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Selection for super traits or sub indices: A practical approach for dairy sheep

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SUMMARY - In France, efforts in research and extension for dairy sheep genetics have been fowsed for the last 30 years on the design and implementation of breeding programs of the French local breeds in their specific area of production. The main goal was to improve the milk yield genetic level of these breeds in the framework of feeding systems based on the use of high quantities of roughage to increase the self-sufficient production of the farms and to account for the regulations of the brand name cheeses. This first objective has actually been reached (especially for the Lacaune breed). Under these conditions, the new objectives in the future will focus on increasing the selection intensity on milk composition and functional traits with the aim of maintaining this production in mountain areas. Thus, research on secondary traits regarding milk traits has been increasing in recent years. A way to construct total indices for dairy sheep based on sub index or super traits is discussed in this paper.

Key words: Dairy sheep, local breed, production environment, brand name cheese, dairy traits, functional traits, super traits, total merit index, sub indices.

RESUME - *"Sélection pour des super-caractères ou sous-index : Une approche pratique chez les ovins laitiers". En France, les efforts de recherche-développement en génétique des brebis laitières ont porté au cours des 30 dernières années sur la conception et la mise en place de programmes de sélection des races locales françaises dans leurs zones spécifiques de production. L'objectif principal de sélection portait sur l'amélioration du niveau génétique laitier de ces races locales dans le cadre de systèmes alimentaires fondés sur une forte utilisation des fourrages pour augmenter l'autonomie des exploitations et pour tenir compte du cahier des charges des fromages de brebis à AOC. Ce premier objectif a effectivement été atteint (particulièrement pour la race Lacaune). Dans ces conditions, les nouveaux objectifs de sélection vont focaliser dans le futur sur un accroissement de la sélection sur la composition chimique du lait et la prise en compte des caractères d'aptitudes fonctionnelles dans le but de maintenir cette production en zones de montagne. C'est pourquoi les recherches intéressant les caractères secondaires vis-à-vis du lait se sont accrues au cours des dernières années. Nous présentons dans ce papier une façon de construire des index globaux de sélection en ovins laitiers fondée sur la définition de sous-index ou super-caractères.*

Mots-clés : *Ovins laitiers, race locale, environnement de production, fromage à AOC, caractères laitiers, caractères d'aptitudes fonctionnelles, super-caractères, index global de sélection, sous-index.*

Introduction

In France, normal husbandry systems for dairy sheep include a suckling period (or a combined suckling plus milking period) of a least one month, before the milking period. Thus these systems have a dual purpose with income from meat and milk, the milk being generally processed into high quality cheese, while meat production usually corresponds to milk-suckled lambs slaughtered at weaning at one month old. Nevertheless the lambs may be fattened up to 100-120 days of age for the Lacaune breed regarding its good growth rate ability.

Furthermore, efforts in research and extension have been fowsed for the last 30 years on the design and implementation of breeding programmes using local breeds in their specific area of production: the Lacaune breed in the Roquefort area, the Basco-Bearnaise and Manech breeds in the Pyrenees Mountains, and the Corsica breed in the island of Corsica. As described above, the French dairy sheep systems have a dual purpose, with 2/3 (to 3/4) income for milk and 1/3 (to 1/4) for meat with one out-of-season lambing period a year. Consequently, the main goal was to improve dairy traits of the French local breeds in their specific area of production. This first objective has been actually reached, specially for the Lacaune breed, since its genetic level for milk yield has increased by about 88 litres (i.e., about 3 standard genetic deviations) between 1980 and 1994 (Barillet *et al.,* 1996).

Under these conditions, the new objectives in the future will focus on increasing the selection intensity on milk composition and functional traits with the aim both of reducing the production costs and of maintaining this production in mountain areas in the framework of brand name cheeses. The purpose of this paper is to discuss the way to construct total indices, as robust as possible, to the economic weighting of each trait.

The difficulties to construct the total merit index (TMI)

We have summarized in Table 1 possible breeding goal traits which could be of interest in dairy sheep breeding. The production traits correspond to milk and meat income, while functional traits may be of interest from an economic or biological point of view in order to support an efficient production in local areas of breeding. According to the classical selection index theory (Hazel, 1943) and its applications to livestock production (Hogset and Nordskog, 1958; Soller *et al.,* 1966; Mc Clintock and Cunningham, 1974; Elsen, 1977) a total merit index (TMI) corresponding to the global breeding goal may be constructed as the sum of estimated breeding values for all traits weighted by their marginal economic values.

Table 1. Summary of possible breeding goal traits in dairy sheep breeding

Breeding goal	Traits
Production traits	
Milk†	Milk yield, fat and protein yield, fat and protein content
Meat (milk suckled lamb)	Prolificacy, suckling ability of the mother
Meat (fattened lamb)	Growth rate, carcass weight, meat quality, conformation
Functional traits	
Efficiency of milk production	Milk, body weight, feed intake capacity, corporal reserves
Reproduction	Sexual precocity, out of season lambing ability, fertility
Milkability	Milking speed, temper, udder traits
Udder health	Somatic cell count, mastitis, teat placement, udder attachment
General health	Longevity, functional survival, feet and legs
Adaptation to local conditions	Flocklife, wool

†Milk after the weaning of the lambs

If we look at Table 1, the number of possible breeding goal traits to select for is up to 29 single traits, but few of them are actually recorded in the breeding programmes and/or are replaced by indirect traits less expensive to record. This makes it nearly impossible to derive accurately all necessary parameters. It must be borne in mind that TMI are the most efficient indices only if the marginal economic values are precisely known and if the genetic parameters between all traits are also well known. It is obvious that we are far away from these conditions in dairy sheep, especially since the economic conditions are just now moving rapidly. Furthermore the possible single traits are too numerous (Table 1) to derive precisely all necessary parameters. To solve the problem, it is necessary to reduce the number of traits to an operational dimension. Thus it makes it also possible to respect the well known condition that the number of traits in a selection index should be limited.

Selection indices for super traits or sub indices

As proposed in dairy or beef cattle (Groen and Ruyter, 1990; Claus and Reinhardt, 1996; Groen, 1996; Visscher and Amer, 1996) the construction of TMI may be carried out in two steps: (i) combine single traits to sub indices or super traits (e.g., "milk production", etc.); (ii) combine sub indices to a total merit index (TMI).

Super traits are aggregate basic traits which present a useful biological meaning from a breeder's point of view and which are generally highly correlated. Thus within a super trait, problems related to uncertain marginal economic values or genetic parameters may often be minimized. The main super traits that we propose to use in dairy sheep breeding are listed in Table 2. Their number is reduced to 4 or 5, compared to the 29 single traits of the Table 1, since the basic traits are summarized in a limited number of "key-traits". In a second step, these sub indices may be combined with a TMI using the classical theory. Thus advantages of selection index theory may be used in super traits, while it can be expected to avoid, at least partly, disadvantages previously described.

Table 2. A proposal for definition of the main supertraits or sub index to be used in dairy sheep breeding

Super trait	Traits in sub index for this super trait
(Efficiency of) milk production	Fat and protein yield and (fat) protein content
Milkability and udder health	Milking speed, somatic cell count (mastitis), linear scored udder type traits
(Efficiency of) milk-suckled lamb production	Prolificacy
(Efficiency of) fattened lamb production	Carcass weight, meat quality, conformation
Reproduction	Sexual precocity, out of season lambing ability, fertility
Flocklife	Lifespan, resistance to disease, linear scored type traits

Examples of construction of sub indices

Efficiency of milk production

As for dairy cattle, the dairy breeding objectives are classically summarized in the increase of milk income (Table 2) rather than in the progress of margin per ewe. Such a simplification is acceptable only if the dairy selection keeps or increases the feed efficiency. Furthermore we must remember the selection framework of the local French dairy sheep breeds located in their specific mountains area with feeding systems based on the use of high quantities of roughage. Thus it is necessary to study in a first step the genetic relationships between the components of the feed efficiency, i.e., body weight, feed intake (of roughage) and balance of corporal reserves, according to the milk yield genetic merit of the ewes. Therefore in the Lacaune breed, a divergent selection experiment is in progress (in the INRA experimental farm of La Fage) since 1988 to answer this question (Colleau *et al.,* 1996). The main results are summarized in Table 3 for the 2 divergent lines which have been selected on milk yield merit from AI rams of the on-farm breeding programme. There is a genetic gap of 60 litres per lactation for the High versus Low line (i.e., 2 standard genetic deviations or 10 years of the Lacaune breeding plan): the ewes were fed a complete total mixed ration including high quality roughage and only 6 to 19% of concentrate. For the first three years of this experiment High line's ewes produced on average 22% more milk during the second and third month of the lactation (as expected) and took in 10% more feed than those of the Low line. Moreover, ewes from the High line had half as much body energy gain as those of the Low line with a similar body weight (Marie *et al.,* 1996). Thus Gross Efficiency (economical criteria) is strongly improved for High Line's ewes (0.36 versus 0.31) and smaller Residual Feed Intake (biological criteria) of High line's ewes tends to show an increase of efficiency for High line. From the biological point of view, the two main results of this experiment regard the absence of indirect genetic response on body weight when selecting on milk yield merit, while the feed intake capacity of roughage has been increased. So, basic traits as body weight, feed intake capacity and corporal reserves balance may be neglected for the construction of the super trait "efficiency of milk production" which may include only the usual dairy traits classically (and more easily) recorded on-farm. Therefore the simplification of dairy breeding goal based on the increase of milk income rather than the progress of margin per ewe appears to be available. We have to keep in mind that such a favourable indirect response is due to the fact that the Lacaune ewes have been on-farm selected in the framework of feeding systems based on the use of high quantities of roughage to increase the self-sufficient production of the farms in the Roquefort area.

Table 3. Components of the feed efficiency of 2 Lacaune divergent (High and Low) lines selected on milk yield merit from AI rams of the breeding programme. (120 ewes lambs at the INRA experimental farm of La Fage between 1994 and 1996) (Marie *et al.*, 1996)

Components (daily)	Least squares means (adjusted for fixed effects)		Difference H - L	Line effect
	Low line	High line		
Days in milk (d)	64	64	0	NS
Milk yield (l/d)	1.55	1.92	+0.37	***
Standard milk yield† (l/d)	1.32	1.65	+ 0.33	***
Feed intake (kg/d)	1.95	2.15	+ 0.20	*
Body weight (kg)	63.0	64.8	1.8	NS
Body condition score	2.98	2.85	- 0.13	NS
Variations of corporal energy (Mcal/d)	0.40	0.17	- 0.23	***

†Milk yield standard in energy on the basis of 1.195 Mcal/l (computed from milk yield and milk composition) (Bocquier *et al.,* 1993)
*P<0.05; **P<0.01; ***P<0.001
NS: P>0.10

In a second step, we have to weight the dairy traits to construct "the milk production subindex (MPS) or super trait for milk production". If we assume that the ewes of the nucleus flocks are recorded both for milk yield and milk composition (fat and protein contents), 5 dairy traits (and their breeding value estimation -BVE-) are available for each candidate to be selected: milk yield (M), fat yield (F), protein yield (P), fat content (F%) and protein content (P%). The ewe milk is mainly processed into high quality cheeses known for their high ratio of fat to dry content. Under these conditions, the main dairy objective is the cheese output which is directly related to the dry matter yield (F+P), while (P%) and (F%/P%) represent respectively the best predictors for cheese yield and fat to dry matter of the cheese. To illustrate this point, we have tested 5 sorts of MPS which are linear combination of the following dairy traits: M, F% & P%, F & P, F & P & P%, P & P%, as described in Table 4.

1955 Lacaune rams and 508 Pyrenean rams, born between 1990 and 1994, all having proofs for all the 5 dairy traits with average repeatabilities near 0.70 for milk yield and 0.80 for fat or protein contents (Table 7) have been used for analysing the effect of the possible weighings (Table 4) for the sub index MPS. The mean milk traits proofs of top-10% ranked rams within alternative MPS are given in Tables 5 and 6 respectively for Lacaune and Pyrenean breeds. The main results may be summarized as follows:

(i) In any case MPS2 or MPS3 may be chosen as sub index because of the high decrease of milk (M) and stagnant dry matter yield (despite increase of F% and P%) which present dramatic negative consequences on milk income.

(ii) If we assume an efficient breeding programme at the equilibrium, selection on milk yield only (MPS1) may be replaced by sub index as MPS4, MPS5 or MPS6 (a_1 F + a_2 P) to remove the antagonism between M and F% or P% and to maximize the genetic response on dry matter yield (F+P), i.e., the cheese output. MPS4, MPS5 and MPS6 are rather robust against economic weights (a_1 or a_2 may range between 0 and 1) due to the very high genetic correlations between M, F and P (as illustrated in Table 7 with the correlations between milk traits proofs) and also because F is more variable than P (Barillet, 1985; Barillet and Boichard, 1987).

(iii) The selection on MPS4, MPS5 or MPS6 leads to a possible decrease in P%. Accordingly it seems preferable to use as MPS a combination of F, P and P%: a_1 F + a_2 P + a_3 P%. But a_3 depends strongly on the payment for the chemical composition of the milk and it can be pointed out that the genetic response on M is decreasing dramatically when a_3 is up to 1/5 (with F or P expressed in kg and P% in g/l).

Table 4. Relative milk traits weights for milk production subindex -MPS-

Milk production subindex MPS	Relative milk traits weights for MPS				
	Milk yield M (l)	Fat yield F (kg)	Protein yield P (kg)	Fat content F% (g/l)	Protein content P% (g/l)
MPS1	1	0	0	0	0
MPS2	0	0	0	1	0
MPS3	0	0	0	0	1
MPS4	0	1	0	0	0
MPS5	0	0	1	0	0
MPS6	0	1	1.85	0	0
MPS7	0	1	1.85	0	1/20
MPS8	0	1	1.85	0	1/10
MPS9	0	1	1.85	0	1/5
MPS10	0	1	1.85	0	1/2
MPS11	0	1	1.85	0	1
MPS12	0	0	1	0	1/20
MPS13	0	0	1	0	1/10
MPS14	0	0	1	0	1/5
MPS15	0	0	1	0	1/2
MPS16	0	0	1	0	1

To summarize, it is recommended "to define MPS as a linear combination of F and P (a_1 F + a_2 P) in replacement of M when the breeding programme reaches the equilibrium", seeing that the choice of a_1 and a_2 is rather robust and leads to marginal economic differences. In reverse "the introduction of P% in the MPS depends on the payment for the chemical composition of the milk", i.e., is not robust to economic weights (Barillet *et al.*, 1995).

Table 5. Mean milk traits proofs of top-10% ranked rams within alternative weighings of milk traits in milk production subindex (MPS) for Lacaune breed (195 sires out of 1955 sires born between 1990 and 1994)

Subindex -MPS-	Top-10% in MPS M (l)	F (kg)	P (kg)	F% (g/l)	P% (g/l)	Δ Milk income (ECU) Milk Price I	Milk Price II	Milk Price III
MPS1	53.5	2.87	2.18	-1.5	-1.4	42.80	41.43	37.17
MPS2	-11.6	0.99	-0.10	6.1	1.7	-9.28	-8.49	-6.31
MPS3	-22.9	-0.53	-0.09	3.3	3.9	-18.32	-16.22	-12.21
MPS4	50.1	3.31	2.22	0.5	-0.8	40.08	39.84	39.11
MPS5	51.0	2.95	2.38	-0.7	-0.3	40.80	40.35	39.07
MPS6	51.3	3.16	2.35	-0.2	-0.5	41.04	40.68	39.63
MPS7	50.2	3.11	2.36	-0.0	-0.2	40.16	40.05	39.72
MPS8	48.8	3.10	2.39	0.2	0.0	39.04	39.12	39.43
MPS9	45.4	3.02	2.34	0.7	0.5	36.32	36.82	38.25
MPS10	29.9	2.38	1.98	1.9	1.9	23.92	24.99	28.07
MPS11	9.4	1.29	1.27	2.8	3.1	7.52	7.93	9.56
MPS12	49.9	2.93	2.38	-0.5	-0.1	39.92	39.67	38.96
MPS13	48.4	2.88	2.37	-0.4	0.1	38.72	38.62	38.35
MPS14	44.1	2.73	2.34	0.0	0.7	35.28	35.62	36.61
MPS15	26.9	1.98	1.91	1.3	2.2	21.52	22.45	25.11
MPS16	8.5	1.12	1.28	2.3	3.2	6.80	7.26	8.56

Milk price I: 0.80 ECU per litre whatever the F% and P%
Milk price II: 0.80 ECU per litre and differential price of 0.008 and 0.011 ECU respectively per g F% and P%
Milk price III: 0.80 ECU per litre and differential price of 0.030 and 0.043 ECU respectively per g F% and P%

Table 6. Mean milk traits proofs of top-10% ranked rams within alternative weighings of milk traits in milk production subindex (MPS) for Pyrenean breeds (50 sires out of 508 sires born between 1990 and 1994)

	Top-10% in MPS					Δ Milk income (ECU)		
Subindex -MPS-	M (l)	F (kg)	P (kg)	F% (g/l)	P% (g/l)	Milk Price I	Milk Price II	Milk Price III
MPS1	34.8	1.53	1.17	-1.3	-1.2	27.84	27.02	24.69
MPS2	-4.6	0.55	-0.06	5.9	1.2	-3.68	-3.40	-2.63
MPS3	-13.3	-0.41	-0.10	1.9	3.2	-10.64	-9.96	-8.09
MPS4	33.3	1.67	1.12	0.3	-0.8	26.64	26.43	25.79
MPS5	34.1	1.51	1.17	-0.8	-0.7	27.28	26.80	25.44
MPS6	34.2	1.60	1.16	0.5	-0.8	27.36	26.92	25.67
MPS7	33.6	1.59	1.16	-0.2	-0.6	26.88	26.60	25.81
MPS8	33.0	1.61	1.18	-0.1	-0.4	26.40	26.23	25.73
MPS9	30.2	1.44	1.09	0.4	0.3	24.16	24.36	24.91
MPS10	17.2	1.06	0.85	1.9	1.9	13.76	14.38	16.15
MPS11	4.0	0.42	0.40	2.7	2.8	3.20	3.41	4.01
MPS12	33.7	1.51	1.17	-0.7	-0.5	26.96	26.58	25.53
MPS13	31.8	1.48	1.15	-0.2	-0.0	25.44	25.39	25.25
MPS14	29.4	1.45	1.16	0.1	0.4	23.52	23.74	24.11
MPS15	16.9	0.96	0.81	1.6	1.9	13.52	14.09	15.71
MPS16	4.7	0.41	0.43	2.3	2.8	3.76	3.99	4.65

Milk price I: 0.80 ECU per litre whatever the F% and P%
Milk price II: 0.80 ECU per litre and differential price of 0.008 and 0.011 ECU respectively per g F% and P%
Milk price III: 0.80 ECU per litre and differential price of 0.030 and 0.043 ECU respectively per g F% and P%

Table 7. Correlations between milk traits proofs and mean repeatability of proofs for Lacaune and *Pyrenean* breeds

	M		F		P		F%		P%		$r_{u\hat{u}}^2$	
M	1										0.70	*0.69*
F	0.91	*0.96*	1								0.70	*0.69*
P	0.93	*0.98*	0.92	*0.97*	1						0.70	*0.69*
F%	-0.25	*-0.22*	0.17	*0.05*	-0.07	*-0.13*	1				0.80	*0.51*
P%	-0.37	*-0.41*	-0.15	*-0.28*	-0.01	*-0.22*	0.52	*0.48*	1		0.80	*0.51*

Meat production (milk suckled lamb)

For meat production based on milk suckled lamb, different studies have been carried out regarding the traits to be measured and the genetic improvement strategy (Barillet *et al.,* 1988): income for milk suckled lamb production depends basically on "prolificacy which represents the second super trait", since the suckling ability of the mothers is sufficient due to the dairy selection. Seeing that prolificacy has a very small heritability (~0.03-0.05) and that the genetic correlation with milk yield is slightly positive (~0.2-0.3), a very slow genetic increase in prolificacy (0.006 lamb born per year) is expected with or without including prolificacy in total merit index (TMI). Nevertheless, it can be useful to define this second super trait (prolificacy) to avoid any possible genetic drift regarding the rather small number of elite progeny tested rams of an efficient breeding programme.

Milkability and udder health

Until now, no dairy sheep breed has been directly selected on milkability. But this does not mean no indirect genetic response on milkability: in case of an efficient breeding program carried out on milk yield we can expect an indirect response on milkability if the ewes are milked by machine and if the breeders of the nucleus flocks have been their milking routine. Therefore we are studying the milkability of our divergent (Low and High) Lacaune lines (described above for feed efficiency purposes) using our automatic milk recording system with its electronic jars (Guillouet *et al.,* 1990; Ricard *et al.,* 1994): there are significant differences between the 2 divergent lines for milk flow curves (unpublished results) showing an indirect response on milkability for Lacaune breed. Moreover we have to keep in mind that any extra records are difficult and therefore expensive to implement in dairy sheep compared to dairy cattle. Seeing that the breeders expected to carry out a direct selection on milkability, we need to be sure that it well be more efficient than the indirect response and we also have to study simultaneously possible negative changes on udder health. Therefore research is carried out in our INRA experimental farm of La Fage (with the 2 divergent lines) on milk flow rates and linear udder traits, and also somatic cell count and mastitis. Our project is to study genetic parameters between all these traits related to milk yield merit with the aim of defining which traits to include in "the third super trait milkability and udder health". In the same way, we can consider the linear evaluation system for udder traits designed for the Churra breed (de la Fuente *et al.,* 1996).

Conclusion

The question of the breeding strategy of dairy sheep has been an ongoing debate for Mediterranean countries, from an on-station closed nucleus flock using modern reproduction techniques such as embryo transfer to an open on-farm breeding programme based on the use of AI. Seeing the indirect genetic responses on feed efficiency components, the on-farm selection may be recommended.

Under these conditions with the aim of implementing the on-farm milk recording on a large scale, it is suitable to select for milk yield only at the starting period of the breeding programme (to reduce the cost of the milk recording). Then when it reaches the equilibrium, a linear combination of fat and protein yield may replace milk yield in the milk production sub index (MPS). Protein content may also be included in MPS depending on the payment for the chemical composition of the milk. When this new goal has been reached, the new objectives will focus on functional traits. Therefore we propose to construct total indices based on sub index or super traits to reduce the difficulties to define the total merit index (TMI). At present research is in progress in France to decide which traits to include in other super traits than MPS and/or to compute BVE for some super traits already defined as meat (milk suckled lamb). Finally we will have to test the sensitivity of TMI for economic weighing of sub index in the same way that MPS for dairy traits. However definition and weighing of super traits (especially those related to functional traits) remain difficult topics requiring a pluri-disciplinary approach including genetic, economic, physiological and modelling competences.

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