Should we breed cows like pigs? A new organisation of dairy cattle breeding

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Abstract
Crossbreeding is the most common breeding system for pigs and poultry, but not for dairy cattle. When selecting purebred lines for crossbred performance, it becomes possible to take advantage of both breed complementarity and heterosis. In this paper, we present a new structure of dairy cattle breeding with the aim to improve crossbred performance in production cows. The structure of the dairy sector can be organised like a pyramid with nucleus herds, multiplier herds, and production herds. Genetic improvement of purebreds takes place in the nucleus. Surplus females from the breeding nucleus are transferred to the multiplier level, where they are used as dams of crossbred animals for production herds. In addition, we hypothesise that joint breeding planning and formulation of breeding goals for each parental breed are necessary in order to optimise crossbred performance.

Introduction
Crossbreeding is the most common breeding system for pigs and poultry. During the last decades, crossbreeding has also increasingly been used in dairy cattle (Clasen, 2021), primarily because of better profitability of crossbred cows due to heterosis for important production and functional traits (Sørensen *et al.,* 2008). Until now, crossbreeding systems in dairy cattle, such as two- or three breed rotational crossbreeding or terminal crossbreeding have only been managed at herd level. To our knowledge, no breeding organisation selects their purebred lines specifically for crossbred performance (CP) and no crossbreeding programs are coordinated at sector level. When purebred lines are specialised to be used in crossbreeding programs, it becomes possible to take advantage of both breed complementarity and heterosis to improve performance of crossbred production animals. Breed complementarity means that the traits of the two breeds complement each other. Breed complementarity may be especially large when traits are unfavourably correlated, such as between milk yield and resistance to mastitis or milk yield and reproduction traits. The use of specialised sire and dam lines as typically used in pig and poultry breeding (Smith, 1964), could previously not be applied for dairy cattle to the same extent because nearly all female offspring were used as replacements due to the low reproduction rate of cattle. Today, the use of sexed semen and multiple ovulation embryo transfer allow for a change of dairy cattle breeding into a multi-layer structure similar to what is found in poultry and pig breeding. Currently, the organisation of dairy cattle breeding is primarily carried out with the purpose of improving the genetic level of purebred populations. Therefore, AI bulls used in crossbred herds can only be selected among AI bulls that are already selected for use in purebred herds. A change in the structure of dairy cattle production at herd and sector level will make it possible to exploit crossbreeding in a better and more efficient way.
In this paper, we present an idea for a new structure of dairy cattle breeding, with the aim to improve CP in production cows. We argue that a multilayer structure as typically seen in pigs and

poultry can improve the competitiveness of the dairy sector by utilising the full potential of crossbreeding between dairy breeds.

A new dairy breeding structure

The structure of the dairy sector can be organized like the pyramidal structure in pig breeding with nucleus herds, multiplier herds, and production herds (Figure 1).

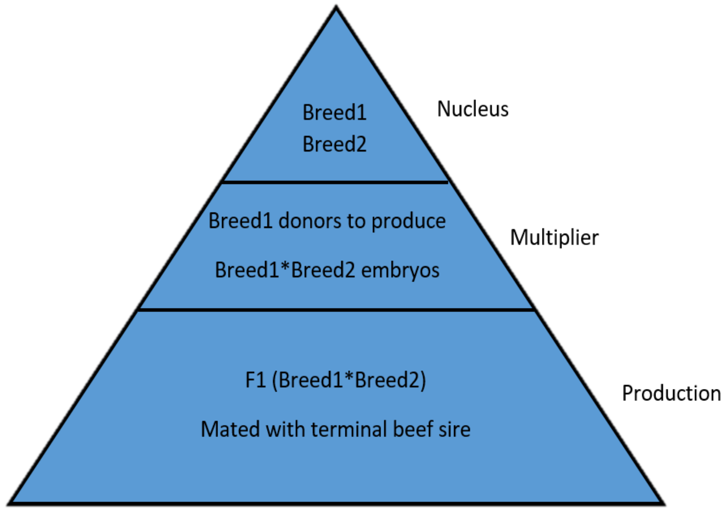

Figure 1. Structure in a terminal F1 dairy crossbreeding program with two breeds.

At the top of the pyramid are the nucleus herds where genetic improvement of the pure breeds takes place. The population sizes of the nucleus herds need to fulfil the requirements for genetic gain given an acceptable level of inbreeding. The breeding scheme in the nucleus herds rely on intensive use of ovum pick-up on young heifers that are selected based on genomic breeding values to increase selection intensity and decrease generation interval. Surplus females from the nucleus herds are transferred to the multiplier herds, where they are used as dams for production of F1 animals. The multiplier herds must be able to deliver enough F1 females to meet the demands from production herds. The demand for F1 females can be reached through intense use of embryo flushing of purebred donors with sexed semen from another dairy breed to produce F1 embryos. Recipients for the embryos will be F1 heifers, which are reared within the multiplier herds. The F1 heifers calve in the multiplier herds and are hereafter sold to the production herds as soon as possible. An alternative is to produce F1 embryos in the nucleus herds, while the recipients remain in the multiplier herds. In that case, management tasks will be more specialized at each level. In either case, the production herds will consist of F1 females and will not be producing their own replacement animals. Instead, all F1 production cows, except if they need to be contracted by the multiplier herds as recipients, are inseminated with beef semen from a terminal beef sire line suited for production of beef on dairy calves (Hjortø, personal communication). Taking this approach, dairy producers in the production herds can fully focus on milk production.
Such a terminal crossbreeding program can be extended by a third breed. The advantage of a three-breed crossbreeding program is to be able to combine the strength of more breeds for specific production systems.

Breeding goals. We hypothesise that joint breeding planning and setting of breeding goals for each pure breed are necessary in order to ensure that genetic levels, heterosis and complementary effects in the crossbred production animals are at the highest possible level. This will lead to higher CP relative to the present situation, where each parental breed is managed independently of the other breeds focusing on purebred performance. Even without assuming non-additive gene action for individual traits, a number of traits combined multiplicatively makes up the total economic merit of an individual. The consequence is that there is an additional crossbred superiority for total economic merit on top of the heterosis. This additional superiority is larger if the individual traits are highly different in the involved breeds. The economic value of this crossbred superiority should be quantified for the whole sector using decision support tools such as SimHerd Crossbred (Østergaard *et al.*, 2018). In addition, economic weights to be used in breeding goals of the parental breeds need to be derived to obtain the crossbred superiority. Setting diverse breeding goals across the breeds which complement each other will increase the overall genetic diversity and sustainability of the dairy cattle populations globally, on top of creating more profitable production animals.

Breeding value estimation. In the new structure for dairy cattle breeding, the aim is to improve the performance of crossbred cows. This performance depends both on genetic merit of the traits for the parental pure breeds but also on heterosis on a given trait. Therefore, selection for CP involves both improving purebred performance and heterosis. In pig breeding, records from crossbred animals in production herds are often lacking and selection is based on performance of purebreds. On the contrary to pigs, most countries routinely register the performance of the majority of dairy cows, providing the opportunity to select purebreds directly for CP. However, Esfandyari *et al.* (2017) demonstrated that selection for CP is only favourable for a few generations. Therefore, combined selection for CP and purebred performance is expected to result in a better performance of crossbred animals in the long term compared to selection for CP only. Statistical models that utilise phenotypic information in crossbred animals to estimate both genetic merit in the purebreds and crossbreds with high accuracy are essential. In the new structure, it is assumed that the selection of purebreds is based on genomic information and crossbred animals providing phenotypes are also genomically tested.

Discussion

In this paper, we presented a new structure of dairy cattle breeding with the aim to improve CP in production cows. The large advantage with the presented structure is that dairy producers will be able to take the benefits of crossbreeding to an increased level, as parental breeds are selected with the aim of improving crossbred performance. Furthermore, producers will be able to fully focus on milk production since breeding is carried out in the nucleus herds, rearing of heifers in the multiplier herds, and fattening of the beef*dairy offspring by meat producers. The presented structure can however only succeed in a cooperative organisation where the parental breeds are managed together and follow the breeding goals set to optimize crossbred performance. These breeding goals may not be the most optimal in case each of the pure breeds are used for commercial production. That is why the number of animals in the nucleus need to be minimized given the constraint on acceptable genetic gain. Whether or not such a breeding program will be economically feasible will depend on the number of production cows in the crossbreeding program, and on the extra economic gain that can be obtained by using breeding material from pure breeds selected for crossbred performance instead of breeding material from pure breeds selected for purebred performance. The program will be economically feasible if the cost of running such crossbreeding programs will be lower than the extra gain obtained in the production

herds due to increased heterosis and improved complementarity from having lines suited for crossbreeding. It needs to be investigated how much extra heterosis is necessary to justify the costs of the breeding scheme, proposed in this paper. In addition we need to estimate how large the crossbred production population needs to be to be able to pay for the extra cost given different levels of increased heterosis and breed complementarity to be achieved. Another advantage of the presented program is increased breed and genetic variation, which may be of value for the future. All these questions are to be answered in the Danish project DairyCross supported by the green development and demonstration programme (GUDP) from the Danish ministry of food, agriculture and fisheries DairyCross project supported by the green development and demonstration programme (GUDP) from the Danish ministry of food, agriculture and fisheries (J. nr. 34009-18-1365).
https://qgg.au.dk/projekter/projektdeltagelse/dairycross-krydsning-optimering-paa-tvaers-af-malkeracer/

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