $P < 0.001$). PMS was significantly influenced by size of teat ($r = 0.177$ and/or 0.113 ; $P < 0.001$) and it was dependent on udder attachment ($r = -0.205$; $P < 0.001$) and general udder shape ($r = -0.141$; $P < 0.001$).

Key words: Ewe, udder morphology, linear assessment, milkability

In Slovakia Lacaune breed is used in a relatively large scope in breeding of native milk breeds (Tsigai, Improved Valachian, Merinos). The intention is to improve mainly milk production in the created crosses and to keep good functional and morphological properties of udder at the same time. Convenient subsidiary selection traits are being looked for that could be used in sheep breeding for better milkability and udder morphology suitable for machine milking. This way of milking develops favourably in Slovakia during recent years. Works of Marie-Etancelin et al. (2001), Serrano et al. (2002), Casu et al. (2002) is obvious that it is

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possible to use with success traits of linear evaluation of udder in breeding of milk sheep. The objective of this work was to analyse selected traits of linear assessment of udder and milkability of ewes of Tsigai, Improved Valachian, Lacaune breeds and their crosses, and to find out to which extent depend the selected traits of milk production and milkability on morphology of udder.

Material and methods

We determined the morphology of udder in ewes of 3 purebred breeds (Tsigai – T, Improved Valachian – IV and Lacaune – LC) and 5 types of crosses created on the basis of them (number of ewes = 286; some ewes were measured several times) during the milking period 2002 – 2004. We evaluated following traits on a 9 points linear scale: udder depth (UD-LA), depth of cistern (DC-LA), teat position (TP-LA), teat size (TS-LA), udder cleft (UC-LA), udder attachment (UA-LA) and general shape of udder (GSU-LA). We measured: udder depth (UD – mm), depth of cistern (DC – mm), length of teat (VC – mm) and angle of teat (PC – degree) by means of measuring tape and protractor. We recorded also selected parameters that characterize milk yield and milkability of ewes in individual control measurements. We studied the following parameters (in ml): amount of milk milked by machine within 30 and 60 seconds (MY30S; MY60S); machine milk yield (MM), machine stripping (MS), total milk yield (TMY), and percentage portion of machine stripping (PMS), portion of MY30S out of TMY (PMY30S) and portion of MY60S out of TMY (PMY60S). To analyse primary data of all variables (583 measurements with each parameter) we used the linear model with fixed effects; we took into consideration the factor genotype (8 levels), parity (3 levels), control year*period of milking (6 levels) and DIM as covariable. Partial correlation coefficients were calculated on residuals after the data adjustment by the mentioned linear model of covariance analysis. Statistical package of SAS programmes (SAS/STAT, 1999-2001), GLM and CORR procedures were used for calculation.

Results

All studied parameters (tab. 1) were highly significantly influenced by the factor genotype ($P < 0.001$). Most parameters were significantly influenced also by the effect of parity. Ewes in 3rd lactation had according to linear assesment significantly larger udder depth (5.57 points), depth of cistern (5.32 p.), larger teats (4.90 p.) and more horizontal position of teats (5.48 p.) than ewes in 1st lactation (4.51; 4.89; 4.27 respectively; $P < 0.05$ to 0.001). Ewes in 1st lactation had better milk ejection (on the basis of amount and portion of milk milked within 30 and 60 seconds) and lower PMS than ewes in 3rd lactation ($P < 0.01$ to 0.001). Comparison of purebred ewes of T, IV and LC breeds showed the greatest udder depth in LC ewes (UD-LA = 6.19), followed by IV (4.55) and the lowest depth was in ewes of T breed (3.68; tab. 1). Differences were highly significant ($P < 0.001$). On the other hand, the worst teat position was in LC ewes (TP-LA = 5.76), followed by IV ewes (4.58) and the best position was with T ewes (4.52). Differences between T and LC ewes were highly

significant ($P < 0.001$). As regards the size of teats, it was significantly larger in IV ewes ($TS-LA = 4.94$) than in LC (4.50) and T ewes (4.14; $P < 0.001$). Crosses IV \times LC and T \times LC with 50 and 75 % genetic portion had larger udders, larger cistern in udder at the same time, however, worse teat position. LC ewes had the highest TMY (536.4 ml; tab. 1) but only the 4th best MM (355.8 ml). However, it was higher than with purebred T (210.9 ml) and IV ewes (305.0 ml). Out of purebred breeds was portion of machine stripping the best in IV ewes (26.0 %), then in T ewes (27.2 %) and the highest in purebred IV ewes (36.3 %). The highest portion of milk milked within 30 and 60 seconds out of TMY was in T ewes (64.5 and 72.6 %, respectively), then IV (58.1 and 73.6 %, resp.) and the lowest one in LC ewes (45.2 and 62.0 %, resp.).

Table 2 shows that udder depth is in highly significant correlation with machine milk ($r = 0.296$ and/or 0.314) as well as total milk yield ($r = 0.465$ and/or 0.518 ; $P < 0.001$) and with milk amount milked within 30 and 60 seconds as well. Portion of machine stripping is highly significantly influenced by teat size ($r = 0.177$ and/or 0.113 ; $P < 0.001$). The larger the teat was the higher was the portion of machine stripping. Teat position did not influence PMS in our experiment. By contrast, both milk yield (MM, TMY) and milkability (MY30s, MY60s, PMS) were highly significantly dependent (tab. 2) on udder attachment and on general teat shape ($P < 0.001$). The better was teat attachment the lower was PMS ($r = -0.205$; $P < 0.001$) and the better was evaluation of general udder shape the lower was PMS ($r = -0.141$; $P < 0.001$).

Our results show that improvement of native breeds T and IV using the LC breed increases not only the size of udder but also milk production (MM and TMY) in the created crosses. However, mainly teat position deteriorates in connection with cisterns of udder growing larger. Traits related to milkability (PMS, PMY30s, PMY60s) are slightly worse in crosses than in purebred T and IV ewes, the worst being in LC breed. From the said follows that in Slovakia it will be necessary to use also data from linear assessment of udder (mainly UD, TS, UA and TP) in breeding of milk sheep.

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Conclusion

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Table 1. Estimates of mean values (LSM) of selected morphological and functional traits of udder in sheep in dependence on their genotype.

Trait	Genotype							
	IV	IVxLC (37,5% LC)	IVxLC (50% LC)	IVxLC (75% LC)	T	TxLC (50% LC)	TxLC (75% LC)	LC
UD-LA	4,55	4,37	5,76	5,76	3,68	5,18	4,86	6,19
UD-mm	13,70	14,10	17,46	16,96	12,22	15,05	15,22	18,52
DC-LA	4,08	4,65	5,76	5,13	4,11	5,82	5,43	5,98
DC-mm	1,91	2,16	3,50	2,94	1,59	2,91	2,33	3,36
TP-LA	4,58	4,83	5,60	5,49	4,52	5,95	5,18	5,76
TP-st.	40,99	42,65	45,79	45,94	40,06	50,51	41,95	46,27
VC-LA	4,94	5,15	4,66	4,68	4,14	4,54	4,35	4,50
TS-mm	3,73	3,75	3,50	3,56	3,38	3,39	3,63	3,47
UC-LA	5,07	5,08	5,58	4,83	4,82	4,99	3,82	4,32
UA-LA	5,61	5,83	5,64	5,71	4,95	5,49	4,86	5,33
GSU-LA	5,24	5,67	5,83	5,89	4,15	5,68	5,34	5,73
MY30S	231,7	194,6	240,09	230,70	183,7	233,1	220,2	243,7
MY60S	305,0	273,1	351,4	343,4	210,9	288,7	321,6	345,0
MM	307,1	279,7	378,4	371,3	211,2	302,2	361,1	355,8
MS	100,3	107,8	136,5	130,5	79,4	114,9	95,2	180,5
TMY	407,4	387,6	514,8	501,8	290,6	417,1	456,3	536,4
PMS	26,0	35,7	27,5	28,8	27,2	28,2	23,5	36,3
PMY30S	58,1	45,8	49,2	46,6	64,5	58,4	51,0	45,2
PMY60S	73,6	63,3	68,4	66,8	72,6	70,0	71,1	62,0

Table 2. Residual correlations among traits of milkability and linear assessment and measures of udder in sheep.

Trait	MY30S	MY60S	MM	MS	TMY	PMS	PMY30S	PMY60S
UD-LA	0,227+++	0,251+++	0,296+++	0,355+++	0,465+++	0,052ns	-0,115++	-0,116++
UD-mm	0,182+++	0,265+++	0,314+++	0,429+++	0,518+++	0,079ns	-0,186+++	-0,145+++
DC-LA	0,148+++	0,156+++	0,153+++	0,77ns	0,184+++	-0,058ns	0,022ns	0,055ns
DC-mm	0,184+++	0,219+++	0,206+++	0,184+++	0,289+++	-0,028ns	-0,013ns	0,034ns
TP-LA	0,067ns	0,191+	0,094+	0,095+	0,139+++	-0,003ns	-0,043ns	-0,008ns
TP-st.	0,063ns	0,035ns	0,031ns	0,066ns	0,064ns	-0,019ns	0,034ns	0,016ns
TS-LA	0,125++	-0,137+++	-0,128++	0,134++	-0,049ns	0,177+++	-0,113++	-0,174+++
TS-mm	-0,95+	-0,148+++	-0,144+++	0,52ns	-0,107++	0,113++	-0,009ns	-0,106+
UC-LA	0,074ns	0,088+	0,079ns	-0,009ns	0,069ns	-0,057ns	0,032ns	0,062ns
UA-LA	0,345+++	0,363+++	0,334+++	-0,033ns	0,296+++	-0,205+++	0,124++	0,213+++
GSU-LA	0,402+++	0,396+++	0,383+++	0,114++	0,419+++	-0,141+++	0,095+	0,134++

The relationship between the milk flow, quantity of drained milk and somatic cell count in milk of Holstein and Simmental cattle breed in Croatia

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Although machine milking has significantly increased the efficiency of working operations in everyday's process of a milking farm, a specific lack of coordination has been observed between the machine and animals. For health udder, a short lasting milking is favourable, at which a maximum milk flow is achieved quickly and held through a longer period of time. The possibilities of treating cow's udder from mastitis are being limited. Research has shown that the least somatic cell count is at Holstein breed cows in first (LSCC = 2,77) and second lactation (LSCC = 3.04) during MMF 2.7-3.6 kg/min, and MQM of 8.94, that is 9.35 kg. The Simmental cows showed at second, third and further lactations the least LSCC = 2.57 and 3.60, at MMF 2.7-3.6 kg/ min and MQM of 7.79 that is 8.76 kg.

Key words: Milk flow, somatic cell count, health udder, cattle

An increasing introduction of milking machines into the production process of milking farms has shown a specific lack of coordination between the machine and animals. The milk flow is an indicator of milking speed at specific quantity of drained milk. The research wanted to show specific relationship between specific milking characteristics, milk quantity and health udder. Research was conducted on 457 Holstein and 61 Simmental cows in Croatia from the 50th to 180th lactation day. The Lacto-Corder machine was used for measuring whereby data for

Summary

Introduction, material and methods

milk quantity per milking (MQM) and maximum milk flow (MMF) were measured. The somatic cell count (SCC) is logarithmically transformed $LSCC = (\log_2 (SCC/100.000) + 3)$.

Results

The least somatic cell count in milk of Holstein cows was in the first (LSCC = 2.77) and second lactation (LSCC = 3.04) at MMF of 2.7 to 3.6 kg/min and MQM of 8.94, in other words 9.35 kg (table 1), and the largest (LSCC = 4.77) at MMF higher than 4.5 kg/min and MQM of 13.50 kg. For Simmental first lactation cows the least SCC in milk (LSSC = 1.47) was observed at the slowest MMF (<2.7 kg/min) and the least MQM (5.24 kg). Cows in second, third and further lactations had the least SCC (LBSS = 2.57 and 3.60) at MMF of 2.7 to 3.6 kg/min and MQM of 7.79 and 8.76 respectively. The largest SCC (LBSS = 4.79 and 4.25) was at MMF of 2.7 and larger than 3.6 kg/min. Milking research has a future for it shows a favourable way of genetic improvement to cow's adjustability to milking machines and its connection to health udder. It is necessary for milking characteristics of cows involved in research to be widely and systematically observed. This specially refers to Simmental breed in Croatia, which the primary productive characteristics have not been developed at yet.

Table 1. Correlation between somatic cell count in milk (LSCC), quantity of drained milk (MQM) and maximal milk flow (MMF) for investigation cattle breeds.

MMF (kg/min)	Lak.	n*	Holstein				n*	Simmental			
			LSCC		MQM			LSCC		MQM	
			\bar{x}	s	\bar{x}	s		\bar{x}	s	\bar{x}	s
< 2.7	1	45	2.90	1.93	8.76	3.30	6	1.47	1.73	5.24	1.14
	2	30	3.23	1.91	9.19	3.96	11	3.53	2.57	7.08	2.41
	≥3	42	3.94	2.27	8.02	4.08	15	4.79	1.76	7.37	2.37
2.7 - 3.6	1	74	2.77	2.04	8.94	2.85	9	3.47	2.09	7.58	2.21
	2	44	3.04	2.63	9.35	3.61	4	2.57	0.42	7.79	3.08
	≥3	67	3.31	2.08	11.20	3.48	4	3.60	2.47	8.76	4.13
3.6 - 4.5	1	21	2.91	1.92	11.04	2.58	4	4.02	1.57	8.00	2.16
	2	20	3.53	2.49	10.21	2.98	4	3.21	3.43	9.45	2.95
	≥3	32	3.20	2.50	11.98	2.83	4	4.25	2.63	10.77	1.95
> 4.5	1	17	3.54	2.06	9.46	1.94					
	2	19	3.79	1.75	11.64	3.37					
	≥3	46	4.77	2.44	13.50	3.38					

*n = no. of cattle

Machine milking problems: trouble shooting

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The Animal Health Service in The Netherlands employs certified specialists in the field of mastitis management, especially trained in the evaluation of the functioning of the milking machine and milking procedures. They visit, on a yearly basis, around 300 dairy farms with mastitis or problems related to the milking machine at the request of the farmer and/or local veterinary practitioner. They report their findings always to the farmer and the local veterinarian.

Two important problems related to the milking machine are restless cows during milking and disturbed milk ejection or removal. In this article possible causes of these two problems are discussed.

Cows should be quiet and relaxed during milking (Bruckmaier, 1998; Reneau 1995). It is considered a herd problem if over 10% of the clusters are kicked off or require reattaching. Possible causes and indications of restless cows during milking are (Aneshansley 1992; Mein 2003; Mein 2004; Southwick 1995) :

Causes	Indications
Insufficient functioning of the milking machine	teat affections restless cows at the end of milking
wrong use of concentrates	restless cows when there no concentrates reattaching is no problem
fly nuisance	cows also restless before milking cows restless during milking
sensitive teats	teat lesions cows restless during udder preparation
stray voltage	cows tripping cows are kicking quite suddenly

Introduction

Restless cows during milking

cow stalls too small parlour	cows are not eager to come into the milking cows are not standing straight in the stalls
restless milker	cows are afraid of the milker

Disturbed milk ejection/removal

Intramammary infections will exist longer if the udder is insufficiently milked out (I.D.F., 1987). The recommended maximum strip yield per udder is 0.5 kg (Mein & Hamann, 1995). The proportion of cows with more than 250 ml of strip yield should not be above 10% (Rasmussen, 2004). Possible causes of disturbed milk ejection/removal are (Bruckmaier, 1998; Reneau 1995):

Causes	Examples
Insufficient functioning of the milking machine	vacuum/pulsation failure, wrong liner design, cracked liners/tubes, wrong position cluster, wrong adjustment automatic cluster removal
insufficient udder preparation	udder prep-lag time too short
variable milking routine	different milkers/milking procedures
cow in bad shape	cow not healthy/in heat/stress
cow factors	udder shape, teat shape, milking speed

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Teat affections caused by the milking machine

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The Animal Health Service in The Netherlands employs certified specialists in the field of mastitis management, especially trained in the evaluation of the functioning of the milking machine and milking procedures. They visit, on a yearly basis, around 300 dairy farms with mastitis or problems related to the milking machine at the request of the farmer and/or local veterinary practitioner. They report their findings always to the farmer and the local veterinarian.

The teat canal is the first defence mechanism against invading bacteria in the udder (Hamann, 1987). Therefore it is essential that the teat orifice and the teat canal are in good condition. Teat affections are caused by infectious diseases but also teat trampling, chemicals, weather changes and mechanical damage by the milking machine.

The Teat Club International suggested a range of teat condition scores for the evaluation of field data and divided them into short- (single milkings), medium- (few days or weeks) and long term effects (several weeks) (Rasmussen, 2003). In this article examples of short-, medium- and long term teat tissue reactions to machine milking are described.

A disturbed blood circulation in the teat can cause hardened, red and even blue teats immediately after milking. Possible causes are: vacuum too high, too short massage phases, too long or too short liners and too long blind milking (Hamann, 1987, Mein 2003). Side effects of a disturbed blood circulation are: open teat orifices; damage of the epithelium and a diminished cell bound resistance (Zecconi & Hamann, 2004). The risk of new infections increases if the swelling of the teat during milking is over 5% (Zecconi et al., 1992). There is a herd problem if this teat affection is seen in more than 20% of the herd (Rasmussen et al., 2003).

A high vacuum in the mouthpiece of the liner causes a swelling, which looks like a ring, at the base of the teat also immediately after milking. This is more pronounced if the vacuum in the mouthpiece of the liner is concurrently too high at the beginning or in the middle of the milking above 20 kPa. In these cases udder health will deteriorate (Rasmussen,

Introduction

Hardened red or blue teats

Swelling at the base of the teat

1997). During milking the teat will rest against the liner if the diameter of the liner is about the same as the diameter of the teat. In such a situation the vacuum in the liner will be low and the blood circulation in the teat will be sufficient. At the end of a milking the teat diameter will diminish and in this case the teat will not follow the movements of the liner. This causes an increase in vacuum at the mouthpiece of the liner. The liner will move up on the udder and the liner will tighten the teat canal. Milking out will then be more difficult. A high vacuum in the liner will happen sooner with wide liners. A wet preparation of the teats before attaching the milking cluster will have the same effect. The air inlet in the liner will be insufficient if there is water residue between the liner and the teat.

Teat lesions

Teat lesions caused by the milking machine are defined as medium-term teat changes. There are open lesions and vascular damages observed as petechial or extensive haemorrhages. We had a problem in a herd with 60 cows where nearly half of the herd had fissures at the base of the hind teats. This was caused by wrong adjustment of the automatic cluster removal. The clusters were removed under vacuum and pulled to the front of the cow. As a consequence, the teats were bended, especially in the hind teats. This resulted in fissures at the base of the teat.

Lesions of the teat skin leads to colonisation with bacteria. Less than 5% of the cows should have open lesions (Rasmussen, 2003).

Teat end callosity

Teat end callosity is a long term effect. Too high pressure on the teat end causes teat end callosity (Mein et al., 1987). Machine milking risk factors are: long machine on time in combination with a low milking flow, pulsation c phases too short, too high vacuum, too slow detachment of the cluster and too tight liners (Mein et al., 2003; Neijenhuis, 2004). Cows with pointed teats show more teat end callosity rings than cows with inverted or flat teat ends (Neijenhuis, 2001). Neijenhuis et al. (2000) developed a teat end scoring system. An increase in the risk of clinical mastitis was observed when thickness and/or roughness of the teat end callosity increased (Neijenhuis, 2004). It is considered a herd problem if more than 20% of the cows have roughened rings extending 1-3 mm from the orifice and that more than 10% of the cows have rings extending > 4 mm (Rasmussen, 2003).

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Protocol for farms with udder health problems

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The Animal Health Service in The Netherlands employs certified specialists in the field of mastitis management, especially trained in the evaluation of the functioning of the milking machine and milking procedures. They visit, on a yearly basis, around 300 dairy farms with mastitis or problems related to the milking machine at the request of the farmer and/or local veterinary practitioner. They report their findings always to the farmer and the local veterinarian.

In this article the protocol for farms with udder health problems will be discussed.

Both for the farmer and the adviser it is important to set a goal at the start of the visit. It should be clear what udder health status the farmer wants to achieve and in which period. Examples of goals are:

Bulk milk cell count	< 250.000 c/ml
Number of cows > 250.000 c/ml	< 15% of the herd
Number new cows > 250.000 c/ml	< 10% of the herd
Clinical mastitis cases	< 20 cases per 100 cows
Number of culled cows for udder health problems	< 5%

A good analysis of farm data, the farm management and the cows is essential for a good advice.

A farm visit starts with the analysis of farm data related to mastitis such as milk recording data, cow SCC data, results of bacteriological culture, test report of the milking machine, data on milk quality control and the ration of the cows. Important in the analysis of farm data is information about new infections. Which cows got new infections and in which period? What is the most important pathogen?

Introduction

Setting the goal

Analysis

The data analysis is followed by a farm inspection. Important points are the hygiene of the lying areas and the bedding, the ventilation and the feeding regime. To get more information about the feeding regime the cow condition, the rumen filling, the rumen mobility and the consistency of cow manure is observed. During milking measurements on the milking machine are carried out and the milking procedures are supervised. The behaviour of the cows, the milking results and the teat condition are judged. The farmer is questioned about preventive measurements, treatment and culling of mastitis cows. Important in the analysis of the farm management is if there were any vital management changes before the outbreak of mastitis.

**Advice and
follow-up**

After the analysis of the farm data, the farm management and the herd, it is possible to tackle the problem. The advice is always twofold: a way to tackle the mastitis cows and a way to tackle the risk factors on the farm. With the cow SCC data, the results of bacteriological culture and the milk recording data for every mastitis cow, the adviser can decide together with the farmer and the local veterinarian about treatment, (early) drying off or culling. Furthermore, the risk factors on the farms are eliminated as much as possible. The advice will be differentiated in short-term and long-term advices. The results of the advice are evaluated on a regular bases by the local veterinarian and, if necessary, corrections are made.

The influence of mechanical stimulation on the milking behaviour of dairy goats

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Due to growing dairy goat stocks it is necessary to develop an animal-friendly and considerate milking procedure for goats. Results of prevailing preliminary investigations have shown that there is yet a lot of work to be done in optimizing the milking procedure and equipment.

1. Analysis of milking behaviour of high yielding dairy goats.
2. Analysis and estimation of influence of stimulation on milking behaviour and on milking routine.
3. Conclusions for milking technique and milking routine.

Effects of stimulation were studied by 38 White German Goats over the lactation period. The animals were divided into three groups and stimulated different: The goats of group 1 were stimulated by massaging the teats for 20 sec. There was no stimulation for the goats of group 2. There were two kinds of stimulation for the goats of group 3: In an alternation of 14 days : High frequently teat rubber oscillation on beginning of milking process for 20 sec and in the following 14-days-period alternating pulsation frequency while the entire milking process.

During all of the stimulation varieties the parameters milk flow rate, milking duration, latency time and the performance characteristics were analysed. Additionally a milking routine was determined to minimise the influence of the milker. Stripping by hand was avoided.

To illustrate the milk secretion inside the udder during milking, thermal imaging was used.

Introduction

Objectives

Methods

Results

Mechanical stimulation effectuates a lower milk flow rate. The goats without stimulation showed the highest milk flow rate.

The poster will concentrate on the following partial results:

- Influence of methods of stimulation on time of latency and milk flow rate
- Assessment of thermal imaging for secretion control

Impact of pre-milking teat preparation practices on milk quality

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This study was conducted to determine the influence of various cow teat pre-milking cleaning regimes on the microbiological quality of raw milk. The benefits of full preparation comprising a teat wash and dry over no treatment were evident in a significantly reduced microbial load for a number of bacterial species when cows were indoors by night. Overall the microbial load in milk was low even in the no preparation treatment reflecting the importance of housing and milking parlour hygiene.

Key words: Microbial load, milk quality, pre-milking, teat preparation

Due to time constraints at milking and a shortage of available farm labour, there is now a trend away from pre-milking teat cleaning practises that may impact negatively on milk quality. This study reports the results of imposing different hygienic practises on cows at milking on the microbiological quality of milk and includes a more extensive range of microbial species of interest than previously reported.

Four treatments for cleaning of teats comprising (i) wash and dry with paper towel (full treatment), (ii) no teat preparation, (iii) washing only and (iv) dry wipe only were applied in a 4x4 latin square designed trial involving four groups of autumn-calving Friesian dairy cows (n=56) and two periods (each of 2 days duration). Cows were maintained at pasture by day and indoor at night on a sawdust/lime bedding. Following 2 days on each treatment, 2.5 litre quantities of milk were collected aseptically at the subsequent milking from each cow group. Triplicate analysis was performed on all treatment milks for total bacterial count (TBC), thermotolerant and spore forming species, staphylococci, coliforms, enterococci and E.coli incidence and sediment levels.

Summary

Introduction

Materials and methods

Results and discussion

TBC, staphylococci, enterococci and coliform bacteria were reduced with full teat preparation compared with other treatments (Table 1). These results are in agreement with those Pankey (1989). Milk from cows on full treatment showed a consistent reduction in sediment compared with other treatments but this was not significantly different. The results suggest that attention to housing and milking parlour hygiene would reduce the need for cleaning teats prior to milking. However, the differences observed in bacterial counts between full and no preparation also indicate that where hygienic conditions are poor and soiling of teats is likely to occur, then a cleaning regime should be implemented.

Table 1. The effect of pre-milking treatments on bacterial counts (cfu/ml) in raw milk.

Treatment	TBC	Thermo	Spores	Staphs	Enterococci	Coliforms	E.coli	Sediment
Full	3800 ^b	10	30	900	10 ^b	14 ^b	2	1.9
Wash	5800 ^{a b}	14	30	1300	14 ^b	20 ^{a b}	3	4.1
Dry wipe	8000 ^a	20	40	2000	40 ^a	50 ^{a b}	4	3.8
None	10500 ^a	30	50	1400	50 ^a	40 ^a	5	3.6
F test	0.05	0.05	0.063	0.142	0.004	0.038	0.395	0.207
Sig.	*	*	-	-	**	*	-	-

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Energy balance between the milk production and the level of feeding in the first hundred days of lactation

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After calving, high nutritional requirements for lactation do impair the body condition during the first 60 days of the milking period. The amount of the milk drawn and the body mass changes during the first one hundred days of milking clearly indicate that the peak of milking curve is reached between the 20 – 40 days of milking. The amount of the feed consumed on contrary peaks during the 40 to 60 days after calving. This disproportion in the energy balance is the cause of the body decrease in the region from 60 % (after first calving) to 88 % (in the cows in the 2nd lactation).

Key words: Dairy cattle, milk production, body mass decrease

In early time of lactation, feed intake is unable to cover the demands of high milk production. The average cow commonly peaks in milk production at 4 to 6 weeks of lactation, but her feed intake reaches the peak about 9 to 11 weeks. This situation gets the organism of cow in to the negative energy balance followed by the body mass decrease. In farmers practice the body condition of cows deserves to be evaluated with respect to their energy resources in the form of fat. This energy

Summary

Introduction

resource, at the begin of lactation, can help to cover the imbalance between the energy content in milk drawn and the energy gained from feed.

Material and methods

The on 22 high pregnant heifers of the Czech pied cattle crossed with Holstein cattle was divided into the experimental group, supplemented two weeks before the expected calving and up to 5 day after calving with additional dose of corn mixture. The animals of the control group were fed with the standard ration. The live body mass of milking cows has been estimated in two weeks period with accuracy of ± 1 kg. The weighing has been don always after the evening and morning period of milking. The milk production was controlled up to 100 days of lactation.

Results and discussion

The body masses of some cows in the first lactation are depressed up to the level of 60 % of the average value. On contrary during the second lactation, in the control group, decreases the body mass only to the level of 80 %. The cows of do exhibit the decrease in body mass in the interval between the 20 up to the 50 days. The body mass in the experimental group decreases only to 80 % of the value before calving. However also in the control group some individuals do exhibit the body mass decrease only to the 95 % during the first 60 days after calving.

The milking curve in the experimental group start at the level of approx. 13 kg of milk per day and reaches the peak between the 40-50 day at the level around 15,5 kg per day. In the control group, the lactation curve start at the level of approx. 9,5 kg per day of milk drawn and did reach the peak in the region of 50 so 60 days at the level of around 12,2 kg per day of milk drawn.

The average body mass of all cows at the begin was 492 kg. Up to the 40 days the body mass decreases to the value of 480 kg. At the same time the lactation curves did approach their peak values in both groups. The lactation curves after reaching the peak go into the auto retardation period and the amount of energy consumed levels the needs for milk production and enables to regain the body mass lost during the previous interval.

The observed coincidence between the auto retardation of the lactation curve and the start of regaining the body mass corresponds with the views presented by Windisch (2003), that the lactation curve is guided by the internal regulatory processes, they do not respect the amount of energy which is in the first 2 to 4 weeks period after calving at disposal from the total mix ration consumed. This corresponds with the general view of Jelínek, Koudela et al. (2003) about the humoral regulatory mechanism they do influence the milk production in the udder.

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Automatic milking with Austrian Simmental and Brown Swiss Cows

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In this investigation the milking performance of double purpose breeds (Austrian Simmental and Brown Swiss Cows) was compared between an automatic milking and a parlour milking system. Both systems resulted in similar milk yield and feed intake after correction for lactation number. Feed intake of cows also show no differences between parlour and robot system. A higher selection rate occurred in the robot system due to udder conformation and character of cows. Costs of investment were higher with AMS compared to the parlour, the robot system owned a potential to save about 60% of milking related labour time.

Key words: Automatic milking, feed intake, milk yield, costs

In 2000 a research project started to compare an automatic milking system with a conventional milking parlour at the Agricultural Research Station in Wieselburg, Austria. The experiments started in July 2001 and lasted until December 2003. The aim of the project was to compare both milking techniques according to economical values, aspects of labour and milk quality.

In addition to a 2x6 herringbone parlour (HAPPEL, Germany; control) a single box automatic milking system (LELY IND., The Netherlands; AMS) was installed. Two groups of 30 cows each were formed according to age, breed (Brown Swiss and Simmental) and days in lactation. Both groups had an average milk yield of about 7.500 kg milk. One group was milked in the parlour, the other group was milked in the AMS. Feed intake was measured using a Calan feeding system (CALAN Inc., USA).

Milk yield and feed intake of cows were measured daily, milk constituents were measured weekly. Data about working hours and number of culled cows were collected additionally.

Summary

Introduction

Material and methods

Results

Milk yield corrected for lactation number showed no differences between the two milking systems. Number of culled cows was significantly higher for the AMS system. The reasons were character (nervous) and udder conformation (high somatic cell content).

Age of cows was significantly higher in the parlour system than in the robot system after three years of investigation.

Total feed intake was not different between the groups, concentrate intake was higher in the control group and roughage intake was higher in the AMS group.

Table 3 shows the costs of the conventional (parlour) and the AMS system. Total costs were higher for robotic milking, mainly due to higher costs of investment. In dependence on the number of milked cows in the robot system the extra costs of AMS were between 215 • (60 cows) and 381 • (40 cows). On the other hand our data indicate a save of labour time of about 60 % of total milking related work time.

Conclusion

Milking with robots results in similar milk yield and feed intake for cows with an average yield of about 7.500 kg per cow and year. If the farmer has the possibility to use the saved labour time for alternative income ressources the family income can be increased.

Table1. Results of milk yield from the trial of cows in the 1 st and 2 nd lactation.

	AMS		Control	
	Lactation 1	Lactation 2	Lactation 1	Lactation 2
Milk yield (45 weeks)	20,4	25,9	20,7	25,1
Standard deviation	4,7	6,1	4,2	6,3
Minimum	7,1	7,4	5,3	8,2
Maximum	36,5	43,3	32,5	40,5
N	16	14	16	21
n	710	704	728	672

Table 2. Concentrate-, TMR- and Total Feed Intake of both groups (2001-2003 n = 53; 58).

Year	Concentrate Intake		TMR Intake		Total Feed Intake	
	AMS	Control	AMS	Control	AMS	Control
2001	1,41 ^a ± 1,28	2,12 ^b ± 2,51	16,44 ^b ± 2,25	15,42 ^a ± 2,61	17,86 ^a ± 2,66	17,54 ^a ± 2,35
2002	1,38 ^a ± 1,32	2,02 ^b ± 1,71	18,07 ^c ± 2,04	17,86 ^c ± 2,60	19,45 ^b ± 2,48	19,88 ^b ± 2,74
2003	1,27 ^a ± 0,85	1,34 ^a ± 0,92	16,28 ^b ± 1,63	16,11 ^b ± 1,58	17,55 ^a ± 1,95	17,45 ^a ± 1,15
Total	1,35 ± 1,34	1,83 ± 2,64	16,93 ± 2,35	16,46 ± 2,64	18,29 ± 2,70	18,29 ± 2,81

* Values with different indices are significantly different (p < 0,05).

Table 3. Costs of Automatic Milking versus Conventional Milking (•).

		Number of milking cows		
		40	50	60
AMS	Writing-off	15.500	15.500	15.500
	Payment off	3.100	3.100	3.100
	Maintenance	4.000	4.000	4.000
	Repair	250	250	250
	Total	22.850	22.850	22.850
Parlour	Writing-off	6.400	6.400	8.300
	Payment of	1.280	1.280	1.660
	Repair	1.280	1.280	1.660
	Total	8.960	8.960	11.620
Extra costs of AMS	Investment and Repair	13.890	13.890	11.230
	Operation stock	1.365	1.605	1.685
	Total per cow	15.255	15.495	12.915
		381	310	215
AMS Saved labour time		60 %	60 %	60%

Associations of the bovine major histocompatibility complex DRB3 (BoLA – DRB3) with mastitis and milk composition in dairy cattle

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Associations of the bovine major histocompatibility complex DRB3 (BoLA – DRB3) with resistance/susceptibility to mastitis have been documented. The BoLA – DRB3 alleles have considerable promise as potential mastitis marker. As a candidate gene for mastitis resistance/ susceptibility BoLA – DRB3 alleles have to be examined for association with milk traits.

The objective of this study was to investigate the association of two alleles (BoLA – DRB3.2*16 and BoLA – DRB3.2*23) of the bovine major histocompatibility complex with somatic cell count (indication of the inflammation of the udder), milk yield and milk composition changes in cattle.

The polymorphism of BoLA-DRB3 gene was identified in blood samples collected from 130 cows. Test - day milk samples were collected monthly. Allele BoLA – DRB3.2*16 was significantly associated with decrease of somatic cell count in milk, increase of milk yield and decrease of protein and fat content. The presence of BoLA – DRB3.2*23 allele was associated with significant increase of somatic cell count and decrease of milk yield.

Key words: Mastitis, milk yield, milk composition, BoLA-DRB3

Introducing resistance to mastitis into breeding programmes for dairy cattle seems to be one of the possible methods for limiting the increasing number of clinical and sub-clinical cases of udder inflammation and thus a method of improving the economic results of cattle husbandry and breeding (Sender and Reklewski 2002). Looking for candidate genes is one of the strategies introducing resistance to mastitis into breeding programmes. Two alleles of BoLA-DRB3 gene were identifying as

Summary

Introduction

affecting occurrence of mastitis (Sharif *et al.* 1998 a, Kelm *et al.*, 1997). As a candidate gene for mastitis resistance/ susceptibility BoLA – DRB3 alleles have to be examined for association with milk traits.

The objective of this study was to evaluate relationships between two BoLA - DRB3 alleles (BoLA – DRB3.2*16 and BoLA – DRB3.2*23) and somatic cell count (indication of the inflammation of the udder), milk yield and milk composition changes of Polish dairy cattle.

Material and methods

A total of 130 Polish Holstein cows in experimental farm in Jastrzêbiec were evaluated for occurrence of mastitis and production traits. Production traits studied were milk yield, fat and protein content of monthly test day - recording. Also test-day milk somatic cell count (SCC) was collected monthly. Test-day SCC was log-transformed to base 10. Cows were genotyped for allelic variation in the BoLA - DRB3 gene using the PCR-RFLP technique (Ledwidge *et al.* 2001). Association between the BoLA - DRB3 alleles and somatic cell count, milk yield, fat and protein content were evaluated using the GLM procedure of SAS.

The model for somatic cell count, milk yield, fat and protein content included the fixed effects of BoLA - DRB3 genotypes, cows (repeated effect) nested in genotype, year and season of examination, parity and regression coefficient on days of lactation. In the model for somatic cell count also the milk yield was included as covariate. Linear contrast between model-adjusted least squares means of SCC, test-day milk yield, fat and protein content were used to test for differences between genotypes.

Results and discussion

In Polish Holstein cows population BoLA allele DRB3.2*16 was significantly ($P \leq 0.01$) associated with decrease of SCC in milk. This allele was also associated with production traits. It was observed increase of milk yield and decrease of protein and fat content in milk from cows carrying this allele comparing to cows carrying DRB3.2*23 or other allele (table 1). Associations were also detected between cows carrying allele DRB3.2*23 and reduced milk yield and increased fat and protein content in milk. In this group of cows somatic cell count was significantly ($P \leq 0.01$) higher than in group of cows carrying allele DRB3.2*16 (table 1). Significant associations between BoLA alleles and production traits have been previously documented (Sharif *et al.* 1998 b). However, there also have been studies that failed to demonstrate these associate (Lunden *et al.* 1993, Arriens *et al.* 1996). These findings should be viewed as preliminary and further studies will be required to confirm or reject the results.

In conclusions, the productions traits recorded in this study were significantly associated with the BoLA alleles associated also with lower or higher SCC (BoLA - DRB3.2*16 and BoLA - DRB3.2*23).

Table 1. BoLA - DRB3 genotype effects for SCC and production traits (least square mean \pm se), (n - unknown allele).

BoLA- DRB3 genotypes	Number of cows	SCC (log)	Milk yield (kg)	Fet (%)	Protein (%)
16/ n	31	5.59 AB \pm 0.45	31.80 AB \pm 2.59	4.47 Ab \pm 0.32	3.66 AbC \pm 0.12
23/ n	20	6.37 AC \pm 0.51	30.14 A \pm 2.85	4.77 A \pm 0.35	3.76 A \pm 0.13
16/ 23	6	6.41 BD \pm 0.48	31.66 \pm 2.72	4.61 \pm 0.34	3.73 b \pm 0.13
other	73	5.72 CD \pm 0.36	30.15 B \pm 2.17	4.63 b \pm 0.27	3.73 C \pm 0.10

Means differ significantly at: small letters - P \leq 0.05; capitals - P \leq 0.01.

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The influence of stress on milk production and its quality

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In the breeds of animals producing raw materials and foodstuffs of animal origin there occur different stress situations. The animals are influenced by the stress factors of different intensity and duration.

The stress situations in beef cattle often leads to the decrease of production, growth, changes in sexual functions, the decrease of resistance to secondary infections.

This work describes the stress situations in relation to milk production and its quality (the way of stabling, cool and warmth, starving, immobilization, transport and physical strain).

The objective of this work was:

- General analysis of the stress situations in animals producing raw materials and foodstuffs of animal origin;
- Analysis of the stress situations in beef cattle;
- Formulating the basis requirements for the creation of optimum living conditions for animals and
- Formulating the individual elements of the system of animal complex care.

Materials and methods were used in compliance with the provisions of the Act 488/2002 Coll., relevant approximation decrees of the Government of the Slovak Republic of the year 2003, Council Directives 92/65/EEC as amended by the Decision of the Commission 95/176 EC and the Decision of the Commission 2001/298, Council Directive 90/425/EEC, as amended by other directives.

Introduction

Material and methods

Results and Discussion

General Analysis of Stress Situations

New knowledge of the course of stress reaction required reevaluation of the original conception. At present the stress is characterized as a specific reaction of organism to the stimuli which threaten homeostasis (Sokol et. al., 2004).

Stress (strain reaction) is a complex response of the organism to acting of stressor.

The main hormonal mechanism of stress is activation of the hypothalamus - sympathicoadrenal system – adrenal medulla axis and activation of hypothalamus (CHR) - adenohipophysis (ACHT) – adrenal cortex (glucocorticoids) axis.

Laboratory examination of the endocrine function of hypothalamo – adenohipophysal system includes:

1. determinations of basal concentrations of adenohipophysis hormones in plasma
2. determinations of hormones of their target glands
3. functional tests

In connections with the problems of stress we must take into consideration also:

- the importance, influence and function of stress proteins, which are responsible for the protection of cells against impairment (Whithey et al., 1999; Coss and Linnemans, 1996; Musch et al. 1999)
- the influence of stress on immune functions, mainly the relation of intensive and long-term stress to single strain
- the influence of immune system on the stress axis (active substances produced by thymus – thymosin and thymoprotein).

Stress situations in beef cattle

They often lead to the decrease of production and growth, changes in sexual functions, decrease of the resistance to secondary infections and increase of susceptibility to these infections.

The most important stress situations include:

- Way of stabling
- Cold and warmth
- Warmth and milk production
- Malnutrition stress in cows
- Starving
- Transport of heifers and milk cows
- Physical strain
- Relation to immunity
- Glucocorticoid diabetes of calves
- Microclimatic stress
- Environmental stress
- Catecholamines and glucocorticoids
- Catecholamines

- Activation of β -adrenoreceptors
- Glucocorticoids
- Increased level of cortisol in milk cows with post-delivery paresis, which may deteriorate the disorders of immunity¹¹
- Energetic strain with the development of hyperglycaemic and hyperinsulinemic ketosis, which evokes ketoses of type II¹⁶
- Disorder of calcium homeostasis of milking cows¹⁷⁻¹⁹ caused by a high consumption of calcium for the production of colostrum and milk and
- Syndrome of peripatal crisis of milking cows.

The stress situations occurring in the breeds of milking cows have an important influence on their health, comfort and production.

Conclusion

In these connections it is necessary to:

- Provide optimum living conditions and to minimize the influence of individual stressors;
- Apply the system of complex care of animals in the chain: man – producer – consumer – economy, legislation and social consensus;
- To objectivise other influences of the environment on stabled animals and related changes of clinico-biochemical processes and immune functions;
- To verify new diagnostic procedures and methods and to introduce them to the laboratory practice.

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The importance of increased levels of oxytocin induced by naloxone to milk removal in dairy cows

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Fast and complete milk removal is related to the release of oxytocin and milk ejection occurrence during whole milking process (Bruckmaier *et al.*, 1994). Milk ejection occurs in response to tactile teat stimulation when oxytocin blood levels reach concentrations above threshold levels of 3-5 ng/l (Schams *et al.*, 1984). However, several studies showed that oxytocin concentrations during milking could be related to the conditions of milk removal and production in cows (Tancin and Bruckmaier, 2001) or ewes (Marnet and McKusick, 2001). Thus more oxytocin in blood during milking could be a result of better welfare of cows (Hopster *et al.*, 2000; Tancin *et al.*, 2000b). On the contrary, stress or discomfort during milking can reduce oxytocin release and milk yield (Rushen *et al.*, 2001; Macuhova *et al.*, 2002, Tancin *et al.*, 2001).

Under normal milking conditions naloxone (opioid antagonist) can stimulate the release of oxytocin during milking (Tancin *et al.*, 2000a). Thus administration of naloxone under the normal milking conditions could be a good approach to see the effect of increased endogenous oxytocin on milking performance. The aim of this study was to test whether higher oxytocin release during milking under the normal milking conditions results in higher efficiency of milk removal.

Eight pregnant multiparous Holstein cows from second to fifth lactations were used for this experiment. The experiment was carried out during three consecutive days, i.e. six milkings (three morning and three evening milkings). During first and third evening milkings in cross over design (four and four animals) 250 mg of naloxone or 10 ml saline was injected 5 min before the start of udder preparation. During these milkings after stripping 2 IU of oxytocin was injected i.v. to cows and the amount of milk after oxytocin injection was measured. Pre-milking naloxone treatment stimulated the release of oxytocin in response to milking

procedure, however, only in six of eight cows. The stimulatory effect of naloxone on oxytocin release in a group of mentioned six cows was also influenced by individuality and ranged from 4 ng/l to 132 ng/l. Naloxone treatment did not influence milk yield before stripping and stripping milk yield. However, naloxone treatment significantly reduced amount of milk after 2 IU of *i.v.* oxytocin. Peak flow rate tended to be higher after naloxone treatment.

In conclusion, oxytocin release seems to be very important and useful parameter involved in the evaluation the effect of different milking routines and milk removal environment on the welfare of dairy cows. Any small disturbance of milking routine seems to reduce or block the ability of naloxone to potentiate oxytocin release.

Table 1. The effect of saline and naloxone treatment on oxytocin and milking removal during evening milking.

	Treatment			
	saline		naloxone	
n=6 cows	Mean	SEM	Mean	SEM
milk yield before stripping, kg	8.32	0.74	8.66	0.78
stripping milk yield, kg	0.62	0.15	0.65	0.21
milk yield after 2 IU of <i>i.v.</i> oxytocin	0.56 ^a	0.15	0.47 ^b	0.12
% of milk yield after 2 IU of <i>i.v.</i> oxytocin	5.81 ^c	1.21	4.86 ^d	1.11
peak flow rate, kg/min	3.47	0.55	3.61	0.63
oxytocin during entire milking, Δ AUC/min, ng/l	11.42 ^a	3.34	64.45 ^b	25.34
oxytocin of last 2 min, Δ AUC/min, ng/l	11.34 ^a	3.48	48.17 ^b	17.73

a,b - P<0.05; c,d - P<0.1;

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Effect of robotic and conventional milking on milk yield and milk composition of primiparous cows

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The introduction of AM-systems has a large impact on milk yield and milk quality. Many authors reported an average increase of milk yield in cows milked by an AMS in comparison with cows milked by a conventional milking parlour (Svennrsten-Sjaunja *et al.*, 2000; Hogeveen *et al.*, 2001). On the contrary, a negative trend in milk fat and protein contents related to automatic milking was observed by several authors (Friggens and Rasmussen, 2001; Wirtz *et al.*, 2002). Between June 2002 and April 2003 a field-based experiment was carried out to evaluate the effect of robotic and conventional milking on milk yield and milk composition of first lactating cows. The experiment involved two groups (Group 1 and Group 2) of 10 animals each, characterized by similar physiological and health conditions. Group 1 was subjected to automatic milking and Group 2 was milked conventionally twice a day. Group 1 showed a higher mean daily production, a lower milk fat and protein contents, and a higher SCC in comparison with Group 2.

Keywords: Automatic milking system, milk yield, milk composition

Between June 2002 and April 2003 a comparison of an Automatic Milking System (AMS) with a conventional milking parlour was carried out in a commercial farm in the North Italy. At the same time 10 primiparous cows (Group 1) were milked automatically by a robot (Fullwood-Merlinä) and 10 primiparous cows (Group 2) were milked conventionally twice a day (12 h interval between milking cycles) in a herringbone milking parlour, 5+5 stalls.

Primiparous involved in the study were selected from the herd of the farm using the following criteria: <30 days in milk (DIM), no intramammary infections (IMI), somatic cell count (SCC) lower than 200.000 SCC/ml, in order to have similar starting conditions.

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Material and methods

Primiparous cows were housed in mat-lined freestalls and were fed by unifeed system. A concentrate amount of 1 kg per day was given in order to lure the primiparous cows into the robot.

The following values were recorded individually for each cow involved in the experiment: daily collection of milk yield, number of visits with milking per day (for Group 1). Every month the milk fat and protein content and the somatic cells count (SCC) were analyzed.

Recorded data were submitted to GLM procedure, SAS statistical package, 2000 to evaluate milking system effects on milk yield and milk composition of the two groups.

Results and discussion

Group 1 milked by AMS showed a higher mean daily production in comparison with Group 2 milked conventionally ($31,58 \pm 0,50$ kg vs. $28,25 \pm 0,49$ kg). Milk fat and milk protein contents in Group 1 were lower than in Group 2 (3,12% vs. 3,85% for fat and 3,29% vs. 3,82% for protein). SCC was higher in Group 1 compared with Group 2 ($5,36 \text{ Log}_{10}$ cells/ml vs. $5,28 \text{ Log}_{10}$ cells/ml) but in both groups no differences were detected in the frequency of clinical mastitis. Results obtained confirm that automatic milking guarantees an average increase of daily milk yield, although the higher number of daily milking cycles decrease fat and protein contents. About SCC cows milked by the AMS showed a higher level of somatic cell/ml of milk in comparison with the animals conventionally milked, although the difference was not statistically significant.

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Managing of mastitis in the herd of dairy cows

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Managing of mastitis in the herd of dairy cows consists of:

- Prevention
- Monitoring
- Treating.

Mastitis prevention is crucial. Mastitis monitoring is important for seeing of results of prevention measures. Treating is mainly for correcting of prevention failings.

The prevention of mastitis is going never to be perfect and that is why we will ever need to monitor the mastitis spreading in the herd. Current monitoring is done by SCC. But the method is expensive, laborious and unpractical for daily monitoring. The same is with CMT monitoring. We can say these two methods are suitable for mastitis indication only, not for daily monitoring of the whole herd of dairy cows. The electronics is the future for many industrial branches. The same we can see in milk production. Robots for milking of dairy cows are spreading throughout Europe. Electronics helps to automate many other processes in dairying. The monitoring of mastitis at milking robots is very important to know about cows with inflamed udders. Currently only one method for this is milk electrical conductivity measurement. But the on-line measurement is less sensitive than off-line because of some technical problems like milk turbulence, air bubbles in milk and dirtying of the electrodes. The monitoring of clinical mastitis is discussable too, because of slow reaction at establishing of infection (delay 48 hours). Mastitis monitoring by means of milk electrical conductivity measurement is good enough for subclinical mastitis monitoring only. For this purpose we have developed REM test (Rapid electronic mastitis test) in our Institute. The REM test is electronic equipment for mastitis monitoring in the herd during whole lactation period. It is a hand-held apparatus for daily use. Milker takes samples of milk from each quarter of the udder before milkings and puts them into the apparatus to subsistent chambers for analysis. The data are evaluated immediately for the purpose of milker's alerting and stored in the apparatus memory for further use. After each series of measurement (60 or 250 cows) the apparatus must be carried to the PC where data are

transmitted through communication channel to computer memory. The stored data are processed for further decision process of mastitis management. The data could be used for separation of ill cows from the herd, for treating in time of lactation period, or for separate treating during dry cow period. Sensitivity and specificity of the method is highly dependent on criteria we use for mastitis indication. For treating mastitis during lactation we use lower sensitivity and higher specificity. In the case of treating in time of dry period are used opposite criteria (high specificity and low sensitivity). It means that in the herd with low mastitis incidence (SCC 150 000) it is needed to treat less than 30% of cows during dry period only. In crisis management when mastitis has very high incidence (SCC>400 000) separation of ill cows is a must. Than we treat the most serious cases of mastitis in the group but the further analysis for treating are needed. We recommend monitoring of individual cow in common herds at least once a week. Daily monitoring we recommend at first lactating cows in the herd with high incidence of mastitis.



Figure 1. Measurement with REM test.

The effect of relocation on milk removal in primiparous dairy cows reared in different rearing systems during early postnatal period

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The milk removal process in dairy cows is negatively influenced by many factors in dairy practice (Tancin and Bruckmaier, 2001). These factors can influence milk removal at central (inhibition of oxytocin release from pituitary) and peripheral levels (inhibition of oxytocin effect in udder). The central disturbances are the main reasons of the milk removal problems in the dairy practice, however, the mechanisms involved are not understood in dairy cows (Bruckmaier et al., 1998). The change of the milking environment is one of the negative factors influencing the milk removal (Macuhova et al., 2001). However, there is a high individual variability in milk removal efficiency during milking in a new milking place (Tancin et al., 2000). The development of responses to stress is dependent on the early experiences of the infant rats (Zimmerberg et al., 2003).

The aim of present experiment was to determine whether different rearing systems for calves in early postnatal period could influence the milk removal in response to unknown milking place in maturity.

During pre-experimental period ninety-six primiparous Holstein calves were reared in three different housing systems (32 in each group) before weaning at 60 days. First group were reared in loose housing and fed by automatic milk replacer drinker; second group were reared in individual hutches and third one were kept in loose housing with nursing cows during first two months of life. After weaning all calves were reared under the same housing and feeding conditions in loose housing barn. Then 33 of them (13 from first group, 12 from second and 8 from third) were used for the experiment as lactating dairy cows. After morning milking the cows were relocated from the loose housing where they were milked in the parlour to tie housing and milked in the stall. The parameters

of both systems of milking were similar. The volume of milk recorded in first three minutes of milking was reduced during first evening and following morning milking after relocation ($P < 0.05$). Furthermore, the negative effect of relocation was stronger in the group reared under nursing cows as compared with other two ones but only during first evening milking ($P < 0.05$).

In conclusion, the first milkings after relocation negatively influenced the commencement of milk ejection, which should be considered by milkers to put more attention to such cows. Also the individual response of the cows to relocation could be influenced by their rearing conditions in early postnatal period of life. However, the endocrine study is needed to explain the possible effects of rearing conditions on milk removal in the new place.

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Analysis of vacuum fluctuation in milking units

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For the vacuum conditions measurement of the clusters the vacuum sensors, placed on 4 points of this clusters were used. Evaluated was the vacuum course particularly in the liner chamber and in the claw within total pulse time in both maximum and minimum phase according to ISO 6690. The measurement was carried out under laboratory conditions and measured values were recorded. Evaluated were 5 different serial produced clusters with the claw volume of 150, 200, 300, 420, 450 and 500 cm³.

By the flow-rate of 5 l.min⁻¹ the vacuum decrease in the liner chamber of the clusters was 1.4 – 3.3 kPa and in the claw 1.7 – 5.3 kPa depended the claw type. By the flow rate of 12 l.min⁻¹ vacuum decrease in the liner chamber of the clusters was 4.1 – 11.2 kPa and in the claw 3.9 – 11.6 kPa.

In evaluation of the vacuum fluctuation within total pulse time no evidential difference was found in comparison with the vacuum fluctuation evaluated only for maximum phase .

The measurements will continue by measuring in the milking parlour during the real milking.

Key words: Measurement, vacuum fluctuation, milking units, milking

The vacuum courses recognition in different points of the milking set and various milking intensity is one of possible ways how to obtain information on milking machine impact on the teat milk gland and to find suitable parameters for technical parameters effect assessment of variant design of the milking units.

The goal of the realised work was to specify the measuring methodology and comparison of selected milking units from the vacuum fluctuation aspect in different points of the milking system in dependence on milk flow rate. For this purpose the milk is replaced by water.

Abstract

Introduction

Method

The measuring was carried-out in laboratory for the milking device testing at the VUZT Prague. The tested milking sets were set up from 10 various milk claw and 5 sets of teatcups. The claws technical parameters are presented in Table 1 and teatcups in Table 2.

The identification code of the tested milking set consists of 2 letters of which the first letter identifies the used claw by Tab. 1 and the second letter identifies the tested teatcups. The measuring was carried-out at the working vacuum of 42 and 50 kPa and at flow rates 1–14 l/min. The rate of pulsation was adjusted for all measurements to 50 pulses/min at pulsation ratio 60:40 and alternate pulsation. For each measuring was chosen 30 s time period for assessment, always after the situation stabilization in the milking set. The vacuum course was recorded in the under teat chamber, pulsation chamber, in claw and in the milking line situated 700 mm under the mountpice lip. The medium flow was evaluated during measuring for each teatcup individually. By this method the affect of eventual irregular media flow through the individual teatcups was excluded. The vacuum levels in particular points of the milking device were scanned by the tensometric sensors with accuracy of 0.3 kPa. The sampling velocity was adjusted to find out 300 values per second in each measured point.

Results

The vacuum course within all time of pulse was evaluated in the time of bouth maximum and minimum phase at nominal vacuum of 50 kPa. The specification of the pulsation curve parameters is based on the pulsation curve definition according to the CSN ISO 3918. Part of the main obtained results is summarized in the graphs in Fig. 1–2.

By the flow-rate of 5 l/min the vacuum decrease in the liner chamber of the clusters was 1.4–3.3 kPa and in the claw 1.7–5.3 kPa depending on the claw type. By the flow rate of 12 l/min vacuum decrease in the liner chamber of the clusters was 4.1–11.2 kPa and in the claw 3.9–11.6 kPa. In evaluation of the vacuum fluctuation within total pulse time no significant difference was found in comparison with the vacuum fluctuation evaluated only for maximum phase.

The more significant vacuum decrease was recorded for claws C and I caused by their different construction. From aspect of the vacuum course in dependence on the flow-rate the best evaluation is evident at the claw A with original teatcup A. Other claws tend more to the vacuum decrease with growing flow-rate, but the differences are not too high.

Similarly was carried-out evaluation of identical milking units at vacuum nominal value of 42 kPa. The vacuum decrease character in dependence on the flow-rate is in fact equal as presented by the graph in Fig. 3 where the vacuum decrease is expressed percentually (nominal vacuum is 100%)

The results have confirmed the original hypothesis that construction and design of the milking unit are influencing the vacuum level during milking and thus also quality of milking process. The differences are evident mainly at high milking intensity. For this reason the attention will be paid to the following research with goal to optimise the milking parameters.

The research will also be focused to measuring of the vacuum course during milking under real conditions and comparison with laboratory measuring results.

One of the first operation measurement of the vacuum course in the under teat chamber, claw and milk line with contemporary measuring of milk flow-rate intensity is presented in graph in Fig. 4.

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Table 1.

Basic technical data of claws									
Code of claw	Shape		Volume (cm ³)	Weight (kg)	Diameter of inlets (mm)	Diameter of outlet (mm)	Air admission (l/min by 50 kPa)	Automatic shut-off valve	Notice
	ground plan	side view							
A	orbicular	half-ball with slope	420	0.412	11	15.5	6	Yes	
B	orbicular	cylinder	195	0.153	8	13.5	6	Yes	
C	trapezoid	trapezoid	450	0.614	14	15	8	Yes	upper outlet
D	orbicular	sidelong cylinder	200	0.295	9	16	6.2	Yes	
E	orbicular	sidelong cylinder	300	0.512	10	18	6	Yes	
F	orbicular	sidelong cylinder	300	0.506	10	18	7.1	No	
G	orbicular	sidelong cylinder	450	0.566	12	17	6	Yes	
H	orbicular	two half-ball	350	0.462	10	14	6.1	Yes	faint tangential inlets
I	orbicular	half-ball with cone	500	0.809	14	16	5.8	Yes	
J	orbicular	truncated cone	300	0.418	10	16	6.1	No	tangential inlets

Table 2.

Parameters of teatcups used for measuring								
Teatcup code	Weight of one teatcup (g)	Pulsation chamber volume (ml)	Diameter of mouthpiece lip (mm)	Length of liner (mm)	Length of short milk tube (mm)	Diameter of short milk tube (mm)	Internal volume of liner (ml)	Volume of under teat (ml)
A	316	95	26	315	150	12	90	50
B	290	90	23	310	170	11	95	56
C	263	90	21	325	160	13	110	66
D	413	130	23	320	150	14	110	64
E	539	90	23	350	135	11	120	84

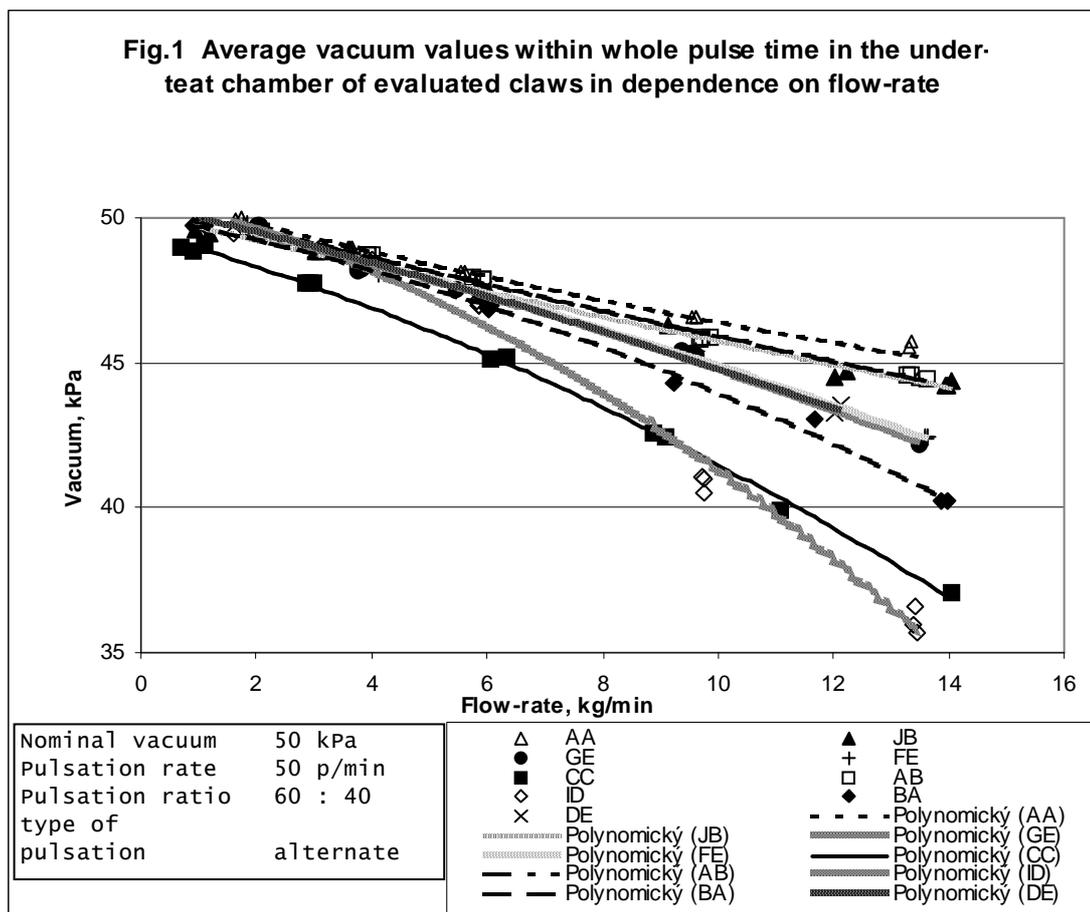
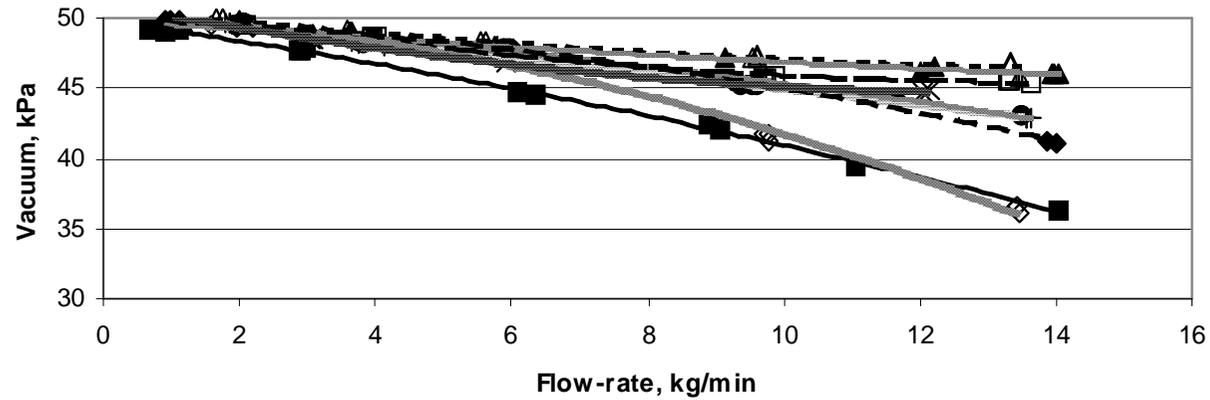
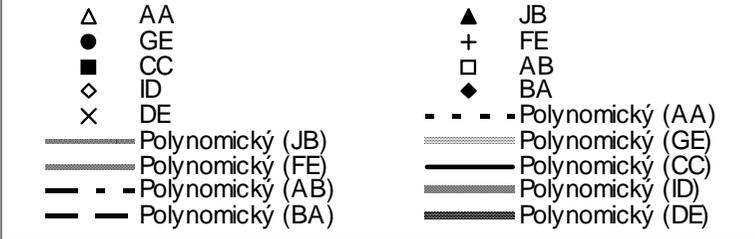


Fig. 2 Average vacuum values in the under-teat chamber of evaluated claws in dependence on flow-rate in the time of suction (B)



Nominal vacuum 50 kPa
 Pulsation rate 50 p/min
 Pulsation ratio 60 : 40
 type of pulsation alternate



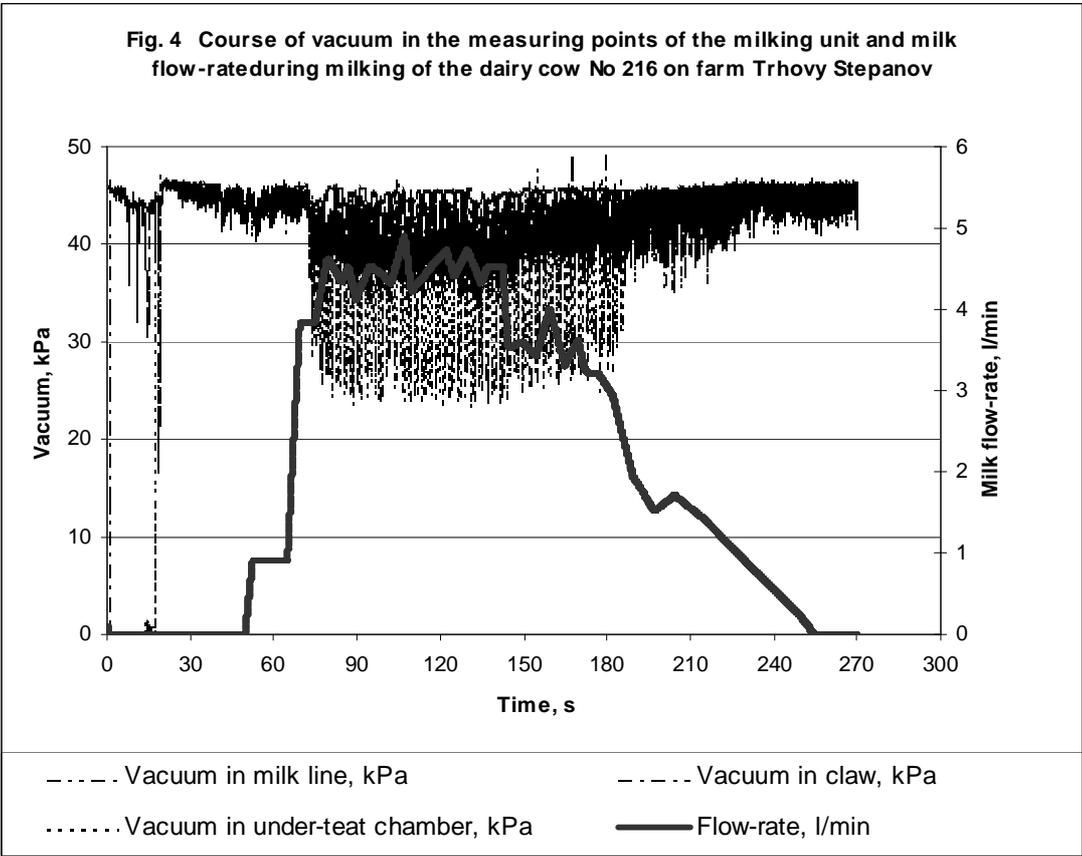
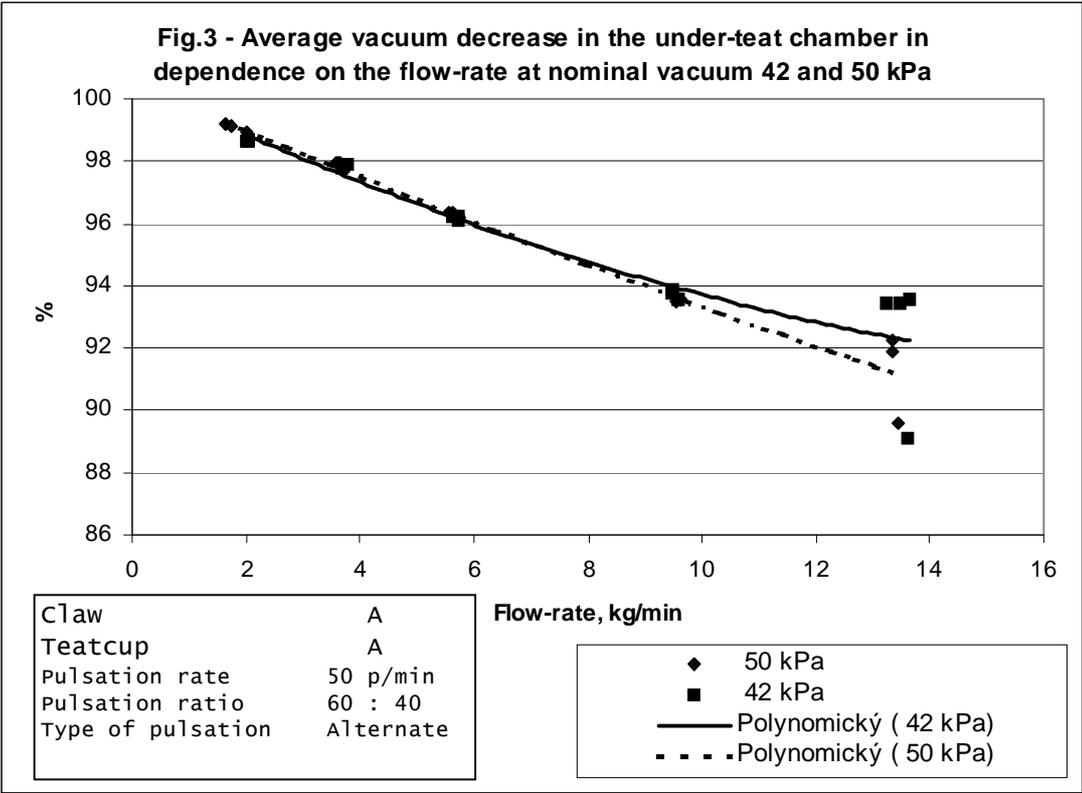


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