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ERNST KALM

Development of cattle breeding strategies in Europe

Dedicated to Prof. Drs. h. c. Franz Pirchner PhD, on the occasion of his 75th birthday

Summary

Modern milk production in Europe will undergo a radical structural change both in terms of the dairy farmer and the breeding companies. Thus, cooperation between breeding companies or breeding associations will be a necessary tool to survive in the global economy. Although some of the new molecular techniques are already in the beginning of its practical implementation, the breeding industry needs to consider international collaborations to obtain higher economic gain of certain breeds. Above that, the dairy breeding industry should think about the implementation of crossbreeding schemes to use the non-additive effects more efficiently. The implementation of crossbreeding schemes requires an even closed collaboration between the acting breeding companies and the commercial producers as it has already been shown in poultry, swine and beef cattle. These rapid developments in the entire dairy breeding industry will also influence the current dairy organizations and require their adjustment to a more flexible economy.

Key Words: cattle breeding, breeding plans

Zusammenfassung

Titel der Arbeit: **Entwicklung der Milchrinderzucht in Europa**

Die intensive Milchproduktion in Europa wird durch einen deutlichen Strukturwandel sowohl in der Produktionsstufe als auch in den Zucht- und Besamungsorganisationen beeinflußt. Die Zusammenarbeit der Zuchtprogramme wird in der globalisierten Welt über Ländergrenzen hinweg organisiert. Die neuesten fortpflanzungs- und molekulargenetischen Methoden sind z.T. schon in der Umsetzungsphase und erfordern bei den wenigen großen Milchviehrassen eine engere Zusammenarbeit um das Rassenpotential zu stabilisieren. Auch die Milchrinderzucht der Zukunft muß sich der Zuchtmethode der Kreuzung widmen, um die nicht additiven Genwirkungen zu nutzen. Wie in der Geflügel- und Schweinezucht fordern Zuchtprogramme unter Einbeziehung der Kreuzungszucht eine engere Kooperation mit der Zucht- und Produktionsstufe. Die derzeitigen Zuchtunternehmen, die vorwiegend auf der Basis bäuerlicher Organisationsformen gewachsen sind, werden sich zukünftig auf diese Entwicklung einstellen.

Schlüsselwörter: Milchrinderzucht, Zuchtprogramm

Introduction

Dairy farmers in Europe need to become more familiar with a new economic situation due to focusing on a global economy. Currently, approximately two third of the 32 million cows within Europe are used for dairy production. Although there are more than 100 different cattle breeds, only six breeds (Holstein, Simmental, Montbeliard, Brown, Normande, Red, Ayrshire) appear to be of major importance across the European countries. Low milk prices and the milk quota system restrict the growth of dairy farms and result in increased economic pressure to substantially reduce the costs of milk production in order to be competitive with other dairy farmers outside the European Union (EU). These economic conditions will result in specialized dairy farms in the size range of 100 to 500 cows with increased demands for healthy cows capable of producing higher milk yields in combination with high protein and fat contents.

One way to counteract the general pressure of low prices for milk is to use improvements in genetics, management, and nutrition which has lead to an increase of the average milk yield and fat yield in Europe as it is shown in Table 1.

Table 1
Development of milk yields kg per cow/ year

Country	1990	1995	2000	90/ 00
Germany	4,857	5,460	6,050	+1,193
France	4,928	5,556	5,700	+ 772
United Kingdom	5,231	5,538	6,200	+ 969
Netherlands	6,084	6,500	7,050	+ 966
Italy	4,381	4,913	5,200	+ 849
Austria	3,791	4,217	4,950	+1,159
EU (15)	4,721	5,407	5,850	+1,129
Fat-kg	188	222	239	+ 51

Source: ZMP, 2001

Although the average milk production per cow in Germany is approximately 6,000 kg, modern, efficient farms already have achieved an average production above 10,000 kg of milk/cow, which might give insight to the trends for the future. Because of the restriction by the EU to limit the total annual milk production to 119 million tons, about 20 Mio. cows with an average milk production of 5,850 kg are kept on 954,000 European dairy farms (Table 2).

Table 2
Development of milk production in the EU

		Quota 2000/ 2001	Quota 2007/ 2008 I		Quota 2007/ 2008 II	
Milk production	(Mio. t)	119	123		123	
Milk yield per cow	(kg)	5,850	7,500		9,000	
Dairy Cows	(1,000)	20,312	16,421	(-19 %)	13,684	(-33 %)
Average herd size		22	22	50	22	50
Dairy herds	(1,000)	954	746 -22 %	328 -66 %	622	273

Source: Hülsemeyer (1999) and personal unpublished data

Due to the progress in production techniques and genetics milk production is expected to increase continuously, resulting in a reduction of the number of cows needed to fulfill the current European milk quota by another 20 to 30% within a timeframe of about 10 years. This will probably also result in a decreasing number of dairy farms in Europe (Table 2).

The primarily breeding goal of the main dairy breeds is to improve the marginal utility of milk production. On one side, farmers and breeding companies want to optimize the production of a dairy cow by increasing the performance on milk yield, fat and protein, while simultaneously reducing the cost of production. Substantial factors contributing to milk production appear to be the feed diet, the costs for replacement and costs for veterinary treatment. Especially the costs for the replacement of cows and costs for veterinary treatment are under the major influence of reproductive traits such as calving difficulties, stillbirth, fertility (non-return-rate 90) and workability traits such as milking speed and temperament (GROEN et al., 1999). These results are a major feature of breeding which is to increase the length of productive life and, thus, may have an impact on future breeding strategies.

Impact on breeding strategies

The structural change in dairy farming towards more specialized farms with a few highly specialized breeds will also have an impact on the breeding companies. Table 3 illustrates a few characteristics of breeding programs in the Holstein population within Europe, Canada, and the US. Although all countries have developed intense testing programs for their dairy cattle population, Germany is still characterized by having a heterogeneous structure within their main breeds of Holsteins and Simmental. Within the German testing program milk recording, herdbook keeping and genetic evaluation is already well organized. But the number of inseminations per test bull is still low compared to France, the Netherlands and the US. This will inevitably result in a higher concentration of the whole breeding sector, and might also initiate some collaboration across countries.

Table 3
Characteristics of breeding programs (Holstein Population)

Characteristics	E U R O P E					Canada	USA
	Germany		France	Nether-lands	Den-mark		
	HF	Sim.					
First Insemination (1000)	2,432	1,988	2,527	1,572	540	900	7,300
Test bulls	900	680	684	450	330	390	1,520
Ratio Insemination/ test bulls	2,700	2,900	3,700	3,500	1,600	2,240	4,800
A.I. organizations	16	12	48	6	5	7	19
Breeding Programs	14 (4)	12	2	2	1 (3)	2	4
Insemination/ Breeding Program (1000)	174 (608)	166	263	970 (HG)	540	750 (Semex)	1,825
Test bulls/ Breeding Programs	64 (225)	56	342	320 (HG)	330	350 (Semex)	380

HF= German Holstein, Sim.= Simmental, HG= Holland Genetics

Breeding programs of the future will lead to a reduction of about 500,000 cows and at least 1 million first artificial inseminations within their testing scheme. This will result in an annually test of 300 young bulls to provide a few favorable elite sires for the population. To optimize the breeding programs, companies will need to use the modern techniques of breeding, which will be enhanced by the results of molecular genetics. Nucleus breeding schemes (i. e. for the Angler breed in Germany) combined with multiple ovulation and embryo transfer (MOET) have been proposed as a way of increasing the rate of genetic change. The use of embryo transfer allows elite females to have many progeny, thus increasing both the intensity and accuracy of selection among females. If the MOET scheme can be successfully used with very young females, then the female generation interval can be substantially reduced. Within such a scheme young heifers are selected, and hormonally induced ovulation of multiple eggs is followed by the transfer of the embryos to recipient dams. After the grown heifer produced its first own calf, the young cow will provide information about its own genetic performance, which allows to select one of the prior born offspring for breeding purposes with a much higher level of certainty. Such programs have already successfully been developed in Canada, France, Germany, the Netherlands and the United States. The Figure presents a short overview.

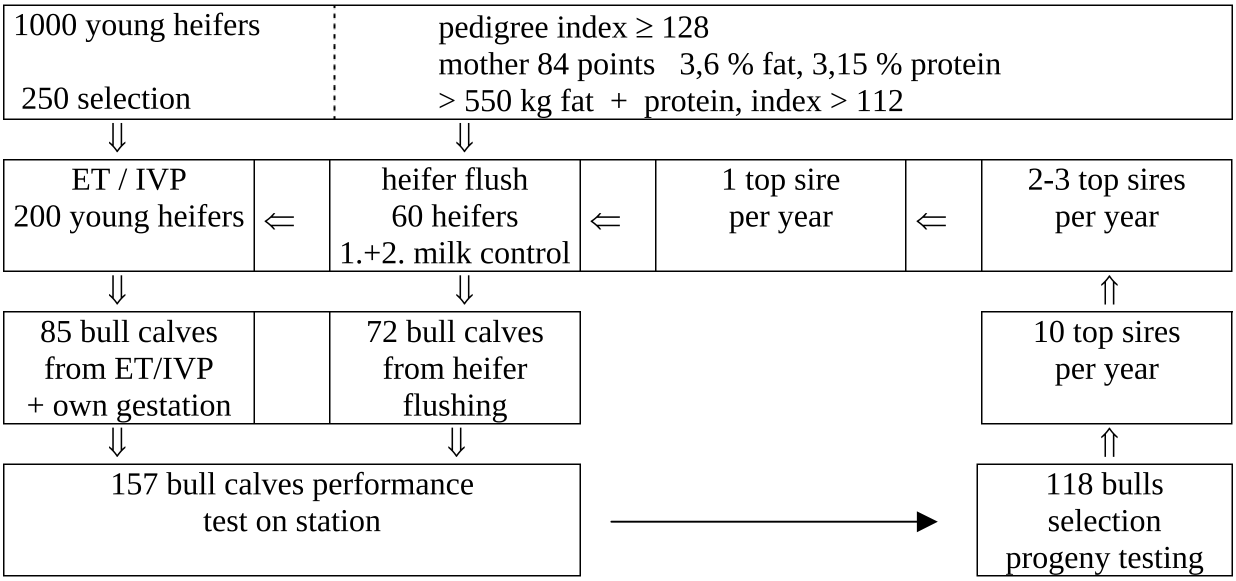

Figure: New breeding program – young heifers

During the implementation of the MOET scheme some breeding companies also implemented a progeny test station for favorable cows to measure their performance under an unique environment. But these test stations do no represent the general conditions of milk production and might therefore be biased by genotype*environment interaction. Performance testing of dairy cows should be conducted under conditions which represent the general environment of the cows production. Therefore, some new features have been developed to provide an increase in genetic gain or to improve the preciseness of current breeding schemes. As one example of a variety of new concepts in breeding value estimation, birth weights of German Holsteins are routinely collected from certain offspring of a widespread number of test bulls on three extraordinary commercial farms (STAMER et al., 2000). The collected data are submitted to a database system and are utilized for the genetic evaluation of calving traits in dairy cattle and provide useful information within the breeding program to improve functional traits.

Molecular genetics

A number of major programs are underway in Europe or the United States and Canada to map genes or chromosomal segments with major influence on production or health of dairy cattle. One approach to detect quantitative trait loci (QTL) is to use either a daughter or a granddaughter design (WELLER et al., 1990), in which a scan of the whole genome is conducted for anonymous QTL with an effect on the trait of interest in any chromosomal region. At least 10 granddaughter designs have so far been conducted throughout the world to detect QTL in dairy cattle (ASHWELL et al., 1996, 1997, 1998; COPPIETERS et al, 1998; GEORGES et al., 1995; GOMEZ-RAYA et al., 1996; HEYEN et al., 1999; LIPKIN et al., 1998; NADESALINGAM et al., 2001; SPELMAN et al, 1996; THOMSEN et al., 2001; VILKKI et al., 1997). Table 4 shows a summary of all major projects. For the scan across the entire bovine genome, the

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focus was initially on production traits and resulted among others in major QTL for milk yield, fat and protein on chromosome 14.

Table 4
QTL-detection experiments with granddaughter design for dairy cattle breeds

Country	Organizations	Breeds	Family	Sons, daughters*	Marker	Criteria
Belgium/ Netherlands	Industry and Uni Liége, WAS	Holstein MRI [1)]	29	1,158	215	milk, health conformation
Canada	Uni Guelph	Holstein	6	450		milk
France	INRA and Industry	Holstein Normande Montb. [2)]	9 3 2	1,154 214 180	169	milk, scc, fertility
Germany	ADR and Universities	Holstein Simmental Brown	16 3 1	1,100	265	milk, scc, fertility
Finland	Research-organizations	Ayrshire	11	453		milk, health
Israel	Research-organizations and Industry	Holstein	7	>1800	138	milk, health
Norway	Industry and Uni Ås	Norwegian Red	6	285	288	milk, health
Sweden	Industry and Uni Uppsala	Swedish Red + White	13	515		milk, health
USA	Industry and Uni Illinois, USDA	Holstein	8	1,068	174	milk, scc, conformation

[1)] MRI = Maas-Rhein-Ijssl Rind; [2)] Montbéliard
Source: Ashwell et al., 1996; Coppieters et al, 1998; Georges et al., 1995; Gomez-Raya et al., 1996; Heyen et al., 1999; Nadesalingam et al., 2001; Ron et al, 1998; Spelman et al, 1996; Thomsen et al., 2001; Vilkki et al., 1997

An alternative approach is to focus on candidate genes for a specific trait under study and to look for associations between polymorphisms within this genes and the trait. So far, genetic tests for diseases such like BLAD, DUMPS and CVM and a test for coat color are successfully used in breeding schemes.

But, although a lot of research has been conducted and a variety of results have been demonstrated, the influence of the results from entire scans of the bovine genome is rather small in dairy breeding programs.

One reason may be an outstanding successful confirmation of the detected QTL, before breeding companies start their first steps to incorporate QTL into their current breeding schemes. Furthermore, the benefit of using MAS depends highly on how accurately the location and effects of QTL are estimated. For these reasons issues like confirmation studies and fine mapping must be addressed. After the confirmation of QTL the implementation of a MAS in breeding strategies can start for certain genomic regions which characterize a QTL or further candidate genes for production traits and disease traits (GELLIN et al., 2000). MAS has emerged as a strategy to complement phenotypic selection and should, in theory, produce higher selection gains than phenotypic selection alone. The main advantages for the utilization of MAS are:

(1) Reduction of the generation interval by selecting very young animals in which the traits have not been recorded,

(2) For cattle using progeny test schemes with many offspring records, additional information can be obtained from genotyping the elite sires

(3) Selection is not limited in sex-limited traits such as milk production

(4) Selection is not limited in traits with low heritabilities (functional traits)

There are many potentially important polygenic traits on which breeders have not placed much selection pressure (i. e. disease resistance) or on which selection has been inconsistent, even contradictory. This makes MAS a useful tool within modern breeding schemes.

To get into the marker assisted selection MACKINNON und GEORGES (1998) proposed the top-down and bottom-up methods for future selection schemes. In the bottom-up scheme the best young sires based on their first progeny-test evaluation and their daughters are genotyped for markers linked to a known QTL. This information can be used to indicate whether the sire is heterozygous for a marked QTL or not, because the two different marker haplotype daughter groups indicate if a significant difference occurs in their production. In case of a significant difference, young bull progenies carrying the favorable haplotype can be selected for further testing schemes. In a top-down scheme bull-sires are included in a prior granddaughter design, allowing for identification of the QTL for which the grandsires are heterozygous. Thus, progeny are selected according to the grandpaternal marker haplotypes. The top-down method appears to have a higher statistical power to detect QTL. Furthermore, within the top-down method, sires outside a closed nucleus breeding scheme can be included into a nucleus. But the top-down method seems less useful for small populations such as Angler and Pinzgauer because of the limited number of test bulls per sire. Thus, for small populations the bottom-up method may be advantageous.

But in general, the ability to use results from multi-generational genome scans in either a top-down or bottom-up method requires a variety of technical prerequisites such as computational and logistical infrastructures. After installing these prerequisites the benefit of selection on a combination of molecular and phenotypic data will result in an genetic improvement (FERNANDO et al., 1989). But do breeding strategies besides the MAS also provide attractive alternatives for future dairy breeding schemes ?

New selection schemes

Current breeding programs for the major dairy populations are based on purebreeding, but long term use of purebreds can lead to inbreeding. Resulting negative side effects from inbreeding occur already with respect to the functional traits. Thus, strategies of crossbreeding or linecrossing, which are very common in poultry, swine, and beef cattle, may be attractive for the future in dairy breeding as well. HILL (1971) illustrated some important conditions for a balanced crossbreeding scheme such as:

(1) Stability: Biological types have to be mixed and matched in such a way that the genetic composition should produce a uniform set of animals and, thus, a consistent product.

(2) Replacement: Replacement of young heifers has to be done equally in all performing herds.

(3) Heterosis: a continuous usage of heterosis has to be maintained through future generations.

All these prerequisites have primarily been fulfilled by using mating strategies based on the rotational crossbreeding system and have been tested in beef cattle for a long time. But a risk would arise if dairy farmers would use sexed embryos of the same genetic origin (i.e. clones). The conditions outlined by HILL (1971) might be accomplished by crossbreeding the Brown Swiss breed and the Holstein breed. Ideally, a crossbreeding system should create animals which at least can result in 90% of the additive genetic value of the Holstein breed. The Brown Swiss breed shows good compliance with these requirements (McALLISTER et al., 1994). Therefore, in the future breeding organizations will be dependent on the cooperation between different breed associations to make sure that crossbreeding systems will achieve good complementarities to produce offspring with superior market characteristics.

Conclusions

Modern milk production in Europe will undergo a radical structural change both in terms of the dairy farmer and the breeding companies. Thus, cooperation between breeding companies or breeding associations will be a necessary tool to survive in the global economy. Although some of the new molecular techniques are already in the beginning of its practical implementation, the breeding industry needs to consider international collaborations to obtain higher economic gain of certain breeds. Above that, the dairy breeding industry should think about the implementation of crossbreeding schemes to use the non-additive effects more efficiently. The implementation of crossbreeding schemes requires an even closed collaboration between the acting breeding companies and the commercial producers as it has already been shown in poultry, swine and beef cattle. These rapid developments in the entire dairy breeding industry will also influence the current dairy organizations and require their adjustment to a more flexible economy.

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