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Individual cheese yield as a selection goal in milking ewes: Experiences and prospects in the Churra breed

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SUMMARY – Milk from dairy sheep is widely used for high quality cheese production in Spain, as elsewhere. Therefore, genetic improvement of chemical milk composition has to account for the transformation of milk into cheese, because it is a major factor determining yield and quality of the final product. A new analytical method to quantify the Individual Laboratory Cheese Yield (ILCY) of ewe's milk, on the basis of milk quantities compatible with those of the Official Milk Recording (OMR), was elaborated. A description of the method is given. The new variable, ICLY, is then discussed as a selection criterion: recording of new traits, corresponding breeding value estimations, relationships with the dairy traits usually retained for the improvement of milk composition, suitability for updating selection objective (taking into account the specific production system in Churra breed) and possibility of implementation in the ovine milk recording schemes.

Key words: Ovine milk, individual laboratory cheese yield, selection objective, results and prospects.

RESUME – *"Le rendement fromager individuel comme objectif de sélection chez les brebis laitières : Expériences et perspectives pour la race Churra". En Espagne, comme ailleurs, l'élevage ovin laitier est orienté vers la production de fromages de haute valeur commerciale, l'objectif étant toujours de veiller notamment au maintien de la qualité chimique et hygiénique du lait, garante de la qualité du produit final, le fromage. L'importance à accorder à l'amélioration génétique de la composition du lait de brebis est, en fait, conditionnée par le débouché exclusivement fromager de ce lait. Une méthode d'estimation du rendement fromager individuel a été mise au point. On donne une description détaillée de la méthode proposée. On discute ensuite la nouvelle variable, le rendement fromager individuel, en tant que critère de sélection, ses relations avec les variables laitières habituellement retenues pour l'amélioration de la richesse du lait, en tenant compte de problèmes spécifiques posés à la sélection de la race Churra, et la possibilité de son incorporation dans le cadre du contrôle laitier qualitatif ovin.*

Mots-clés : *Lait de brebis, rendement fromager individuel, objectif de sélection, perspectives futures.*

Introduction

In the last decades, the socio-economic context of the Mediterranean basin, where milk from sheep is widely destined to cheese production, incited the profession to get involved in a global research-development work aiming to construct an effective economic system, for both milk producers and cheese makers. It was about, for the milk producer, to obtain sufficient income in a region completely vowed to agriculture and for the cheese maker, to be able to transform milk of good quality, in sufficient quantity, to satisfy the ever increasing clientele of ovine cheese amateurs. Today the region of Castilla y León, as others, constitutes a pole of original farming and industrial development based on a mixed production system, milk and meat, and on the cheese manufacture. In few years, modern systems of production supplanted traditional forms of raising and milk production increased considerably. This evolution is from an integrated research, in particular in the domain of genetics and animal physiology, and has led notably to the mechanisation of milking and the implementation of a selection schema associated to a better control of reproduction.

In this economic context, it is indispensable to reorient the strategies of dairy production development, the main aim being to improve the chemical and hygienic quality of milk and cheese.

In the Churra breed, as in others, the selection program has been started in order to increase the production level of the entire population. Since the 1980's the main selection goal was limited to milk yield. The resulting increase in milk production gave rise to a reduction in the milk richness, which can contribute to the reduction of cheese yield. Then the selection program has included the protein content since four years ago, in 1998, in order to take into account the milk composition and attenuate such a reduction in the main milk components.

In principle, considering the vocation of ovine milk, it seems that the most important qualitative aspect would be its own cheese yield. However, there are few studies on individual cheese yield, which is difficult to estimate directly. It is therefore indispensable to indirectly quantify this variable or to find another, of easy evaluation, that presents high correlations with cheese yield. Different milk components, particularly the most important ones, present high correlations with cheese yield. Among these components are the fat, protein, useful matter and total solid contents. Most of them have been experimented, separately or combined, without getting results that can be considered definitive. It is not yet clear what the variable is – or what are and, in this case, with what weighing – determining for the production of the biggest quantity of cheese, with a given milk quantity, that seems to be the ideal objective.

To answer some of these questions, a technique that allows direct or indirect prediction of individual cheese yield using small amounts of milk, compatible with those normally collected for the OMR, must be perfected. The Individual Laboratory Cheese Yield (ILCY) therefore acts as a basis for the survey on the relations between the composition of milk and its cheese ability in a more reliable manner. Only in that way can results be actually applied to the evaluation and selection of individual ewes on their cheese yielding aptitude. In this study, we describe a method allowing appraisal of individual milk cheese aptitude before cheese making. We then go on to discuss the suitability of ILCY, and the traits inherent in milk, as selection criteria for more cheese yield under the Churra breed conditions.

Previous attempts to predict cheese yield

There has been interest in relating the yield of cheese to components in milk. The main reason is economics; cheese yield is vital in an economic sense for cheese makers since small differences in yield translate into big differences in profit (Emmons *et al.*, 1990; Lacroix *et al.*, 1993). Predicting cheese yield in a reliable manner before milk into cheese transformation will contribute to increasing the cheese yield and thereby the profit in cheese making.

There is a genetic interest in predicting the cheese ability of milk. No genetic parameters were estimated for individual cheese yield nor their genetic relationships with the main milk components. In fact, estimation of such parameters is of great interest, especially in dairy ewes – if the process of individual cheese yield estimation, from small amounts of milk, can be easily applied to a large number of samples as required for genetic studies, with a margin of error no higher than those generally allowed for milk recording and without high additional expenses – and would help in re-examining the selection programmes in the future.

Several tests have been tested with the aim of increasing cheese yield, such as its relationships with rheological parameters or the predictive formulae for yield of cheese. For ewes' milk, some authors (Duranti and Casoli, 1991; Manfredini *et al.*, 1992; Hurtaud *et al.*, 1993; Delacroix-Buchet *et al.*, 1994; Pellegrini *et al.*, 1997) have studied the correlations among some physicochemical variables and renneting properties of milk such as clotting time, gel firming rate and gel strength. It was concluded that an increase in fat and protein contents in ovine milk might result in reduced clotting time and increased curd firmness. There is, however, some variation between reports as to the incidence of renneting properties on cheese yield which had not always been checked in experimental manufacture, at least in dairy cattle (Remeuf *et al.*, 1991; Colin *et al.*, 1992).

Cheese yield formulae have been developed based on the fat content of the milk on the one hand and on the crude protein content or casein content of milk on the other (Table 1). Cheese yield formulae appear to have application as control procedures in predicting yields and as comparisons in assisting cheese makers to obtain maximum yields (Emmons *et al.*, 1990). According to the same authors, they are central to developing pricing formulae based on yield of products from composition of milk and they may be useful in expressing yield of cheese as percentage of theoretical yield. Not all, however, advocate the use of predictive yield formulae. Others have examined the question of whether yield formulae are necessary and concluded that they are not useful. For example, some prefer to judge the performance of cheese factories on the basis of conformity to a constant, or range of, moisture in fat-free cheese (Lawrence *et al.*, 1984). Whereupon, both the coagulation properties (Remeuf *et al.*, 1991) and the fat and protein contents (Delacroix-Buchet *et al.*, 1994) seem useful but insufficient to determine yield and quality of the final product.

Table 1. Examples of predictive formulae for yield of cheese (Y) from composition of ovine milk

Authors	Predictive equations†	Unit of regressors
Anifantakis and Kaminarides (1983)	Y = 0.830 C + 2.13 F + 2.28	g/kg
Pirisi *et al.* (1994)	Y = 1.733 P + 1.257 F	g/100 g
Pellegrini (1995)	Y = 0.334 P + 0.056 F + 0.63	g/l

†C: casein content; F: fat content; P: protein content.

Moreover, cheese yield formulae are usually derived from regression equations established from practical experience carried out with bulk milks and no studies have been carried out on individual cheese yield. It may be helpful to understand what is going on when cheese yield is directly estimated from small individual milk samples as collected within the milk recording scheme for dairy ewes.

Cheese making process (method description)

The method we present here is a result of various studies (Othmane *et al.*, 1995, 1999, 2002a; Othmane, 2000) since 1994. Several experiments were carried out first in order to choose the appropriate amount of milk and rennet dose.

Materials

Pyrex glass tubes with a spherical base (longitude 100 mm, diameter 15 mm, volume 14 cm^3), identified by glass engraving and tared, are used. Milk heating and temperature regulation during cheese making are carried out in a water bath. Two racks with a 60 tube capacity form the support with the tubes kept in vertical position during milk coagulation. A glass Silber Brand pipette (BRAND, Germany) is used to measure the volume (±0.075 ml) of milk. A Gilson pipetman (GILSON, France) is used to measure the volume (±0.01 μl) of rennet added. A generic agitator allows accurate rennet distribution. The vertical cut of the curd in the form of a cross is done manually with a suitable tool, adaptable to tube diameter. A 108 tube capacity centrifuge is used to separate the whey from the curd. A generic balance, Mettler AE 160, is used to measure the weight (±0.0001 g) of the curd.

Rennet preparation

The rennet used is a Dutch commercial product (MAXIREN-15, 100% chymosin, rennet strength 15,000 MICU/ml). For each manufacture, a rennet is to be prepared by diluting the commercial product 10-fold with bidistilled water. To avoid rennet activity losses, dilution will be carried out just before the rennet is added.

Cheese making procedure

The "micro-cheese manufacture" from individual milk samples is outlined in Fig. 1. Ten millilitres were extracted from each individual milk sample, warmed to 30°C and mixed by shaking, and then transferred to an already tared tube. Sixteen microlitres of the 10-fold diluted rennet was added, giving a dosage of 16 ml of undiluted rennet per 100 l of milk. Rapid stirring ensured uniform distribution of the rennet. Coagulation was carried out at 37°C in a water bath for an hour. The gel obtained (curd + whey) was vertically cut manually in the form of a cross. It was then centrifuged at

1750 g for 15 minutes at 36°C. After expulsion of the whey, the remaining whey drained from the curd during 45 minutes with the test-tube face downward (the curd remained quiescent at the bottom of the tube). The weight of the centrifuge residue (curd obtained after expulsion of whey and draining in the open air) is expressed in kg per 100 litres of milk and represents an experimental estimate of ILCY. ILCY was then expressed in % (w/v) so as to be understood and easily compared to real cheese yield. As regards the milk sampling and the accuracy of the analyses, the usual shaking precautions are sufficient.

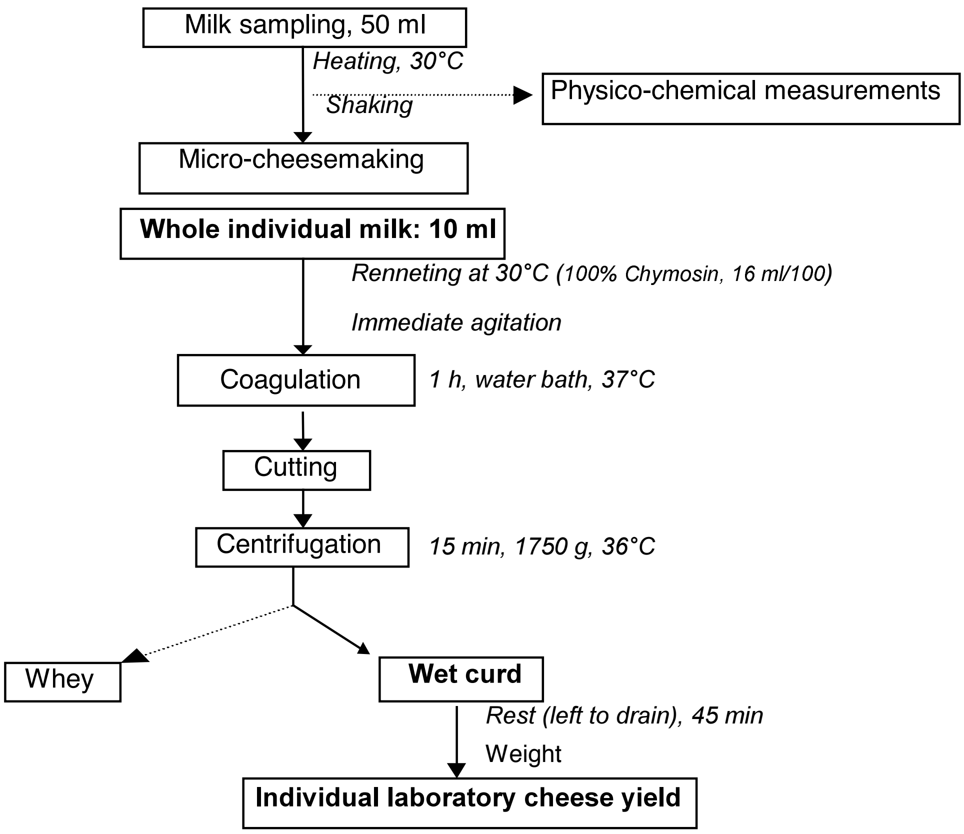

Fig. 1. Flow chart for the manufacturing of individual laboratory cheese from sheep milk.

What about the method?

The method has been applied to a large number of milk samples, representative of all the milk produced in the activity area of our milk analysis research laboratory, in order to study the ILCY behaviour as a new trait. Over a 3-year period, monthly milk samples (50 ml) were collected, in compliance with the OMR, throughout different lactation periods, from 1119 Churra ewes.

The results obtained, with a data set sufficient for a robust statistical study, demonstrated the relevance and the validity of the tests of microfabrication, destined to simulate industrial manufactures from small milk amounts. ILCY obtained (test-day mean: 26.55 kg/100 l; lactation mean: 26.71 kg/100 l) falls within the range of those reported for real cheese yield in dairy ewes (Anifantakis and Kaminarides, 1983; Pirisi *et al.*, 1999), although we are dealing with a different manufacturing process. ILCY, like that of cottage cheese, tends to be higher than industrial cheese yield, perhaps because of the very small amounts of milk used and the forced draining. In real manufacture, draining lasts about 12 hours, depending on the type of cheese, whereas whey removal in the laboratory is accelerated by centrifugation, which can have a negative influence on adequate whey evacuation.

It is nevertheless true that, in spite of its clear advantages, the ILCY estimation method also has its limitations and it is important to put it within its context (laboratory conditions, rennet strength, very reduced amount of individual milk, atmospheric conditions, etc.), in other words, results must be interpreted with certain prudence, more so if they are compared to their counterparts in real conditions of cheese manufacture. In fact, and considering our objective, the cheese manufacture procedure is marked out at the stage of wet curd before salting (Fig. 1), a stage which is common to all types of manufactures, leaving aside the maturation process whose consequences on the quality of the final product are essential and in any case proper for each factory.

The trait "individual laboratory cheese yield"

Presentation

The laboratory assessment of potential cheese yield, ILCY, is a new variable; there are no previous studies on dairy ewes or dairy cattle to compare it with. However, results on some usual traits (milk fat and protein) from the same data set are sometimes presented comparison with the behaviour of ILCY. The distribution of values for ILCY is shown in Fig. 2 and the variation coefficient is about 21% and 15% for test-day and lactation measures respectively, with the microfabrication process being identical all through the analysis period, with a satisfactory repeatability (Othmane *et al.*, 2002a). Such a variability reveals the incidence of the physico-chemical characteristics of milk, among others, on its technological behaviour. Other factors such as rennet strength, pH, hygienic and atmospheric conditions, sample volume, etc., could in fact participate in the marked variation of the ILCY. Among the identified environmental factors, variations in ILCY depend mainly on flock-test-day (or flock-year-season), stage of lactation, age of ewe, and number of lambs weaned.

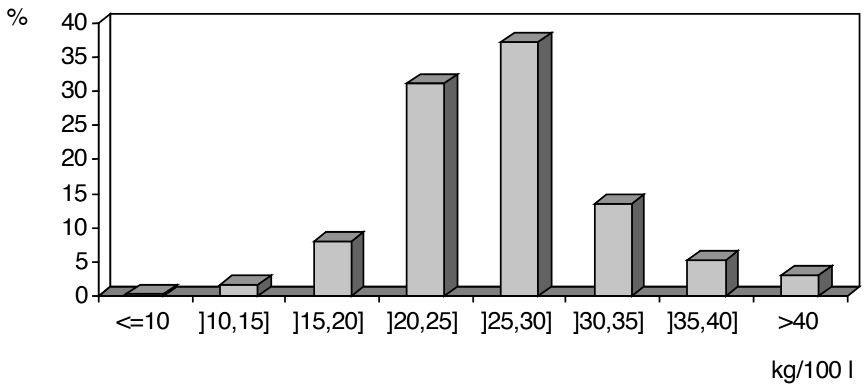

Fig. 2. Distribution of the Individual Laboratory Cheese Yield (ILCY) from 7492 test-days.

Behaviour throughout the lactation period

Apart from our studies (Othmane *et al.*, 2002a,b), as mentioned above, no studies have described the change in potential cheese yield during the course of lactation. Our results show that the lactation curve of ILCY was ascendant (Fig. 3). It attained its minimum value (23.5 kg/100 l) one month postpartum, which coincided with the peak in milk yield (El-Saied *et al.*, 1998; Fuertes *et al.*, 1998; Othmane *et al.*, 2002b), and this was followed by a gradual increase during the latter part of lactation to 28.7 kg/100 l in the 6^{th} month of lactation. The increase in ILCY as lactation progressed (20%) was comparable to those indicated by the main milk components (fat and protein contents), which support the hypothetical influence of these traits on cheese yield. Furthermore, it can be pointed out that the best ILCY were obtained in late lactation, when milk yield is lower but the milk is richer in fat and protein.

Possibility of implementation within the OMR scheme

Because of the cheese making exploitation of ovine milk, individual cheese yield is an economyyield parameter of maximum significance in dairy ewes. Hence selection goals and criteria in dairy ewes are tangibly different from those in dairy cattle since bovine milk has a ready market as other milk products. To improve cheese ability of ovine milk, it seems that the most important qualitative aspect should be its own cheese yield. However, implementation of such a trait within the OMR scheme must obey some criteria, the most important being the economic and genetic aspects. From a genetic point of view, any trait that is a candidate for selection criterion will be heritable, closely related to milk cheese ability, easy to determine and something whose determination could be automated. Judging by our previous results on this topic, the variable ILCY, as something new, is a useful predictor of cheese yield capacity. It corresponds to easy measurement that can be recorded for the ewe – milk recording – and the flock – bulk milk tank – and it may also be a suitable criterion to study and estimate the cheese ability of the milk before the cheese making process. Automation of the method within milk recording schemes with an acceptable rate may be feasible without additional expenses. We were successful in developing an accurate automated method for ILCY. For day-to-day routine analysis, milk samples can be analyzed at a rate of 35 to 40 samples/h and results may be directly transferred to a database. Automating the ILCY determination is a tentative advance in order to make it part of the ordinary analysis of OMR. Availability of ILCY measurements for a large number of samples, as required for selection programs, makes it worthy of consideration as a selection criterion for higher cheese yield, at the expense of the knowledge of its genetic parameters.

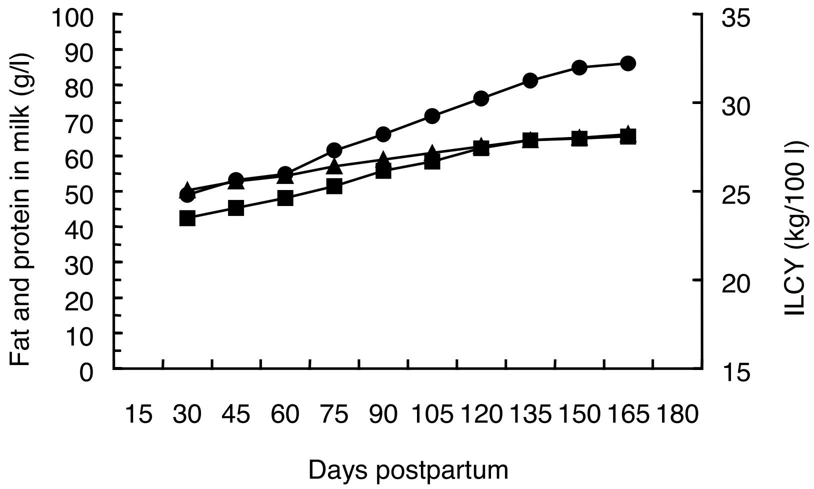

Fig. 3. Changes in individual laboratory cheese yield (■), milk fat (●) and protein (▲) during lactation.

Genetic parameters

Several studies have demonstrated that variability of milk composition, especially casein and fat contents, significantly affects cheese yield (Barbano and Sherbon, 1984; Ng-Kwai-Hang, 1993). Accordingly, it may be assumed that the genetic parameters for ILCY would be markedly affected by their counterparts for fat and protein contents in milk. In this way, results from several previous studies on all indigenous Spanish breeds showed low genetic estimates for milk fat content. Heritability and repeatability estimates for fat content are always lower than those reported for other components such as protein content (Jurado *et al.*, 1995; Legarra, 2002). Even in some experiments specifically designed to check both estimates for fat content (de la Fuente *et al.*, 1997; Othmane *et al.*, 2002d), results were still lower than those reported for other dairy sheep breeds. For further details see Othmane *et al.* (2002c,d).

Having mentioned such a conditioning, let's get back to the matter in hand. Our study showed low heritability (0.08 ± 0.04) and repeatability (0.16) for the ILCY test-day. Similar estimates were obtained when lactation means are considered (0.09 ± 0.02 and 0.16, respectively). These results are undoubtedly influenced by the low heritability and repeatability (Table 2) and the high variability of fat content. These values also indicate the existence of other unidentified and/or non-identifiable factors, such as rennet strength, initial pH, atmospheric conditions, etc., in addition to the genetic component, which control the efficacy of the transformation of milk into cheese.

Table 2. Heritabilities (h^2) and repeatabilities (r) for Individual Laboratory Cheese Yield (ILCY), milk fat and milk protein (n = 7492)

Trait	Test-day		Lactation means	
	h^2	r	h^2	r
ILCY (kg/100 l)	0.08 ± 0.04	0.16	0.09 ± 0.02	0.16
Fat in milk (g/l)	0.06 ± 0.04	0.26	0.10 ± 0.03	0.21
Protein in milk (g/l)	0.23 ± 0.07	0.35	0.31 ± 0.03	0.38

Such results suggest that selection for ILCY is not advisable under the present conditions of the Churra breed. Selection programs in Churra breed, as well as in all indigenous Spanish dairy breeds, will then focus on the study of protein fractions, either separately or in combination, as selection criteria. However, because this new method plays a key role in estimating milk cheese ability before cheese making, the method is still to be judged justly and a genetic study of ILCY on any other dairy breed, free of the fat handicap, is welcome on this topic. It would be very useful to have more information and to investigate the heritability of ILCY and its genetic relationship with the main milk constituents, especially since the literature on that topic is not available for dairy ewes or dairy cattle.

Discussion and conclusion

In the industry, cheese ability of milk is generally known only after its transformation into cheese, the manufacturing being carried out and the balance sheet being calculated. Therefore, technological tests aiming to appreciate, on small individual milk samples, the cheese ability before milk into cheese transformation seem necessary to characterise the cheese potential of milk in a reliable way. The high content in useful matter of sheep milk and its particularities led us to develop specific analytic techniques. Among these, is the method of ILCY determination as a process of fast and easy assessment of the richness of milk as raw matter for cheese making.

Repeatability and validation of the method have been checked (Othmane, 2000; Othmane *et al.*, 2002a). The method proved to be useful for cheese yield prediction, on a laboratory scale, with values in general accordance with the results reported in dairy ewes, although the technological parameters maintained for these microfabrications are not strictly identical to those adopted on a large scale. In fact, we chose to work at constant technology throughout our experimentation without taking into account the change of the physico-chemical characteristic of milk with the stage of lactation. In the dairies, the technological times are instead adapted to the milk richness and present slight evolutions depending on the stage of lactation. On the other hand, some differences must be due to the use of too small and individual milk samples, since such a difference is not noticed when cheese yield is made from large quantities of bulk tank milk. Although the parameters of manufacture are not always optimal, it is as well to indicate that the method constitutes an important tool for surveying the cheese ability of too small individual milk samples. This is so much certain if we specify that, in both ovine and bovine milk, it has been demonstrated that the rheological parameters are not sufficient to characterise the milk cheese ability. The method also presents some interesting qualities: measurement repeatability, rapidity, simplicity and possibility of automation.

The results obtained during the different studies carried out on the ILYC bring us to conclude that this trait depends on the essential components of milk, but also on many other factors of variations that must explain a certain percentage of the total variance and that still have not been identified with precision. It is to be remembered that, besides the genetic potential of the individual (including the genetic variants of the different casein fractions in milk), there are other factors, in relation with the coagulation process, at times difficult to control, that intervene in the expression of cheese yield.

In principle, the new trait, ILCY, is undoubtedly a measure closer to the real cheese yield than the measures of the milk components (fat, protein, etc.) and therefore, it could be considered as a selection criterion for cheese yield improvement. However, the low heritability (0.08), the low repeatability and the high variability of the ILCY make that decision seem inadvisable. Such a conclusion is surely highly conditioned by the high variability and the low heritability (<0.10) of fat in milk, which became usual in Spanish dairy sheep breeds. It is however likely that in other dairy breeds the ILCY gives higher genetic estimates and the panorama may be different from the situation in the Churra breed.

If the ILCY is not advisable as a selection criterion at least in the Churra breed, we have to make do with the milk composition traits to improve cheese yield, with the fat content being discarded. On the other hand, the low heritability of milk fat affects not only the ILCY but also the milk traits of which the fat content forms part. The useful matter, as a combination of fat and protein contents, and the total solids in milk also present lower genetic estimates (0.12-0.18 and 0.28-0.30 for heritability and repeatability, respectively) than those expected (Othmane, 2000). So, to tackle this major inconvenience, people involved in the Churra breeding programme (geneticists, breeders and all actors) are called on to survey the reasons at the origin of this fact. Among the remaining milk components, we just have the protein fractions. We know also from experience that selection by casein content as an alternative to selection by protein content is not advantageous in sheep (Othmane *et al.*, 2002c,d), since the protein content corresponds to a routine measurement that can easily be recorded for the ewe (milk recording) and the flock (bulk milk tank). Under these conditions, it would therefore be more logical to maintain a selection by protein content as the routinely recorded and easier trait. Furthermore, given the high genetic correlation between ILCY and protein in milk (Table 3), selection by protein content will also induce an important correlated increase in ILCY and consequently in cheese yield. However, it is very useful to have more research on this topic in order to know what happens when the ILCY is estimated in another dairy breed, without the fat conditioner.

Table 3. Genetic correlations among some test day (above the diagonal) and lactation (below the diagonal) traits in Churra breed

Trait (i/j)†	1	2	3	4	5
1 Milk yield (ml/d)		–0.63	–0.68	–0.58	–0.75
2 Fat (g/l)	–0.56		0.80	0.60	0.86
3 Protein (g/l)	–0.64	0.85		0.76	0.85
4 ILCY†† (kg/100 l)	–0.59	0.80	0.85		0.72
5 Useful matter†††	–0.83	0.96	0.94	0.83	

†i/j = trait i and trait j.
††ILCY = individual laboratory cheese yield.
†††Fat + protein.

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