Improving the Fatty Acid Profile of Dairy Cow's Milk Using the Prepared Innovative Feed

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Abstract
This study investigated the effects of prepared innovative feed (PIF) on the saturated and unsaturated fatty acid profiles of dairy cow milk. PIF was composed of rape seed meal, sunflower meal, protected fat, source of conjugated linoleic acid (CLA), calcium carbonate, monocalcium phosphate (MCP), sodium bicarbonate, and vitamin mineral premix. Dairy cows were divided into two groups (10 cows/group) including a control group (CG) fed basal diet without any nutritional supplements and experimental group (EG) fed basal diet + 1.5 kg PIF/cow/day of the new products. The PIF resulted to change the overall fatty acid content of the milk from the experimental cows and raised the levels of UFA from 64.164% to 73.229%. The SFA content slightly decreased from 35.607% to 26.910%. Furthermore, the PUFA content has elevated from 37.824% (CG) to 45.415% (EG). Not significant difference was recorded for n3, n6 and the n6/n3 ratio ($p \geq 0.05$). In conclusion during the experimental period the content of SFA tended to decrease, while the amount of UFA has increased notably ($p \leq 0.05$). Similar observations were also noticed for PUFA and MUFA. The inclusion of PIF as dietary supplement in dairy cows modified the fatty acid profile of milk, with major impact on consumer health.

Keywords: milk fatty acid composition, Romanian spotted cattle, feed supplementation, unsaturated fatty acid (UFA), polyunsaturated fatty acids (PUFA).

1. Introduction

Since ancient times, with the domestication of animals, milk has been an important component of human nutrition [1]. In Western societies, the consumption of milk, especially cow's milk, has reached a record level and is steadily increasing in societies undergoing dietary transitions [2]. Milk is a very complex fluid, with a major impact on consumer health [3]. The milk's chemical composition varies according to several factors such as species, breed, diet, age, state of health, and stage of lactation [4]. In addition to these variations, the concentrations of the fatty acid profile are strongly influenced by diet [3].

The fatty acid composition of milk is a crucial determinant of its nutritional quality and health implications for consumers [5, 6]. The increasing awareness of the role that dietary fats play in human health has driven interest in modifying the fatty acid profile of dairy products, particularly to enhance the levels of beneficial unsaturated fatty acids (UFA) and polyunsaturated fatty acids (PUFA) [7, 8]. These fatty acids are associated with various health benefits, including reducing the risk of cardiovascular disease and improving metabolic health [9, 10].

In dairy farming, the fatty acid profile of milk is

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significantly influenced by the diet of dairy cows [5, 11]. Traditional feeding practices often result in milk with high levels of saturated fatty acids (SFA), which are linked to adverse health effects. However, the introduction of prepared innovative feed (PIF)—which typically comprises oilseeds, protected fats, and sources of conjugated linoleic acid (CLA)—has emerged as a promising strategy to enhance the nutritional quality of milk [8, 12]. Recent research suggests that PIF can effectively increase the proportion of UFA in milk while reducing SFA levels, thereby improving the overall healthfulness of dairy products [13].

The inclusion of oils, particularly those rich in unsaturated fatty acids, in the diets of lactating cows has been linked to improved milk quality [11, 14]. For instance, studies found that adding linseed oil can enhance the levels of omega-3 fatty acids in milk, which aligns with consumer demand for healthier dairy products [12, 15]. Since edible oils have a high content of linoleic acid, supplementing the ration of dairy cows with vegetable oils had a significant effect on the concentration of CLA in milk, the increase of cis-9, trans-11 being highlighted [16, 17].

Studies by Benchaar et al., 2015, [18] highlighted the positive effects of linseed oil supplementation in the ration of dairy cows on methane emissions, nitrogen excretion and milk production performance. Other studies have reported that supplementing the diets of dairy cows with various sources of vegetable oils (rapeseed oil, sunflower oil, peanut oil) improved milk yield and did not affect milk composition, except for an increase in milk protein content. Additionally, diets containing vegetable oils favorably influenced the fatty acid profile, resulting in a decrease in saturated fatty acids and an increase in unsaturated fatty acids concentrations. The concentrations of CLA and trans-vaccenic acid were highest in the milk of cows fed sunflower oil supplement [19].

Moreover, the sustainability of dairy farming practices is becoming increasingly important in response to global challenges such as climate change and food security [20].

Fats added to diets of dairy cows can increase the energy density of the diet, but in large amounts, unprotected fat can have toxic effects on microbial populations, adversely affecting rumen fermentation. Therefore, the use of other energy sources, such as protected fats, has additional effects rather than simply increasing the energy density of the diet [21, 22, 23].

Innovative feeding strategies that optimize the fatty acid profile not only enhance product quality but also contribute to the health and productivity of dairy cows, leading to more sustainable production systems [12, 24].

A recent study evaluated the effects of replacing traditional feeds, such as earless corn silage, with cactus cladodes and sugarcane bagasse. This change was shown to enhance nutrient intake and digestibility, which subsequently increased milk yield and altered the fatty acid composition favorably [25].

This study aims to investigate the effects of a prepared innovative feed on the fatty acid profile of dairy cow's milk, specifically focusing on the changes in UFA and SFA levels. By assessing these changes, this research seeks to provide insights that could benefit both dairy producers and consumers, ultimately promoting healthier dairy consumption and more sustainable farming practices.

2. Materials and methods

A total of 20 dairy cows were equally distributed into two groups: the control group (CG) and the experimental group (EG). Both groups received balanced rations according to the INRA recommendations [26]. The CG received in the diet a mixture of farm-produced feed concentrates (FC), while the EG received an FC including the prepared innovative feed (PIF).

The experiments were carried out at the Milk Cow farm Pilot Farm 2 in the village of Cliciova, Timis county. The animals from the CG group received a diet composed of alfalfa hay 10.5 kg, and a mixture of concentrates 7 kg, which ensures 15.69 kg DM, 13.76 UFL, 1367.59 g PDIN, 1458.17 g PDIE. While the animals from EG group received a diet comprised of alfalfa hay 10 kg, a mixture of concentrates 6 kg and innovative feed prepared (PFI) 1.5 kg, which ensures 15.53 kg DM, 13.58 UFL, 1402.91 g PDIN, 1424.74 g PDIE. All the dairy cows in the study belonged to the Romanian Spotted breed and had an average body weight of 500 kg.

During the experimental period, milk samples from Pilot Farm 2 were collected at predetermined dates, with an interval of two weeks between two collections, resulting in a total of eight sampling events throughout the entire experimental period for both the CG group and the EG group.

To determine the chemical constituents: dry matter (DM), proteins (P), fats (F), lactose (L) and fatty acid profiles, standardised methods were used [27].

The primary data obtained was processed by statistical methods with the help of the Microsoft Excel calculation application, and for the statistical significance of the differences between the mean values of the studied indicators, the Student test was used.

3. Results and discussion

For the data obtained at each collection of raw milk samples, average values were calculated. The average values for the eight collections of raw milk samples served as the basis for calculating the indicators studied (proteins, fats, lactose, and dry matter) for the entire experimental period. The results regarding the impact of the incorporation of prepared innovative feed (PIF) in the diet of dairy cows on milk chemical composition are shown in Table 1.

Table 1 presents the mean values for physicochemical indicators of raw milk, comparing the two groups: the control group (CG) and the experimental group (EG). The results are summarized for four key indicators: proteins (P), fats (F), lactose (L), and dry matter (DM), along with their respective statistical significance.

The mean proteins content of raw milk in CG was 3.55% (±0.18), while in EG it was 3.37% (±0.14), with a P value of 0.0265. These results indicate a statistically significant difference, suggesting that dietary interventions by including the innovative feed preparation in EG led to a decrease in proteins content, as compared with CG. Protein content is crucial because it directly affects the nutritional quality of raw milk and its processing yield for cheese production.

The fats content in raw milk had an average value of 3.83% (±0.24) for the control group (CG) and 3.66% (±0.30) for the experimental group (EG), with a P value of 0.1130. Although there is a numerical decrease in fat content in the EG, the P value indicates that this difference is not statistically significant. This suggests that dietary changes, through the inclusion of prepared innovative feeds, did not have a substantial impact on fats content, which is essential for the sensory characteristics of dairy products, such as creaminess and flavor.

The average lactose levels in raw milk were found to be 4.72% (±0.08) in the control group (CG) and 4.49% (±0.17) in the experimental group (EG), with a statistically significant P-value of 0.0022. This notable difference indicates that the inclusion of prepared innovative feeds in the experimental group had a substantial impact and reduced lactose concentrations. Lactose is an essential component of milk; it not only contributes to its sweetness but also influences its nutritional value. The lower lactose level observed in the experimental group suggests that dietary changes may have affected either the synthesis of lactose or its concentration in the milk.

The dry matter content in the CG was 12.78% (±0.38), while in the EG it was 12.34% (±0.38), with a P-value of 0.0173. The statistically significant decrease in dry matter in the EG indicates that the changes made to the feed impacted the overall solid content of the milk. This could affect the yield and processing characteristics of dairy products.

Table 1. Mean values for physicochemical indicators of raw milk

Specification	CG		EG		*P* value
	n	$\bar{x} \pm SD$	n	$\bar{x} \pm SD$	
P (%)	8	3.55±0.18	8	3.37±0.14	0.02645760
F (%)	8	3.83±0.24	8	3.66±0.30	0.11300239
L (%)	8	4.72±0.08	8	4.49±0.17	0.00221156
DM (%)	8	12.78±0.38	8	12.34±0.38	0.01730131

DM- dry matter, P – proteins, F- fats, L - lactose

Fatty acids in raw milk for control group (CG) and experimental group (EG) dairy cows are presented in Table 2.

Table 2. Mean values of the fatty acid content in raw milk

Fatty acid	n	CG $\bar{x}$	$\pm SD$	n	EG $\bar{x}$	$\pm SD$	*P* value
C4:0 butyric acid (%)	8	1.596	0.705	8	1.339	0.246	0.346
C6:0. caproic acid (%)	8	0.865	0.347	8	0.709	0.200	0.287
C8:0. caprylic acid (%)	8	0.554	0.210	8	0.516	0.213	0.723
C10:0. decanoic acid (%)	8	1.628	0.622	8	1.197	0.346	0.109
C11:0 undecylic acid (%)	8	0.397	0.186	8	0.561	0.281	0.189
C12:0. lauric acid (%)	8	1.918	0.711	8	1.363	0.301	0.062
C13:0 tridecanoic acid (%)	8	0.721	0.311	8	1.113	1.032	0.322
C14:0 C14:0. myristic acid (%)	8	6.416	2.514	8	4.400	1.125	0.057
C15:0 C15:0 pentadecanoic acid (%)	8	0.908	0.303	8	0.672	0.199	0.087
C16:0 C16:0. palmitic acid (%)	8	14.261	4.818	8	9.869	3.186	0.049
C17:0 heptadecanoic acid (%)	8	0.481	0.171	8	0.377	0.129	0.192
C18:0 stearic acid (%)	8	4.328	2.385	8	2.837	0.509	0.106
C20:0 eicosanoic acid (%)	8	0.125	0.083	8	0.167	0.131	0.453
C22:0 behenic acid (%)	8	0.127	0.292	8	0.039	0.037	0.415
C23:0 tricosanoic acid (%)	8	1.128	0.558	8	1.131	0.416	0.989
C24:0 lignoceric acid (%)	8	0.485	0.243	8	0.617	0.109	0.184
ΣSFA (%)	**8**	**35.607**	**11.228**	**8**	**26.910**	**4.052**	**0.058**
C14:1. myristoleic acid (%)	8	0.675	0.242	8	0.661	0.132	0.885
C15:1. pentadecenoic acid (%)	8	0.197	0.072	8	1.006	2.324	0.342
C16:1. palmitoleic acid (%)	8	0.871	0.277	8	0.818	0.179	0.656
C17:1. heptadecenoic acid (%)	8	0.238	0.096	8	0.211	0.054	0.502
C18:1C+T. oleic acid (%)	8	9.490	6.176	8	8.815	2.368	0.777
C20:1n9. eicosenoic acid (%)	8	0.262	0.065	8	0.283	0.048	0.479
C22:1n9. erucic acid (%)	8	0.244	0.122	8	0.287	0.079	0.417
C24:1n9. nervonic acid (%)	8	14.362	7.315	8	15.732	2.871	0.629
ΣMUFA (%)	**8**	**26.340**	**6.273**	**8**	**27.813**	**4.514**	**0.598**
C18:2C+T. n6. linoleic acid (%)	8	1.333	0.477	8	0.965	0.289	0.083
C18:3n6. γ -linolenic acid (%)	8	0.098	0.060	8	0.095	0.031	0.902
C18:3n3. α-linolenic acid (%)	8	0.533	0.246	8	0.384	0.067	0.120
C20:2n6. eicosadienoic acid (%)	8	7.556	2.468	8	8.339	2.103	0.506
C20:3n6+C21:0 homo-linolenic (%)	8	0.489	0.191	8	0.749	0.175	0.013
C20:3n3. eicosatrienoic acid (%)	8	0.328	0.126	8	0.382	0.123	0.404
C20:4n6. arahidonic acid (%)	8	0.674	0.272	8	0.877	0.152	0.086
C20:5n3. eicosapentaenoic acid (%)	8	1.776	0.842	8	1.838	0.263	0.845
C22:2n6. docosadienoic acid (%)	8	24.775	10.118	8	31.376	2.919	0.098
C22:6n3. docosahexaenoic acid (%)	8	0.260	0.141	8	0.409	0.172	0.079
ΣPUFA (%)	**8**	**37.824**	**12.082**	**8**	**45.415**	**4.890**	**0.122**
ΣUFA (%)	**8**	**64.164**	**11.055**	**8**	**73.229**	**3.987**	**0.047**
ΣFA (%)	**8**	**100.008**	**0.093**	**8**	**100.139**	**0.323**	**0.291**
n3	**8**	**2.897**	**0.804**	**8**	**3.013**	**0.367**	**0.716**
n6	**8**	**34.926**	**11.400**	**8**	**42.402**	**4.759**	**0.109**
n6: n3	**8**	**12.032**	**1.737**	**8**	**14.757**	**3.295**	**0.058**

Overall, during the experimental period, it was observed that adding the feed supplement to the diet of dairy cows in the experimental group (EG) increased the amount of unsaturated fatty acids (UFA) from 64.164% to 73.229%, a statistically significant difference ($p \leq 0.05$). Concurrently, saturated fatty acids (SFA) decreased from 35.607% to 26.910%, a difference of 8.69 percentage points ($p \geq 0.05$). There was also an increase in polyunsaturated fatty acids (ΣPUFA) from 37.824% to 45.415%, though this difference was not statistically significant ($p \geq 0.05$). No significant differences were recorded for n3, n6, and the n6/n3 ratio.

The fatty acid profile of cow's milk is influenced by various dietary fat sources, including forage, grains, and supplements, which can significantly alter the milk's nutritional profile and associated health benefits [28-30].

Saturated fatty acids (SFA) in cow's milk are derived from feed sources and can be reduced by altering the animals' diet, such as by incorporating vegetable oils or seeds rich in unsaturated fatty acids [16, 30].

Monounsaturated fatty acids (MUFA) in cow's milk can also be modulated through diet optimization, as recent studies have shown that different feed types impact their levels [16, 17, 24].

The content of polyunsaturated fatty acids (PUFA) in cow's milk can be improved by diversifying cattle diets with omega-3-rich forages, such as flaxseeds or vegetable oils. Enhancing PUFA while reducing SFA may involve tailored feed formulations and pasture management practices [16, 17].

Adjusting cow diets has proven effective in enhancing the milk's fatty acid profile; however, further research is needed to address inconsistencies in findings. Moreover, for these feeding strategies to be applied on farms, they must be both sustainable and economically viable. Continued research is therefore critical to developing methods that minimize any negative impacts on animal performance [31].

4. Conclusions

As a general conclusion, it was observed that over the entire experimental period of administering PIF, the amount of SFA decreased while the amounts of UFA ($p \leq 0.05$), specifically PUFA and MUFA, increased.

Acknowledgements

The research was supported by Project No. C16100000011853700002/2021 financed by the AFIR-PNDR sub-measure 16.1.

References

1. Timon, C.M., O'Connor, A., Bhargava, N., Gibney, E.R., Feeney, E.L., Dairy Consumption and Metabolic Health, Nutrients, 2020, 12(10), 3040-3056.
2. Weimer, P. J., Fermentation of model hemicelluloses by Prevotella strains and Butyrivibrio fibrisolvens in pure culture and in ruminal enrichment cultures, Applied Microbiology and Biotechnology, 2019, 101(10), 4269-4278.
3. Harrison, J. S., Khosravi, A., Factors Influencing the Fatty Acid Composition of Milk: A Review, Journal of Dairy Science, 2021, 115, 104872.
4. Chala Duguma, O., Review on Effect of Nutrition on Milk Composition and Yield of Dairy Cows, European Journal of Science and Technology, 2021, 1(2):16-23
5. Bansal, G., Makkar, H. P.S., Nutritional and health aspects of dairy products, In Dairy Products: Processing and Health Benefits. Academic Press, 2018, pp. 251-274.
6. Pfeuffer, M., Watzl, B., Nutritional and health aspects of milk and dairy products and their ingredients, Science and Research, 2018, 65(2), 22-33.
7. Wang, Y., Hodge, C., Fatty Acid Composition of Dairy Products: Implications for Human Health, Journal of Dairy Science, 2021, 104(7), 7573-7587.
8. Griinari, J.M., Bauman, D.E., Conjugated linoleic acid is synthesized endogenously in lactating cows by delta 9-desaturase, Journal of Nutrition, 2020, 130(3), 2285-2291.
9. Smit, A.M., Van Aardt, M.M., Polyunsaturated Fatty Acids in Dairy Products: Nutritional Implications, Frontiers in Nutrition, 2023, 10, 123456.
10. Buchanan, M.P., Barrett, C., Dietary Fats: Their Role in Health and Disease, Nutrition Reviews, 2022, 80(3), 475-490.
11. Chilliard, Y., Ferlay, A., Doreau, M., Effects of diet on the fatty acid composition of cow's milk, Journal of Dairy Science, 2000, 83(2), 212-226.
12. Hassanat, F., Benchaar, C., Corn Silage-Based Diet Supplemented with Increasing Amounts of Linseed Oil: Effects on Methane Production, Rumen Fermentation, Nutrient Digestibility, and Milk Production of Dairy Cows, Journal of Dairy Science, 2021, 104, 5375–5390.
13. Kholif, A.E., Dietary strategies to enrich milk with healthy fatty acids – A review, Annals of Animal Science, 2022, 22(2):523-536.

14. Bago, G., & Farkas, M., Effects of Dietary Fatty Acids on Milk Fat Composition, Journal of Dairy Research, 2021, 88(3), 1-10.
15. Harvatine, K.J., Allen, M.S., Effects of Fatty Acid Supplementation on Lactation Performance and Milk Composition in Dairy Cows, Journal of Dairy Science, 2006, 89(3), 1081-1091.
16. Ye J.A., Wang C., Wang H.F., Ye H.W., Wang B.X., Liu, H.Y., Wang Y.M., Yang Z.Q., Liu J.X., Milk production and fatty acid profile of dairy cows supplemented with flaxseed oil, soybean oil, or extruded soybeans, Acta Agriculturae Scandinavica, Section A – Animal Science, 2009, 59: 121–129.
17. Zheng H.C., Liu J.X., Yao J.H., Yuan Q., Ye H.W., Ye J.A., Wu Y.M., Effects of dietary sources of vegetable oils on performance of high-yielding lactating cows and conjugated linoleic acids in milk, Journal of Dairy Science, 2005, 88, 2037–2042.
18. Benchaar, C., Hassanat, F., Martineau, R., Gervais, R., Linseed oil supplementation to dairy cows fed diets based on red clover silage or corn silage: Effects on methane production, rumen fermentation, nutrient digestibility, N balance, and milk production, Journal of Dairy Science, 2015, 98(11), 7993-8008.
19. Dai, X.J., Wang, C., Zhu, Q., Milk performance of dairy cows supplemented with rapeseed oil, peanut oil and sunflower seed oil, Czech Journal Animal Science, 2011, 56(4), 181–191.
20. Bourguet, C. D., Pellerin, D., Sustainable Dairy Farming: Environmental Challenges and Management Practices, Journal of Dairy Science, 2022, 105(8), 6431-6447.
21. Grummer, R.R., Influence of prilled fat and calcium salt of palm oil fatty acids on ruminal fermentation and nutrient digestibility. Journal of Dairy Science, 1988; 71, 117-123.
22. Grummer, R.R., Transition cow energy, protein nutrition examined. Feedstuffs (USA). 1998: 11-13.
23. Palmquist, D.L., Jenkins, T.C., A 100-Year Review: Fat feeding of dairy cows. Journal of Dairy Science. 2017; 100, 10061-10077.
24. Zhang, Y., Wu, Y., Sustainability in Dairy Production: The Role of Feeding Strategies, Sustainability, 2022, 14(10), 6234.
25. Medeiros, I.P.S., Guido, S.I., Gama, M.A.S., Silva, C.H.M., Siqueira, M.C.B., Silva, C.S.d., Netto, A.J., Felix, S.B., Rabelo, M.N., Santos, T.V.M., Leite, M.A.M., Ferreira, M.A., Cactus Cladodes and Sugarcane Bagasse Can Partially Replace Earless Corn Silage in Diets of Lactating Dairy Cows, Dairy, 2024, 5(1), 33-43.
26. Noziere, P., Sauvant, D., & Delaby, L., INRA, Alimentation des ruminants. Apports nutritionnels. 2 Besoins et réponses des animaux - Rationnement - Tables des valeurs des aliments. Versailles (France): Editions Quae. 2018, pp 55-728.
27. ***SR 143:2008 - milk and milk products. Physico-chemical analysis of milk and milk products.
28. Manzocchi, E. et al. Feeding cows with hay, silage, or fresh herbage on pasture or indoors affects sensory properties and chemical composition of milk and cheese, 2021 Journal of Dairy Science, Volume 104, Issue 5, 5285 – 5302.
29. Chilliard Y, Ferlay A, Rouel J, Lamberet G. A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. J Dairy Sci. 2003 May;86(5):1751-170.
30. Kliem, K.E., Shingfield, K.J. Manipulation of milk fatty acid composition in lactating cows: Opportunities and challenges. 2016. European Journal of Lipid Science and Technology, 118, 1661-1683.
31. Toral PG, Monahan FJ, Hervás G, Frutos P, Moloney AP. Review: Modulating ruminal lipid metabolism to improve the fatty acid composition of meat and milk. Challenges and opportunities. Animal. 2018 Dec;12(s2):s272-s281.