Fat and protein percentage
- relationships with NTM and trait indices
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NAV has been asked to investigate potential benefits of inclusion of fat and protein percentages in the NAV yield index.

From a practical point of view it is of interest to produce milk with increased concentrations of milk solids to increase profit by selling more milk solids and to decrease cost related to transportation of milk from farm to processing plant and to decrease feed costs.

The current NAV yield index is composed of milk, protein and fat yield. Fat and protein percentage are functions of fat and protein yield, respectively, and milk yield and is *per se* already included in the current yield index. NAV has published traditional breeding values for fat and protein percentage since 2005 and provided official genomic breeding values for fat and protein percentage since February 2016.

Relationship between fat and protein percentage and NTM
In Table 1, 2, and 3 correlations between fat and protein percentage and NTM and NTM traits including fat, protein and milk yield are presented for proven bulls (born 2009-2012) and genomic bulls (born 2013-2016) for Holstein, RDC and Jersey, respectively. For all breeds the correlations between NTM and both fat percentage and protein percentage were moderately positive (r = 0.14-0.32). Thus, selecting for increased NTM will result in increased fat and protein percentages. The correlation strength reflects the weight of the yield index in NTM (0.75, 0.87, and 1.00 for Holstein, Jersey and RDC, respectively) and how fat and protein yield is weighted in the yield index (Table 4).

Relationship between fat and protein percentage and yield index
The correlations between fat and protein percentage and the yield index were also positive (r = 0.06 - 0.27). Thus, increased index values for yield will also result in increased fat and protein percentages. The correlations between milk yield and fat and protein percentage were in all cases strongly negative (r = -0.57 - -0.82, strongest in Jersey because of higher relative weights in fat and protein in the yield index. This implies that increased milk yield will result in lower fat and protein percentages (dilution effect). The correlation between fat yield and fat percentage were strongly positive in both Holstein and RDC (≈ 0.50) but low in Jersey (0.18). The correlations between fat yield and protein percentage were moderately positive (r = 0.10 – 0.24) in all three breeds. Also, the correlations between protein yield and protein percentage were slightly negative or close to zero (r = -0.13 – 0.05). Finally, the correlations between fat and protein percentage were very strong (r = 0.75 – 0.92) in all three breeds especially in Jersey.
The weighting factors in Table 4 reflect the correlations structure among the yield traits, i.e. negative weight needs to be put in milk yield (less water) and positive weights on the solids (fat and protein). The results will be less milk, increased fat and protein yield, and increased concentrations of fat and protein, i.e. increased fat and protein percentages.
Fat percentage can be expressed as a function of milk yield and fat yield and fat yield as a function of milk yield and fat percentage - similar for protein. Thus, given the current yield index both fat and protein percentages are already accounted for. It is not possible to include milk yield, fat yield and fat percentage in an index; the same holds for milk yield, protein yield and protein percentage.

Relationship between fat and protein percentage and other NTM traits
In RDC and Jersey the correlations to milking speed were moderately positive. This makes sense since cows with more concentrated milk (less milk) will milk faster. For all three breeds the correlations between fat and protein percentage and mastitis and other diseases were low to moderately positive (r = 0.08 – 0.25). For the remaining NTM traits the correlations between fat and protein percentages and the indices were in most cases close to zero.

Genetic trends for fat and protein percentage
Genetic trends for Holstein, RDC and Jersey cows regarding fat and protein percentage can be found in the documents: *HOL_cow_trends2017*, *RDC_cow_trends2017*, and *JER_cow_trends2017*.

Conclusion
Given that fat and protein percentages are linear combinations of milk yield and fat and protein yield, respectively, it is not possible to include fat percentage and fat yield in a NAV yield index at the same time. The same applies to protein. From the correlations among the current yield traits, the yield index and fat and protein percentages, it can be concluded that despite neither fat or protein percentage being included in the current NAV yield index, the results of the current selection scheme for yield is still increased fat and protein percentage. Finally, as a take home message selection after NTM (increased NTM) will result in increased fat and protein percentages.

Table 1. Correlations between indices for fat and protein percentage and NTM including sub-indices for Holstein bulls born between 2009 and 2012 (proven) and between 2013 and 2016 (genomic[1]).

	Proven, N = 929		Genomic, N = 444	
Trait	Fat %	Protein %	Fat %	Protein %
NTM	0.19	0.30	0.22	0.19
Yield	0.19	0.27	0.18	0.12
Milk yield	-0.63	-0.60	-0.69	-0.76
Protein yield	-0.21	0.03	-0.28	-0.16
Fat yield	0.51	0.24	0.52	0.14
Protein %	0.75	1.00	0.78	1.00
Fat %	1.00	0.75	1.00	0.78
Growth	0.01	0.07	-0.08	-0.11
Fertility	0.04	0.12	0.09	0.10
Birth	-0.01	0.03	0.07	0.04
Calving	-0.09	-0.06	0.03	-0.05
Udder health	0.14	0.16	0.10	0.14
Other diseases	0.11	0.20	0.12	0.22
Frame	-0.03	-0.07	0.03	-0.01
Legs & Feet	0.05	0.02	0.03	0.06
Udder	-0.01	-0.05	0.02	0.07
Milking speed	0.08	0.04	0.04	-0.02
Temperament	-0.01	-0.07	-0.13	-0.14
Longevity	-0.10	-0.07	0.06	0.07
Claw health	0.03	0.08	0.06	0.07
Young stock survival	-0.03	0.01	-0.03	-0.04

[1]When studying the results it should be taken into consideration that the bulls in this group are strongly selected.

Table 2. Correlations between indices for fat and protein percentage and NTM including sub-indices for RDC bulls born between 2009 and 2012 (proven) and between 2013 and 2016 (genomic[1]).

	Proven, N = 836		Genomic, N = 451	
Trait	Fat %	Protein %	Fat %	Protein %
NTM	0.26	0.32	0.15	0.14
Yield	0.18	0.25	0.16	0.13
Milk yield	-0.61	-0.57	-0.64	-0.70
Protein yield	-0.16	0.05	-0.18	-0.07
Fat yield	0.44	0.24	0.38	0.04
Protein %	0.78	1.00	0.77	1.00
Fat %	1.00	0.78	1.00	0.77
Growth	0.06	0.11	0.00	-0.04
Fertility	0.10	0.17	-0.11	-0.03
Birth	-0.08	-0.07	-0.06	0.01
Calving	0.18	0.20	0.08	0.17
Udder health	0.12	0.08	0.06	0.01
Other diseases	0.17	0.18	0.04	0.13
Frame	0.11	0.11	0.11	0.08
Legs & Feet	0.02	0.06	0.09	0.09
Udder	0.09	0.05	0.03	0.03
Milking speed	0.22	0.21	0.16	0.08
Temperament	0.09	0.02	0.14	0.10
Longevity	0.00	-0.03	-0.18	-0.16
Claw health	-0.01	-0.03	-0.09	0.02
Young stock survival	-0.06	-0.06	0.03	0.14

[1]When studying the results it should be taken into consideration that the bulls in this group are strongly selected.

Table 3. Correlations between indices for fat and protein percentage and NTM including sub-indices for Jersey bulls born between 2009 and 2012 (proven) and between 2013 and 2016 (genomic[1]).

	Proven, N = 265		Genomic, N = 192	
Trait	Fat %	Protein %	Fat %	Protein %
NTM	0.26	0.29	0.20	0.32
Yield	0.12	0.16	0.06	0.19
Milk yield	-0.74	-0.71	-0.82	-0.74
Protein yield	-0.25	-0.13	-0.36	-0.10
Fat yield	0.18	0.10	0.18	0.08
Protein %	0.92	1.00	0.86	1.00
Fat %	1.00	0.92	1.00	0.86
Growth	0.12	0.06	0.12	-0.01
Fertility	-0.11	-0.13	0.05	0.00
Birth	0.03	0.04	-0.01	-0.10
Calving	-0.16	-0.17	-0.04	-0.01
Udder health	0.25	0.22	0.10	0.09
Other diseases	0.14	0.19	0.25	0.20
Frame	-0.12	-0.07	0.02	0.12
Legs & Feet	0.03	0.00	-0.11	-0.06
Udder	0.18	0.25	0.21	0.31
Milking speed	0.31	0.32	0.19	0.20
Temperament	-0.10	-0.16	-0.02	-0.10
Longevity	0.01	0.01	0.04	0.04
Claw health	0.09	0.10	-0.05	-0.02
Young stock survival	-0.08	-0.11	0.05	0.03

[1]When studying the results it should be taken into consideration that the bulls in this group are strongly selected.

Table 4. Weight factors for sub-traits in yield index for Holstein, RDC and Jersey

	Weight factor in yield index		
Breed	Milk yield	Fat yield	Protein yield
Holstein	-0,20	0,40	0,80
RDC	-0,20	0,40	0,80
Jersey	-0,30	0,50	0,80