Review Article

Fatty acid profile and characteristics of Butterfat/ Ghee

Abstract

Milk fat is observed to have high nutritional properties and other health benefits. The fat in milk is the most complicated natural fat since it comprises over 400 distinct fatty acids. The fatty acid composition of milk fat determines its nutritional value. The fatty acids found in milk vary in terms of their structure, cis or trans isomers, amount and location of double bonds, and chain length. The chemical makeup and content of the fatty acids present determine the physical and nutritional characteristics of the fat. The fatty acids in milk also have nutritional value and offer certain health advantages. Eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and other polyunsaturated fatty acids are considered to help prevent coronary artery disease (CAD) and other age-related neurodegenerative illnesses. Many of these therapeutic properties are unknown even today. The impact of fatty acids on human health is a topic that is always under dispute. Here we discuss how fatty acids act in terms of human health. Regulations have been implemented to ensure reduced risk due to the intake of fatty acids like trans fatty acids. Trans fats can increase the risk of CHD.

Keywords: Milk fat, Ghee, Butter at, Butyric acid, Palmitic acid

1. Introduction

For young children to grow and develop, maintain their bodies, and be protected from infectious and non-communicable diseases (NCDs) as adults, they must have access to a healthy diet and appropriate nutrition. For poverty reduction and economic and social growth, a healthy and productive population is a crucial condition. The Millennium Development Goals (MDGs) focus on reducing child mortality and eradicating extreme hunger and poverty. According to estimates from the FAO, during the past 20 years, substantial progress has been made in eliminating undernourishment worldwide.

Milk fat is highly complex. Cow milk contains approximately 4 g of fat/100 g. Milk fat predominantly consists of triacylglycerols of about 97–88 percent of total lipids by weight. In Cow milk, the triacylglycerol portion is 97.5 percent whereas in buffalo milk it is 98.6 percent by weight. More than 400 fatty acids have been identified in milk fat. Studies show that milk fat contains approximately 1.9 grams of saturated fatty acids (SFAs) per 100 grams of milk fat. Oleic acid (C18:1 cis-9) is the most abundant unsaturated fatty acid in milk and its quantity is about 0.8 grams/100 grams. To lower the risk of coronary heart disease (CHD), the FAO and WHO advise replacing SFAs in the diet with PUFAs and limiting total SFA intake to no more than 10% of energy intake. Elevated blood levels of low-density lipoprotein (LDL)-cholesterol have been linked to lauric (C12:0), myristic (C14:0), and palmitic (C16:0) acids. LDL-cholesterol is unaffected by stearic acid (C18:0), which is little absorbed in the stomach. Milk fat contains almost 0.2 grams of PUFA/100 grams of milk fat.

2. Fatty acid profile of milk fat

Milk fat contains many different fatty acids and is a mixture of short-chain and long-chain fatty acids. The concentration of long-chain saturated fatty acids is higher in buffalo (Domestic Asian water buffalo) milk fat which makes it harder than the cow-milk fat; the melting point of buffalo fat is also high. The animal-body fats contain a high proportion of saturated fatty acids such as palmitic and stearic acids of high melting points and hence are solid or semisolid at room temperature [1]. The melting points of triglycerides in milk fat range from –40°C to 72°C.

2.1.1 Composition of milk lipid

Lipid Class	Amount(%w/w)		
	A	B	C
Triacylglycerols	98.3	97.5	97-98

Diacylglycerols	0.3	0.36	0.28-0.59
Monoacylglycerols	0.03	0.027	0.16-0.38
Free Fatty Acids	0.1	NR	0.10-0.44
Phospholipids	0.8	0.596	0.2-1.00
Sterols Cholesterol	0.3 NR	 0.31	 0.419

A: [2] B: [3] C:[4]

NR: Not Reported

Due to the presence of a wide range of constituent fatty acids, variation in molecular weight, and unsaturation, milk fat triglycerides are complex and unique. Various workers identified and determined the fatty acid composition of milk fat by using GLC [5]. Although over four hundred and six different fatty acids have been identified in bovine milk fat, only a few (~12) of these are present at concentrations exceeding 1.0 % [6].

In addition to being high in medium-chain fatty acids, ruminant milk fats have low concentrations of polyunsaturated fatty acids (PUFAs). The special fatty acid found in bovine milk is butyric. Strong, distinctive flavours and scents are associated with short chain fatty acids. Comparing bovine milk fat to artificially hydrogenated (hardened) vegetable oils, the former has a higher concentration of trans fatty acids of about 5%.

Numerous hundred fatty acids make up goat milk fat, and each one's proportion to the overall fatty acid pool varies significantly. Over 75% of the total FA in milk is made up of the shares of five of those acids (C10:0, C14:0, C16:0, C18:0, and C:18-1 cis) [7]. According to [8], the fat present in goat milk is a rich source of short-chain fatty acids (SCFA – C6:0, C8:0, C10:0), which are in the mammary gland. Saturated fatty acids (SFA) make up most of the fat in goat milk, with a percentage ranging from around 67% [9] to about 75% [10] One feature that sets goat milk apart from cow milk is how the lauric acid and capric acid are related [11].

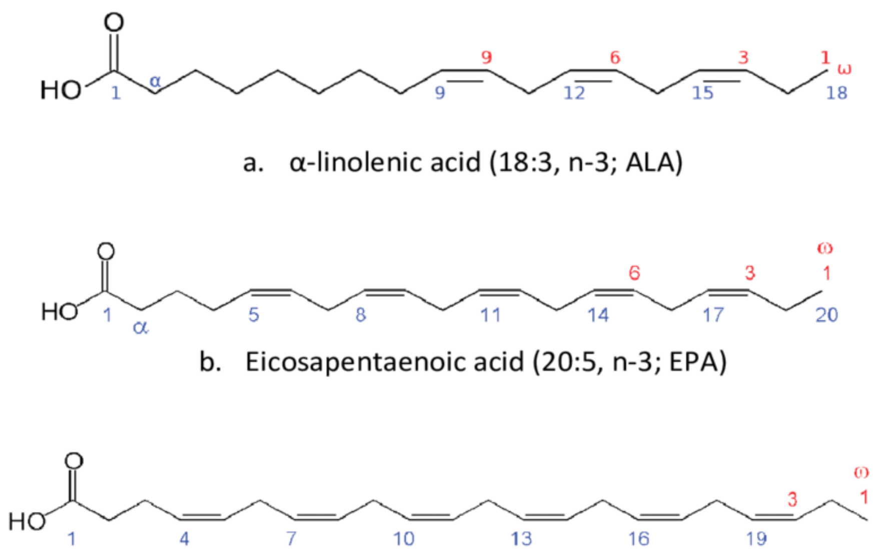
Table 1 : Principal fatty acids in milk

Abbreviated designation	Structure	Systematic name	Common name
Saturated			
$C_{4:0}$	$CH_3(CH_2)_2COOH$	Butanoic acid	Butyric acid
$C_{6:0}$	$CH_3(CH_2)_4COOH$	Hexanoic acid	Caproic acid
$C_{8:0}$	$CH_3(CH_2)_6COOH$	Octanoic acid	Caprylic acid
$C_{10:0}$	$CH_3(CH_2)_8COOH$	Decanoic acid	Capric acid
$C_{12:0}$	$CH_3(CH_2)_{10}COOH$	Dodecanoic acid	Lauric acid
$C_{14:0}$	$CH_3(CH_2)_{12}COOH$	Tetradecanoic acid	Myristic acid
$C_{16:0}$	$CH_3(CH_2)_{14}COOH$	Hexadecanoic acid	Palmitic acid
$C_{18:0}$	$CH_3(CH_2)_{16}COOH$	Octadecanoic acid	Stearic acid
Unsaturated			
	ω9 family		
18:1	$CH_3(CH_2)_7CH=CH-CH_2-(CH_2)_6-COOH$	Δ9-octadeconoic acid	Oleic acid
	ω9 family		
18:2	$CH_3(CH_2)_4(CH=CH-CH_2)_2-(CH_2)_6-COOH$	Δ9,12-octadecdienoic acid	Linoleic acid
18:3	$CH_3(CH_2)_4(CH=CH-CH_2)_3-(CH_2)_6-COOH$	Δ6,9,12-octadectrienoic acid	γ Linolenic acid

20:4	$CH_3(CH_2)_4(CH{=}CH{-}CH_2)_4{-}(CH_2)_6{-}COOH$	Δ5,8,11,14-ecosatetraenoic acid	Arachidonic acid
	ω3 family		
18:3	$CH_3CH_2{-}(CH{=}CH{-}CH_2)_3{-}(CH_2)_6{-}COOH$	Δ9,12,15-octadectrienoic acid	α Linolenic acid
	Δ9 family		
18:1	$CH_3(CH_2)_7{-}CH{=}CH{-}CH_2{-}(CH_2)_6{-}COOH$	Δ9-octadeconoic acid	Oleic acid
16:1	$CH_3(CH_2)_5{-}CH{=}CH{-}CH_2{-}(CH_2)_6{-}COOH$	Δ9-hexadecenoic acid	Palmitoleic acid

[12].

n-3 Fatty acids



a. α-linolenic acid (18:3, n-3; ALA)

b. Eicosapentaenoic acid (20:5, n-3; EPA)

c. Docosahexaenoic acid (22:6, n-3; DHA)

Role of Milk Fatty Acids on human health

Humans have several types of fatty acids in their food, blood, and tissues and cells. Fatty acids are components of membranes and sources of energy. Their biological actions affect the metabolism, function, and reactivity of cells and tissues to hormones and other signals. Through these effects, fatty acids influence health, well-being, and disease risk. The effects of saturated, *cis* monounsaturated, ω-6 and ω-3 polyunsaturated, and trans fatty acids are discussed.

Recent research has demonstrated the impact of oleic acid (OA) on human health and illness. It has recently been shown that oleic acid, a monounsaturated fatty acid that is not necessary for human health, regulates immunological response and health. Generally, it is accepted that unsaturated fatty acids are beneficial [13]. In the last years, many studies described the contribution of oleic acid in the reduction in cholesterol levels, atherogenesis risk, host versus graft response, blood pressure, and daily anti-hypertensive drug intake. By interfering with many immune system components, including neutrophils, lymphocytes, and macrophages, oleic acid-containing diets may enhance the immune response linked to more successful removal of pathogens like bacteria and fungi, even though the exact role of oleic acid in immune responses is still up for debate. The properties of unsaturated fatty acids, such as oleic acid, might then be used to generate innovative potential therapeutics for inflammatory and infectious disorders. The amount and composition of fatty acids appear to affect how modulatory an effect oleic acid has on the immune response. obtained by the participants, the type of animal, or the immunological parameter assessed, even though the majority of research offer compelling proof of this MUFA's significant role in immunity regulation. Aside from its ability to expedite the healing of wounds, some research indicates that it may also have a beneficial effect on autoimmune, malignant, and inflammatory conditions.In summary, it is possible to describe oleic acid as an anti-inflammatory fatty acid that contributes to the activation of many immunological competent cell pathways. [14])

One of the significant C4 organic acids with several uses is butyric acid which has a well-known anticancer action[15]. Butyric acid is extremely volatile [16]. It can stop the beginning of the inflammatory process [17] and is also used to treat gastrointestinal issues (Banasiewicz et al., 2020). There is proof that butyric acid has wide-ranging lipid-regulating capabilities in cells, animals, and people. The butyric acid affects on lipid metabolism including the cofactors of gene expression, modification of transcription factors, activity of the HDAC enzyme, regulation of the quantity of lipid-related enzymes via gene expression, and suppression of the activity of cell surface transporters. Studies state that colonic bacteria producing butyric acid act as mediators in a system that reduces the incidence of colon cancer by 75% in mice-fed diets high in fibre. The researchers discovered that oral sodium butyrate administration promotes photodynamic therapy's anti-cancer efficacy in astrocytoma cells, most likely through a mechanism based on controlling the differentiation and gene expression of cancer cells[18].

According to Labarthe et al., 2008, the medium chain fatty acids in milk are capric, capric acid, and caprylic acid, which are employed in metabolic therapy for cardiac disorders. The main sorces of medim chain fatty acids are milk products, palm kernel oil and coconut oil. [19]. Research has shown that capric, caprylic, and caproic acids significantly inhibited the growth of human colorectal, skin, and breast cancer cells when cultivated under in vitro conditions, suggesting that they may one day be utilised to prevent and/or cure these malignancies.[20]. Additionally, caprylic acid is known to have neuroprotective properties against neurodegenerative illnesses and to lower blood sugar levels [21]. According to {19}, humans' metabolic characteristics and cognitive function can both be enhanced by dietary supplements containing MCFAs as they have a specific system for transportation and metabolism in the body. MCFAs have the potential to directly influence bodily metabolism through receptor-mediated intracellular pathways and also function as metabolic regulators that can change the levels of hormones and metabolites in the blood.

[22] suggested that lauric acid shows antiviral, antibacterial and antiprotozoal functions mainly by monolaurin activity. Monolaurin is a derivative of lauric acid which is synthesized in the body. Lauric acid is found to be effective against gram positive bacteria and also shows inhibitory activity towards *Staphylococcus* species. It also have broad spectrum antibiotic properties. According to [23], lauric acid's amphiphilic qualities cause the membrane to become more permeable, which is important for the admission of antibacterial drugs into the bacterial cell.

Myristic acid is said to be hypercholesterolemic in nature . It is also found to have the ability to increase HDL cholesterol levels which can be beneficial for heart health[24]. Some studies showed that palmitic acid present in milk is found to be the reason for increased coronary heart disease and some tumour effects [25].[26] observed that it also contributes to elevated cholesterol level-mainly LDL in obese patients.

Stearic acid showed minor changes in serum lipid and lipoprotein values [27]. However, many studies reveal that hypercholesterolemic activity is not shown by stearic acid[28]

α-linolenic acid (ALA), docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA), and docosapentaenoic acid (DPA) are the primary n-3 LC-PUFA found in dietary sources. Arachidonic acid and linoleic acid are examples of long chain PUFA. The immune system, blood clotting, neurotransmitters, cholesterol metabolism, and the formation of membrane phospholipids in the brain and retina are all influenced by long chain fatty acids[29]. These long chain fatty acids, particularly omega-3 fatty acids, are useful for conditions other than heart and blood vessel illnesses. Skin conditions, asthma, arthritis, nephritis, lupus erythematosus, and multiple sclerosis are among the illnesses. PUFAs have the ability to directly or through conversion into locally acting bioactive metabolites influence a broad range of homeostatic and inflammatory processes associated with several illnesses[30].

Linoleic acid has a critical function in the development of fetuses and newborns. As the precursor to arachidonic acid, which is necessary for both appropriate growth and correct neural development, linoleic acid plays a function in the growing brain. Arachidonic acid is the primary polyunsaturated fatty acid in muscles, along with linoleic acid. It has been demonstrated that insufficient n-6 consumption causes suboptimal development in preterm newborns. The enzymes elongases and desaturases can break down linoleic acid into polyunsaturated fats (PUFA) with a longer carbon chain and more double bonds. Arachidonic acid is the most prevalent and physiologically significant of these PUFA. The ability of various cell types to metabolise linoleic acid varies. For instance, there is little linoleic acid conversion to arachidonic acid in endothelial cells, indicating that the endothelium needs a supply of preformed arachidonic acid to sustain its intracellular arachidonate reserves like in THP-1 monocytes, the conversion of linoleic acid is approximately 40%, while in HepG2 cells it is about 10% and in astrocytes, but not neurons, can convert linoleic acid to arachidonic acid, thus supporting the neuronal need of this fatty acid.In humans, the conversion of linoleic acid to long chain-PUFA (essentially arachidonic acid) is very limited (<1%). As a result, consuming more linoleic acid in the diet has no discernible effect on the levels of arachidonic acid in tissue or on the production of prostaglandins or other metabolites derived from arachidonic acid. In the epidermis of human skin, it is the most prevalent PUFA. One of linoleic acid's primary functions is to support the body's epidermal water barrier. The deficit causes hair loss, scaly skin, etc. Despite the assertions of several writers that a high linoleic acid diet may exacerbate human inflammation[31].

Milk fat is the richest natural dietary source of Conjugated Linoleic Acid/CLA .Conjugated linoleic acid (CLA) refers to a family of positional and geometric isomers of linoleic acid (an n-6 omega fatty acid) predominantly found in the milk and meat of ruminants. Out of the 28 isomers, the cis-9, trans-11 isomer makes up 75–90% of the total milk fat, while the trans10, cis-12 CLA is found in a much smaller amount. These isomers are capable of preventing certain cancers, hypertension, atherosclerosis, and diabetes, as well as enhancing immune function and body composition. In a study, it was discovered that the blood lipid profiles of healthy guys with normal lipid profiles might be slightly improved by cis-9, trans-11. When taken in quantities greater than those already found in dairy foods, this CLA isomer failed to decrease LDL cholesterol.CLA is also found to have anti-inflammatory properties and may play a role in the management of chronic inflammation, such as inflammatory bowel disease and rheumatoid arthritis [32].

Ruminant trans fatty acids (rTFAs) are found naturally in dairy and meat products and are structurally different from industrial TFAs. Vaccenic acid (trans-11-octadecenoic acid) constitutes the main TFA in milk fat and it can be partially converted into CLA in humans and that vaccenic acid from ruminant sources is not a risk factor for CVD. iTFA increases CHD risk factors and CHD events and probable evidence of an increased risk of fatal CHD, sudden cardiac death, metabolic syndrome and diabetes from iTFA. There is not a large body of evidence to suggest either a deleterious or a beneficial effect of trans fats on cancers. The quantity of trans fats consumed may also be a factor in the disease risk.

The concentration of TFAs in ruminant fats varies with season and animal feed.In adults, the estimated average daily ruminant TFA intake in the US is about 1.5g for men and 0.9 g for women. Even when total ruminant fat intake is relatively high, the potential amount of TFA from this source is still quite modest. rTFA do not appear to be major contributors to CHD risk. According to European union guidelines, food business operators shall ensure that information on amount of trans fat should be provided where the amount of trans fats shall not exceed 2 grams per 100 g. Efforts to reduce TFA contents of diets have primarily involved nutritional labelling of TFA content in foods. n-3 fatty acids are essential for normal physiological functioning and for the maintenance of health. Replacing SFAs with PUFAs decreases the risk of Coronary Heart Diseases. PUFA intake can also reduce diabetes risk. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) contribute to the prevention of CHD & other degenerative diseases of ageing.

Linolenic acid which is also an essential fatty acid that can lower the risk of cardiovascular diseases and fatal coronary disease[33]. It reduces the symptoms of rheumatoid disease activity. It can also reduce hypertension.Studies show that humans have the capacity to convert α-linolenic acid (ALA) to EPA and DHA, but efficiency of conversion is low. Fish and fish oils are rich sources of n-3 long chain PUFAs. Increase in EPA and DHA in cow milk can be achieved through the addition of fish oil or fish by-products to the cows' diet. ALA in the form of plant oils and oilseeds has had little effect on EPA and DHA levels.

Arachidonic acid (ARA) is a 20-carbon chain fatty acid.Arachidonic acid is necessary in functioning of nervous system, skeletal muscle and immune system. It serves as a protection from infections and tumor initiation [34]. This fatty acid is critical for infant growth and brain development and thus used in infant formulas [35].Arachidonic acid metabolism is important for human health and tissue homeostasis. Arachidonic acid itself confers cell membranes with flexibility and fluidity, serves as a lipid second messenger in cellular signaling, acts as an inflammatory intermediate and induces vasodilatation [36].

Docosahexaenoic acid (DHA) is a fatty acid containing 22 carbon which is essential for the maintenance of normal brain function in adults and for the growth and functional development of the brain in infants. DHA can enhance learning ability and its deficiency causes deficits in learning. DHA is taken up by the brain in preference to other fatty acids. It is synthesized from long chain fatty acid precursors linoleic acid and a-linolenic acid. This fatty acid is observed to have positive effects on diseases such as arthritis, atherosclerosis, hypertension, depression, diabetes mellitus, myocardial infarction, neurological abnormalities and thrombosis. Studies reveal that DHA supplements can increase the HDL to LDL cholesterol ratio and thus reducing the total cholesterol to HDL ratio and a decreased risk for coronary artery disease[37].

Eicosapentaenoic acid (EPA) belongs to the n-3 fatty acid class and is a long chain fatty acid. There have been reports of the positive impact of certain EPA-rich foods on risk factors for arterial thrombosis and cardiovascular disease. Recent research indicates that EPA may also benefit people with other illnesses like psoriasis, arthritis, renal problems, and maybe even cancer[38].

3. Conclusions

Importance of Ghee/Butterfat

Ghee / Butterfat is widely produced and consumed in India, Sudan, Ethiopia and, Middle East [39]; nevertheless, in the last decade, the American continent, with the USA, Argentina, and Paraguay, as the main producer, has increased its production of cow ghee between 3000 and 12000 tons per year [40]. In the same way, Western countries have displayed increasing ghee intake [41] because of the globalization process and the replacement of the consumption of margarine due to the high content of industrial trans fatty acids (iTFA). Ghee is also gaining popularity in Australia, Arabian countries, the United States, the United Kingdom (UK), Belgium, New Zealand, Netherlands, and many other African and Asian countries [42].

Ghee is a unique fat to its characteristic flavour which is the basic criterion for its acceptance and is greatly influenced by the processing methods i.e.as, fermentation of cream, butter or milk, and even heating processes. It is fairly shelf-stable because of its low moisture content and possible natural antioxidant contents. As human food, ghee has been accepted universally as superior fat to other fats, mainly because of its characteristic short-chain fatty acid content, which is responsible for its better digestibility and anti-cancer properties. Ghee is also an important carrier of fat-soluble vitamins (A, D, E, K) and essential fatty acids (linolenic acid and arachidonic acid), apart from having rich and pleasant sensory properties. Ghee is believed to be a coolant, capable of increasing mental power, physical appearance, and prognosis of ulcers, and eye diseases.

The view that dietary saturated fatty acids (SFA) should be minimized to reduce the metabolic syndrome and cardiovascular disease (CVD) risk has dominated nutritional guidelines for decades and the high content of saturated fatty acids in milk fat (about two-thirds of total fatty acids) has been currently employed as an argument to link dairy product consumption with an increased incidence of those pathologies. However, recent scientific studies do not justify the maintenance of those recommendations in a healthy population [43].

In the past, it was widely accepted that the intake of 12:0, 14:0, and 16:0 SFA, which are detected in relevant quantities in dairy fat, would be unhealthy in excessive amounts. However, the matrix in which these saturated fatty acids contain may influence health outcomes. Recent research has shown that several dairy matrix components, mainly calcium, peptides, phosphorus, and the milk fat globule membrane, modify blood lipid responses to SFA intake [44].

Eventually, milk fat is a natural and almost exclusive source of certain bioactive fatty acids with potential benefits for human health. Some of them are not found in our diets in significant amounts elsewhere and the consumption of low-fat or fat-free dairy products would limit their intake. For instance, dairy fat is almost the only source of butyric acid (4:0), conjugated linoleic acid (CLA) as well as branched-chain FA in the human diet. Although these FA constitute only a minor percentage (2% of total milk fat) in dairy fat, small amounts may still be biologically relevant, alone or within the context of the dairy matrix [45].

Data Availability declaration:

The authors confirm that the data supporting the findings of this study are available within the article.

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