Butter Composition and Texture from Cows with Different Milk Fatty Acid Compositions Fed Fish Oil or Roasted Soybeans

A.S. Leaflet R2302

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Summary

Nutritional and physical properties of dairy products can be improved by changing milk fatty acid composition toward more unsaturation. Diet of cows, e.g., feeding supplemental fish oil (FO) or roasted soybeans (RSB), and cow selection can improve the nutritional and physical properties of dairy products and their acceptability to consumers. We examined whether feeding supplemental FO or RSB to cows that had a more unsaturated milk fatty acid composition acted additively to produce butter with improved fatty acid composition and texture. Multiparous Holstein cows chosen for producing either more or less unsaturated milk fatty acid composition (n = 6 in each group) were fed for three 3-week periods a control diet and two experimental diets that included additionally 0.9% of FO or 5% of RSB. The milk, collected in the third week of feeding, was used to make butter, which was analyzed for its fatty acid composition and physical properties. Dry matter intake, milk yield, and milk composition were not significantly affected by cow diet or by cow selection. Cows that produced, prior to the feeding study, a more unsaturated and healthful milk fat using a "health-promoting index" (HPI = [sum of % of unsaturated fatty acids] / [%C12:0 + 4 x %C14:0 + %C16:0]) maintained during the feeding study a higher HPI in their butter than did cows with a low HPI. Milk from cows fed supplemental FO or RSB yielded more unsaturated butters with higher HPI. This butter also was softer when the cows were fed RSB. Feeding RSB to cows chosen for their high milk HPI yielded the most unsaturated butter with the highest HPI and softest texture. Thus, selecting cows with a more healthful milk fatty acid composition and feeding cows supplemental RSB additively improved butter fatty acid composition and texture.

Introduction

Butter has a desirable flavor and is regarded as "natural" by consumers. The image of butter can be improved further by making it more spreadable at refrigeration temperatures. A concern to consumers is the high ratio of saturated to unsaturated fatty acids because of the linkage between intake of saturated fatty acids and cardiovascular disease risk in humans. Modifying the fatty acid composition of butter by decreasing the proportion of C12:0, C14:0, and C16:0 and increasing the proportion of unsaturated and short-chain fatty acids improves its spreadability and its nutritional properties.

Feeding cows' supplemental fish oil or soybean products are common nutritional approaches to achieving less saturated and more spreadable butters. Our group demonstrated previously that segregating milk of cows with high HPI milk fatty acid composition yields dairy products, including butter, with a more unsaturated fatty acid composition that were softer and had a satisfactory flavor. The combination of cow nutrition and selection to improve fatty acid composition and textural properties of dairy products has not been tested. Thus, the objective of this study was to test whether milk fatty acid composition could be improved further by feeding supplemental FO or RSB to cows already producing a more health-promoting milk fatty acid composition. Would these variables act in an additive manner to produce butter with a more health-promoting fatty acid composition and a softer texture?

Materials and Methods

Using a 3 x 3 Latin-Square design with two replications, multiparous Holstein cows (60 to 200 DIM) chosen for producing either more or less unsaturated milk fatty acid composition (n = 6 for each group) were fed for three 3-week periods the following diets:
1) Control (Control): Containing 3.7% crude fat, and the two experimental diets that contained on a dry matter basis 0.8% of additional lipids.
2) Fish oil (FO): Control diet supplemented with 0.9% (on DM basis) of menhaden FO, and
3) Roasted soybeans (RSB): Control diet without fish meal supplemented with 5.0% (on DM basis) of cracked RSB.

The first 2 weeks of each feeding period were used for adaptation to the diets, and the third week was used for data collection. Cows were housed in a free-stall barn starting one week before the start of the feeding period, and Calan Broadbent feeder doors (American Calan, Inc., Northwood, NH) were used to measure individual feed intakes. Cows were fed diets individually as a fresh TMR twice daily at 05:00 and 17:00 for ad libitum intake. Amounts fed and refused were recorded daily, and the average DMI for week 3 of each feeding period was used for statistical analysis. Cows were milked twice daily at 05:00 and 17:00. The average milk yield in week three of each feeding period was calculated for statistical analyses. Milk samples were collected for three days during the last week of each feeding period and sent refrigerated at 4°C to Swiss Valley Farms

(Davenport, IA) to be analyzed for fat, protein, lactose, total solids, and urea N by mid-infrared spectrophotometry (Milk-O-Scan 203, Foss Food Technology Corp., Eden Prairie, MN) and for SCC by using a Fossomatic 90 (Foss Food Technology Corp.). The averages of the three days were used for statistical analysis.

At the end of each feeding period, milk was collected for one day from each cow separately. After the milk was weighed and pasteurized individually at 63 °C for 30 min, cream with 30% fat was separated at 20 °C by using an Elecrem Model 1 cream separator (Elecrem, Vanves, France). Butter was churned at 10 °C for 34 – 53 min using a 4-L electric churn. After churning, butter was adjusted to 80% fat and 1% NaCl. Fatty acid composition of butter from each cow was determined by forming butyl esters of fatty acids that were quantified by gas chromatography by using appropriate internal and external standards.

For textural analysis, a TA-XT2i texture analyzer (Stable Microsystems, Surrey, UK) was used. Butter texture was analyzed at 4°C 1 wk after manufacture. A conical probe with an angle of 40° was advanced at 0.5 mm/sec until it reached 300 g force, and the penetration distance was recorded as measure of softness. Additionally, the speed by which the probe penetrated at 300 g force for an additional 30 sec was recorded as creep compliance. The measurements were replicated seven times for each sample, and the averages were used for statistical analyses.

Data for milk and butter fatty acid composition and butter texture were analyzed by using mixed models procedures. The fixed effects in the model were HPI index of milk samples collected from the same cow prior to the feeding study (low HPI, high HPI), cow diet (control, FO, RSB), the interaction between HPI and diet, and replication (summer, fall). A completely unrestricted variance-covariance matrix was used to account for correlations between samples from the same cow. Effects of HPI (low versus high), diet (control versus FO, control versus RSB), and the interactions between HPI and diet (HxF, HxR) were determined by using a two-sided t-test.

Results and Discussion

Results are shown in Table 1. On average, butter HPI values were 13% higher from cows chosen for their high milk HPI than those from cows chosen for their low HPI ($P = 0.05$). The HPI differences resulted mostly from increased proportions of C18:1 in the butter fat ($P = 0.06$). Butter manufactured from milk of cows that were fed additionally FO or RSB had a 31.0% ($P = 0.02$) and 33.5% ($P = 0.01$) higher HPI value, respectively, than did butter from cows fed the control diet. Type of supplement affected the fatty acid profile but not the degree of saturation of the butter with greater increases in C18:3 when fed FO and greater increases in C18:2 when fed RSB.

Butter texture was not affected significantly by cow grouping. The penetration distance at 4°C was 7.3% longer in cows chosen for their high HPI (penetration = 6.11 mm) than in cows chosen for their low HPI (penetration = 5.69 mm). Feeding cows 0.8% of additional lipids in the form of RSB but not of FO yielded significantly softer butter. The penetration distance at 4°C was 11.1% longer in butter from cows fed RSB (penetration = 6.28 mm) than in butter from cows fed the control diet (penetration = 5.65 mm; $P = 0.05$). In comparison, butter from cows fed FO had a penetration distance of 5.77 mm which was only 2.1% longer than in butter from cows fed the control diet ($P = 0.79$).

Feeding supplemental FO or RSB increased HPI in butter fat to higher values in cows that produced prior to the feeding study milk with high HPI values in comparison to cows with low HPI values. Feeding supplemental RSB instead of the control diet to cows chosen for their high milk HPI increased butter HPI by 48.5% in comparison to 18.6% for cows chosen for low HPI. This change was achieved mostly through decreasing the proportions of C14:0 and C16:0. Consistent with the effect on the HPI values, the softest butter was produced from cows chosen for their high HPI milk fatty acid composition that were fed supplemental RSB. No significant interactions between RSB feeding and HPI grouping were detected for butter fatty acid composition and texture. Neither cow selection nor cow nutrition altered significantly DMI, milk yield, and milk composition (data not shown). Thus, our results indicate that feeding cows chosen for their high milk HPI 0.8% of supplemental lipids in the form of 5% of RSB acts additively in improving milk fatty acid composition without adverse effects on DMI, milk yield, and milk composition.

Conclusion

In conclusion, selecting cows with a more health-promoting milk fatty acid composition and feeding supplemental RSB act additively to produce a softer butter at refrigeration temperature with higher HPI values. Thus, a combination of cow selection and feeding supplemental unsaturated fats could be used as a method to produce butter and possibly other dairy products, which have a consumer-friendly texture and a healthful fatty acid profile.

Acknowledgement

The authors thank Swiss Valley Farms (Davenport, IA) for analysis of milk samples, Omega Protein (Hammond, LA) for donation of menhaden fish oil, M. Reuber for technical assistance with the milk-processing equipment, and the management and employees of the Iowa State University Dairy Breeding Research Facility (Ankeny, IA), in particular J. Dedrick and D. H. Kelley, for care of the cows and assistance in obtaining research data and milk samples.

Table 1. Least squares means and significance of differences in fatty acid composition and texture of butter samples from cows with varying health promoting index (HPI) fed the control diet, supplemental fish oil (FO), or supplemental roasted soybeans (RSB).

Item	Low HPI			High HPI			SEM	Type III SS $P > F$ for main comparisons[1]				
	Control (n = 6)	FO (n = 6)	RSB (n = 6)	Control (n = 6)	FO (n = 5)	RSB (n = 6)		HPI	FO	RSB	HxF	HxR
			g/100 g of fatty acids									
Fatty acid composition												
HPI[2]	0.37	0.46	0.44	0.37	0.52	0.55	0.05	*	*	**	NS	NS
$C_{10:0}$	3.77	3.07	3.38	3.78	3.06	3.21	0.41	NS	*	†	NS	NS
$C_{12:0}$	4.58	3.38	4.05	4.40	3.52	3.43	0.62	NS	*	*	NS	NS
$C_{14:0}$	12.73	12.68	12.40	12.55	11.54	10.92	0.75	NS	NS	†	NS	NS
$C_{14:1}$	1.52	1.66	1.78	1.40	1.65	2.05	0.27	NS	NS	NS	NS	NS
$C_{16:0}$	32.15	30.65	29.49	33.10	30.32	27.47	1.59	NS	†	**	NS	NS
$C_{16:1}$	2.05	3.23	2.54	2.12	2.66	2.71	0.59	NS	*	NS	NS	NS
$C_{18:0}$	9.72	7.41	9.27	9.41	7.97	9.72	0.76	NS	*	NS	NS	NS
$C_{18:1}$	20.45	21.63	20.96	20.56	24.90	22.76	1.04	†	**	NS	NS	NS
$C_{18:2}$	2.98	3.69	4.21	3.08	3.61	4.38	0.65	NS	NS	**	NS	NS
$C_{18:3}$	1.54	3.12	1.74	1.76	3.28	2.21	0.30	NS	**	NS	NS	NS
CLA[3]	1.21	1.60	1.74	1.13	1.02	1.25	0.36	NS	NS	NS	NS	NS
Saturated	67.53	61.85	63.87	67.63	59.95	59.83	2.68	NS	*	*	NS	NS
Monounsaturated	25.95	28.76	27.94	25.78	30.70	31.08	1.72	NS	*	**	NS	NS
Polyunsaturated	6.52	9.38	8.19	6.52	8.62	9.08	1.47	NS	†	NS	NS	NS
Texture[4]:	(n = 6)	(n = 5)	(n = 6)	(n = 6)	(n = 4)	(n = 5)						
Penetration (mm)	5.54	5.43	6.10	5.76	6.10	6.46	0.60	NS	NS	*	NS	NS
Creep (mm/min)	5.07	4.94	5.43	5.08	5.31	5.25	0.36	NS	NS	NS	NS	NS

[1] HPI compares low- versus high-HPI group samples, FO compares samples from cows fed fish oil versus control, RSB compares samples from cows fed roasted soybeans versus control, HxF compares the effect of feeding fish oil versus control in cows with low- versus high HPI milk fatty acid composition, HxR compares the effect of feeding roasted soybeans versus control in cows with low- versus high HPI milk fatty acid composition.

[2] HPI = [sum of % of unsaturated fatty acids] / [$\%C_{12:0} + 4 \times \%C_{14:0} + \%C_{16:0}$].

[3] CLA = Isomers of conjugated linoleic acid.

[4] Textural properties of butter were measured at 4 °C seven times for each sample with a TA-XT2 texture analyzer.

NS > 0.10.

†$P \leq 0.10$.

*$P \leq 0.05$.

**$P \leq 0.01$.