Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 2, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

CONTEMPORARY PERSPECTIVES ON THE COMPOSITION OF MILK FATTY ACIDS AND IMPLICATIONS FOR HUMAN HEALTH

Roxana Elena (VASILIU) STEFAN[1], Daniela IANIȚCHI[1], Livia VIDU[1], Elena RĂDUCANU[1], Carmen Georgeta NICOLAE[1], Victoria CONSTANTIN[1, 2], Monica MARIN[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Veterinary Sanitary Directorates of Karditsa, Greece

Corresponding author email: ela.irimia91@yahoo.com

Abstract

In the past few years, there has been a notable rise in global demand for milk and dairy products. Milk fat represents an important component of milk, playing a crucial role in energy provision and contributing to numerous physical characteristics and manufacturing qualities of both milk and dairy products. The fatty acids found in milk fat are regarded as important nutritional components in the human diet. Generating milk with an increased concentration of polyunsaturated fatty acids (PUFAs), particularly from the n3 category, is advantageous because dietary patterns containing more n3 fatty acids and fewer n6 fatty acids are considered healthier for humans. There are numerous factors that influence the fatty acid in the milk profile, with nutrition being the most critical aspect among them. Primary dietary factors, including the type and quantity of either forages or concentrates within the dietary regimen, extensive research has been conducted on the balance between forage and concentrate ratios, as well as the inclusion of fat or oil supplements in diets.

Key words*: alternative food, dairy cattle, fatty acids, feeding, health.*

INTRODUCTION

In recent times, there has been a worldwide inclination towards a heightened request for milk and dairy items (OECD/FAO, 2020; EC, 2020). Milk fat represents a significant constituent of milk, playing a pivotal role in energy provision and contributing to numerous physical attributes and manufacturing qualities of both milk and dairy products (Bauman & Griinari, 2001; Alatas et al., 2015).
Fatty acids (FAs) present in milk fat are deemed significant nutritional elements in the human diet (Hanus et al., 2018). From a nutritional standpoint, it is desirable to produce dairy with a larger amount of polyunsaturated fatty acids (PUFAs), particularly those from the n3 group, because diets containing more n3 and less n6 fatty acids are considered healthier for humans (Simopoulos, 2002; Moallem, 2018). Fatty acids can be classified into several categories, including saturated, monounsaturated, polyunsaturated, and acetylenic fatty acids. Additionally, there are fatty acids with unique structural features, such as branched, cyclic, epoxy, hydroxyl, and those containing a ketone group (Pece et al., 2007; Danila et al., 2022).
There are numerous factors that impact the fatty acid (FA) composition of milk, nutrition playing a pivotal role. Key dietary factors, such as the type and amount of forages or concentrates consumed, the balance between forages and concentrates, and the incorporation of fat or oil supplements into diets, have been thoroughly investigated (Hanus et al., 2018).

MATERIALS AND METHODS

For the completion of this study, a systematic search of other relevant scientific articles on the chosen subject was conducted in the Google Scholar, PubMed, and MDPI databases. Relevant articles published in recent years were examined, and the references of included studies were also consulted to obtain additional bibliographic sources.

RESULTS AND DISCUSSIONS

Exploring the role of milk fatty acids in nutrition and human health

Fatty acids found in milk fat are crucial nutritional constituents in the diets of many people, with significant implications for human health. While historically associated with adverse effects, recent scientific understanding has led to a more favorable perception of milk fat's influence on human health (Nicolosi et al., 1997; Parodi, 1997; Parodi, 1999; Dhiman et al., 2005; German et al., 2009; Parodi, 2009; Chung et al., 2018; Hadrova et al., 2021).

Historically, there has been an association between fatty acids and adverse health effects. However, over the past decade, this perception has been significantly reassessed.

Milk fat contains numerous compounds with potential anticarcinogenic properties, including conjugated linoleic acid, sphingomyelin, other sphingolipids, butyric acid, 13-methyltetradecanoic acid, ether lipids, as well as vitamins A and D. Research suggests that milk fat provides protection against various types of cancer, including breast, skin, stomach, prostate, and colon cancer (Parody, 2004; Danila et al., 2022).

Dairy products serve as significant sources of conjugated linoleic acid (CLA), particularly the cis-9, trans-11 isomer. The level of CLA found in milk fat typically ranges from 3 to 5 mg/g, with the cis-9, trans-11 CLA isomer comprising approximately 80-90% of this concentration (Parody, 1997; Sehat et al., 1998; Danila et al., 2022). The dietary composition of ruminants, particularly dairy cows, significantly influences alterations in milk FAs, indicating the potential for targeted dietary adjustments to yield milk with a favorable fatty acid profile, aligning with human nutritional guidelines (Shingfield et al., 2008).

Generally, there is a health-oriented preference for increasing the levels of n3 fatty acids in milk and dairy products, while concurrently reducing the presence of specific saturated fatty acids (SFAs) due to their association with heightened atherosclerotic risks (Lock & Garnsworthy, 2001; Socha et al., 2007). The content of PUFA and SFA in milk fat can be altered by adjusting the proportion of fresh grass, hay and maize silage in the dietary intake.

Additionally, the consumption of fresh grass boosts the level of CLA, a biologically active compound known for its anticarcinogenic effects (Ip et al., 2003; Bargo et al., 2006). The reaction in milk production and composition exhibits more variability when fat supplements are added to the diet compared to diets based on corn silage as forage. Conversely, diets with higher concentrate contents can potentially cause milk fat depression and alterations in the milk fatty acid profile (Reno et al., 2013; Liu et al., 2008; Bauman & Griinari, 2003). Supplementation of dairy cow diets with linseed oil, sunflower oil, or fish oil can influence the PUFA content in milk, particularly ALA and CLA isomers. Controlling the ruminal biohydrogenation process can enhance improving the health profile of cow milk by augmenting the levels of CLA and n-3 fatty acids (Mach et al., 2013; AbuGhazaleh, 2008; Thanh & Suksombat, 2015; Silvia et al., 2015). Dairy cows primarily acquire fatty acids for milk fat synthesis from various sources, including the diet itself, rumen microorganisms, adipose tissues, and biosynthesis occurring anew in the mammary gland (Walker et al., 2004). The proportion of fatty acids from each source in milk fat production varies significantly based on factors such as feed intake, diet composition, and lactation stage (Shingfield et al., 2008). Increased starch intake is linked to enhanced de novo synthesis, resulting in a higher proportion of saturated milk fat, whereas higher intake of polyunsaturated fatty acids from pasture leads to elevated concentrations of specific fatty acids in milk fat (Parodi, 2009).

Milk fat content typically rises with the increasing fiber content of various forages. Incorporating forage, especially fresh grass, increases the ratio of unsaturated fatty acids to saturated fatty acids in cow milk fat (Bauman & Griinari, 2001; Lock & Garnsworthy, 2001; Elgersma et al., 2013; Dewhurst et al., 2006). Additionally, the intake of fresh grass elevates the concentration of specific fatty acids with beneficial effects on human health (Parodi, 2009). When fat supplements are introduced into the diet, the reaction in both milk production and composition varies in comparison to diets primarily reliant on corn silage as the main forage source. Diets with higher concentrate contents can potentially cause alterations in the milk fatty acid profile, highlighting the importance of balanced dietary compositions (Bauman & Griinari, 2001; Lock & Garnsworthy, 2001). Supplementation with linseed oil, sunflower, and fish oil can impact the fatty acid composition of milk, presenting opportunities to enhance its healthiness

(Shingfield et al., 2008; Parodi, 2009). Fish oil, rich in EPA and DHA, modulates the biohydrogenation process, influencing the synthesis of specific fatty acid isomers with potential health benefits (Simopoulos, 2002). The consumption of certain fatty acids has been associated with several health advantages, such as lowered cardiovascular risks and enhanced neurological function (Rizos et al., 2012; Simopoulos, 2002). Continued research in this field is essential to comprehend fully the effects of animal diets on milk composition and human health (Griinari & Bauman, 1999). This could lead to the development of more effective dietary strategies and the promotion of healthier lifestyles (Parodi, 2009; Rizos et al., 2012). Dairy products with an optimal fatty acid composition could positively impact consumer health and well-being (Simopoulos, 2002).

Alternative feeding resources for dairy cows

When it comes to dietary characteristics, substituting forage with oilseed brings about notable shifts in certain fatty acid (FA) profile outcomes. Meta-regression findings indicate that as the difference in forage inclusion increases (supplemented minus control values), there's a reduction in CLA content ($\beta = -0.09$; $p < 0.05$) and Σ omega-6 ($\beta = -0.11$; $p < 0.05$). Moreover, there's an observed increase in unsaturated fatty acid (UFA) milk content with a rise in NDF difference ($\beta = 0.19$; $p < 0.001$). Elevated levels of linoleic acid (LA) in the supplemented group are significantly associated with decreased values of lactose ($\beta = 0.005$; $p < 0.001$), linolenic acid (LNA) ($\beta = -0.13$; $p < 0.001$), oleic acid (OA) ($\beta = -0.23$; $p < 0.001$), and vaccenic acid (VA) in milk ($\beta = -0.04$; $p < 0.05$). Additionally, there's a negative correlation between the difference in LNA and OA effect size ($\beta = -0.15$; $p < 0.001$) (Vargas-Bello-Perez et al., 2020).

Incorporating oilseeds into the diet doesn't impact remains unaffected by the isoenergetic balance between diets observed in most trials, thus not influencing the productive behavior of ruminants (Vargas-Bello-Perez et al., 2020). Similarly, Rabiee et al. in 2012 didn't find a statistical difference when using oilseeds; nevertheless, it can improve milk production with the utilization of an alternative lipid source, where the variation is linked to the dry matter intake and energy content of the diet.

Sunflower, cottonseed, and soybeans significantly contribute to a decrease in milk fat, possibly linked to the quantity of LA (greater than 50 g 100 g^{-1} FA), although this remains unclear. Nevertheless, LA is believed to serve as a substrate in the formation of trans isomers, which have been associated with milk fat depression syndrome. Conversely, supplementation with flaxseed and rapeseed has a has a lesser impact on LA content, possibly due to saturation by alternative pathways of their main fatty acids, resulting in fewer intermediate isomers inhibiting de novo synthesis of FA in milk fat (Bauman & Griinari, 2003; Leduc et al., 2017).

Oilseed use in diets for ruminants can elevate propionic acid production and decrease acetic acid production proportionally. This occurs as a result of glycerol release from triglycerides during lipolysis. At this shift in the rumen, the ratio of acetic to propionic acids does not impact milk yield but promotes conditions (primarily rumen pH and/or microbial population) for increased unsaturated fatty acid (UFA) content. Long-chain polyunsaturated fatty acids (PUFA) escaping biohydrogenation are absorbed by the intestine, increasing the UFA ratio in milk at the expense of saturated fatty acids, possibly due to an inhibitory effect of acetyl-CoA carboxylase and fatty acid synthetase enzymes at the mammary gland level (Martinez et al., 2013; Kholif et al., 2018; Pi et al., 2019; Vargas-Bello-Perez et al., 2020).

The significance of enhancing the PUFA proportion in milk lies in its potential to decrease obesity and mortality from cardiovascular issues by as much as 30% and decrease diabetes incidence by up to 50%. Omega-3 PUFA exhibited a 20% decrease in mortality among patients with cardiac issues (Livingstone et al., 2013; Maki et al., 2018).

The abundant presence of linoleic acid (LA) in sunflower seeds, comprising 60.4% of fatty acids (FA), has a significant impact on the fat content of milk. Introducing polyunsaturated fatty acid (PUFA)-rich sources as supplements leads to a reduction in acetic and butyric fermentation in the rumen, thereby leading to a reduction in the synthesis of new fats within the mammary gland and the inhibition of lipogenic enzymes (Ueda et al., 2003). In contrast, the incorporation of sunflower into the diets of cows has a beneficial effect on the content of oleic acid (OA), likely attributable to the potential escape of fatty acids from ruminal biohydrogenation and their subsequent absorption by the small intestine for secretion in milk, or through the activity of the delta-9 desaturase enzyme in the mammary gland (Rabiee et al., 2012). Moreover, the inclusion of rapeseed and soybean in the rations of dairy cows shows a positive correlation with OA content, presumably due to the elevated concentration of this fatty acid in these types of oilseeds.

Higher levels of oilseed supplementation exhibit a positive linear impact on unsaturated fatty acid content when linseed, rapeseed, and soybean are utilized. The forage level in the diet strongly correlates with saturated fatty acid contents in milk. Interestingly, experimental washout periods impact unsaturated fatty acid contents, specifically rumenic (CLA), vaccenic, linolenic, and oleic fatty acids (Plata-Perez et al., 2022).

Marine algae encompass a wide array of valuable, biologically active compounds, including polysaccharides, proteins, PUFAs, various pigments, and antioxidants, divided into macroalgae and microalgae based on size. Genera and species like *Ascophyllum nodosum*, *Laminaria* sp., and others hold potential for use as animal feeds. Despite low lipid content, macroalgae are rich in PUFAs, particularly EPAs and AAs, found primarily in brown and red seaweeds. Scientific data on the effect of macroalgae supplementation in ruminant diets on milk yield and composition are limited but indicate increased milk fat yields with supplementation of certain species like *Lithothamnion calcareum*. Microalgae produce a variety of bioactive compounds, rendering them suitable supplements not just in human diets but also in animal diets. Chlorella and Spirulina, among others, are notable for their high protein content and are rich sources of various fatty acids. Their supplementation in cow diets can influence milk FA profiles, impacting rumenic acid, n3 FAs, and DHA transfer efficiency into milk fat. (Dawczynski et al., 2007; Cruywagen et al., 2015; Makkar et al., 2016; Khan et al., 2018; Neville et al., 2019; Morais et al., 2020).

Oilseeds, rich in PUFA, can be provided to dairy animals to alter milk fatty acid profiles, producing nutritionally beneficial milk. Flaxseed decreases short- and medium-chain FA concentrations while increasing long-chain FA content in milk fat. Fish oil addition has been suggested to increase long-chain n-3 FA contents in milk. Clover in organic forage may reduce rumen biohydrogenation of unsaturated FA (Chilliard et al., 2001; Dewhurst et al., 2003). Linseed supplementation elevates nutritionally desirable FA content in milk, which could be important for human nutrition (Butler et al., 2011). Although oilseed supplementation reduces SFA concentrations and increases desirable FA, it may not completely offset the absence of fresh forage in the diets of housed cows. Rapeseed is inferior to linseed in improving milk fat composition. Proposed dietary combinations can maximize positive impacts on milk FA profiles without compromising milk production and solids content (Stergiadis et al., 2014).

Linseed supplementation reduces C16:0 proportion while increasing omega-3 fatty acids and conjugated linolenic acid concentrations, improving milk quality. Additionally, linseed supplementation affects gene expression related to metabolism and immune response in the liver and mammary gland, providing insight for improving milk quality and animal health (Mach et al., 2013).

CONCLUSIONS

The understanding of the role of fatty acids found in milk fat has evolved significantly over time, with recent research highlighting their potential benefits for human health. While historically associated with adverse effects, scientific advancements have led to a more favorable perception of milk fat's influence on human well-being.

Milk fat contains compounds with potential anticarcinogenic properties, providing protection against various types of cancer. Dairy products, particularly those rich in conjugated linoleic acid (CLA), offer significant health benefits. The composition of fatty acids in milk can be influenced by dietary adjustments, with targeted strategies yielding milk with a favorable fatty acid profile. Increasing levels of certain fatty acids, such as n3 fatty acids, while reducing specific saturated fatty acids, align with health-oriented dietary preferences.

Furthermore, supplementation with oilseeds and other dietary modifications can enhance the healthiness of milk by altering its fatty acid composition. Continued research in this field is crucial for developing effective dietary strategies and promoting healthier lifestyles, as dairy products with optimal fatty acid profiles could positively impact consumer health and well-being.

ACKNOWLEDGEMENTS

This research work is a part of the PhD thesis elaboration, and was carried out with the support of Faculty of Engineering and Management of Animal Production, University of Agronomic Sciences and Veterinary Medicine of Bucharest.

REFERENCES

AbuGhazaleh, A. A. (2008). Effect of fish oil and sunflower oil supplementation on milk conjugated linoleic acid content for grazing dairy cows. *Animal Feed Science and Technology, 141*, 220–232.

Alatas, M. S., Cıtıl, O. B., Kahraman, O., & Ozbılgın, A. (2015). Causes of milk fat depression in dairy cows. *Scientific Papers. Series D. Animal Science*, LVIII, 80-85.

Bargo, F., Delahoy, J. E., Schroeder, G. F., Baumgard, L. H., & Muller, L. D. (2006). Supplementing total mixed rations with pasture increase the content of conjugated linoleic acid in milk. *Animal Feed Science and Technology, 131*, 226-240.

Bauman, D. E., & Griinari, J. M. (2001). Nutritional regulation of milk fat synthesis. *Annual Review of Nutrition, 21*(1), 203-227.

Bauman, D. E., & Griinari, J. M. (2001). Regulation and nutritional manipulation of milk fat: low-fat milk syndrome. *Livestock Production Science*, 70, 15-29.

Bauman, D. E., & Griinari, J. M. (2003). Nutritional regulation of milk fat synthesis. *Annual Review of Nutrition, 23*, 203–227.

Bauman, D. E., & Griinari, J. M. (2003). Nutritional regulation of milk fat synthesis. *Annual review of nutrition*, *23*(1), 203-227.

Butler, G., Stergiadis, S., Seal, C., Eyre, M., & Leifert, C. (2011). Fat composition of organic and conventional retail milk in northeast England. *Journal of Dairy Science*, *94*(1), 24-36.

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. *Livestock Production Science*, *70*(1-2), 31-48.

Chung, I.M., Kim, J.K., Lee, K.J., Son, N.Y., An, M.J., Lee, J.H., ... & Kim, S.H. (2018). Discrimination of organic milk by stable isotope ratio, vitamin E, and fatty acid profiling combined with multivariate analysis: A case study of monthly and seasonal variation in Korea for 2016–2017. *Food Chemistry*, 261, 112–123. doi: 10.1016/j.foodchem.2018.04.017.

Cruywagen, C. W., Taylor, S., Beya, M. M., & Calitz, T. (2015). The effect of buffering dairy cow diets with limestone, calcareous marine algae, or sodium bicarbonate on ruminal pH profiles, production responses, and rumen fermentation. *Journal of Dairy Science*, *98*(8), 5506-5514.

Danila, C.M., Marginean, G.E., Marin, M.P., Nicolae, C.G., & Vidu, L. (2022). Review of the Fatty Acid Content of Domestic Milk and Its Importance. *Scientific Papers. Series D. Animal Science*, *LXV*(1), 346-351.

Dawczynski, C., Schubert, R., & Jahreis, G. (2007). Amino acids, fatty acids, and dietary fibre in edible seaweed products. *Food Chemistry*, *103*(3), 891-899.

Dewhurst, R. J., Evans, R. T., Scollan, N. D., Moorby, J. M., Merry, R. J., & Wilkins, R. J. (2003). Comparison of grass and legume silages for milk production. 2. In vivo and in sacco evaluations of rumen function. *Journal of Dairy Science*, *86*(8), 2612-2621.

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. *Animal Feed Science and Technology, 131*, 168–206.

Dhiman, T.R., Nam, S.H., & Ure, A.L. (2005). Factors affecting conjugated linoleic acid content in milk and meat. *Critical Reviews in Food Science and Nutrition*, 45, 463–482.

EC (2020). Short-Term Outlook for EU Agricultural Markets in 2020. European Commission, DG Agriculture and Rural Development, Brussels. Accessed in 26 March, 2024 https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/short-term-outlook-summer-2020_en.pdf

Elgersma, A., Tamminga, S., & Ellen, G. (2006). Modifying milk composition through forage. *Animal Feed Science and Technology, 131*, 207–225.

German, J.B., Gibson, R.A., Krauss, R.M., Nestel, P., Lamarche, B., van Staveren, W.A., ... Destaillats, F. (2009). A reappraisal of the impact of dairy foods and milk fat on cardiovascular disease risk. *European Journal of Nutrition,* 48, 191–203. doi: 10.1007/s00394-009-0002-5.

Griinari, J. M., & Bauman, D. E. (1999). Biosynthesis of conjugated linoleic acid and its incorporation into meat and milk in ruminants. *Advances in Experimental Medicine and Biology, 447*, 173-192.

Hadrová, S., Sedláková, K., Křížová, L., & Malyugina, S. (2021). Alternative and unconventional feeds in dairy diets and their effect on fatty acid profile and health properties of milk fat. *Animals, 11*(6), 1817.

Hanuš, O., Samková, E., Křížová, L., Hasoňová, L., Kala, R (2018). Role of fatty acids in milk fat and the influence of selected factors on their variability—A

review. *Molecules*. 23:1636. doi: 10.3390/molecules23071636.
Ip, M. M., Masso-Welch, P. A., & Ip, C. (2003). Prevention of mammary cancer with conjugated linoleic acid: role of the stroma and the epithelium. *Journal of Mammary Gland Biology and Neoplasia, 8*(1), 3-18.
Khan, M. I., Shin, J. H., & Kim, J. D. (2018). The promising future of microalgae: current status, challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. *Microbial cell factories*, 17, 1-21.
Kholif, A. E., Morsy, T. A., & Abdo, M. M. (2018). Crushed flaxseed versus flaxseed oil in the diets of Nubian goats: Effect on feed intake, digestion, ruminal fermentation, blood chemistry, milk production, milk composition and milk fatty acid profile. *Animal Feed Science and Technology*, 244, 66-75.
Kovač, D. J., Simeunović, J. B., Babić, O. B., Mišan, A. Č., & Milovanović, I. L. (2013). Algae in food and feed. *Food and Feed Research*, 40(1), 21-32.
Leduc, M., Létourneau-Montminy, M. P., Gervais, R., & Chouinard, P. Y. (2017). Effect of dietary flax seed and oil on milk yield, gross composition, and fatty acid profile in dairy cows: A meta-analysis and meta-regression. *Journal of Dairy Science*, *100*(11), 8906-8927.
Liu, Z. I., Yang, D. P., Chen, P., Lin, S. B., Jiang, X. Y., Zhao, W. S., Li, J. M., & Dong, W. X. (2008). Effect of dietary sources of roasted oilseeds on blood parameters and milk fatty acid composition. *Czech Journal of Animal Science, 53*, 219–226.
Livingstone, K. M., Lovegrove, J. A., Cockcroft, J. R., Elwood, P. C., Pickering, J. E., & Givens, D. I. (2013). Does dairy food intake predict arterial stiffness and blood pressure in men? Evidence from the Caerphilly Prospective Study. *Hypertension*, *61*(1), 42-47.
Lock, A. L., & Garnsworthy, P. C. (2001). Seasonal variation in milk conjugated linoleic acid and Δ9-desaturase activity in dairy cows. *Livestock Production Science, 70*(1-2), 59-63.
Mach, N., Zom, R. L. G., Widjaja, H. C. A., van Wikselaar, P. G., Weurding, R. E., Goselink, R. M. A., van Baal, J., Smits, M. A., & van Vuuren, A. M. (2013). Dietary effects of linseed on fatty acid composition of milk and on liver, adipose and mammary gland metabolism of periparturient dairy cows. *Journal of Animal Physiology and Animal Nutrition, 97*, 89–104.
Mach, N., Zom, R. L. G., Widjaja, H. C. A., Van Wikselaar, P. G., Weurding, R. E., Goselink, R. M. A., ... & van Vuuren, A. M. (2013). Dietary effects of linseed on fatty acid composition of milk and on liver, adipose and mammary gland metabolism of periparturient dairy cows. *Journal of Animal Physiology and Animal Nutrition*, 97, 89-104.
Maki, K. C., Eren, F., Cassens, M. E., Dicklin, M. R., & Davidson, M. H. (2018). ω-6 polyunsaturated fatty acids and cardiometabolic health: current evidence, controversies, and research gaps. *Advances in Nutrition*, *9*(6), 688-700.
Makkar, H. P., Tran, G., Heuzé, V., Giger-Reverdin, S., Lessire, M., Lebas, F., & Ankers, P. (2016). Seaweeds for livestock diets: A review. *Animal Feed Science and Technology*, 212, 1-17.
Martínez, M. A. L., Pérez, H. M., Pérez, A. L. M., Carrión, P. D., Gómez, C. G., & Garzón, S. A. I. (2013). Efecto de los aceites y semillas en dietas para rumiantes sobre el perfil de ácidos grasos de la leche. Revisión. *Rev. Mex. Cienc. Pecu*, 4, 319-338.
Moallem, U. (2018). Invited review: Roles of dietary n-3 fatty acids in performance, milk fat composition, and reproductive and immune systems in dairy cattle. *J. Dairy Sci.,* 101, 8641–8661. doi: 10.3168/jds.2018-14772.
Morais, T., Inácio, A., Coutinho, T., Ministro, M., Cotas, J., Pereira, L., & Bahcevandziev, K. (2020). Seaweed potential in the animal feed: A review. *Journal of Marine Science and Engineering*, *8*(8), 559.
Neville, E. W., Fahey, A. G., Gath, V. P., Molloy, B. P., Taylor, S. J., & Mulligan, F. J. (2019). The effect of calcareous marine algae, with or without marine magnesium oxide, and sodium bicarbonate on rumen pH and milk production in mid-lactation dairy cows. *Journal of Dairy Science*, *102*(9), 8027-8039.
Nicolosi, R.J., Rogers, E.J., Kritchevsky, D., Scimeca, J.A., & Huth, P.J. (1997). Dietary conjugated linoleic acid reduces plasma lipoproteins and early aortic atherosclerosis in hypercholesterolemic hamsters. *Artery*, 22, 266–277.
OECD/FAO.OECD-FAO (2020). Agricultural Outlook 2020–2029. OECD Publishing; Paris, France: FAO; Rome, Italy
Parodi, P. W. (2009). Conjugated linoleic acid and other anticarcinogenic agents of bovine milk fat. *Journal of Dairy Science, 82*(6), 1339-1349.
Parodi, P.W. (1997). Cows' milk fat components as potential anticarcinogenic agents. *Journal of Nutrition*, 127, 1055–1060. doi: 10.1093/jn/127.6.1055.
Parodi, P.W. (1999). Conjugated linoleic acid and other anticarcinogenic agents of bovine milk fat. Journal of Dairy Science, 82, 1339–1349.
Parodi, P.W. (2009). Has the association between saturated fatty acids, serum cholesterol and coronary heart disease been over emphasized? *International Dairy Journal,* 19, 345–361. doi: 10.1016/j.idairyj.2009.01.001.
Parody, P.W. (1977). Conjugated octadecadienoic acids of milk fat. Journal of Dairy Science, *60* (10), 1550-1553.
Parody, P.W. (2004). Milk fat in human nutrition. Australian Journal of Dairy Technology, 59 (1), 3.
Pece, A., Coroian, C., Ghita, B., & Muresan, G. (2007). Distribution and physiological role of fatty acids in milk. *Agriculture - Science and practice*, 3-4 (63-64).
Pi, Y., Ma, L., Pierce, K. M., Wang, H. R., Xu, J. C., & Bu, D. P. (2019). Rubber seed oil and flaxseed oil supplementation alter digestion, ruminal fermentation and rumen fatty acid profile of dairy cows. *Animal*, *13*(12), 2811-2820.
Plata-Pérez, G., Angeles-Hernandez, J. C., Morales-Almaráz, E., Del Razo-Rodríguez, O. E., López-González, F., Peláez-Acero, A., ... & Vieyra-Alberto, R. (2022). Oilseed supplementation improves milk

composition and fatty acid profile of cow milk: a meta-analysis and meta-regression. *Animals*, *12*(13), 1642.

Rabiee, A. R., Breinhild, K., Scott, W., Golder, H. M., Block, E., & Lean, I. J. (2012). Effect of fat additions to diets of dairy cattle on milk production and components: A meta-analysis and meta-regression. *Journal of dairy science*, *95*(6), 3225-3247.

Rennó, F. P., José Esler de Freitas Júnior, Gandra, J. R., Verdurico, L. C., dos Santos, M. V., Barletta, R. V., Venturelli, B. C., & Vilela, F. G. (2013). Fatty acid profile and composition of milk protein fraction in dairy cows fed long-chain unsaturated fatty acids during the transition period. *Revista Brasileira de Zootecnia, 42*(11), 813–823.

Rizos, E. C., Ntzani, E. E., Bika, E., Kostapanos, M. S., & Elisaf, M. S. (2012). Association between omega-3 fatty acid supplementation and risk of major cardiovascular disease events: a systematic review and meta-analysis. *JAMA, 308*(10), 1024-1033.

Sehat, N., Kramer, J.K., Mossoba, M.M., Yurawecz, M.P., Roach, J.A., Eulitz, K., ... & Ku, Y. (1998). Identification of conjugated linoleic acid isomers in cheese by gas chromatography, silver ion high performance liquid chromatography and mass spectral reconstructed ion profiles. Comparison of chromatographic elution sequences. *Lipids, 33*(10), 963-971.

Shingfield, K. J., Reynolds, C. K., & Lupoli, B. (2008). Toomer, P. J., & Griinari, J. M. (2013). Comparison of fatty acid content of milk from Jersey and Holstein cows consuming pasture or a total mixed ration. *Journal of Dairy Science, 96*(9), 5704-5721.

Shingfield, K. J., Reynolds, C. K., Hervás, G., & Griinari, J. M. (2008). A meta-analysis of the effects of feeding diets containing linseed oil on milk fatty acid composition of dairy cows. *Journal of Dairy Science, 91*(10), 4015-4029.

Silva, R. R., Rodrigues, L. B. O., Lisboa, M. de M., Pereira, M. M. S., & de Souza, S. O. (2014). Conjugated linoleic acid (CLA): A review. *International Journal of Applied Science and Technology, 4*, 154–170.

Simopoulos, A. P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomedicine & Pharmacotherapy, 56*(8), 365-379.

Simopoulos, A.P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomed. Pharmacother.* 56:365–379. doi: 10.1016/S0753-3322(02)00253-6.

Socha, M. T., Blanchard, P. J., Sechler, S. J., & Kahl, S. (2007). Conjugated linoleic acid (CLA) in milk fat of dairy cows as influenced by dietary supplements of soy hulls and whole cottonseed. *Journal of Dairy Science, 90*(2), 473-480.

Stergiadis, S., Leifert, C., Seal, C. J., Eyre, M. D., Steinshamn, H., & Butler, G. (2014). Improving the fatty acid profile of winter milk from housed cows with contrasting feeding regimes by oilseed supplementation. *Food Chemistry*, 164, 293-300.

Thanh, L. P., & Suksombat, W. (2015). Milk yield, composition, and fatty acid profile in dairy cows fed a high-concentrate diet blended with oil mixtures rich in polyunsaturated fatty acids. *Asian-Australasian Journal of Animal Sciences, 28*(6), 796–806.

Ueda, K., Ferlay, A., Chabrot, J., Loor, J. J., Chilliard, Y., & Doreau, M. (2003). Effect of linseed oil supplementation on ruminal digestion in dairy cows fed diets with different forage: concentrate ratios. *Journal of Dairy Science*, *86*(12), 3999-4007.

Vargas-Bello-Pérez, E., Robles-Jimenez, L. E., Ayala-Hernández, R., Romero-Bernal, J., Pescador-Salas, N., Castelán-Ortega, O. A., & González-Ronquillo, M. (2020). Effects of calcium soaps from palm, canola and safflower oils on dry matter intake, nutrient digestibility, milk production, and milk composition in dairy goats. *Animals*, *10*(10), 1728.

Vargas-Bello-Pérez, E., Robles-Jimenez, L. E., Ayala-Hernández, R., Romero-Bernal, J., Pescador-Salas, N., Castelán-Ortega, O. A., & González-Ronquillo, M. (2020). Effects of calcium soaps from palm, canola and safflower oils on dry matter intake, nutrient digestibility, milk production, and milk composition in dairy goats. *Animals*, *10*(10), 1728.

Walker, G.P., Dunshea, F.R., Doyle, P.T. (2004): Effects of nutrition on the production and composition of milk fat and protein: a review. *Australian Journal of Agricultural Research, 55*, 1009–1028.