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Prospects of obtaining favourable fatty acid composition of cows milk by feeding

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ABSTRACT

Information from the literature and own data show that the ratio of unsaturated to saturated fatty acids in milk fat, the level of CLA and ω-3 fatty acids can be improved by dietary factors. However, none of the components can be changed without a concomitant increase in *trans* fatty acids, some with unknown human health effects. Diets that effectively affect milk fat composition, often lead to milk fat depression due to inhibition of expression of the genes coding for key enzymes. Potential negative effects on technological and sensory quality cannot be ignored.

KEY WORDS: unsaturated fat, CLA, *trans* fatty acids, milk fat depression, gene expression, antioxidants, vitamin E

INTRODUCTION

Despite a decrease in the relative value of milk fat compared to milk protein, the demand for milk fat is likely to remain high. This is mainly due to its essential impact on the organoleptic quality of milk and most milk products, but also for cultural reasons. However, the image of milk fat has been tainted by the negative human health effects attributed to dietary fat in general and milk fat especially. The alleged negative human health effects include increased risk of cardiovascular diseases and cancer (Williams, 2000; Moorman and Terry, 2004; Mozaffarian et al., 2006).

The negative effects of milk fat have been linked to its high content of saturated fat (up to 65%), especially the short and medium chain fatty acids. Negative health effects of dietary fat have also been linked to low content of ω-3 fatty acid, especially when the ratio of ω-3 to ω-6 fatty acids is low. In milk fat the content of ω-3 is low,

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but the ratio of ω-3 to ω-6 can be rather high. More recently negative health effects of dietary fat have also been linked to mono-unsaturated fatty acids, especially *trans*-fatty acids from industrial saturation of vegetable fat. Milk also contains *trans*-fatty acids, but no negative effects have been linked to the main *trans*-fatty acid isomer in milk fat, *trans-11* C18:1 (also called vaccenic acid). Nevertheless, milk can contain considerable amount other *trans*-fatty acid, such as *trans-10* C18:1. In contrast to these negative effects linked to the composition of milk fat, potential positive health effects has been linked to conjugated linoleic acids (CLA) present only in fat from ruminants, especially milk fat (Bauman et al., 2006).

As a consequence of the general negative view of the health effects of milk fat, the potential for changing milk fat composition has been widely investigated. The prospects for altering milk fat composition through dietary changes are good, because fatty acids from feed are incorporated directly into milk, and can constitute up to 60% of the fatty acids in milk. In recent years much research has focused on the potential for increasing the amount of CLA.

In line with the large body of work carried out, a large number of reviews are available on the topic. Yves Chilliard from INRA is the author of several excellent reviews on the effect of nutrition on milk fat composition; among these are Chilliard et al. (2000, 2001) and Chilliard and Ferlay (2004). Dale Bauman and co-workers have written reviews on milk fat composition with special attention to CLA, such as Griinari and Bauman (1999), Bauman and Griinari (2003) and Bauman et al. (2006). We would also like to draw the attention to recent reviews by Jensen (2002), Dewhurst et al. (2006) and Jenkins and McGuire (2006).

It is the objective of this paper to give a brief overview of the topic illustrated mainly by examples from own data. We refer to the reviews mentioned for a more detailed coverage of the topic.

MILK FAT SYNTHESIS

As mentioned above, milk fat consists of up to 60% preformed fatty acids taken up directly from the feed. The rest is synthesized *de novo* in the mammary gland from acetate and beta-hydroxy butyrate originating from microbial fermentation of polysaccharides in the rumen. The key regulatory enzymes of *de novo* milk fat synthesis are acetate CoA carboxylase (ACC) and fatty acid synthase (FAS). The activities of these enzymes are inhibited by long chain fatty acids, especially unsaturated long chain fatty acids.

The fatty acids synthesized *de novo* are all saturated and the chain length is variable but not higher than 16. The short chain (C4:0-C8:0) and medium chain (C10:0-C14:0) fatty acids originate almost exclusively from *de novo* synthesis. Approximately 50% of C16:0 originate from *de novo* synthesis. The activity of the desaturase enzyme in the mammary gland is low for fatty acids with chain length below 16. Therefore almost all fatty acids synthesized *de novo* are remain saturated.

The long chain fatty acids in milk originate almost exclusively from the feed except in early lactation, where fatty acids mobilized from body stores contribute to a minor degree. Consequently, the composition of the long chain fatty acids in milk fat reflects the fatty acid composition of the feed but only to some extent because the ingested fatty acids undergo considerable modifications in the animal body. The modifications occur partly in the rumen and partly in the mammary gland. In the rumen the fatty acids undergo isomerization and hydrogenation. The rumen modifications depend to a large extent on the fatty acid composition of the fat in the ration, but other factors, such as starch and fibre content, that affect rumen fermentation also play a role. The modifications in the mammary gland are catalysed by desaturation enzymes, especially delta-9-desaturase that converts *trans-11* C18:1 to *cis-9*, *trans-11* C18:2, the most abundant CLA and C18:0 to C18:1.

The majority of the fatty acids in milk (97-98%) are incorporated into triglycerides before being excreted into the milk in lipid droplets coated by the milk fat globule membrane (Jensen, 2002).

DIETARY MANIPULATION OF MILK FAT COMPONENTS

Dietary factors

The potential for altering milk fat composition by dietary means is good - within limits. Overall, the milk fat composition can be altered both by the amount and the fatty acid composition of the diet as well as choice of forage type and forage: concentrate ratio.

The fatty acid content varies widely between feedstuffs. It ranges from 1-3% in most forages, including pasture, up to 95% in vegetable oils. The composition of the fatty acids also varies considerably among feedstuffs. In maize silage almost 50% of the fat is linoleic acid and only around 5-10% is linolenic acid. In contrast, grass silage contains 50% linolenic acid and less than 10% linoleic acid. Sunflower oil contains more than 60% linoleic acid and almost no linolenic acid, whereas linseed oil contains approximately 50% linolenic acid and only 15% linoleic acid. The ratio of linoleic to linolenic acid is important due to the different dehydrogenation pathways in the rumen (Griinari and Bauman, 1999). Fresh grass and fish oil are good sources of ω-3 fatty acids.

In view of these large differences in fatty acids content and fatty acid composition it is possible to create rations with very different amount and composition of fatty acids. Due to the importance of the rumen modifications, factors influencing the rumen environment, such as forage: concentrate ratio and starch content, also affect milk fat composition.

Saturated and unsaturated fatty acids

The obvious way to alter the ratio between saturated and unsaturated fatty acids in milk is to increase the amount of unsaturated fat in the diet. This leads to an increase in the amount of unsaturated long chain fatty acids in milk fat, even if a considerable part of the unsaturated fatty acids are hydrogenated in the rumen. This is illustrated by results from one of our experiments (Nielsen et al., 2005a), where cows were fed increasing amount of sunflower seeds (Experiment 1). Intake and milk production data are shown in Tables 1 and 2.

Table 1. Influence of diet composition on intake of DM, fatty acids and starch

Treatment		Intake per day				
lipid source	forage type	DM kg	FA g	C18:2 g	C18:3 g	starch g
Experiment 1						
sunflower[1]						
0	grass silage	17.9	376	149	85	3565
5		17.5	771	397	83	3312
10		14.4	963	534	69	2371
15% of DM		14.6	1318	760	72	1405
P		*	*	*	*	*
Experiment 2						
fat source (S)[2]						
rape seed	maize silage	20.1	1244	261	100	4808
+ vit. E		17.8	1101	231	89	4254
sunflower		19.7	1103	546	12	4590
+ vit E		20.4	1144	566	12	4753
P[A]- S/E/X		NS/NS/*	NS/NS/*	*/NS/NS	*/NS/NS	NS/NS/*
Experiment 3						
forage type (F)[3]						
rapeseed cakes	grass silage	18.4	957	211	180	70
	+ barley (B)	19.4	985	275	167	1948
	maize silage	18.4	1139	345	105	3818
	+ barley (B)	20.0	1260	390	114	4874
P[A]- F/B/X		NS/*/NS	*/*/NS	*/*/NS	*/NS/*	*/*/*

[1] Nielsen et al., 2006a; Sejrsen and Bjørn, unpublished; n=24; [2] Sejrsen and Schaltz, unpublished, n=40; [3] Nielsen et al. (2006), n=40; * - $P<0.05$; [A] effect of main factors: S - fat source; E - vitamin E supplementation; F - forage type; B - barley supplementation; X - interaction, * $P<0.05$; NS - no significant difference

Table 2. Influence of diet composition on feed intake, milk yield and milk fat content

Treatment		Yield per day		
lipid source	forage type	milk kg	fat %	fat g
Experiment[1]				
sunflower[1]				
0	grass silage	28.9	3.8	1095
5		26.5	3.8	971
10		22.0	4.0	924
15% of DM		21.0	4.4	884
P		*	NS	NS
Experiment 2				
fat source (S)[2]				
rape seed	maize silage	32.0	3.17	1013
+ vit. E		27.5	3.01	815
sunflower		28.5	3.97	1160
+ vit E.		28.5	4.03	1116
P[A]- S/E/X		NS/*/*	*/NS/NS	*/*/NS
Experiment 3				
forage type (F)[3]				
rapeseed cakes	grass silage	24.4	4.16	1003
	+ barley (B)	25.6	4.13	1053
	maize silage	23.4	3.41	786
	+ barley (B)	23.7	3.05	726
P- F/B/X		NS/NS/NS	*/NS/NS	*/NS/NS

[1] Nielsen et al., 2006a; Sejrsen and Bjørn, unpublished. n=24; [2]Sejrsen and Schaltz, unpublished, n=40; [3] Nielsen et al. (2006), n=40; * - P<0.05; [A] effect of main factors: S - fat source; E - vitamin E supplementation; F - forage type; B - barley supplementation; X - interaction, * P<0.05; NS - no significant difference

As the inclusion of sunflower oil increased so did the ratio between long (chain length >16) and short chain fatty acids (chain length <16) (Table 3) as well as the relative part of unsaturated fatty acids in the long chain fatty acids.

The type of unsaturated fatty acids can also be altered by the type of lipid supplement used (Chilliard et al., 2000; Chilliard and Ferlay, 2004). We intended to study this effect in another experiment (Experiment 2) where we compared the effect of rape seed and sunflower cakes - not seeds as in the previous experiment (Sejrsen and Schaltz, unpublished). The intention was to study the effect of changing the ratio between linoleic and linolenic acid in the diet. As can be seen in Table 1, the intakes of fatty acids were similar on both treatments. This can be confirmed by the effect of vitamin E-status (Table 5). As expected the relative amount of long chain fatty acids in milk from the cows fed rape seed was very high - 60% - and the relative amount of unsaturated fatty acids in the long chain fatty acids was also high - compared to the milk fat from the control cows in the experiments with sunflower seeds (Experiment 1) (Table 3). The unexpected lack of increase in long chain and unsaturated fat in the milk from cows receiving the sunflower cakes, indicate that the lipids from these cakes were not absorbed from the small intestine probably due to events during handling of the seeds during processing.

Table 3. Influence of diet composition on short chain, long chain and unsaturated fatty acids in milk fat[1]

Treatment		Fatty acid composition		
lipid source	forage type	<C16 - SCFA[4] % of total FA	>C16 - LCFA[5] % of total FA	C18:1-3 % of LCFA
Experiment 1				
sunflower [1]				
0		33.8	35.1	47.6
5	grass	27.4	46.3	50.6
10	silage	22.8	56.2	56.4
15%		21.2	58.5	58.1
P		*	*	*
Experiment 2				
fat source (S)[2]				
rape seed		21.2	60.1	56
+ vit. E	maize	20.2	60.8	58
sunflower	silage	32.5	38.3	42
+ vit E.		33.0	38.3	43
P[A] - S/E/X		*/NS/NS	*/NS/NS	*/NS/NS
Experiment 3				
forage type (F)[3]				
	grass silage	21.0	55.1	50
rapeseed	+ barley	21.5	54.9	51
cakes	maize silage	18.2	60.6	58
	+ barley	17.6	61.3	58
			calculated from mean values	

[1] Nielsen et al., 2006a; Sejrsen and Bjørn, unpublished, n=24; [2] Sejrsen and Schaltz, unpublished, n=40; [3] Nielsen et al. (2006), n=40; [4] SCFA - short and medium; [5] LCFA - long chain fatty acids; chain fatty acids; * - $P<0.05$; [A] effect of main factors: S - fat source; E - vitamin E supplementation; F - forage type; B - barley supplementation; X - interaction, * $P<0.05$; NS - no significant difference

This underlines the importance of the availability of the lipids from the feeds. Due to the hydrogenation in the rumen, the transfer of unsaturated fatty acids feed to milk is relatively low and it decreases with increasing level in the feed. To increase the transfer encapsulation of the oil can be used to prevent the lipid hydrogenation in the rumen. This can be an effective tool (Chilliard et al., 2000). The transfer efficiency also varies between different feedstuffs and depending on the treatment of the lipid supplement (as unfortunately illustrated in our experiment).

In a third experiment (Tables 1 and 2) we have confirmed the importance of the basal diet for milk fat composition (Nielsen et al., 2006). In contrast to most other comparisons of forage types we compared grass silage with maize silage using diets with high level of supplementation of unsaturated fat - in this case rape seed. In most comparisons of grass silages with maize silage without extra lipid supplementation the highest content of unsaturated fatty acids in milk is found when the grass or clover based diets are fed. Our results, in contrast, show the highest level of preformed fatty acids and the highest content of unsaturated fatty acids in the milk fat from the cows on the maize silage diet (Table 3). The reason most likely is due to an effect on rumen fermentation caused by the high starch content. We found a significant positive relationship between starch intake and milk content of several unsaturated fatty acids. This hypothesis is supported by the exacerbation of the effect by increasing the level of barley in the diet. The interaction between forage type and lipid content is thoroughly treated in the review by Chilliard and Ferlay (2004).

In summary, the ratio of saturated to unsaturated fat can be altered considerably by the amount and source of fat in the diet. The ratio is also affected by the type of forage used in the basal diet. In our experiments we were able to increase the level of preformed fatty from 35 to over 60% of the milk fat and the content of unsaturated fatty acids in the long chain fatty acids could also be increased considerably, from 40 to almost 60%. The change in the content of unsaturated fatty acids is caused partly by the transfer of unsaturated fat into milk and partly by a negative effect of unsaturated fatty acids on *de novo* milk fat synthesis (see later).

Trans-fatty acids

Increasing the amount of unsaturated fatty acids in the diet increases the amount of *trans* fatty acids in milk fat. The results of our experiments are in agreement with this conclusion (Table 4). From our results it is obvious that the increase in total *trans* fatty acids is highest when the unsaturated fatty acids are fed in combination with maize silage and that the effect is exacerbated by adding extra barley/starch to the diet. A further effect is that the higher level of *trans* fatty acids involves a shift from *trans-11* to *trans-10* C18:1. In our experiment comparing grass silage with maize silage, the ratio of *trans-10,* to *trans-11* in milk fat increased from 0.3 to 1 on the grass silage diet to 3.9 to 1 on the maize silage diet at the highest level of barley inclusion. The highest average concentration of *trans-10* (6.05% of milk fatty acids) in milk was observed on the diet consisting of rapeseed cakes given with maize silage and high level of barley. The relevance of this for human health is not certain (see later).

Table 4. Influence of level of diet composition on *trans* fatty acids and CLA in milk fat[1]

Treatment		Fatty acid composition, % of total FA			
lipid source	forage type	*trans FA* total	*trans-11* C18:1	*trans-10* C18:1	*cis-9, trans-11* CLA
Experiment 1					
sunflower [1]					
0	grass silage	1.04	1.04	-	0.46
5		2.55	1.98	-	0.69
10		3.87	3.06	-	1.07
15% of DM		4.05	3.21	-	1.33
P		*	*		*
Experiment 2					
fat source (S)[3]					
rape seed	maize silage	8.64	2.48	4.05	1.20
+ vit. E		9.25	1.80	5.11	1.28
sunflower		1.87	0.55	0.41	0.29
+ vit E.		1.93	0.54	0.51	0.30
P[A] - S/E/X		*/NS/NS	*/NS/NS	*/NS/NS	*/NS/NS
Experiment 3					
forage type (F)[2]					
rapeseed cakes	grass silage	4.86	1.74	0.60	0.89
	+ barley (B)	5.08	1.79	0.66	0.92
	maize silage	9.25	2.80	3.14	1.61
	+ barley	10.53	1.55	6.05	1.17
P- F/B/X		*/NS/NS	NS/*/*	*/*/*	*/*/*

[1] Nielsen et al., 2006a; Sejrsen and Bjørn, unpublished, n=24; [2] Sejrsen and Schaltz, unpublished, n=40; [3] Nielsen et al. (2006), n=40; * - $P<0.05$; [A] effect of main factors: S - fat source; E = vitamin E supplementation; F - forage type; B - barley supplementation; X - interaction, * $P<0.05$; NS - no significant difference

So in summary, the same diets that result in improved ratio between saturated and unsaturated fatty acids cause an increase in *trans* fatty acids, especially when given in combination with diets containing high levels of starch. These diets also cause a switch in the ratio of *trans-11* to *trans-10* C18:1.

CLA

CLA (*cis-9*, *trans-11* conjugated linoleic acid) is formed in the rumen *via* biohydrogenation of linoleic acid and in the mammary gland by desaturation of *trans-11* C18:1 formed *via* the biohydrogenation of both linoleic and linolenic acid in the rumen. Therefore the level of CLA in milk can be raised by addition of unsaturated fatty acids to the diet. We observed the same in our experiment with increasing level of sunflower (Table 4). Usually the CLA is higher in milk from cows fed grass based diets compared with maize silage diets due to the higher content of unsaturated fatty acids in pasture. This difference, however, is masked by the addition of high level of unsaturated fat from the rape seed. The CLA in milk from the rape seed fed animals fit nicely with the level expected from the sunflower experiment. The higher level of CLA in milk from the maize silage than the grass silage fed cows also related fairly well to the amount of *trans-11* content in milk.

The high level of *trans-10* correspond to a significant increase in *trans-10-cis- 12* CLA in milk (0.014 vs 0.029; $P<0.01$). In the comparable treatment in the experiment comparing rape seed with sunflower cakes the levels of both CLA and *trans* fatty acids were similar, but the amount of *trans-10*, *cis-12* C18:1 was below the detection limit. The amount of *trans* fatty acids and CLA in the milk from the cows in Experiment 3 supports the notion that the unsaturated fatty acids from the sunflower cakes unfortunately were not absorbed.

Besides these experiments we have conducted a number of trials in private and experimental herds (Nielsen et al., 2005b). The overall conclusions are in agreement with the literature. CLA in milk can be influenced by amount and source of fat in the diet, by forage type, by season and by breed (HF>Jersey). Furthermore there are consistent differences between cows on the same diet. Thus, it is possible to produce milk with elevated level of CLA if the consumers demand it.

ω-3 fatty acids

The level of ω-3 fatty acids in milk fat can be increased by using fresh grass due to its high content of α-linolenic acid (Chilliard and Ferlay, 2004). Of the vegetable fat supplements only linseed provides high level of α-linolenic acid and use of linseed can raise the level of ω-3 fatty acids in milk. Unfortunately the content of ω-3 fatty acids is reduced by conservation, but we did see a significant higher level of ω-3 fatty acids in the milk from the cows fed grass silage compared with maize silage (6.4 vs 3.9 mg/g FA; $P<0.001$) (Nielsen et al., 2006). The ω-3 content of C20 and C22 can be raised by fish oil or other marine feed sources in the diet (Chilliard et al., 2001).

Conclusions

In conclusion it is possible to improve the ratio of unsaturated to saturated fatty acids in milk fat and the levels of CLA and ω-3 fatty acids can also be raised. These effects are all considered favourable in connection with the human health effects attributed to milk fat. However, it is impossible to improve the level of one component without also affecting the others, and most importantly the effects cannot be obtained without a concomitant increase in the level of *trans* fatty acids. A raise in *trans-11* is considered safe. We have data from a human invention trial that support this (Raff et al., 2006; Tholstrup et al., 2006). However, the effect of *trans-10* is less certain. This is unfortunate because, as illustrated by our experiments, the content of *trans-10* in milk fat can be very high especially when lipid supplementation is given together with maize silage/high starch diets.

CORRELATED RESPONSES

The previous section shows that it is possible to obtain a more favourable milk composition through dietary mean. However, it is important to realize that the diets that most effectively improve the milk fat composition also can have other correlated effects.

One aspect is reduced *de novo* milk fat synthesis. In fact the increase in the observed relative content of unsaturated fatty acids in the milk fat is to a great extent achieved by a reduction in *de novo* milk fat synthesis caused by the addition of high levels of unsaturated fatty acids to the diet. Such diets, especially when containing high levels of concentrate, lead to a reduction of *de novo* milk fat synthesis (Bauman et al., 2006). This also occurred in our experiment. In the experiment with increasing amount of sunflower the relative amount of fatty acids with chains length below 16, reflecting *de novo* synthesis, was decreased from 33 to 21%, as a result of more than 30% reduction in the daily production of <C16 fatty acids ($P<0.001$) The result of feeding diets with high level of unsaturated fatty acids in combination with high level of concentrate - or maize silage with high starch content - usually is a decrease in the overall milk fat percentage. This is confirmed in the two other Experiments 2 and 3 (Nielsen et al., 2006; Sejrsen and Schaltz, unpublished). Interestingly, in the Experiment 1 with increasing sunflower the reduction in *de novo* synthesis was compensated by an increased in the uptake of preformed fatty acids such that daily total milk fat production remained the same. However, in the other experiments, with high fat supplementation, the reduction in *de novo* synthesis was reflected in a much lower milk fat content (Table 2).

The mechanism of action behind the milk fat depression - or more precisely - the inhibition of *de novo* milk fat synthesis in the mammary gland - caused by feeding high level of unsaturated fat and starch involve inhibitory effects of the fatty acids produced during rumen biohydrogenation. It has been proven that *trans-10*, *cis-12* CLA reduces mammary lipogenesis, but this isomer cannot alone explain all the reduction (Baumgard et al., 2001; Griinari and Bauman, 2006). However, the other factors are unknown, but it has been shown that *trans-10* C18:1 does not cause reduction in mammary lipogenesis (Lock et al., 2007).

It has furthermore been shown that dietary fatty acids can lead to inhibition of the expression of the genes coding for enzymes central for regulation of milk fat synthesis; acetyl CoA carboxylase and fatty acid synthase (Bernard et al., 2006). Recently attention has focused on sterol response element binding protein-1 (SREBP-1), a factor thought to play a key role in the overall regulation of lipogenesis. We have also studied the expression of these genes. Our results (Figure 1) also show that the expression of the genes related to mammary lipogenesis was reduced in cows having reduced milk fat synthesis (Sejrsen, Bjørn, Schaltz, Theil and Sørensen, unpublished).

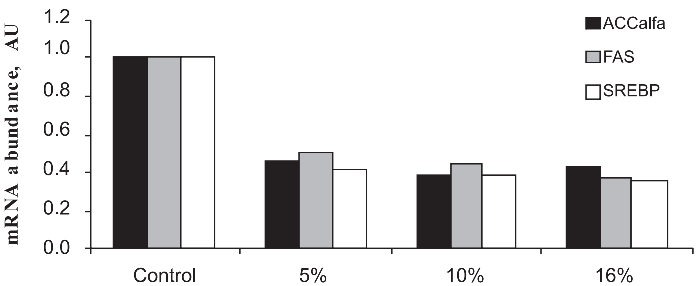

Figure 1. The effect of increasing level of sunflower seeds on the expression genes coding for enzymes involved in regulating milk fat synthesis. ACC- acetyl CoA caboxylase ($P<0.05$), FAS-fatty acid synthase ($P<0.05$), SREBP - sterol response element binding protein-1 ($P<0.05$) (Sejrsen, Bjørn, Schaltz, Theil and Sørensen, unpublished)

Other important aspects relate to feeding the high amounts of unsaturated fatty acids required to changes fatty acid composition. First of all, it is important to consider the possible content of anti-nutritional compounds present in some feed items, such as glucosinolates in rape seed, and gossypol and aflatoxin in cottonseed meal and other tropical oilseed meals. These anti-nutrients have the disadvantage that they or their degradation products can be transferred into the milk and act like toxicants. Thus the degradation products goitrin and thiocyanate from glucosinolates can produce goiter by impairing the iodine secretion into milk and its metabolism (Nørgaard and Hvelplund, 2003).

It is also important to consider the effect of unsaturated fat on vitamin status. In Experiment 2 we observed that the unsaturated fatty acids caused a reduction in the amount of vitamin E in the milk (Table 5). The content was reduced more in milk from cows fed sunflower cakes than in milk from cows fed rapeseed cakes, due to the higher content of unsaturated fatty acids in oil from sunflower compared to oil from rape seed. However, addition of 1450 mg vitamin E (RRR-α-tocopherol) was able to prevent the reduction of the vitamin E level in the milk. These effects are likely to occur in the rumen since the fatty acids from the sunflower diet, as mentioned, most likely were absorbed from the gut (Jensen et al., 2005).

Table 5. Concentration of α-tocopherol in milk from cows fed rape seed or sunflower meal with or without a daily supplement of 1450 mg RRR-α-tocopherol on top of diets containing 300 mg *all-rac*-α-tocopheryl acetate and sunflower or rapeseed cake[1]

Group	Vitamin E mg	Date initial	Date 1 week	Date 5 week
Rape seed	300	0.47	0.40	0.35
	1750	0.45	0.61	0.82
Sunflower	300	0.41	0.27	0.15
	1750	0.49	0.61	0.61
P		NS	*	*

[1,2] adapted from Jensen et al. (2005); * - $P<0.05$

Finally, it is also important to take other milk quality aspects into consideration. These include technological aspects, such as shelf life and spreadabilty, as well as sensory aspects, such as taste, aroma and flavour. These aspects are not covered in this presentation. The readers are referred to the review by Chilliard and Ferlay (2004) to get a lead to this aspect.

OVERALL CONCLUSION

The results discussed show that the prospects for obtaining a favourable milk fat composition of cow's milk through dietary means are good. It is clear from the data that it is possible to reduce the relative amount of saturated fatty acids and increase the relative amount of unsaturated fatty acid by using elevated amounts of unsaturated fatty acids in the diet. The milk fat content of CLA can be increased in the same way and the amount of ω-3 fatty acid can also be increased, especially by using fresh grass in the diet. Unfortunately the same diets lead to an increase in milk fat content of *trans* fatty acids that are suggested having unfavourable effects on human health. However, *trans* fatty acids in milk have been considered without negative effect because most of the *trans* fatty acids in milk usually are *trans-11*. However, when the basal diets are high in starch, the content of *trans-10* can be very high. The importance of this for human health is not known.

Diets required to obtain the favourable milk fat composition have other effects that need to be taken into consideration. These include milk fat depression, vitamin E status, the risk of anti-nutritional factors in the fat sources and last, but not least, the technological and sensory quality of the milk and milk products.

REFERENCES

Bauman D.E., Griinari J.M., 2003. Nutritional regulation of milk fat synthesis. Ann. Rev. Nutr. 23, 203-227

Bauman D.E., Lock A.L., Corl B.A., Ip C., Salter A.M., Parodi P.W., 2006. Milk fatty acids and humane health: potential role of conjugated linolic acid and trans fatty acids. In: K. Sejrsen, T. Hvelplund, M.O. Nielsen (Editors). Ruminant Physiology. Wageningen Academic Publishers, Wageningen (The Netherlands), pp. 529-561

Baumgard L.H., Sangster J.K., Bauman D.E., 2001. Milk fat synthesis in dairy cows is progressively reduced by increasing supplemental amounts of trans-10, cis-12 conjugated linoleic acid (CLA). J. Nutr. 131, 1764-1769

Bernard L., Leroux C., Chilliard Y., 2006. Charaterisation and nutritional regulation of the mail lipogenic genes in the ruminant lactating mammary gland. In: K. Sejrsen, T. Hvelplund, M.O. Nielsen (Editors). Ruminant Physiology. Wageningen Academic Publishers, Wageningen (The Netherlands), pp. 295-326

Chilliard Y., Ferlay A., 2004. Dietary lipids and forages interactions on cow and goat milk fatty acid composition and sensory properties. Reprod. Nutr. Develop. 44, 467-492

Chilliard Y., Ferlay A., Doreau M., 2001. Effect of different types of forages, animal fat or marine oils in cow‘s diet on milk fat secretion and composition, especially conjugated linoleic acid (CLA) and polyunsaturated fatty acids. Livest. Prod. Sci. 70, 31-48

Chilliard Y., Ferlay A., Mansbridge R.M., Doreau M., 2000. Ruminant milk fat plasticity: nutritional control of saturated, polyunsaturated, trans and conjugated fatty acids. Ann. Zootech. 49, 181-205

Dewhurst R.J., Shingfield K.J., Lee M.R.F., Scollan N.D., 2006. Increasing the concentrations of beneficial polyunsaturated fatty acids in milk produced by dairy cows in high-forage systems. Anim. Feed Sci. Tech. 131, 168-206

Griinari J.M., Bauman D.E., 1999. Biosynthesis of conjugated linolic acid and its incorporation into meat and milk in ruminants. In: M.P. Yurawecz, M.M. Mossoba, J.K.G. Kramer, M.W. Pariza G.J., Nelson (Editors). Advances in Conjugated Linolic Acid Research. AOCS Press, Champaign, Illinois. Vol. 1, pp. 180-200

Griinari J.M., Bauman D.E., 2006. Milk fat depression: concepts, mechanisms and management applications. In: K. Sejrsen, T. Hvelplund, M.O. Nielsen (Editors). Ruminant Physiology. Wageningen Academic Publishers, Wageningen (The Netherlands), pp. 389-417

Jenkins T.C., McGuire M.A., 2006. Major advances in nutrition: Impact on milk composition. J. Dairy Sci. 89, 1302-1310

Jensen R.G., 2002. The composition of bovine milk lipids: January 1995 to December 2000. J. Dairy Sci. 85, 295-350

Jensen S.K., Kristensen N.B., Lauritsen C., Sejrsen K., 2005. Enrichment of cows‘ milk with natural or synthetic vitamin E. 10th Symposium: Vitamins and Additives in Nutrition of Man and Animal. Jena/Thuringia (Germany), pp. 78-83

Lock A.L., Tyburczy C., Dwyer D.A., Harvatine K.J., Destaillats F., Mouloungui Z., Candy L., Bauman D.E., 2007. Trans-10 octadecenoic acid does not reduce milk fat synthesis in dairy cows. J. Nutr. 137, 71-76

Moorman P.G., Terry P.D., 2004. Consumption of dairy products and the risk of breast cancer: a review of the literature. Amer. J. Clin. Nutr. 80, 5-14

Mozaffarian D., Katan M.B., Ascherio A., Stampfer M.J., Willett W.C., 2006. Medical progress - Trans fatty acids and cardiovascular disease. N. Engl. J. Med. 354, 1601-1613

Nielsen T.S., Andersen R.H., Sørensen M.T., Weisbjerg M.R., Straarup E.M., Sejrsen K., 2005a. Conjugated linoleic acid (CLA) and vaccenic acid in Danish milk - influence of feeding and other production related factors (in Danish). DJF Raport 64, pp. 73

Nielsen T.S., Straarup E.M., Sørensen M.T., Sejrsen K., 2005b. Increasing amounts of sunflower seeds increase CLA and vaccenic acid content in milk fat from dairy cows. 56th EAAP Annual Meeting. Uppsala (Sweden). Book of Abstracts. 11, 135

Nielsen T.S., Straarup E.M., Vestergaard M., Sejrsen K., 2006. Effect of silage type and concentrate level on conjugated linoleic acids, trans-C18:1 isomers and fat content in milk from dairy cows. Reprod. Nutr. Develop. 46, 699-712

Nørgaard P., Hvelplund T., 2003. Anti-nutritional factors and unwanted components in feedstuffs and poisoness plants (in Danish). In: T. Hvelplund, P. Nørgaard (Editors). Cattle Nutrition and Physiology. Raport 53, Vol.1, DJF, pp. 87-118

Raff M., Tholstrup T., Sejrsen K., Straarup E.M., Wiinberg N., 2006. Conjugated linoleic acid (CLA) and vaccenic acid (VA) have no effect on blood pressure and isobar arterial elasticity in healthy young men. FASEB J. 20, A1016

Tholstrup T., Raff M., Basu S., Nonboe P., Sejrsen K., Straarup E.M., 2006. Effects of butter high in ruminant trans and monounsaturated fatty acids on lipoproteins, incorporation of fatty acids into lipid classes, plasma C-reactive protein, oxidative stress, hemostatic variables, and insulin in healthy young men. Amer. J. Clin. Nutr. 83, 237-243

Williams C.M., 2000. Dietary fatty acids and human health. Ann. Zootech. 49, 165-180