Effects of liner buckling pressure and teat length on pulsation chamber a- and c-phases

H. Worstorff[1] & E. Bilgery[2]

[1]Inst. of Physiology, FML, Techn. University Weihenstephan, Weihenstephaner Berg 3, D 85354 Freising, Germany
e-mail: physio@weihenstephan.de

[2]BITEC Engineering, Rütistraße 15, CH 8590 Romanshorn, Switzerland
e-mail: bitec@tgnet.ch

Summary

6 x 4 silicone liners covered buckling pressures from 6.5 to 17.9 kPa. Hard PVC teats provided penetration depths from 50 - 110 mm. Teat length increased liner stiffness by 39 - 55% which decreased a- and c-phases by 34, 83, 58 ms and 45, 48, 60 ms at 40 kPa alternate pulsation, 40/32 kPa alternate (8 kPa vacuum drop) and 40 kPa simultaneous, respectively. A- phases were shortest with vacuum drop and stiff liners while c- phases were generally shortest with soft liners and vice versa.

Key words: *Machine milking, liner, teat penetration, pulsator phases*

Introduction

The milking machine pulsator controls the pulsation chamber wave form but liner wall movement is determined by differential pressure (1,4,9). Liners open and close, respectively, when the latter falls short of or exceeds liner buckling pressure (6,7). With fairly stable liner vacuum, differential pressure is a more or less inverted pulsation curve. Under milking conditions, however, high capacity clusters with alternate pulsation show more or less a parallel shift of liner vacuum in combination with an increasing dip between b- and c- phase. By contrast, simultaneous pulsation alters the shape of the cyclic fluctuation with increasing flow rate (5,8) requiring measurement under actual “wet” conditions. ISO testing is based on teatcup plugs of 59 mm length. Longer teats, however, exist and teatcups are manufactured in different lengths. Pulsation failure will occur if teat penetration is too high (2,3). The present paper analyses interactions of liner buckling pressure and teat penetration.

Material and Methods

Liners and teatcup plugs

For the laboratory trials, 6 x 4 silicone liners (SL M23, Siliconform, D 86842 Türkheim) with 42, 51, 58 Shore and 2.80 / 3.25 mm barrel wall, respectively, were mounted in transparent 147 mm shells (# 457800897, Impulsa, D 4910 Elsterwerda). To study teat penetration effects, a series of hard PVC teatcup plugs was tooled on a CNC lathe. The construction based on the ISO 6690 specification, but the cylindrical shaft was modified in steps of 10 mm resulting in total plug lengths of 49 - 109 mm.

Nominal and effective buckling pressure

For conditioning, all liners were stored at room temperature for more than 24 h and pulsated for 10 min (40 kPa, 60 c / min, 60%) before measurement. Nominal buckling pressure (BP_n) is defined as touch point of opposite walls of liners closed by a glass plate (6). Effective buckling pressure (BP_{eff}) was defined as measurement with a teatcup plug in place. The touch point was observed through the transparent shell and liner held against a lamp. For slow evacuation, a small hand pump (Mityavac II, Neward Ent. Inc., Cocamonga CA) was connected to the short milk tube with the pulsation nipple open. BP was measured by strain gauge equipment (Pulsotest II, Bitec Engineering, CH 8590 Romanshorn). Measurement frequency was 1 kHz, pressure readings (better than class 0.6) were displayed in intervals of 0.5 s, time recording was better than 1 ms.

Measurement of pulsator phases

Electronic pulsators supplied alternate (Autopuls P, Westfalia Landtechnik, D 59302 Oelde) and simultaneous pulsation (Flow Processor, Lemmer Fullwood, D 53797 Lohmar). A dry laboratory milking plant provided constant vacuum conditions (40 kPa) and vacuum drop (40 / 32 kPa), respectively. The latter was restricted to alternate pulsation, because simultaneous pulsation would have required specific wet conditions, exceeding this basic study. Short pulse tubes (230 x 7 mm i.d.) and 2.40 m long pulse tubes were applied for alternate (2 x 7.5 mm i.d.) and simultaneous pulsation (1 x 9 mm i.d.), respectively. Pulsator phases were recorded by Pulsotest. Nominal pulsator phases (PP_n) were measured with ISO plugs in place while effective pulsator phases (PP_{eff}) were measured with 50 and 70 -110 mm teat penetration depth (TPD). The difference of +1 mm to the teat length accounts for liner head deformation under vacuum. Each set of liners was run 3 min for conditioning to the actual plug length before measurement.

Results and discussion

Nominal and effective buckling pressure.

Table 1 summarises mean buckling pressure data of all tested liners without teat (zero TPD; BP_n) as well as for 7 teat lengths (BP_{eff}), measured twice. The BP_n figures indicate a selection from very soft to fairly stiff liners. The standard deviation increased with Shore hardness and was dominated by differences between liners, while repeated measurements typically lay within 0.1 kPa. BP_{eff} remained unchanged or was even lower than BP_n for TPD 50 and 60 mm, respectively. The slight decrease is attributed to different liner deformation: When the mouthpiece is covered by a glass plate, the entire shaft deforms while a teat limits the buckling area to the space underneath. Starting from 70 mm TPD, liner stiffness increased progressively by max. 39 - 55%. As expected, Shore hardness and liner wall thickness acted together and partly interchangeable.

Table 1. Buckling pressure (kPa) and teat penetration depth (TPD) of liners with different Shore hardness (4 x 48 x 2 measurements).

TPD	42 ShA			51 ShA			58 ShA		
(mm)	BP	SD	Δ %	BP	SD	Δ %	BP	SD	Δ %
Swingliner SL M23, 2.80 mm barrel wall									
0	6.49	0.12	-	8.71	0.14	-	12.50	0.61	-
50	6.49	0.16	0	8.65	0.17	- 0.1	12.49	0.45	0
ISO 60	6.41	0.11	- 0.1	8.61	0.25	- 0.1	12.46	0.49	0
70	6.76	0.12	+ 0.4	8.91	0.12	+ 0.2	12.79	0.43	+ 0.2
80	6.95	0.15	+ 0.7	9.28	0.11	+ 0.7	13.69	0.26	+ 1.0
90	7.48	0.23	+ 1.5	9.88	0.30	+ 1.3	14.74	0.52	+ 1.8
100	8.18	0.29	+ 2.6	10.99	0.22	+ 2.6	16.39	0.80	+ 3.1
110	9.43	0.33	+ 4.5	12.68	0.57	+ 4.6	19.35	0.77	+ 5.5
Swingliner SL M23, 3.25 mm barrel wall									
0	9.18	0.11	-	13.81	0.20	-	17.88	0.45	-
50	9.01	0.15	- 02	13.55	0.35	- 0.2	17.36	0.31	- 03
ISO 60	9.09	0.27	- 01	13.88	0.33	0	17.39	0.49	- 03
70	9.35	0.15	+ 0.2	14.24	0.30	+ 0.3	18.38	0.33	+ 0.3
80	9.74	0.17	+ 0.6	15.11	0.46	+ 0.9	19.26	0.48	+ 0.8
90	10.41	0.20	+ 1.3	16.38	0.43	+ 1.9	20.64	0.43	+ 1.5
100	11.11	0.37	+ 2.1	18.18	0.47	+ 3.2	22.99	0.50	+ 2.9
110	12.75	0.26	+ 3.9	21.31	0.50	+ 5.4	27.64	0.96	+ 5.5

Effects of teat penetration depth on a- and c-phases.

Generally, BP_{eff} increased with TPD causing less liner deformation and volume change during the pulsator a- and c- phases (PP_{eff}). For alternate pulsation at 40 kPa, an increase of BP_{eff} from 6.5 to 27.6 kPa caused a pulsator a- phase reduction from 141 to 107 ms. This is a maximum difference of 3,4% and a relative change of -18 to -30% for soft and hard liners, respectively. For simultaneous pulsation at 40 kPa, the a- phase reduced from 199 to 141 ms (5,8%). For alternate pulsation with 8 kPa vacuum drop, the a- phases reduced from 185 to 102 ms (Figure 1). The length of the a- phases decreased with increasing TPD and BP_{eff} forming an undisturbed BP-sequence.

Figure 2 illustrates the c- phase reduction with increasing TPD at 40 kPa for simultaneous and alternate pulsation, respectively. Data for 12.5 kPa BP_{eff} was omitted for clearness because of overlapping with 13.6 kPa. The

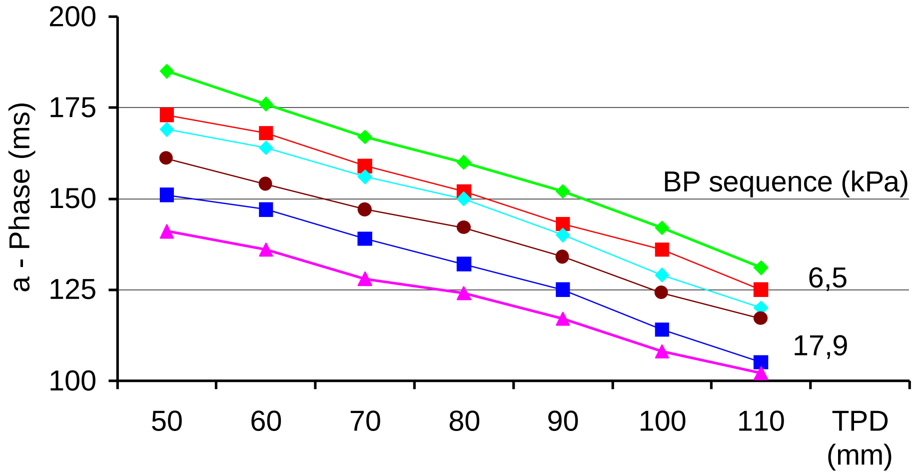

Figure 1. A-phase reduction with increased liner Shore hardness and teat penetration depth (60 c/min, 60% alternate, 40 kPa, 8 kPa vacuum drop).

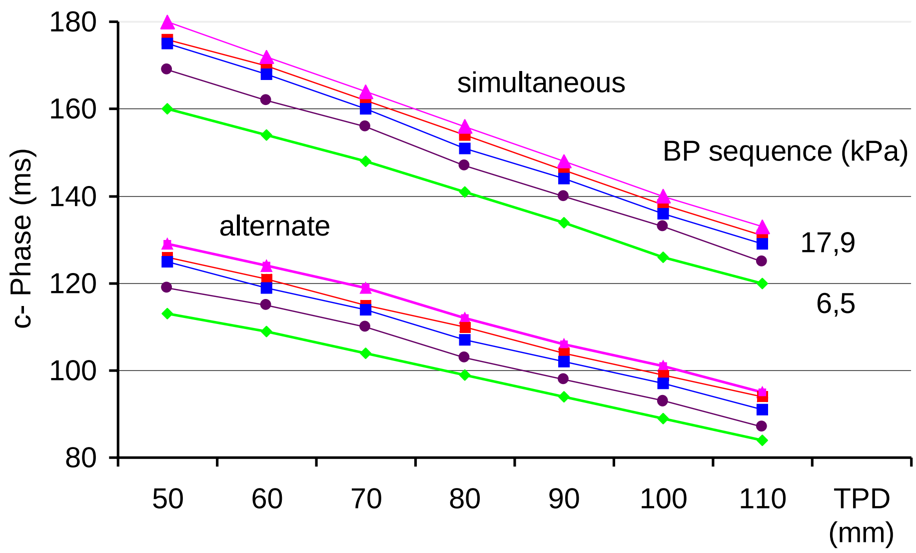

Figure 2. C-phase reduction with increased liner Shore hardness and teat penetration depth (60 c/min, 60%, 40 kPa).

series 40/32 kPa had profiles very similar to alternate pulsation without vacuum drop and is not shown either. All recordings yielded parallel lines ranked with BP_n. C-phases were shortest for 6.5 kPa BP_n and longest 17.9 kPa BP_n . This sequence is opposite to its influence on the a- phase with vacuum drop (Figure 1).

Implications

ISO tests are carried out with standard teatcup plugs of 59 mm length. While short teats are common in the field, longer teats exist and penetration increases during milking (3,9). In the present analysis, teat length increased liner stiffness and reduced a- and c- phases due to less volume change. Caution is commanded when shortening teat cups to increase cluster flexibility or milkability of low udders because pulsation failure must be excluded. Effects of a- and c- phase changes will be analysed with regard to liner-open phase and release (10).

References

Butler, M.C. & J.E. Hillerton, 1989; Methods of assessing teatcup liner performance. J. Agric. Eng. Res. 44, 77-86

Mein, G.A., M.R. Brown & D.M. Williams, 1983; Pulsation failure as a consequence of milking with short teatcup liners. J. Dairy Res. 50, 249-258

Ronningen, O. & A.D. Reitan, 1990; Teat lenght and penetration into teatcup during milking in Norwegian Red Cattle. J. Dairy Res. 57, 165-170

Thiel, C.C., P.A. Clough & D.N. Akam, 1964; Mechanics of machine milking. J. Dairy Res. 31, 303-313

Thiel, C.C., P.A. Clough, D.R. Westgarth & D.N. Akam, 1968; Factors affecting vacuum within the teatcup liner during milking. J. Dairy Res. 35, 303-316

Thum, E., H.-J. Rudovsky & B. z. Linden, 1975; Zur Bestimmung der Grenznut-zungsdauer für Zitzengummis. Agrartechnik 25, 78-81

Worstorff, H. & H. Stanzel, H., 1977; Untersuchungen zur Bewegung des Zitzengummis in Abhängigkeit von Einfaltdruck, Pulszyklus und Vakuumhöhe in Melkanlagen. Grdl. Landtechnik 27, 8-12

Worstorff, H., 1978; Vakuumverhältnisse im Melkzeug in Abhängigkeit von der Pulsierung. Milchwissenschaft 33, 159-162

Worstorff, H. & D. Schätzl, D., 2000; Zur Bedeutung des Einfaltverhaltens von Silicon-Zitzengummis für deren Melkeigenschaften. Milchwissenschaft 55, 183-186

Worstorff, H., E. Bilgery & H.H.D. Meyer, 2001; Effects of buckling pressure and teat length on calculated liner-open phases. Milchwissenschaft, submitted.