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Socio-economic dynamics and innovative technologies affecting health-related lipid content in diets: Implications on global food and nutrition security

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ABSTRACT

The recent increase in human population coupled with rural-to-urban migration has led to challenges in managing a balanced diet in both food 'secure' and food 'insecure' regions. As a result of this geographic phenomenon, the human population continues to suffer from caloric-related conditions and diseases, including obesity and coronary heart diseases. In addition, fat and fatty acid composition of the diet has come under severe attack from the media and different human nutrition corridors in the past as they have been implicated in aiding the increase in cases of coronary heart diseases despite their important roles in cellular functions. In this view, fat and fatty acids is of great significance to the modern society, which aims at balancing their dietary proportions for efficient functionality of the human body systems. To improve food and nutrition, understanding the physiological function of the body and biochemical function of the fatty acids and polar lipids and getting a clearer view of the socio-economic aspects surrounding food consumption is also important. However, to further enhance the utilisation of fats accessed from diets, it is important to highlight significant current innovative technologies used to improve food fatty acid profiles and the influence of media on dietary and food consumption patterns. This review discusses the significance of health-related fatty acids, socio-economic aspects governing their presence in food and consumption, and how all these factors have a bearing on achieving the goal of human health, well-being and food and nutrition security.

Contents

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1. Introduction

The World Health Organisation (WHO) estimates that the global population of obese and overweight individuals is close to 1.4 billion and continues to increase, whilst close to a billion people do not acquire sufficient calories and essential nutrients in their diets (World Health Organisation, 2003). In addition, industrialised societies' diets are characterised by increases in cereal carbohydrates, energy, *trans*-fatty acids and decrease in energy expenditure, fruit and vegetables (Dunbar, Bosire, & Deckelbaum, 2014). This is despite the tremendous efforts made by many governments in improving access to physical facilities, media education drives, adequate and nutritious food through various food and health programmes.

These challenges have led to an increase in diet related diseases, particularly those of coronary and cardiovascular nature, leading, in many instances, to death (Garnett, 2014). In the developed world, these trends in food dynamics are linked to growing financial freedom, excess food in supply chains resulting in increased food consumption (Chang & Chow, 2007). This change in the environment, i.e., food and exercise, is observed to be the major catapulting factor affecting human wellbeing, health and causing deaths. In addition, diet-migratory individuals especially those moving and residing in urban centres where access to natural plant and animal products is limited, are at more risk of developing such epidemic lifestyle diseases (Simopoulos, 2003). Recent research in human nutrition has emphasised the need to quantify the exact amount of health-related nutrients especially, fatty acids, essential to human needs in foodstuffs in order to promote quality human health.

Lipids, fats and fatty acids are an integral part of the human diet responsible, in general for energy provision, growth and development (Chang & Chow, 2007). The high energy content of lipid and fat fraction make it a debatable component of the diet, often blamed for excess energy which results in obesity, and high blood cholesterol levels. It is important to note that not all, but a certain groups of fatty acids such as saturated fatty acids are responsible for weight gain, obesity and heart diseases (Haug, Hostmark, & Harstad, 2007). However, special groups of health-related fatty acids such as unsaturated fatty acids help in reducing blood cholesterol contents are anti-carcinogenic, anti-diabetic and improve immunomodulation (Simopoulos, 2003). In addition the inclusion of polar lipids has been identified as a potential alternative to general essential fatty acids (Nasopoulou, Tsoupras, Karantonis, Demopoulos, & Zabetakis, 2011). From a health point of view, it can be observed that the positives outweigh the negatives associated with fatty acid consumption, thus more wide scope studies are required as suggested in a commentary by Zabetakis, Antonopoulou, and Demopoulosm (2013).

It is also important to note that reports of such risks do not give a strong description of consumption and implications of fat and fatty acid consumption between different social and economic influences as there is varying perceptions of fat and fatty acids across different strata in the world (Damman, Eide, & Kuhnlein, 2008). This has led to misrepresentation, misinterpretation, clumsy and mis-timed reporting of nutritional opinions and facts by researchers (Vlachopoulos, Richter & Stefanadis, 2013) and the media, resulting in consumers foregoing other foods containing vital nutrients which could result in deficiencies and compromise in health (Nagler, 2014). In this respect, lack of necessary nutrients resulting from disturbance of the food system flow will ultimately hamper food security. Provided some essential fatty acids are not available in the diet, the goal of food security will never be met as provision of a balanced diet is a pre-requisite for food and nutrition security.

Research has been done on effects of fatty acids on human health, socio-economic factors affecting food consumption and their effects on food security but in a fragmented way. The aim of this review is to discuss the effects of fatty acids from plant and animal sources in the human diets on health, media effects, improved technologies, the relevance of socio-economic pressure and their overall effects on food nutrition security.

2. Health-related fatty acids common in human diet and their implications

On average, milk, ground beef, stewed chicken breast and cooked lamb contain about 33, 15, 8 and 21%, respectively, total lipid important as an energy source for humans (FAO, 2006). However, the exact composition of triacylglycerol and subsequently fatty acids type is genetically determined and differs in all species and product (Nantapo, Muchenje, & Hugo, 2014). The resulting fatty acids composition in food consumed differs according to protocol of preparation, with food prepared using fats and oils increasing content of certain fatty acids common in those oils (Williams, 2000; Wolmarans, 2009).

Fatty acids are made up of linear skeleton of hydrocarbons attached to a carboxyl group at one end (Livingston, Lovegrove, & Givens, 2012). Fatty acids are classified as saturated (no double bond), mono-unsaturated; MUFA (one double bond) and poly-unsaturated; PUFA (more than one double bond) depending on the presence and number of double between carbon atoms. Other classes of fatty acids include *trans*-fatty acids and free fatty acids (Williams, 2000) and polar lipids, micro- and macro-constituents of the Mediterranean diet (Nasopoulou et al., 2011). Saturated fatty acid are either short-chain containing 4–12 carbon chains, mid-chain containing 13–16 carbon long chains and long-chain fatty acids of 17–26 carbon chains.

2.1. Saturated fatty acids

Common health-related short-chain saturated fatty acids C4:0–C10:0 are found in milk of most animal species and only a few seed fats, the longer the carbon chain the more prominent they are in other plant parts such as leaves (Wolmarans, 2009). Traces of 4:0 have been detected in lamb muscle and fat but not in pork, chicken, eggs and plant material (Woods & Fearon, 2009). However, the quantity of medium chain to longer chain fatty acids greatly improves in plant material as the carbon chain grows. Medium chain saturated fatty acids, lauric acid (12:0), myristic acid (14:0) and palmitic acid are common in both plant and animal sources (Garaffo et al., 2011). These fatty acids especially palmitic acid, can constitute more than 50% of the fatty acid portion of plant fatty acids and beyond 75% in milk and milk products (Nantapo et al., 2014). However, it is important when reporting to clearly indicate that the effect of different saturated fatty acids on human health varies and should be looked at carefully in order to avoid confusion to consumers. Concerted and targeted research should therefore aim at unfolding the relationship between each individual fatty acid to human disease (Roca Fernandez & Gonzalez Rodriguez, 2012).

Evidence supports that some very short chain fatty acids are not atherogenic, despite being in this group. Short-chain saturated myristic acid is responsible for increasing plasma total and LDL cholesterol concentrations and perception of fatty acids (Williams, 2000). However, the cholesterol increasing properties of lauric acid and atherogenicity of palmitic acid have not been well defined (Roca Fernandez & Gonzalez Rodriguez, 2012). Long chain saturated fatty acids are more common in most animal and plant fats, but no evidence supports their involvement in increasing the risk of coronary heart diseases. Clinical evidence suggests that some long chain saturated fatty acids such as stearic acid do not have a relationship with increase in occurrence of cancer and CVDs. In general, animal tissue is considered to contain the highest saturated fatty acid content (Wolmarans, 2009). To deal with the unhealthy saturated to unsaturated fatty acid ratio in beef meat, some researchers have proposed breeding and farming of breeds with a higher proportion of unsaturated fatty acid, as discussed later (Muchenje, Dzama, et al., 2009; Muchenje, Hugo, et al., 2009).

2.2. Unsaturated fatty acids

Oleic acid and *trans*-vaccenic acid (TVA) are the most common monounsaturated fatty acids (MUFA). Oleic acid is the second most abundant fatty acid in milk and is regarded as a desirable component of dietary lipid (Roca Fernandez & Gonzalez Rodriguez, 2012). *Trans*-vaccenic acid is a monounsaturated *trans*-11 fatty acid produced by rumen microorganisms and is unique to ruminant fat and should be distinguished from the health exposing *trans*-fatty acid class. Diets containing high MUFA content are known to reduce the risk of developing coronary heart diseases (Garaffo et al., 2011). Williams (2000) observed that the cholesterol lowering responses of MUFA is lower than that of PUFA, hence, monounsaturated fatty acids have been used to substitute SFA in many feed diets resulting in a lower SFA content in animal products. Strong advances have also been made in substitution of SFA in processed foods and margarines, with positive health implications reported (Livingston et al., 2012).

Polyunsaturated fatty acids are scientifically known for human health benefits, provided that they are consumed in right proportions. Most PUFAs are commonly grouped under omega-3 and omega-6 fatty acids, with each fatty acid having individual and unique properties (FAO, 2013). The common PUFA and their biosynthesis pathways are depicted in Fig. 1. The most prominent polyunsaturated fatty acids include, the omega-3 polyunsaturated fatty acid (n − 3 PUFA), alpha-linolenic acid (ALA, 18:3 n − 3), eicosapentaenoic acid (EPA, 20:5 n − 3) and docosahexaenoic acid (DHA, 22:6 n − 3). Polyunsaturated linoleic acid (LA, 18:2 n − 6) is the most common omega-6 fatty acid (Calder, 2014; Deckelbaum & Calder, 2010; Dunbar et al., 2014; Fraeye et al., 2012).

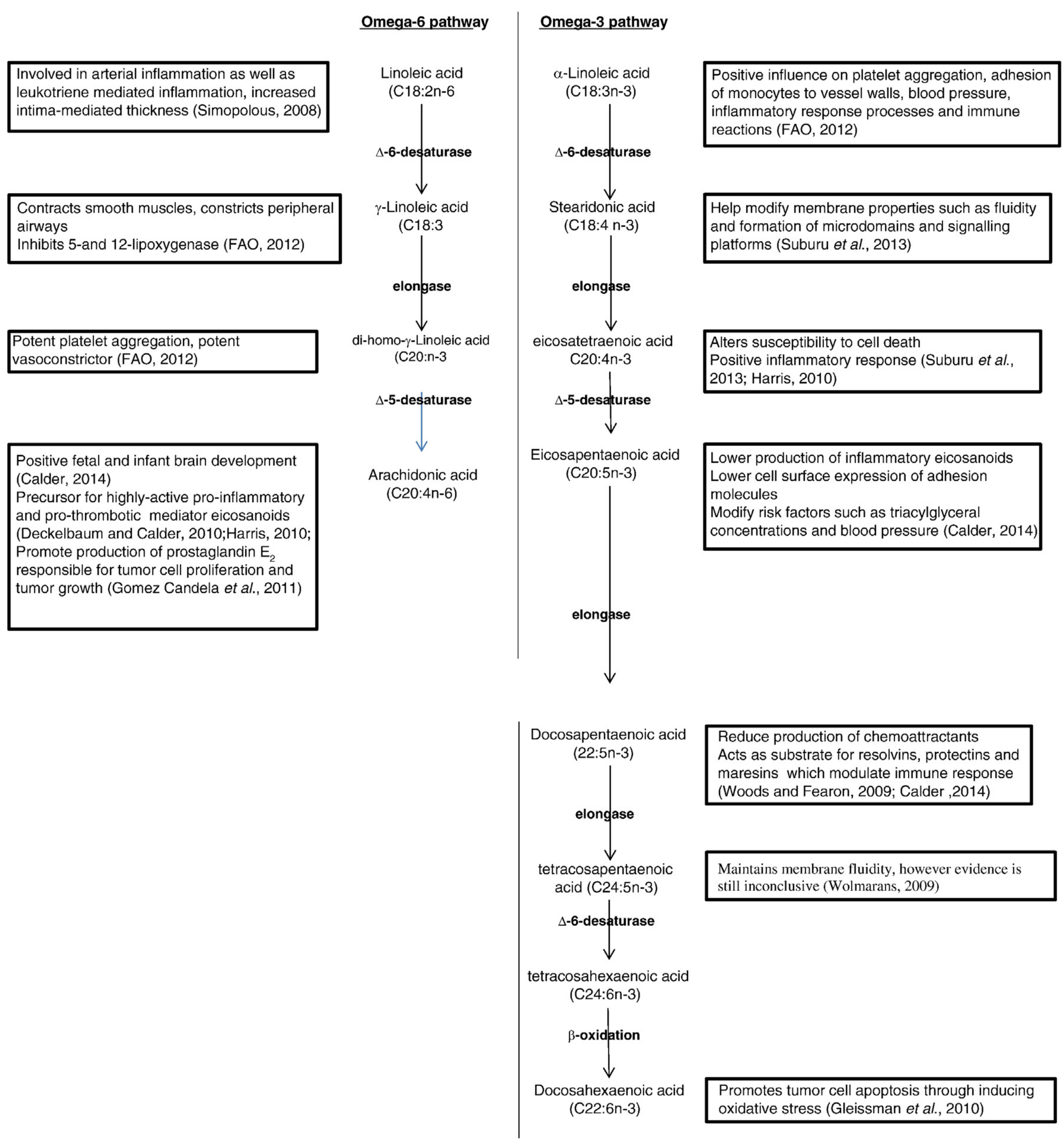

Fig. 1. Metabolic pathways and human health effects of essential n − 3 and n − 6 fatty acids (Harris, 2010).

Long chain fatty acids DPA, EPA and DHA are synthesised from the simple plant derived essential fatty acid α-linolenic acid in an enzyme dependant pathway. Initially, α-linolenic acid is converted to EPA by delta-6 desaturase and delta-5 desaturase and elongase enzymes and then to DPA and finally DHA (Calder, 2014). Fraeye et al. (2012) highlighted that the health benefits of n − 3 fatty acids are more as a result of long chain EPA and DHA, rather than ALA. Dunbar et al. (2014) noted that not all n − 3 fatty acids, especially those in great abundance in land plants such as linseed and rapeseed, confer health benefits when fed to humans. Long chain length fatty acids with high number and complex positioning of double bonds are more responsible improved cellular function and disease control than short chain n − 3 fatty acids. This was also corroborated by Wolmarans (2009) and Garaffo et al. (2011) who highlighted the significance of APA and DHA present in sea food, especially fatty fish and marine algae as good contributors to human health.

Delta-6 desaturase and delta-5 desaturase enzymes are also shared by the pathway that converts n − 6 linoleic acid (LA) to n − 6 arachidonic acids (AA). This situation introduces a substrate level competition, thus oversupply in n − 6 linoleic acid is a rate limiting factor to the more favoured and health benefiting conversion of ALA to EPA and DHA (Williams, 2000). The strong affinity of delta-6 desaturase for ALA is then cancelled by a strong presence of LA whose concentrations are always high in diet (Dunbar et al., 2014). However, the conversion of ALA to EPA and DHA is naturally less than 5% and the result is even lower in adults (Gomez Candela, Bermejo, & Loria Kohen, 2011). This rate is affected by other factors such as age, sex, physiological status (Fraeye et al., 2012), genetics, diseases and blood concentration of hormones such as oestrogen (Calder, 2014). The need for enrichment of common foods becomes necessary especially in western diets where recommended levels are rarely met. Other sources of omega-3 fatty acids include fish oils, cod liver oil, krill oil and pharmaceutical grade preparations (Calder, 2014; Lund, 2013). The role of DPA is lesser understood than other n − 3 DHA and EPA whose presence in the diet has been linked to improved health and cellular function. It is important to note that, if supplied in lower proportions relative to n − 3 ALA, n − LA has more benefits to human health and wellbeing. Arachidonic acid is needed in foetal and infant brain development and should be to promote good health.

Unfortunately, both monogastrics and ruminants cannot synthesise monounsaturated and polyunsaturated fatty acids and these essentially have to be supplied by diet or any other ways (Dunbar et al., 2014) as depicted in Table 1. Wolmarans (2009) regarded plant and vegetable oil as an important source of both monounsaturated and polyunsaturated fatty acids necessary in promotion of human health, which is usually low in animal sources.

Despite all the health promoting evidence supporting n − 3 PUFA intake, the mechanism of action is not yet clear (Gladine et al., 2015; Saravanan, Davidson, Schmidt, & Calder, 2010; Zabetakis, 2013). This has led to doubt and scrutiny on most past research associated to n − 3 PUFA supplementation. A recently published systematic review and meta-analysis research by Rizos, Ntzani, Bika, Kostapanos, and Elisaf (2012) reports that n − 3 PUFA supplementation was not associated with a lower risk of all-cause or mortality, cardiac death, sudden death, myocardial infarction or stroke. The debate grew as several researchers scrutinised the work by Rizos et al. (2012). Lewis (2013) argued that dietary intake or supplements intake and source of n − 3 PUFA are 2 factors that may not have been adequately addressed in the study. To augment on this, Sethi, Singh and Arora (2013) suggested that authors did not explore the type of n − 3 PUFA supplements and other co-administered medication. Vlachopoulos et al. (2013) warned that results from Rizos et al. (2012) should be interpreted with caution due to methodological shortcomings of the study and issues pertaining to interpretation of result findings. In this respect, Galli and Brenna (2013) suggested that a meta-analysis used by Rizos et al. (2012) be applied to treatments with manufactured drugs with a well-defined composition. As such, omega-3 PUFA are usually acquired through diet and their requirements and uptake are greatly influenced by physiological status of an individual resulting in variability in concentration of active ingredients such as EPA and DHA for uptake. In light of these outcomes, Rizos et al. (2012) admitted that their study did not give a distinction of the origin of n − 3 PUFA used on test subjects as such information was not provided. In this respect, authors did not see the need to avoid n − 3 PUFA through diet or on the counter supplementation as pro-initiators of cardiovascular diseases. Saravanan et al. (2010) and Gladine et al. (2015) attribute the protective nature of n − 3 PUFA to their ability to lower triglyceride levels, prevent serious arrhythmias, and decrease of platelet aggregation and lowering of blood pressure. However, the doubt in nature of function of n − 3 PUFA will continue resulting in constructive arguments and more research towards identifying the mechanism of action of n − 3 PUFA consequently benefiting human health. In this respect, alternative sources of lipids whose mechanical and physiological function such as polar lipids, discussed later in the section, whose endpoints are known to be similar to n − 3 PUFA should be promoted in diets for the benefit of the consumer (Zabetakis, 2013); (Zabetakis et al., 2013). In addition, profiling of bioactive lipid mediators and oxygenated metabolites of n − 3 PUFA may be of novelty into the understanding of mechanisms of action of n − 3 fatty acids (Gladine et al., 2015).

CLA is a group of 28 geometric and positional isomers of octadecanoic acid with conjugated double bonds ranging from 6, 8 to 12, 14 (Collomb, Schmid, Sieber, Wechsler, & Ryhanen, 2006; Williams, 2000). These fatty acids are more of ruminant origin and common in meat and dairy products, especially cheese. CLA is noted for numerous human health benefits such as anti-carcinogenic, anti-atherogenic, anti-diabetic, immunomodulation and anti-adipogenic (Savoini et al., 2010). Most studies do not give a specific value for each fatty acid isomer when measured experimentally but base the quantity from their sample on the main isomer *cis*-9, *trans*-11 CLA isomer or rumenic acid, and usually report it as CLA. Williams (2000) highlighted the high cost of analysis procedure as restrictive in fully analysing fatty acid profiles. It is important to note that each and every fatty acid has a different contribution to the physiology and function in the human body, but such lack of clear and specific data will not help in advancing human health.

2.3. Trans-fatty acids

Trans-fatty acids are unsaturated fatty acids with at least one double bond in the *trans*-fatty acid (EFSA, 2004). Dietary *trans*-fatty acids can either be ruminant derived and partially hydrogenated vegetable oils. Sources of ruminant derived *trans*-fatty acids include dairy products, beef and lamb (Williams, 2000), whilst latter are mainly found in industrially prepared foods (Roca Fernandez & Gonzalez Rodriguez, 2012). Research has linked the effects of hydrogenated vegetable oil *trans*-fatty acids in increasing the risk of coronary heart disease by raising LDL cholesterol/HDL ratio (Livingston et al., 2012). Only a few individual *trans*-fatty acids such as TVA are known to have health positive benefits as reported in Section 2.2. This has led to legislation aimed at limiting the content of *trans*-fatty acids in the diet especially in industrial foods (FAO, 2013; Givens, 2009; Nagler, 2014; Wolmarans, 2009).

2.4. Polar fatty acids

Polar lipids are a group of lipid micro-constituents present in Mediterranean diets possessing anti-thrombotic and anti-inflammatory properties (Zabetakis, 2013; Zabetakis et al., 2013). These properties help in reducing atherosclerosis by inhibition of Platelet Activating Factor (PAF, 1-*O*-alkyl-2-acetyl-sn-glycero-3-phosphocholine) responsible for sedimentation, clotting and blocking of coronary channels (Nasopoulou et al., 2011). This action is controlled by down-regulating PAF biosynthesis and upregulating PAF catabolism. The presence of

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Table 1
Essential fatty acid availability and consumption in food 'secure' and 'insecure' regions.

Fatty acid	Health effects	Main sources	Food secure region	Food insecure regions	Reference
Butyric	Gene function modulator Cancer prevention	Milk lipid	+	+	Goldberg & Hellwig (1997) Haug et al. (2007)
Caproic	Antiviral activity Delays tumour growth	Milk lipid	+	+	Haug et al. (2007)
Caprylic	Delays tumour growth	Milk lipid, coconut and palm kernel oil	+	+	Haug et al. (2007)
Capric acid	Inhibit COX-I and COX-II	Milk lipid, coconut and palm kernel oil	+	+	Haug et al. (2007)
Lauric	Anti-caries and anti-plaque functions Antiviral and antibacterial nature Increase	Coconut oil, palm kernel oil	+	+	Haug et al. (2007), FAO (2010)
Myristic	Increase LDL cholesterol blood levels, increase risk of CVD	Milk lipid, coconut oil palm kernel oil	+	+	Nantapo et al. (2014)
Palmitic	Increase LDL cholesterol blood levels, increase risk of CVD	Most fats and oils	+	+	Nantapo et al. (2014)
Palmitoleic		Marine oils, macadamia oil, most animal and vegetable oils	Available but at higher cost than normal	Limited consumption	FAO (2010)
Oleic	Improves stability of membranes Lowers plasma LDL-cholesterol, Cancer protection	Bovine milk, All fats and oils, especially olive oil, canola oil and high sunflower and safflower oil	+	+	Nantapo et al. (2014) Haug et al. (2007)
Gadoleic	Improves membrane signalling	Marine oils	Limited as they are available in specific fish	Limited	FAO (2010)
Linoleic	Increase risk of inflammation and oxidative stress	Most vegetable oils	+	+	Ahmed et al. (2014) Haug et al. (2007)
Arachidonic	Enhance platelet aggregation and CHD chances, pro-inflammatory	Animal fats, liver, egg lipids, fish	+	+	Hosseini-Vashan et al. (2011)
DPA	Reduce production of chemoattractants Acts as substrate for resolvins, protectins and maresins which modulate immune response	Fish, especially oily fish like mackerel, salmon, trout, herring, tuna, and sardines	Limited marine fish and farm fish consumption Medical supplements improve concentrations	Farm fish available but concentrations low Limited marine fish consumption Promoted by consumption of diversity of animal and plant	Deckelbaum and Calder (2010); Lund, 2013
α-Linolenic	Protects against oxidative stress,	Flaxseed oil, perilla oil, canola oil, soybean oil	+	+	FAO (2010) Chang and Chow (2007)
EPA	Promote cardiovascular health, anti-inflammatory response, promote mental and help in neurodegenerative diseases, Inhibits tumor genesis	Fish, especially oily fish like mackerel, salmon, trout, herring, tuna, and sardines	Limited marine fish and farm fish consumption Medical supplements improve concentrations	Farm fish available but concentrations low Limited marine fish consumption Promoted by consumption of diversity of animal and plant	Simopoulos (2003) Dunbar et al. (2014) Gomez Candela et al. (2011)
DHA	Promote cardiovascular health, anti-inflammatory response, promote mental and help in neurodegenerative diseases	Fish, especially oily fish mackerel, salmon, trout, herring, tuna, and sardines found in modest amounts in eggs and meat	Limited marine fish and farm fish consumption Medical supplements improve concentrations	Farm fish available but concentrations low Limited marine fish consumption Promoted by consumption of diversity of animal and plant	Mori and Hodgson (2013) Al-khalifa, Givens, Rymer, and Yaqoob (2012)

+: denotes moderate to high availability in most diets.

PAF in a diet improves its nutritional value (Nomikos, Karantonis, Skarvelis, Demopoulos, & Zabetakis, 2006).

Contrary to the well accepted omega-3 PUFA hypothesis, a recent evaluation of all randomised trials (20 studies on 68,680 patients) on the supplementation of omega-3 PUFAs to adults found no statistically significant association between omega-3 PUFA intake and cardiovascular disease (Rizos et al., 2012). The beneficial effect of omega-3 PUFA on cardiovascular disease was previously attributed to reducing plasma cholesterol and triacylglycerol levels (Shearer, Savinova, & Harris, 2012) or by inhibiting some of the stages of atherogenesis (Mori, Beilin, Burke, Morris, & Ritchie, 1997; Sneddon, McLeod, Wahle, & Arthur, 2006; Weber, Aepfelbacher, Lux, Zimmer, & Weber, 1991). To explain the lack of association between omega-3 PUFA intake and cardiovascular disease observed by (Rizos et al., 2012) it was postulated that the development of atherosclerotic lesions was not influenced by the levels of cholesterol and triacylglycerol but by the actions of polar lipids that acted as platelet activating factor inhibitors (Karantonis, Antonopoulou, & Perrea, 2006; Nasopoulou, Karantonis, Perrea, Theocharis, & Iliopoulos, 2010; Tsantila et al., 2007; Tsantila et al., 2010). These polar lipids may therefore be responsible to inhibit the onset of atherosclerosis and the development of cardiovascular disease (Nasopoulou et al., 2014). Such polar lipids with platelet activating factor inhibitors have been found in food such as red and white wine (Fragopoulou, Antonopoulou, & Demopoulos, 2002), yoghurt (Antonopoulou, Semidalas, Koussissis, & Demopoulos, 1996), fish (Nasopoulou, Nomikos, Demopoulos, & Zabetakis, 2007; Nomikos et al., 2006; Rementzis, Antonopoulou, & Demopoulos, 1997), olive oil (Karantonis et al., 2006), and olive pomace (Tsantila et al., 2007). However, as previously Vlachopoulos et al. (2013) strongly argues that the research by Rizos et al. (2012) lacked statistical significance and correct interpretation, therefore n − 3 PUFA related theories and practical research on human health should stand. Due to these conflicting theories, future research should therefore be focused on mechanisms by which atherosclerosis develop and by correlating the structure of fatty acids and polar lipids such as phospholipids and glycolipids to the mechanisms in the development of atherosclerosis in experimental animals and humans.

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2.5. Fatty acid indices and ratios

The most common ratio used to describe acceptable proportions of health-promoting and health-negative fatty acids is the omega-6:omega-3 ration. It has been generally accepted that an increase in omega-6 fatty acids may be detrimental to health, given the pathways some of which these fatty acids undergo when in excess (Ahmed, Balogun, Bykova, & Sukhinder, 2014; Roca Fernandez & Gonzalez Rodriguez, 2012). In this respect, from scientific evidence nutritionists have over the years urged for a decrease in this ratio. The accepted standard in the diet is anything below 5, and can be as low as 1 (Hosseini-Vashan et al., 2011). However, research has also shown that in western diets this ratio can be as high as 15:1.

Atherogenicity Index (AI) measures the relationship between the sum of the main saturated fatty acids and that of the main classes of unsaturated, the former being considered pro-atherogenic (favouring the adhesion of lipids to cells of the immunological and circulatory system), and the latter anti-atherogenic (inhibiting the aggregation of plaque and diminishing the levels of esterified fatty acid, cholesterol, and phospholipids, thereby preventing the appearance of micro- and macro-coronary diseases). It is represented by the following equation;

$$\mathrm{IA} = [(4 \times \mathrm{C14:0}) + \mathrm{C16:0} + \mathrm{C18:0}] \Big/ \left[\sum \mathrm{MUFA} + \sum \mathrm{PUFA\text{-}n6} + \sum \mathrm{PUFA\text{-}n3}\right].$$

Thrombogenicity index (TI): showing the tendency to form clots in the blood vessels. This is defined as the relationship between the pro-thrombogenetic (saturated) and the anti-thrombogenetic fatty acids (MUFAs, PUFAs − n6 and PUFAs − n3).

It is represented by the following equation;

$$\mathrm{IT} = \frac{\mathrm{C14:0} + \mathrm{C16:0} + \mathrm{C18:0}}{0.5 \times \mathrm{MUFA} + 0.5 \times \mathrm{PUFA\text{-}n6} + 3 \times \mathrm{PUFA\text{-}n3} + \mathrm{PUPA\text{-}n3/PUPA\text{-}n6}}.$$

There is evidence that improved atherogenicity index and trombogenicity index due to the consumption of omega-3 PUFA from marine origin lead to lower incidence of coronary heart disease (Albert, Hennekens, & O'Donnell, 1998; He, Song, & Daviglus, 2004; Konig, Bouzan, & Cohen, 2005; Whelton, He, Whelton, & Muntner, 2004). It is unclear exactly how omega-3 PUFAs prevent atherosclerosis but it is postulated that omega-3 PUFAs prevent atherosclerosis by lowering the levels of triacylglycerol, preventing arrhythmias, decreasing platelet aggregation or lowering blood pressure (Saravanan et al., 2010). It is however, important to improve indices used when referring to health implications of fatty acids in order to give the public up to date and true information. Ulbricht and Southgate (1991) added that it is important to keep the atherogenecity index as it gives a guide to relationship between health promoting and negative fatty acids.

3. Socio-economic factors affecting consumption of essential fatty acids in developed and developing regions and implication on food and nutrition security

Food and nutrition security exists when “all people and at all times have access to sufficient, safe, nutritious food to maintain a healthy and active lifestyle” — (FAO, 2006). This is based upon an individual's, household, community or the world population ability in having adequate resources to access sufficient and stable quantities of quality and nutritious food which he or she can effectively utilise to maintain a healthy body system. It is worthwhile to appreciate that this system is difficult to achieve but certain components of one's socio economic status especially income, will help promote food and nutrition security thereby improving one's health status (Bowman, 2007). However, it is important to realise that all components of socio-economic status including, education and occupation, are intertwined together and need to be well defined to understand the needs of an individual in the attainment of a healthy wellbeing (Adler & Newman, 2002). However, other factors such as gender, customs, cultural beliefs and religion have a bearing on the attainment of food and nutrition security especially in more spiritual communities than observed in most third world countries. It has been over emphasised in recent research for a need for bigger population-based studies to address the lack of information on the needs, availability and effects of fat and fatty acid consumption on human health of all socio-economic strata.

3.1. Financial and economic determinants

Greater socioeconomic changes especially in the last 100–150 years, due to the industrial revolution, have led to dietary changes (Gomez Candela et al., 2011). This is especially true as there is a great improvement in the income, a key component in one's socio economic status (Bowman, 2007). Data from various literature shows that the Palaeolithic nutrition/diet was low in total fat and saturated fat, low sodium, negligible *trans*-fatty acids and a n − 6:n − 3 ratio of 1:1 (Dunbar et al., 2014; Gomez Candela et al., 2011; Simopoulos, 2004; van Elst et al., 2014). However, recent studies have indicated the presence of an unhealthy n − 6:n − 3 ratio exceeding 15:1 attributed to the ever presence of vegetable oil in modern diets. This is especially true for low to medium income groups who seldom have time to shop around for highly nutritious food but mainly depend on quick prepared fast foods whose fat content of the ingredients are not known. The situation becomes worse when these people reside where marine fish is less consumed. Rural communities whose per capita income is lower than the mid-income groups are more likely to consume diets with a health fatty acid profile due to diversity of animal and plan products (Loring & Gerlach, 2009). It is important to note that high income groups resort to nutritionists' recommendations in purchasing of nutritious food and supplements. In addition, the increase in wealth in most parts of the world promotes per capita consumption of seafood. This is true for Japan, China, East Asia and North Africa where there is increased demand and consumption of seafood (Lund, 2013).

3.2. Cultural, gender and religious perspectives

In a study in Alaska, it was observed that most households preferred wild foods intake to store-bought foods. As a results the diet sampled contained higher amounts of nutrients especially n − 3 fatty acids (Loring & Gerlach, 2009). It is important to note that diet diversification plays a critical role in improving nutrient balance and consequently good health. These preferences of diverse fish were also noted in parts of Asia and were noted for promoting social wellbeing (Belton & Thilsted, 2014). However, access to food is also based upon gender dynamics. Ownership of livestock resources in small-scale is biased towards man, thus depriving woman headed households of important nutrients and income to acquire health foods. Vegetarians avoid the risk of consuming SFA and TFA, however, their diets may lack crucial n − 3 PUFA abundantly available in fish and other animal sources (Loring & Gerlach, 2009) as depicted in Table 1.

3.3. Lifestyle vs diet

It is important to realise that for any nutrient to impart positive results, all other factors affecting the physiological function of the human body should be effectively operational. In many instances, as reported by many researchers including Rizos et al. (2012), the results of supplementing fatty acids or any nutrient in the diet have not achieved desired/expected levels due to unexplainable reasons. The body readily responds to external or environmental stimuli, thus, any change that may negatively impair cellular function is detrimental to promotion of growth and development. From this principle, it can be observed that chronic cardiovascular disease remain a challenge in middle-to-high income communities (Willet et al., 2006) due to certain lifestyles despite

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an improved education on diet regulating, especially sugars, fats and fatty acids.

Willet et al. (2006) observed a high incidence of cardiovascular disease among many communities in developed world. Overwhelming evidence from experimental results in the developed countries has linked lifestyle characteristics such as smoking, alcohol and lack of physical activity to high incidence of cardiovascular diseases (Kromhout, Menotti, Kesteloot, & Sans, 2002). Consumption of improved diet, especially, an increased omega-3 PUFA or polar lipids intake will have less impact on cardiovascular outcomes provided lifestyle activities remain the same. To prevent the occurrences of these diseases it is important to avoid tobacco, maintain a healthy weight avoiding obesity, having daily physical activity, eating a healthy diet containing high polar lipids and n − 3 PUFA (marine fish and oils), fruit and vegetables, cereal and high fibre content, whilst maintaining a reduced saturated and *trans*-fatty acid, sugars and sodium concentration (Willet et al., 2006).

4. Fatty acids relevance to food 'secure' and food 'insecure' regions

The provision of a balance diet is crucial in qualifying any food system in terms of food and nutrition security. This is especially relevant to most agro-dependent communities who mostly reside in rural African and Asian states. These communities are considered resource poor and at times depend on food-aid for supplementary nutrition needs as there are recurring crop and livestock losses. In this regard, they are commonly referred to as food 'insecure' regions. Due to this fact harvesting and consumption of meat from large stock such as cattle and water buffalo from the farmer's own herd is limited, at times depriving the household of several essential fatty acids. However, diversification of crop and livestock production in most food 'insecure' regions gives these communities a nutrition advantage over other more defined production systems (Toledo & Burlingama, 2006). These farmers raise small stock such as goats, sheep, rabbits, pigs, domestic fowl (geese, guinea fowl, chickens and turkey) and donkey to supplement their meat intake. Additional fatty acid sources include milk and eggs gathered from these species for daily consumption, occasionally game meat and fish. Most animals reared in these production systems are allowed to graze and feed on naturally occurring forage and fodder, resulting in meat and eggs high amounts of MUFA and PUFA and less amounts of SFA, cholesterol and TFA compared to intensively raised animals commonly consumed in food 'secure' regions (Fraeye et al., 2012; Wolmarans, 2009). According to FAO (2010), 79.8 million tonnes of fish was consumed in the developing world compared to 24.4 million tonnes in the developed world. Fish are the cheapest source of protein frequently consumed in low-income food 'insecure' regions of the world and are a rich source of micronutrients and essential fatty acids necessary for infant growth and brain development (Belton & Thilsted, 2014). Considering the n − 3 PUFA, EPA and DHA, content in farmed fish (though fairly lower than of wild capture fisheries commonly supplied to food 'secure' regions), diets of small scale communal households may have a better fatty acid profile that modulate good health (Suburu et al., 2013). Drying, salting, smoking preservation allows storage and transport, making these essential nutrients available to areas where fish is limited (Belton & Thilsted, 2014). Diversification of animal derived foods and consumption of naturally and/organically produced red and white meat, eggs and milk, though not adequate in quantity in food 'insecure' regions of Africa and Asia helps in effectively supplementing fatty acid profiles in diets and combat malnutrition at an individual's, household and society level. Furthermore, it helps reduce the risk of cardiovascular diseases associated with SFA and TFA (Williams, 2000) and improving the health status of food 'insecure' individuals provided there is access to other fruit and vegetables (Belton & Thilsted, 2014; Monge-Rojas, Aragon, Chinnock, Campos, & Colon-Ramos, 2013).

It is important to realise that not only meat and animal products are important in improving the dietary fatty acid profile in the human diet, but the presence of both popular and lesser known plant and fruits has an impact in reducing cardiovascular and metabolic diseases (Toledo & Burlingama, 2006) and make an 'irreplaceable' contribution to food and nutrition security (Belton & Thilsted, 2014; Stadlmayr et al., 2011). Locally consumed foods such as wild berries, nuts, fruits and vegetables usually not found on the commercial markets have received more attention in recent reports due to their nutrient profiles. However, some of these food varieties have long been relegated to and associated with food 'insecure' regions, however, biotechnology have allowed for commercial production and their availability. This factor, together with the presence of good incomes has allowed individuals in the food 'secure' regions to access and consume these high quality animal products, vegetables and fruits (Loring & Gerlach, 2009). Examples include *Moringa oleifera* leaf meal consumed in different forms and noted for the high presence of essential n − 3 fatty acids (Melesse, Getye, Berihun, & Banerjee, 2013; Qwele et al., 2013; Nkukwana et al., 2014). However, some of these foods often act as functional foods as they have health-enhancing physiologically active components (Pang, Xie, Chen, & Hu, 2012). Price distortions on some of these food items are a limitation at times for low income food 'insecure' individuals. Therefore, there is need for subsidise fish and fish oils food items in order to meet dietary fatty acids in food insecure communities in order to improve health, wellbeing and meet food and nutrition security.

5. News media influence on fatty acids perception, consumption and food security dynamics

The implications of fat and fatty acids on human health continue to be a strong subject area drawing a lot of attention from nutrition science community and the general public. This follows numerous scientific journal articles, especially in early 1990s (Borra & Bouchoux, 2009) which were investigating the effects of certain fatty acids such as saturated and some *trans*-fatty acids linked to upsurge or continued presence of certain cardiovascular diseases (Simopoulos, 2004). However, these scientific outcomes do not reach the consumers directly from the researchers, but are conveyed to the general public through print and electronic media (Borra & Bouchoux, 2009). Therefore, the media has the mandate of effectively transmitting key news on human health and raising public awareness on any such health risks or benefits (Gollust & Lantz, 2009; Jarlenski & Barry, 2013).

This role of media on the coverage of scientific research has a strong influence on improving global awareness and shaping the public perception on important health issues linked to dietary fatty acids (Borra & Bouchoux, 2009). Public opinion can thus be shaped by the media in identifying causative fatty acid and source, those responsible for solving it and society groups affected by consumption of these fatty acids (Gollust & Lantz, 2009), in a manner commonly referred to as agenda-setting and framing (Jarlenski & Barry, 2013). These news feeds benefit the consumer or improves the general public's awareness in making informed decisions on foods with fatty acids that are harmful or beneficial to health.

The problem arises when contradicting reports on health issues are reported through the media, with Nagler (2014) reporting adverse outcomes from the public after exposure to such information. More researchers have questioned the accuracy of reporting and misrepresentation of research evidence in media as a great threat to acceptance of scientific outcomes by the general public (Chapman et al., 2014). Furthermore, strong authoritative statements and recommendations given by news media lack scientific basis and are reported as fact especially when reporters fail to read the research thoroughly and understand the statistical models involved (Goldberg & Hellwig, 1997). This creates confusion, builds frustration and unnecessary doubt within consumer groups as they is little modest public knowledge on effects of several fatty acids on health (Goldberg & Hellwig, 1997). In addition, there is little organisation and understanding of scientific research results by the reporters who in turn report directly to the consumers without researcher–journalist dialogue to fully explain the study (Fresco, 2009). The resulting effects include confusion on what foods to eat and if there is any need at all to

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continue following product nutrition labels. In worse situations the agenda-setting reports by the media have pushed for change in food policy and even total ban on certain crop and animal products before strong scientific evidence in support of products has been availed, thereby slowing progress in food research. This has an important impact on the economy as some of these products are ingredients of almost every foodstuff consumed by the global population (Wolmarans, 2009). Such a situation led to a reduction in consumption of whole milk and an increase in low-fat and skimmed milk as it was deemed to contain "bad fats" or "saturated fatty acids" by the media (Deckelbaum & Calder, 2010). The results include loss of good quality bioavailable nutrients, changes in organoleptic quality of the milk and a process where consumers had to adjust to the increased cost of processed milk whilst farmers faced the burden of adjusting animal feed ingredients and reduced milk demand (Goldberg & Hellwig, 1997). Reduced milk demand reduces food and nutrition security capacity and halts socio economic progress of the society (Fresco, 2009). A recent incept, below, from a popular public daily on hydrogenated vegetable oil commonly used in most households made comments enough to frighten the general consumer, produce panic and outrage from both consumers and producers;

> "*Recent scientific research suggests that it may be responsible for an unknown, but certainly very large, number of heart attacks. Clinical researchers have discovered that ingesting just two grams a day of HVO – the amount contained in just one doughnut fried in this type of fat – increases an individual's risk of heart disease by 23 per cent. This makes HVO much more dangerous to health than the saturated fats such as butter it often replaces. It distorts cholesterol levels, encourages obesity, causes inflammatory conditions, and can even be a cause of infertility*" (The Independent.co.uk).

It is important to appreciate that vegetable oil do contain *trans*-fatty acid, due to the partial hydrogenation process, but the presence of essential mono- and polyunsaturated fatty acids necessary for good health receives little or no media coverage. This is the same for the high CLA content present in milk linked to positive health benefits (Wolmarans, 2009). These statements asserts the point highlighted by Goldberg and Hellwig (1997) indicating the power of media in influencing consumer attitudes and behaviour in food consumption patterns. To reduce the *trans*-fatty acid content of vegetable oil, cholesterol content in eggs and the saturated fatty acids in meat, milk and all animal products may seem beneficial to human health given their link to cardiovascular diseases. However, that may seem the next best choice but challenges in maintaining product organoleptic quality, integrity, and shelf life will present more economic challenges to both consumers and producers and remain far from achievable. In addition, it would seem counterproductive to remove most of the food products containing some negative fatty acids as almost all these foods have health benefiting fatty acids (Givens, 2009). However, more research should aim at reducing these harmful components whilst maintaining the wholesomeness of the food. It is then important to integrate a transparent approach linking the researcher, the media and the consumer in order to avoid situations that may disturb the food security and nutrition equilibrium.

6. Innovative technologies in improving fatty acid profiles of common foodstuffs

It has long been established that the public choose products based on taste (Goldberg & Hellwig, 1997), healthfulness (Borra & Bouchoux, 2009), and price (Niederdeppe & Frosch, 2009). However, with the growing conscience and the knowledge of health risks associated with certain foods in the diet, there has been a growing pattern of consumers demanding tailor made foods designed for different individuals (Fresco, 2009). Many novel methods have been formulated to improve nutrient composition of human foods to promote wellbeing. Functional foods have become attractive and aim at solving deficiencies and other nutritional related problems facing the world's population.

The high fat, SFA and iTFA in animal products continue to be a threat to human health affecting blood lipid concentration, insulin sensitivity and endothelium function (Monge-Rojas et al., 2013). Naturally occurring *trans*-fatty acids benefits have not been fully understood, thus researchers continue to treat them the same as iTFA and aim to reduce their concentration in meat and milk through several protocols (Givens, 2009). Several strategies commonly aim at combating SFA and *trans*-fatty acids in combination by limiting the microbial hydrogenation in the rumen. The fatty acids profiles of meat can be enhanced through the use of novel oil sources such as marine algae, chia seeds, lupin, hemp and camelina. In addition, feeding dairy cows with diets containing *cis*-MUFA varieties of rape or sunflower seed, calcium saponification of unsaturated fatty acids and use and fractionation of oil and oilseed (Givens, 2009; Wolmarans, 2009). Other long term benefits associated with this trend include reduced methane production by the animal and financial returns to the producers as such products fetch a premium on the market and encouraging consumption of milk. Hydrogenation of plant derived oils such as canola has resulted in a healthier fatty acid with reduced TFA composition. Microcapsulation of important plant oils containing high ALA alternatives of $n-3$ fatty acids has improved fatty acid profiles of the diets (Gallardo et al., 2013).

7. Conclusion and perspectives

This review asserts the fact that each lipid component of the diet has a critical role in maintaining physiological balance and health of the human being and its function can never be over emphasised. However, the challenge is to provide a fatty acid profile containing a balanced TFA, SFA, $n-3$ and $n-6$ which helps promote good health and reduce the risks of cardiovascular diseases. This can be done through fish incorporation into the diet which contains important polar lipids and PUFAs necessary for human health. This has to be addressed besides the challenges of maintaining product stability, identity, quality and functionality that may be altered through different processing procedures. In addition, economic, cultural and religious aspects and environment strongly influence the overall consumption of the sources of the health affecting fatty acids thereby requiring a more practical approach to solve diet issues. The news media is therefore encouraged to work closely with researchers in order to disseminate factual data that may help improve healthy eating habits among the general public, thereby improving the food and nutrition goals of the world. Supply of the much needed CLA, $n-3$ and $n-6$ through fish and fish oils alone will not be sustainable in future, therefore requires novel and innovative technologies and reverting to under-utilised plant and animal food sources still dominant in low-income, resource-poor and food 'insecure' regions of the world. In addition, research centred on all human health and fat content of food should be improved to gain acceptance.

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