

SUMMARY

Results obtained in the last 15 years on the use of the genetic polymorphism of the milk proteins in the field of animal breeding are shortly reviewed. A picture as complete as possible of all the implications that arise for setting up practical breeding scheme for the cheesemaking characteristics of the milk is drawn. 4958 first lactations of cows genotyped at loci of α , β , K-casein and β -lactoglobulin were analyzed using a least square model containing the following effects: herd, (age x season), genotypes for the single loci, interaction among loci.

Results on milk yield, fat % and protein % are synthetically reported.

A list of further investigations that need to be done for clarifying open problems in setting up selection strategies for the cheesemaking characteristics is proposed.

INTRODUCTION

In 1955, Aschaffenburg and Drewry published the first results on the discovery of genetic polymorphism in β -lactoglobulin. After that genetic variants have been found in all major milk proteins (for a review, see Thompson and Farrell, 1974). They differ from each other by substitution of a limited number of amino acids that is electrophoretically detectable. The importance of detecting these variants is due to the following aspects:

- in milk proteins the amino acid substitutions seem to be reflected in the physicochemical and technological properties of individuals milks;
- polymorphic milk proteins are controlled by autosomal genes, which are inherited in accordance with Mendelian inheritance.

Therefore selection of cows and bulls for specific milk protein variants is feasible and it could be possible to breed for variants associated to the yield of milk with specific technological properties. To set up operative breeding schemes for such traits the following picture should be clarified by not conflicting experimental results.

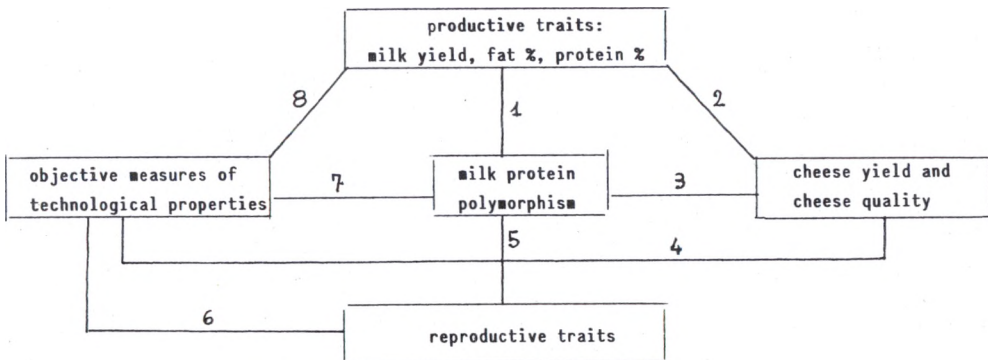


FIGURE 1.

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About the connections shown by fig. 1, this paper reports experimental results on the line 1 and gives a short review of the main findings about the other lines together with a list of problems considered still open for setting up an operative breeding scheme.

MILK PROTEIN POLYMORPHISMS: RELATIONSHIPS WITH TECHNOLOGICAL PROPERTIES OF MILK.

In Italy during the 1970's researchers of Bologna and Parma universities started many investigations that lead to some of the most important results in the area indicated by the line 3 in the fig. 1. Mariani et al. (1976) and Morini et al. (1979) showed that the milk yielded by cows having a BB genotype at k-casein loci has a shorter coagulation time, produces a coagulum of better consistency with an higher curd strength, retains the fat in the curd to a much higher degree and yields about 10% more Parmesan cheese after 19 month of aging. The effects of milk protein variants on the cheese making properties of milk was studied by many other authors using different approaches (EI-Megoumy, 1971; Feagan et al., 1972; EI-Megoumy, 1974; Schaar, 1984). Most of these experiments have generally been performed using objective measurements of the technological characteristics of the milk such as the coagulation time and curd firmness determined by a thrombelastograph. The results of these experiments are often difficult to interpret and some reports are not consistent. Therefore there is a need of further investigation in the area indicated by the line 7 in the fig. 1.

Particularly important it seems to analyze interactions among different protein variants jointly considered. Sets of data with too few observations for some genotypes may be a major problem in modelling for unbalanced data analysis.

In addition, being the traits expressed by a lactodynamographic chart measurements of operationally rather than physically defined entities, there is a strong need to investigate to which extent they are good indicators of the yield and quality of the final product, the cheese (line 4 in fig. 1).

MILK PROTEIN POLYMORPHISMS: RELATIONSHIPS WITH YIELD AND COMPOSITION OF MILK.

What will be the impact of the change in gene frequency for a particular protein variant on the productive traits already under selection?

Hoogendoorn et al. (1969) Munro (1978), Ng-Kway-hang et al. (1984), Mc Lean et al. (1984) have investigated this area of problems (line 1 in fig. 1) but reports are few and conflicting. The lack of consistency among different results can likely be due to the small number of observations for fitting complete models for all the environmental source of variation, with a serious risk of disconnectness among factors. In addition none of the previous analysis took into account interactions effect among milk protein loci. To avoid such risk a set of 4958 first lactations of Holstein cows recorded in 385 herds was analyzed using the following model:

$$y = \mu + \text{herd} + (\text{age} \times \text{season}) + \alpha - \text{cs} + \beta - \text{cs} + k - \text{cs} + \beta - \text{Lg} + (\alpha \times \beta \times k \times \beta) + e$$

As shown in table 1. none of the interactions were significant.

TABLE 1. Sequential Sums of Squares and significance of the sources of variation. (**P<.01 ***P<.001)

Source	d.f.	milk yield (x 10 ⁶)	fat %	protein %
Herd	384	15606.3 ***	376.2 ***	41.8 ***
Age x season	23	646.8 ***	5.5 ***	1.3 ***
k-cs	2	.7	0.1	0.5 ***
α-cs	1	4.4	0.1	0.3 ***
β-cs	2	8.1	0.0	0.1
β-lt	2	3.4	2.5 ***	0.2 **
interactions	37	270.7	4.3	1.1
Residual	4507	39968.2	571.0	117.3

The fact that the interaction among the 4 considered loci of milk proteins is not significant, doesn't mean that there are not effects due to epistasis and/or to dominance. For example the effect of the complete genotype BBBBABAB respectively at loci of κ -cs, α -cs, β -cs, and β -Lg, was estimate +.114 for protein percent; that is a value twice larger than the sum of the single effects reported in table 2 (=+.052). Similar effects were found also at β -Lg locus for fat percent. No significance at all was shown by the effects of the milk protein polymorphisms on milk yield.

MILK PROTEIN POLYMORPHISMS: RELATIONSHIPS WITH REPRODUCTIVE TRAITS.

Meyer (1967) found an highest percentage of stillbirth in the calves born from homozygote cows at locus of β -lactoglobulin. The same author reported a significant effect of the AB -genotype at same locus on the fertility of bulls and cows. Hargrove et. al. (1980) found that the effects of milk protein polymorphisms on conception rate, days open and first service period were not significant. This area of problems (lines 5 and 6 in fig. 1) needs of further investigations before setting up any breeding strategies that could modify frequencies of genes important for the reproduction.

OPEN PROBLEMS AND SELECTION STRATEGIES.

In quantitative genetics, if we are dealing with heritable traits than there must be quantitative-trait-loci (QTL) affecting them. As stated by Smith and Simpson (1985) any information, direct or indirect on these QTL individually and their effects is theoretically useful.

Dealing with the cheesemaking properties of the milk the first step is to define the trait and/or the combination of traits to select for, and only later to see how much the milk proteins loci, as QTL, can help the selection effort. Of course the most straightforward could be the cheese yield but it is not convenient, in operative terms, to attribute to individual cows a measure of cheese yielded by its milk.

Protein content of milk could be a selection goal since high protein content, in general, means good cheesemaking properties (Barabanshchikov, 1978). However, milks with the same protein content from different cows may considerably differ in their properties affecting both cheese yield and quality. In addition the area of problems indicated by the line 2 in figure 1 should be investigated with particular regard to the production of the so-called typical cheeses, where the optimum combination of fat, caseins, whey proteins, calcium, phosphate and citrate contents, in association with the size and stability of micelle is fundamental for the improvement of the quantity of high quality cheese. Because of that traits other than protein and/or fat percent could be more suitable for improving cheese production.

To have an objective measurement of the technological characteristics of the milk as a whole, the thrombelastograph seems to be an interesting tool. But before of using lactodynamometric measurements (LM) as traits to select for, the following aspects need to be solved:

- the repeatability estimate of LM within and among lactations;
- the heritability estimate of LM;
- the genetic correlation estimates between LM and the productive and reproductive traits (line 8 and 6 in fig. 1);
- the accuracy in predicting the cheese yield and quality through LM (line 4 in fig. 1) for different types of cheese.

If LM will show "acceptable" genetic and phenotypic parameters, then it could be include in the breeding scheme as trait to select for. In such a case other questions will arise: how good are the milk proteins loci as QTL for LM? How much gain in terms of genetic improvement for cheese yield is obtainable using milk proteins polymorphisms as markers to assist selection (line 7 + 4 in fig. 1)? These questions are related to many factors: the heritability of the LM trait, the genetic variation

explained by the identified QTL, the correlation between LM and cheese yield, and the time and form of selection.

Information on milk proteins polymorphisms could be used in two ways: to increase the accuracy of selection for LM; affect the time of selection. With highly heritable traits there is less scope for increase in accuracy of selection; for lowly heritable traits the scope is larger. However, as pointed out by Smith and Simpson (1985), this is the situation where QTL effects are smaller and harder to determine accurately. With respect to time of the selection. Direct selection for milk proteins variants as QTL could only lightly reduce generation intervals being LM a sex-limited trait still using progeny test to evaluate sires.

In conclusion, we think that to improve the cheesemaking properties of milk yield the major efforts should be oriented to investigate line 4 of fig. 1 to define a quantitative trait highly correlated with cheese yield with enough additive genetic variance, not antagonist with reproductive traits. Then it should be investigated if milk proteins loci can assist in selecting for such a trait.

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