Dairy cows enabling circular production systems

A.E. van Breukele1, B.J. Ducro, R.F. Veerkam and R. Hoving

Wageningen University & Research, Animal Breeding and Genomics, P.O. Box 338, 6700AH Wageningen, The Netherlands
Corresponding Author: anouk.vanbreukelen@wur.nl

Abstract

The transition towards circular agriculture is about careful management of soil, feed, animals, biodiversity and money, to achieve a near-to-closed-loop system of resources. A tailored breeding approach is an essential building block, to ensure cows' health, welfare and production in new farming systems related to resource availability. In this study, we defined circular production systems and related cow traits and compared the performance of two types of cows on a dairy farm in the Netherlands that strives to be circular. To define characteristics of circular dairy production systems and breeding goal traits required to transition towards circular production, a workshop was organized with multidisciplinary experts. In this workshop, nine characteristics of circular dairy production systems were defined: flexible, cooperative, efficient without losses, healthy cows, low input without concentrates, extensive nature and landscape, multipurpose, pasture based, and closed. Connecting to these characteristics, cow traits were prioritized which fitted to one or more types of circular dairy production systems, for example, roughage efficiency, grazing behaviour, coping with dietary fluctuations, and environmental footprint. A quick scan was performed at research farm "Knowledge Transfer Centre De Marke", where innovative measures are designed and tested to minimize nutrient losses to work towards circular farming. The performance and variation in breeding goal traits of two types of cattle was investigated. Half of the in total ninety dairy cows at "De Marke" is of the Holstein Friesian breed, the other half is a three-breed rotational cross (Holstein Friesian, Montbéliarde, and Scandinavian Red cattle), which are managed together. Preliminary analysis on production and reproduction traits indicate that both types of cattle perform well within this extensive farming system. In recent years, the variation within breeding goal traits for Holstein Friesian AI bulls greatly increased and in combination with the implication of genomic selection, this helped to improve longevity and fertility traits. The quick scan highlights the importance of a large pool of genetic variation within or between cattle breeds. This variation will be essential for breeding programs when cows have to perform in a different environment, as will be the case when transitioning towards circular dairy farming.

Keywords: Dairy cows, circular farming, genetic diversity, animal breeding.

Introduction

To reduce the impact of agriculture on climate change, the ministry in the Netherlands calls for a transition to circular farming by 2030 (Rijksoverheid, 2018). In this transition there is an aim to achieve a near-to-closed loop system of resources involving the nutrient cycle between livestock, manure, land and crops (Figure 1). This transition

may impact the resources available to dairy cows, which can have an impact on health, welfare and production. Animal breeding can support the transition towards circular farming, where we make use of the natural variation between cows, to select cows that perform well and are easy to manage in new farming systems. Breeding is a process of which the impact is observed after multiple generations, therefore it is important to think ahead when defining breeding goals.

The current selection index for the Dutch national breeding goal for dairy cattle consists of fifteen characteristics for the following categories: milk production, milk components, feed efficiency, health, reproduction, longevity and conformation (CRV, 2018). The selection index is the sum of weighted breeding values, whereby weighting is currently mainly determined on the basis of economic value and desired gains. To enable the circularity of dairy farming, the environmental impact can be considered as changing the desired gain and reweighing the index traits. Also, new traits can be added to if they are clearly described, measurable on a large enough scale for an affordable price, have phenotypic variation, are heritable, and have limited adverse genetic correlations with other breeding goal traits. These factors have to be investigated before a trait can be applied to breeding practices. Furthermore, common traits for which breeding values exist, may have to be re-evaluated in an environment that differs from conventional Dutch dairy farms.

The aim of our study was to investigate which cow traits can be used in breeding programs to ensure the health, welfare and production of dairy cows in new farming systems related to resource availability. First, we defined characteristics of a circular dairy farm and corresponding cow traits. Second, we performed a case study on research farm “De Marke”, a dairy farm where innovative measures are designed and tested to minimize nutrient losses. Here we investigated the effect of resource availability on two types of dairy cows: Holsteins and three-way-crosses.

Figure 1. The nutrient cycle between livestock, manure, land, and crops.

Material and methods

A workshop with fourteen multidisciplinary experts (with expertise on dairy farming, animal breeding and genetics, animal production systems, the effect of livestock on the environment, nature inclusive dairy farming, and plant systems) was organised to define characteristics of circular dairy production systems. The system definitions give a framework of the environment under which a dairy cow should perform, and is the first step before a new breeding goal can be defined (Oldenbroek & Van Der Waaij, 2015). Based on the system definitions, cow traits were defined relating to one or more of definitions of circular dairy production systems. Traits can be either new or existing traits that may have to be re-evaluated in a new farming system.

A case study was performed on data from research farm "De Marke", a dairy farm where innovative measures are designed and tested to minimize nutrient losses, where we investigated the effect of resource availability on the production and reproduction of two types of dairy cows: Holsteins and three-way-crosses. The crosses were a three-breed rotational cross, between Holstein, Viking Red and Montbéliarde cattle, for which crossbreeding started in 2010. The analysis included 446 lactations between 2014 and 2019 from 187 cows. A correction was applied for parity number and calving season.

Results and discussion

In the workshop with multidisciplinary experts nine characteristics for circular dairy farms were defined. We came to the conclusion that there will likely not be one circular system that fits all, but tailor-made solutions for individual farms. The characteristics of circular dairy farms were: flexible, cooperative, efficient with minimal losses, healthy cows, low input, extensive with the focus on nature and landscape, extensive which is pasture based, multipurpose, and closed housing.

Flexibility is important when the input of nutrients becomes variable in circular systems where, for example, a farm strives to use regionally produced feed. Similarly, when the feeding of substrates is reduced the cow becomes more dependent on the quality or quantity of roughage and grass. In such a system cows will need to be resilient and produce milk efficiently from a roughage based diet. Circular farms can also aim to be cooperative, where cows are used to process losses of regional arable farmers (Van Zanten, 2016) which can cause variability in the feed available. To be able to process a variable diet, cows need a healthy rumen. An important characteristic applicable to all circular farms is to minimize the losses of nutrients, both on the farm, crop and animal level. On cow level there is interest in monitoring the losses of nitrogen, phosphate, and potassium, because of their negative environmental impact when oversupplied. Similarly, the reduction of greenhouse gasses emitted directly into the air, such as methane, offers potential to reduce the environmental impact of both circular and conventional dairy farming (van Bruggen et al., 2019). It is important to monitor the wellbeing of cows when the farming systems changes, as healthy cows make a farm easier to manage for a farmer. Furthermore, good health contributes to the longevity of a cow, which reduces the number of replacements to be reared and helps to increase both sustainability as well as profitability of the sector (Van Pelt, 2017). A characteristic that was highlighted before is low input. Currently, many soy-based substrates are fed to livestock which can be used as food for humans (Dei, 2011). A grass-based diet reduces the feed-food competition between humans and livestock. To improve a cows' production from a grass-based diet, it can be of interest to study the grazing behaviour in the future. This grass-based diet fits into the view of extensive farming systems. Which can either be pasture based, with pastures with highly nutritional grass types, or adapted to maintain nature and landscapes, where the diversity of plants and animals (e.g., insects and meadow birds) is a priority. Another characteristic of a circular farm can be to keep cows for multiple purposes. A high quality and quantity of meat, after the milk-productive lifetime of a cow, can reduce the environmental impact per kg of product. Furthermore, it may be of interest to investigate the manure

composition of cows, to be used as a qualitatively good fertilizer in arable farming. A final system definition can be closed housing, which to many does not correspond with circular farming. However, closed housing offers potential to minimize to spilling of nutrients into the environment by using, for example, air washers.

Many cow traits can be applied in various types of systems, and all contribute to the reduction of the environmental impact of dairy farming in circular and conventional farming systems. Some traits already exist but may have to be re-evaluated in a new farming system. Some traits are new and should be investigated before they can be applied in breeding programs. The cow traits that are important for a dairy cow to perform well in circular farming systems, and traits that help to reduce the environmental impact of dairy farming, that we defined are: longevity, health, claw health, udder health, rumen health, robustness, conformation, fertility, resilience, milk components, milk yield, roughage intake and efficiency, water use, nitrogen, phosphate, and potassium efficiency, greenhouse gas emissions, grazing behaviour, and multipurpose (meat and manure).

The case study on dairy farm “De Marke” showed that both types of cattle performed well (Ducro et al., 2021). The Holstein cows produced more kilograms of milk, whereas the crosses had a higher fat and protein percentage in the milk. Furthermore, the crosses had a shorter time between calving partly due to less time between the first and last insemination. Information on health was not available. Differences in production and reproduction between the two types were reflected by different breeding goals, and also by the estimated breeding values for these traits. Which shows that the breeding goal largely influences the desired characteristics of different types cattle. The variation within breeding goal traits for Holstein AI bulls greatly increased over the recent years, which helped to improve longevity and fertility of Holstein cows. Together with genomic selection, genetic variation helps to breed for circularity and improve traits for Holstein cows and all other breeds.

Conclusion

Breeding is a process that may take multiple generations, and therefore it is important to think ahead when defining a breeding goal. In the transition towards circular agriculture, we need to re-think breeding goals. In this study we defined cow traits which can enable the transition towards circular farming, for example: longevity, rumen health, resilience, roughage efficiency, water use, grazing behaviour, and greenhouse gas emissions. For some traits breeding values exists, however re-evaluation may be required in environments that differ from conventional Dutch dairy farms. Some traits are new and need further investigation before they can be added to the selection indexes.

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