Consequences of Selection for Milk Quality and Robustness Traits

C. Bastin [1], D.P. Berry [2], M.P. Coffey [3], E. Strandberg [4], J.I. Urioste [4,5], R.F. Veerkamp [6], and N. Gengler [1,7]

[1] Animal Science Unit, Gembloux Agro-Bio Tech, University of Liège, B-5030 Gembloux, Belgium
[2] Moorepark, Teagasc, Ireland
[3] Sustainable Livestock Systems Group, Scottish Agricultural College, EH25 9RG United Kingdom
[4] Dept. Animal Breeding and Genetics, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden
[5] Depto. Prod. Animal y Pasturas, Fac. de Agronomía, UDELAR, Garzón 780, 12900 Montevideo, Uruguay
[6] Animal Breeding and Genomics Centre, Wageningen University, Wageningen, the Netherlands
[7] National Fund for Scientific Research, B-1000 Brussels, Belgium

Introduction

A multitude of studies in dairy cattle (Pryce and Veerkamp, 2001) have shown that selection for higher milk yield alone is associated with reduced health and fertility. For this reason, most countries are now including an increasing number of non-productive and functional traits (e.g., conformation, longevity, udder health, calving performances, workability) in their national dairy breeding objectives. Breeding programs could also include other functional and robustness traits (e.g. feed efficiency or energy balance) but also other traits like animal welfare, human health, environmental impact of milk production, or product quality. Even if these new traits currently have no (or undefined) monetary value, it is suggested that better overall economic efficiency could be achieved if they are included in breeding goals. However, before doing this, the consequences of shifting emphasis from the current traits in the breeding objective to these new traits should be investigated particularly given that genomics is likely to lead to accelerated rates of gain.

The objective of this study was to estimate the consequences of selection for new robustness and milk quality traits on genetic gain in other economically important traits. The study was conducted in 3 steps. First the total merit indexes of five European countries/regions participating in the EU project ROBUSTMILK were compared and several scenarios of selection were defined. Second, genetic correlations among traits were estimated based on the estimated breeding values (**EBV**) of Walloon Holstein bulls. Finally consequences of selection under the different scenarios (e.g. inclusion of new robustness and milk quality traits) were studied using selection index theory. New traits considered were body condition score (**BCS**) for robustness and dUNSAT and dMONO for milk quality. These two indices represent the relative part of milk fat that is unsaturated or mono-unsaturated.

Materials and Methods

National selection indices

Table 1 shows the relative emphasis on traits in national breeding objectives for EBI (Ireland), £PLI (Great Britain), NTM (Denmark, Finland and Sweden; DFS), NVI (Flanders and the Netherlands), and V€G (Walloon Region of Belgium).

Table 1. Relative emphasis on traits in national selection indices in June 2011.

Index	EBI	£PLI	NTM	NVI	V€G
Production	**35**	**45.2**	**31**	**33**	**48**
− Milk yield[1]	10	10.9	5	9	10
− Fat yield	4	12.4	5	5	9
− Protein yield	21	21.9	21	19	29
Functionality	**44**	**45.1**	**54**	**45**	**28**
- Udder health (SCS)	3	5.5	14	6	5
- Fertility	25	18.5	13	19	
- Longevity	8	21.1	5	20	23
- Calving index	7		7		
- Birth index	1		6		
- Other disease			5		
- Milkability			3		
- Temperament			1		
Beef/maintenance	**20**		**2**		
Type	**1**	**9.7**	**13**	**22**	**24**
- Udder		5.6	7	11	14
- Body					1
- Feet and legs	1		6	11	9

[1] All countries placed negative weights on milk yield.

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Values from Table 1 were updated from the review of Miglior *et al.* (2005). Traits were grouped together under 4 components: production, functionality, beef/maintenance, and conformation. Relative emphasis was expressed as a percentage and was computed as the ratio of every economic weight multiplied by the corresponding breeding value standard deviation divided by the sum of the absolute values of these.

Approximate genetic correlations among traits

Estimated breeding values of the August 2011 routine run for the Walloon region of Belgium were extracted for Holstein bulls with a reliability ≥ 0.85. Breeding values were available for the following traits:

- **production**: milk, fat, and protein yield (1274 bulls),
- **udder health**: somatic cell score (under the Walloon definition, lower values of SCS are desirable; 1192 bulls),
- **longevity**: survival over successive lactations (275 bulls),
- **fertility**: pregnancy rate (589 bulls),
- **udder**: overall udder score (548 bulls),
- **feet and legs**: overall feet and legs score (371 bulls),
- **BCS**: EBVs are expressed as the minimum daily EBV for BCS before 200 DIM (Bastin *et al.,* 2010) (higher values are desirable; 231 bulls),
- **milk fatty acids**: dUNSAT and dMONO (these two indices represent the relative part of milk fat that is unsaturated or mono-unsaturated, high values are desirable; 314 bulls).

Genetic correlations among traits were approximated as correlations among EBVs. Table 2 shows the approximate genetic correlations obtained and the number of bulls used to estimate each correlation. Most of the bulls used to approximate genetic correlations originated from the United States, then the Netherlands, Canada, France and Germany.

Response to selection

Six alternative "European" total merit indexes were defined and included traits for which breeding values were available in the Walloon Region. Relative genetic changes for each trait from selection based on these alternative total merit indexes were estimated as $r = b'G$ where r = vector of relative genetic gain on all traits; and b = optimal index weights; G = matrix of genetic covariances between index traits and goal traits. Optimal index weights b were calculated as $b = P^{-1}Gv$ where P = matrix of genetic covariances among index traits, and v = vector of relative economic values of goal traits. Selection intensity was set to 1 and for one generation. All scenarios are listed in Table 3.

Table 2. Genetic correlations (r_g) approximated as correlations among EBVs and the number of bulls used to estimate the correlations; all traits are defined above.

Traits		Fat	Protein	Longevity	SCS	Fertility	Udder	Legs	BCS	dUNSAT	dMONO
Milk	r_g	0.54	0.88	0.36	0.08	-0.55	0.05	0.02	0.01	-0.23	0.04
	N	1274	1274	275	1192	574	536	369	231	314	314
Fat	r_g		0.68	0.24	0.04	-0.45	-0.19	-0.06	-0.04	-0.25	-0.15
	N		1274	275	1192	574	536	369	231	314	314
Protein	r_g			0.29	0.12	-0.47	-0.08	0.01	0.10	-0.07	0.16
	N			275	1192	574	536	369	231	314	314
Longevity	r_g				-0.39	-0.22	0.42	0.26	-0.04	-0.34	-0.01
	N				275	274	224	190	162	248	248
SCS	r_g					-0.15	-0.20	-0.02	-0.06	0.06	0.06
	N					574	534	365	231	314	314
Fertility	r_g						-0.12	0.02	0.30	0.25	0.02
	N						417	322	223	299	299
Udder	r_g							0.34	-0.17	-0.14	-0.03
	N							337	231	228	228
Legs	r_g								0.05	0.06	0.11
	N								219	174	174
BCS	r_g									0.06	0.02
	N									150	150
dUNSAT	r_g										0.79
	N										314

Scenario 2 was the reference point for scenarios 3 to 6: changes in relative emphasis for one or several trait(s) affected proportionally all other traits. Scenarios were:

1) *selection for production traits only*: included only milk, fat, and protein yield derived from the average values of Table 1;
2) *"current" European selection*: included traits that are currently in the national indices; relative emphasis were derived from the average values of Table 1;
3) *more emphasis on the current functional traits*: overall emphasis on functionality was 55% (as for DFS index) with greater emphasis on fertility (20%) and udder health (15%) but the same emphasis on longevity (20%) than in scenario 2;
4) *selection pressure on the new robustness traits*: included BCS (10% of emphasis) which is considered as an indicator of the extent of negative energy balance in dairy cows;
5) *selection for the new milk quality traits*: included dUNSAT and dMONO (10% of emphasis), these indices represent the relative part of milk fat that is unsaturated or mono-unsaturated; higher proportion of unsaturated FA in milk fat are considered as beneficial for human health;

6) *selection for both milk quality traits and functionality/robustness traits*: combination of scenarios 3 to 5 and placed 15% emphasis on udder health, 20% emphasis on fertility, 10% emphasis on BCS, and 10% on milk quality traits .

Table 3. Selection scenarios .

Scenario	1	2	3	4	5	6
Production	100	45	33.75	40.5	40.5	18.75
- Milk yield[1]	22	10	7.50	9	9	4.17
- Fat yield	18	8	6.00	7.2	7.2	3.33
- Protein yield	60	27	20.25	24.3	24.3	11.25
Functionality		40	55	36	36	55
- Longevity		20	20	18	18	20
- Udder health		5	15	4.5	4.5	15
- Fertility		15	20	13.5	13.5	20
Type		15	11.25	13.5	13.5	6.25
- Udder		7	5.25	6.3	6.3	2.92
- Feet and legs		8	6	7.2	7.2	3.33
New traits				10	10	20
- BCS				10		10
- dUNSAT					5	5
- dMONO					5	5

[1] All scenarios placed negative weights on milk yield.

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Results and Discussion

National selection indices

Table 1 indicates that countries/regions in this study place 31% to 48% emphasis on production traits while Miglior *et al.* (2005) reported in 2005 that most countries placed at least 50% emphasis on the production component. This observation confirms the increasing emphasis given to the non-production traits. Moreover, national indices differ in the number of functional traits included in the indices. DFS includes a total of 8 functional traits while the Walloon Region includes only longevity and udder health. Also, Ireland and DFS place some emphasis on beef /maintenance traits, 20% and 2% of relative emphasis, respectively. Finally, relative emphasis placed on type traits vary from 1% to 24% but is rather related to the "functional type traits" such as udder and feet and legs traits.

Expected genetic changes under several selection scenarios

Relative genetic gains expected on all traits under the different scenarios are presented in Table 4.

It should be noted that results have to be interpreted carefully. First, because expected genetic gains under all selection scenarios are greatly influenced by the genetic correlations among traits (Table 2). These correlations were approximated as the correlations among EBVs. Although only EBVs with reliability greater than 0.85 were used, the number of bulls used to estimate correlations remains low: from 150 to 1274. Further studies should provide more reliable correlation estimates among traits, especially for the novel traits for which low number of bulls have breeding values estimated with high reliability. Second, the responses presented in Table 4 assume that all breeding values for all traits have equal reliability. That might not be the case at the moment of selection. It is therefore somewhat idealized scenarios for demonstration purposes. In practice accuracy will differ due to heritability and different recording (e.g. longevity and fertility).

Results in Table 4 indicated that selection for production traits only (scenario 1) lead to large

improvements in yield, especially protein yield (+53%). However, such selection resulted in higher SCS (+6%), and to poorer fertility performance (-25%). These results were as previously suggested by several authors who indicated that selection for milk yield alone is likely to reduce fertility (Pryce and Veerkamp, 2001). Also unfavorable correlated responses were also observed for overall udder score (-10%). Selection indexes with balanced emphasis on both production and non-production traits (scenarios 2 to 5; from 34 to 45% emphasis on production traits) resulted in improvements of milk, fat, and protein yield (genetic gain from +10% to +21%) but also favorable genetic gains in most of the other traits. Finally, selection with scenario 6 (only 19% emphasis on production) provided low genetic gain for milk, fat and protein yield (genetic gain between +1% and +6%) but great improvements of functional traits: +24% for longevity, -25% for SCS, and 17% for fertility.

The "current European" breeding goal (scenario 2) gave desirable genetic gain on all traits except for dUNSAT (-6%) and fertility (0%). Greater emphasis should therefore be placed on fertility to achieve genetic improvement in that trait. Emphasis of 20% on fertility combined with greater emphasis on udder health (scenario 3) lead to improved fertility (+9%) and reduced SCS (-25%). Inclusion of BCS into the total merit index (scenario 4) was associated with slightly improved fertility (+3%), while selection under scenario 6 (i.e. lower emphasis on production, 20% emphasis on fertility, and 10% emphasis on BCS) resulted in 17% improvements in fertility. These results reinforce that selection for higher BCS is related to improved fertility. The approximate genetic correlation between pregnancy rate and BCS was 0.30 (Table 2).

Under all scenarios, favorable genetic gain was expected for longevity: from +14% to +30%. These results could be explained by the positive genetic relationships between longevity and milk, fat, and protein yield, and SCS. Furthermore, current selection (scenario 2; 5% emphasis on udder health) lead to reduced SCS (-14%) but greater improvements (-25%) could be achieved with 15% emphasis on udder health under scenarios 3 and 4.

Slightly favorable genetic gain was expected on BCS (+5%) under scenario 1 while previous studies indicated that selection for higher milk yield is related to lower BCS. This was probably due to the low correlations between EBVs for BCS and milk, fat, and protein yield (Table 2). Higher emphasis on BCS (scenario 4) did not affect greatly traits other than fertility as genetic correlations were low (Table 2). However including BCS in a selection index should be considered as BCS is an indirect indicator of health and fertility rather than a trait of economic importance.

Changes in the balance between production and functional traits did not seem to affect genetic gain on milk quality traits: genetic gains were low under scenarios 1 to 4 and ranged between +2% and +6% for dMONO and -4% and -6% for dUNSAT. A relative emphasis of 2.5% on dUNSAT and dMONO would be required to have no genetic changes on dUNSAT; such economic index would lead to 7% of genetic gain for dMONO. Under scenarios 5 and 6, 5% emphasis on dUNSAT and dMONO provides favorable genetic gain: about 5% for dUNSAT and 10% for dMONO. However further studies should be conducted to determine what would be the optimal emphasis on both classical production traits and new milk quality traits to maximize incomes from milk with desirable fatty acids profile.

Table 5. Relative genetic gain expected on all traits under each scenario.

Scenario	1	2	3	4	5	6
Production						
- Milk yield	40.5	17.9	11.3	16.2	15.2	4.3
- Fat yield	46.9	17.0	9.6	14.9	13.3	0.8
- Protein yield	52.9	21.3	12.0	20.2	19.6	5.7
Functionality						
- Longevity	13.6	29.8	29.8	26.4	25.1	23.9
- Udder health	6.2	-13.9	-24.9	-13.1	-11.9	-25.3
- Fertility	-24.6	-0.3	9.1	2.8	1.1	17.4
Type						
- Udder	-9.6	13.1	13.1	10.1	10.9	8.8
- Feet and legs	-1.1	15.6	13.5	14.5	14.9	11.6
New traits						
- BCS	5.2	5.6	7.3	15.1	5.4	17.2
- dUNSAT	-3.8	-5.5	-4.3	-4.3	4.0	6.0
- dMONO	5.6	3.1	1.8	3.0	11.8	9.9

Conclusion

Current breeding goals put more balanced emphasis on both production and non-production traits which lead to total merit indexes including an increasing number of functional traits. Such indices lead to favorable genetic gains on production but also on most of the other traits. Also current selection indices do not affect greatly new traits: BCS and dMONO are slightly favorably affected and dUNSAT is slightly negatively affected.

Further studies will focus on two major points: 1) providing more reliable estimates of genetic correlations among traits as these estimates influence largely the results, and 2) including other new robustness and milk quality traits (energy balance indicators, new udder health traits, etc.) in the alternative indexes.

Acknowledgments

References

Bastin, C., Gillon, A., Massart, X., Soyeurt, H., Vanderick, S., Bertozzi, C. & Gengler, N. 2010. Genetic evaluation for body condition score in the Walloon Region of Belgium. *Interbull Bulletin 42*, 85-90.

Miglior, F., Muir, B.L. & Van Doormaal, B.J. 2005. Selection indices in Holstein cattle of various countries. *J. Dairy Sci. 88*, 1255-1263.

Pryce, J.E. & Veerkamp, R.F. 2001 The incorporation of fertility indices in genetic improvement programs. *BSAS Occasional Publication 26*, 237–250.