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Nutraceutical Ingredient “Poly-Unsaturated Fatty Acids” (PUFAs) Fortification in Milk and Dairy Products: A Review

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ABSTRACT: In recent years, interest towards foods containing natural food components that improve the well-being of the general public, has increased. Those components, termed nutraceuticals or functional compounds, have been clinically proven to prevent the occurrence of certain diseases as long as they are consumed at recommended levels on a daily basis. Over the past 10 years, efforts have been accelerated to develop suitable vehicles by which nutraceuticals are delivered to the human body. Dairy fortification is one of the most important processes for improvement of the nutrients quality and quantity in food. It can be a very effective public health intervention, due to the high consumption rate of dairy products. Dairy products provide a package of essential nutrients that is difficult to obtain in low-dairy or dairy-free diets, but Poly unsaturated fatty acids PUFA are low in both conventional and organic milk and for many people it is not possible to achieve recommended daily calcium intakes with a dairy-free diet..Therefore fortification dairy products with Nutraceutical ingredient Poly-unsaturated fatty acids (PUFAs) make them very important nutraceutical foods . Fortification of dairy products with oils high in poly-unsaturated fatty acids is extremely susceptible to oxidative deterioration. This problem is targeted by many studies,

I-The Importance of Fortification Milk and dairy products with poly-unsaturated fatty acids (PUFAs):

Milk and its products must be fortificated with poly-unsaturated fatty acids for the following reasons:

A-The nutraceutical effects of poly-unsaturated fatty acids

The group of poly-unsaturated fatty acids (PUFAs) is divided into two groups: omega-3 (n-3) and omega-6 (n-6) poly-unsaturated fatty acids (PUFA), differing in the position where the first double C-bound is located. Two PUFAs are called “essential fatty acids” since they cannot be synthesized in the human body and are vital for physiological integrity. Therefore, they must be obtained from the diet. One is linoleic acid (LA, C18:2n-6) and belongs to the n-6 family. The other one is α-linolenic acid (LNA, C18:3n-3) belonging to the n-3 family. These essential parent compounds can be converted in the human body to long-chain (LC) fatty acids, but humans cannot interconvert n-3 and n-6 fatty acids .LA can be converted to arachidonic acid (AA, C20:4n-6) and further on to longer chain derivates, and LNA to eicosapentaenoic acid (EPA, C20:5n-3) in a first step and docosahexaenoic acid (DHA) (C22:6n-3) in a next step. Foods supplemented with omega-3 fatty acids (especially with long-chain polyunsaturated fatty acids or LCPUFAs including docosahexaenoic acid or DHA and eicosapentaenoic acid or EPA) provide extensive nutritional and health benefits .They have obtained from marine sources and attracted much attention in the past decade (Drusch et al. 2007). The EPA and DHA will able to control lipoproteins, blood pressure, cardiac function, endothelial function, vascular reactivity and cardiac electrophysiology, and they have antiplatelet and anti-inflammatory effects (Hooper et al. 2004). Overall, omega-3 with LCPUFA has ability to prevent coronary heart disease, hypertension, type 2 diabetes, rheumatoid arthritis, Crohn’s and obstructive pulmonary diseases (Simopoulos 1999; WHO 2002). According to Kris-Etherton 1999, when 5 % saturated fatty acids is replaced with oleic acid or polyunsaturated fatty acids (PUFA), the coronary heart disease is reduced by 20–40 % mainly by less consumption of LDL-cholesterol. An increase in the intake of oleic acid may be beneficial because it limits the intake of saturated fat which is higher than recommended levels in many countries. This goal can be achieved by altering dietary patterns, such as replacing butter with olive oil, or using new technique in food processing to modify the fatty acid profile of foods naturally rich in saturated fatty acids with oleic acid (Lopez-Huertas 2010). Eicosapentaenoic acid and DHA are essential for development of the brain,

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concentration, and the learning ability of children, as well as promoting health in the general population (Milner and Alison 1999

Artemis2010 mentioned that today, Western diets are characterized by a higher omega-6 and a lower omega-3 fatty acid intake, whereas during the Paleolithic period when human's genetic profile was established, there was a balance between omega-6 and omega-3 fatty acids. Their balance is an important determinant for brain development and in decreasing the risk for coronary heart disease (CHD), hypertension, cancer, diabetes, arthritis, and other autoimmune and possibly neurodegenerative diseases. Both omega-6 and omega-3 fatty acids influence gene expression. Because of single nucleotide polymorphisms (SNPs) in their metabolic pathways, blood levels of omega-6 and omega-3 fatty acids are determined by both endogenous metabolism and dietary intake making the need of balanced dietary intake essential for health and disease prevention. Whether an omega-6/omega-3 ratio of 3:1 to 4:1 could prevent the pathogenesis of many diseases induced by today's Western diets (AFSSA, 2010), a target of 1:1 to 2:1 appears to be consistent with studies on evolutionary aspects of diet, neurodevelopment, and genetics. A target of omega-6/omega-3 fatty acid ratio of 1:1 to 2:1 appears to be consistent with studies on evolutionary aspects of diet, neurodevelopment and genetics. A balanced ratio of omega-6/omega-3 fatty acids is important for health and in the prevention of CHD and possibly other chronic diseases. Tabea Brick et al 2016 found that continuous farm milk consumption in childhood protects against asthma at school age partially by means of higher intake of ω-3 polyunsaturated FAs, which are precursors of anti-inflammatory mediators.

Omega-3s are the most widely purchased nutritional supplement in the United States. But they took a dip in popularity in 2015 after several clinical trials failed to show a positive effect. A lower ratio of omega-6 to omega-3 fatty acids is desirable to reduce the risk of many chronic diseases of high prevalence in Western societies, but the typical American diet contains 14- to 25-times more omega-6s than omega-3s.

Omega-3 is considered an essential nutrient since it is the precursor of EPA and DHA, which cannot be synthesised in the human body (Awaisheh et al. 2005). Eicosapentaenoic acid and DHA are essential for development of the brain, concentration, and the learning ability of children, as well as promoting health in the general population (Milner and Alison 1999). among the general properties of PUFAs, is it possible to determine some concrete facts showing the interest of consuming reasonable amounts of omega-3 and to see an improvement of skin health conditions (De spirt et al 2008)

Jean-Marc Maurette 2008 mentioned that the too low level of omega-3 intake in the modern diet is a fact which is worrying health professional and authorities. Among the "traditional" recommendation for a safe and equilibrated diet, recommending food containing omega-3, is there, out of the inescapable fish oil leading to some digestive discomforts, any alternative? Two human clinical trials conducted to verify the effective efficiency of this re equilibrated diet on various skin parameters (hydration, surface evaluation, inflammation) are reviewed here. The results of the clinical trials on various skin parameters (hydration, trans epidermal water loss, roughness, scaling, superficial inflammation and blood flow) were quite convincing about the interest of such a supplementation.

B-The low content of Poly unsaturated fatty acids PUFA in milk

Poly unsaturated fatty acids PUFA are low in both conventional and organic milk, Most full-fat dairy products contain CLA in quantities varying from 6 to 16 mg/g of total fat content, with lesser amounts in meat (Parodi, 1977), 85 to 95% of which is present as the C18:2 cis-9, trans-11 isomer. Therefore, estimates of CLA daily intake from food sources range from 150 to 212 mg/d (McGuire et al., 1997) or from 300 mg to 1.5 g (Fritsche et al., 1999) although actual intake appears to be dependent on gender and intake of food from animal or vegetable origins. Ip et al. (1994)) estimated that a 70-kg human should consume 3.0 g of CLA/d to achieve maximum health benefits. Similarly, CLA supplementation in overweight subjects after weight loss seems to aid the regain of fat-free mass at experimental doses of 1.8 and 3.6 g/ d (Kamphuis et al., 2003). Nevertheless, the extrapolation of CLA effects observed in animals to the human situation should be made with caution.

Cis-polyenoic acids are present at low concentrations in milk fat, because of the biohydrogenation reactions that take place in the rumen. These acids are comprised almost exclusively of linoleic acid (9c, 12c-18:2), about 1.2 to 1.7% and a-linolenic acid (9c, 12c, 15c-18:3), about 0.9 to 1.2%. These two fatty acids are essential fatty acids; they cannot

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be synthesised within the body and must be supplied by the diet. In recent times, the usage of the term ‘‘essential’’ has been extended to include derivatives of these fatty acids, which are not synthesised in signiWcant quantities (e.g., eicosapentaenoic acid, 20:5 and docosahexaenoic acid, 22:6). The proportion of a-linolenic acid appears to be aVected by the cow’s diet; the concentration is higher in milk from pasture-fed cows than in milk from barn-fed cows (Hebeisen et al., 1993; WolV et al.,1995) Cis-polyenoic acids are present at low concentrations in milk fat, because of the biohydrogenation reactions that take place in the rumen. These acids are comprised almost exclusively of linoleic acid (9c, 12c-18:2), about 1.2 to 1.7% and a-linolenic acid (9c, 12c, 15c-18:3), about 0.9 to 1.2% (Table 1.2). These two fatty acids are essential fatty acids; they cannot be synthesised within the body and must be supplied by the diet. In recent times, the usage of the term ‘‘essential’’ has been extended to include derivatives of these fatty acids, which are not synthesised in signiWcant quantities (e.g., eicosapentaenoic acid, 20:5 and docosahexaenoic acid, 22:6). The proportion of a-linolenic acid appears to be aVected by the cow’s diet; the concentration is higher in milk from pasture-fed cows than in milk from barn-fed cows (Hebeisen et al., 1993; WolV et al.,1995) In the case of linoleic acid, the picture is less clear with diverting trends being reported by the two research groups. While milk and dairy products are perceived as good sources of bioavailable calcium, milk fat contains about 70 % saturated fatty acids (mainly Myristic and Palmitic acids) and have potentials to raise total and LDL cholesterol and increase the risk of cardiovascular disease (AHA 2006). To reduce the intake of saturated fatty acids in favor of healthier fatty acids, it is a good nutritional strategy to substitute the milk fat of dairy products with a combination of oleic acid and fish oil (Lopez-Huertas 2010; Hibbeln et al. 2006).

Milk and milk products have an n-6 : 12-3 ratio of 2 : 1, and they currently contribute only 6 % of the average daily intake of n-3 PUFA (British Nutrition Foundation, 1992). In a 2003–2004 study, Ellis et al. (2006) observed no significant differences in CLA content in the milk from 17 organic and 19 conventional dairies in the UK, although the n-6:n-3 ratio in the organic milk was consistently and significantly lower in the organic milk. The only individual fatty acids reported in that paper were CLA and trans-18:1 (vaccenic acid, which is not a trans fatty acid thought to be harmful). Benbrook et al. (2013) analysed organic and conventional milk from 14 commercial processors from across the US and determined that over a 12-month-period organic milk averaged 62% more n-3 fatty acids and 25% fewer n-6 fatty acids than conventional milk. They reported individual fatty acids, finding that the CLA concentration was 18% higher in organic milk. These analyses were performed on retail samples and not on farm milk. Schwendel et al. (2015) recently concluded that researchers generally have not controlled sufficient variables to allow for valid comparisons between organic and conventionally produced milk.

Dominika Średnicka-Tober et al 2016 reported that there were no significant differences in total SFA and MUFA concentrations between organic and conventional milk. However, concentrations of total PUFA and n-3 PUFA were significantly higher in organic milk, by an estimated 7 (95 % CI −1, 15) % and 56 (95 % CI 38, 74) %, respectively. Concentrations of α-linolenic acid (ALA), very long-chain n-3 fatty acids (EPA+DPA+DHA) and conjugated linoleic acid were also significantly higher in organic milk, by an 69 (95 % CI 53, 84) %, 57 (95 % CI 27, 87) % and 41 (95 % CI 14, 68) %, respectively. As there were no significant differences in total n-6 PUFA and linoleic acid (LA) concentrations, the n-6:n-3 and LA:ALA ratios were lower in organic milk, by an estimated 71 (95 % CI −122, −20) % and 93 (95 % CI −116, −70) %. It is concluded that organic bovine milk has a more desirable fatty acid composition than conventional milk.

Michael et aL 2016 study of two adjacent dairy farms, one using conventional confined herd management and the other organic management, revealed significant differences in the fatty acid composition of the milk. Compared with conventional milk, organic milk had higher levels of conjugated linoleic acid (CLA) and α-linolenic acid (the major omega-3 fatty acid in milk), and less stearic and linoleic acid (the major omega-6 fatty acid in milk) during the spring–summer grazing season. When discarding geography and weather as variables, organic milk appears to yield more CLA and α-linolenic acid, which should be beneficial to health.

C-Milk and dairy products are suitable vehicles by which nutraceuticals are delivered to the human body fortification is one of the most important processes for improvement of the nutrients quality and quantity in food. It can be a very effective public health intervention, due to the high consumption rate of dairy products, Hadi et al 2015.Dairy products provide a package of essential nutrients that is difficult to obtain in low-dairy or dairy-free diets, and for many people it is not possible to achieve recommended daily calcium intakes with a dairy-free diet. Serge Rozenberg et al

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2016.Therefore fortification dairy products with Nutraceutical ingredient Poly-unsaturated fatty acids (PUFAs) make them very important nutraceutical foods .

D-Daily dose of EPA and DHA:

Various studies have recommended that the daily dose of EPA and DHA for an average person is approximately 300 mg (190–330 mg) and represents the consumption of two portions of fish per week (one oily). The amount 2–10 g of oleic acid has been suggested to use daily instead of fatty acids from milk fat. It represents only 1–4 % of the energy in a 2500 kcal diet (AHA 2006; AFSSA 2003).

II-Fortifiction milk and dairy product with poly-unsaturated fatty acids (PUFAs):

A. How to prevent oxidation of fortified oil in dairy products:

Numerous challenges exist in the production, transportation, and storage of polyunsaturated fatty acids (such as omega-3, omega-6 fatty acids) fortified functional food products because oils high in poly-unsaturated fatty acids are extremely susceptible to oxidative deterioration (Kolanowski et al., 1999, Michelsen et al., 2001). It has been a challenge for oil refiners to inhibit lipid oxidation of oils high in omega-3 fatty acids during processing, shipping, and storage. Additional challenges exist in preventing the oxidation of omega-3 fatty acids when they are incorporated into processed foods (Adler-Nissen and Meyer, 2001).Techniques used to control the oxidation of omega-3 fatty acids in bulk oils are limited to temperature control, oxygen-free atmospheres, and lipid-soluble antioxidants (Nawar, 1996;

McClements and Decker, 2000). The most effective antioxidants in bulk oils are polar-free radical scavengers. These polar antioxidants are often not effective once the oils are dispersed into water-based foods because the antioxidant will migrate from the lipid into the aqueous phase where it is not as effective at protecting lipids (Frankel, 1998). Oilin-water emulsions may be better systems to increase the oxidative stability of lipids than bulk oils because additional protective measures such as water-soluble antioxidants, chelators ,and emulsion droplet interfacial engineering can be used to inhibit lipid oxidation (Donnelly et al., 1998; Mancuso et al., 1999; Mei et al., 1999; Silvestre et al., 2000). Oil-in-water emulsions may be easier to disperse into water-based foods such as beverages, dairy products, salad dressings, and muscle foods than bulk oil that could physically separate from the aqueous phase during storage. Because the emulsion would maintain similar physical structures when incorporated into water-based foods, systems (for example, emulsion droplet interfacial engineering) could remain intact Proteins represent GRAS food additives that can form physically stable oil-in-water emulsions while altering the properties of the emulsion droplet interface in a manner that increases the oxidative stability of the lipid core (Hu etal. 2003a& Pei-En Lee et al 2015)The use of microencapsulated long-chain polyunsaturated oils eliminates fishy odor and taste and enables the development of improved products enriched with these fatty acids.oil encapsulated in gelatin may be provided for addition to infant formulae to achieve a milk composition approximating that of human Infant milk (Gibson et al. 1996). Martini et al 2003 mentioned that the effects of added conjugated linoleic acid (CLA) on the sensory, chemical, and physical characteristics of 2% total fat (wt/wt) fluid milk were studied. Milks with 2% (wt/wt) total fat (2% CLA, 1% CLA:1% milk fat, 2% milk fat) were made by the addition of cream or CLA triglyceride oil into skim milk followed by HTST pasteurization and homogenization. The effects of adding vitamin E (200 ppm) and rosemary extract (0.1% wt/wt based on fat content) were investigated to prevent lipid oxidation. HTST pasteurization resulted in a significant decrease of the cis-9/trans-11 isomer and other minor CLA isomers. The cis-9/trans-11 isomer concentration remained stable through 2 wk of refrigerated storage. A significant loss of both the cis-9/trans-11 and the cis-10/trans-12 isomers occurred after 3 wk of refrigerated storage. The loss was attributed to lipase activity from excessive microbial growth. No differences were found in hexanal or other common indicators of lipid oxidation between milks with or without added CLA ($P > 0.05$). Descriptive sensory analysis revealed that milks with 1 or 2% CLA exhibited low intensities of a “grassy/vegetable oil” flavor, not present in control milks. The antioxidant treatments were deemed to be ineffective, under the storage conditions of this study, and did not produce significant differences from the control samples ($P > 0.05$). CLA-Fortified milk had significantly lower L* and b* values compared with 2% milk fat milk. No significant differences existed in viscosity. Consumer acceptability scores ($n = 100$) were lower ($P < 0.05$) for CLA-fortified milks compared to control milks, but the addition of chocolate flavor increased acceptability ($P < 0.05$). Formulae preparations fortified with microencapsulated spray dried marine oil powders have been successful in the market place.Yoghurts, fermented milks

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and processed cheese with tuna oil encapsulated with processed milk proetein-carbohydrate films (Driphorm 50) made using MicroMAX technology (Sanguanri and Augustin, 2001) have higher sensory scores than those fortified with an equivalent amount of encapsulated oil (Sharma et al., 2003). Martini et al 2009 fortify 50% reduced fat Cheddar cheese with n-3 fatty acids and evaluate whether this fortification generated specific off-flavors in the cheese. Docosahexaenoic (DHA) and eicosapentaenoic (EPA) fatty acids were added to the cheese to obtain 3 final fortification levels [18, 35, and 71 mg of DHA/EPA per serving size (28 g) of cheese representing 10, 20, and 40% of the suggested daily intake level for DHA/EPA. The presence of oxidized, rancid, and fishy flavors as a function of fortification level and cheese aging (6 mo) was evaluated using a sensory descriptive panel. No differences were found in the oxidized and rancid flavors as a consequence of DHA/EPA fortification, with only slight intensities of these flavors. The presence of fishy off-flavor was dependent on the fortification level. Cheeses with low fortification levels (18 and 35 mg of DHA/EPA per serving size) did not develop significant fishy off-flavor compared with the control, whereas at the highest fortification level (71 mg of DHA/EPA per serving size) the fishy off-flavor was significantly stronger in young cheeses. The fishy flavor decreased as a function of age and became nonsignificant compared with the control at 3 mo of storage. Even though fishy flavors were detected in the fortified cheeses, the DHA/EPA content during storage remained constant and complied with the suggested values for food fortification. Results obtained from this research indicate that 50% reduced-fat Cheddar cheese aged for 3 mo can be used as a vehicle for delivery of n-3 fatty acids without generation of off-flavors.

Experimental studies have shown that the addition of Omega-3 fatty acids to probiotic yogurt causes no aroma and flavour defects in set-type products. On the contrary, the texture of the final product was adversely affected by Omega-3. This problem can be overcome by adding Omega-3 and whey protein concentrate (WPC) together (Stagnitti et al. 2001;

Helenaet al 2013 evaluating the potential of maltodextrin combination with different wall materials in the microencapsulation of flaxseed oil by spray drying, in order to maximize encapsulation efficiency and minimize lipid oxidation. Maltodextrin (MD) was mixed with gum Arabic (GA), whey protein concentrate (WPC) or two types of modified starch (Hi-Cap 100TM and Capsul TA®) at a 25:75 ratio. The feed emulsions used for particle production were characterized for stability, viscosity and droplet size. The best encapsulation efficiency was obtained for MD:Hi-Cap followed by the MD:Capsul combination, while the lowest encapsulation efficiency was obtained for MD:WPC, which also showed poorer emulsion stability.. During the oxidative stability study, MD:WPC combination was the wall material that best protected the active material against lipid oxidation.

Rebecca Walker et al 2015 reported that nanoemulsions offer a promising way to incorporate omega-3 fatty acids into liquid food systems like beverages, dressing, sauces, and dips. Nanoemulsions are colloidal dispersions that contain small oil droplets ($r < 100$ nm) that may be able to overcome many of the challenges of fortifying foods and beverages with omega-3 fatty acids. The composition and fabrication of nanoemulsions can be optimized to increase the chemical and physical stability of oil droplets, as well as to increase the bioavailability of omega-3 fatty acids.

Ankit Goyal et al 2015 developed a stable flaxseed oil emulsion for the delivery of omega-3 (ω-3) fatty acids through food fortification. Oil-in-water emulsions containing 12.5 % flaxseed oil, 10 % lactose and whey protein concentrate (WPC)-80 ranging from 5 to 12.5 % were prepared at 1,500, 3,000 and 4,500 psi homogenization pressure. Flaxseed oil emulsions were studied for its physical stability, oxidative stability (peroxide value), particle size distribution, zeta (ζ)–potential and rheological properties. Emulsions homogenized at 1,500 and 4,500 psi pressure showed oil separation and curdling of WPC, respectively, during preparation or storage. All the combinations of emulsions (homogenized at 3,000 psi) were physically stable for 28 days at 4–7 ºC temperature and did not show separation of phases. Emulsion with 7.5 % WPC showed the narrowest particle size distribution (190 to 615 nm) and maximum zeta (ζ)–potential (−33.5 mV). There was a slight increase in peroxide value (~20.98 %) of all the emulsions (except 5 % WPC emulsion), as compared to that of free flaxseed oil (~44.26 %) after 4 weeks of storage. Emulsions showed flow behavior index (n) in the range of 0.206 to 0.591, indicating higher shear thinning behavior, which is a characteristic of food emulsions. Results indicated that the most stable emulsion of flaxseed oil (12.5 %) can be formulated with 7.5 % WPC-80 and 10 % lactose (filler), homogenized at 3,000 psi pressure. The formulated emulsion can be used as potential omega-3 (ω-3) fatty acids delivery system in developing functional foods such as pastry, ice-creams, curd, milk, yogurt, cakes, etc.

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B. The sources of poly-unsaturated fatty acids (PUFAs) used for dairy products fortification: Eicosapentaenoic acid and DHA are naturally present in oily fish, and ALA is found in flax seed and various vegetable oils and nuts (Dave et al. 2002; Martin-Diana et al. 2004; Awaisheh et al. 2005andGruenwald 2009).).
Fish oil is considered to be the best source of Omega-3 fatty acids, but is notoriously difficult to incorporate into formulations since it is highly susceptible to heat and light oxidation (Sharma 2005). Before Omega-3 fatty acids could be added to milk products, the fishy taste and odour should be disguised and oxidation of the oil should be overcome. This can be achieved by leaving minimal headspace in the package, using packaging material having low transperancy to light and sometimes adding specific anti-oxidants, emulsifiers or sequestrants (Mellema and Bot 2009). According to recent market surveys, Omega-3 enriched foods make up the strongest sector of the functional food market in the USA (Heller 2008). Due to the high content of LCPUFAs in liquid fish oil, it is difficult to protect them against oxidation. Microencapsulation of LCPUFAs offer the possibility for the protection and release controlling of lipophilic food ingredients and can be used for supplementation of foods almost without oxidation (Drusch et al. 2007).

Microencapsulation also has been used to mask unpleasant taste in food sciences as well as to protect against light and airborne oxidation (Gibbs et al. 1999; Kolanowski et al. 2004). Microencapsulation of fish oil produces a dry powder from liquid fish oil, which can be used for enrichment of different food with omega-3 LCPUFA (Thautwein 2001; Kolanowski and Laufenberg 2006). Kolanowski et al. (2007) reported that this process has a good potential to protect the nutritional aspects of instant foods fortified with fish oil powder. Bermudez-Aguirre and Barbosa-canovas (2011) used flaxseed oil and fish oil powder to fortify cheddar and mozzarella cheeses with omega-3 and concluded that sensory scores and shelf life of the both cheeses enriched with fish oil powder were much better and more than the ones enriched with flaxseed oil. Barrow et al. (2009) compared the encapsulated and microencapsulated fish-oil and found out that both processes provide equivalent bioavailability of omega-3 fatty acids for the consumers as long as they delivered in soft-gel capsules. Cumin has been used for decades for its good taste –as a spice- and medicinal purposes (Jalali-Heravi 2007). It is also used as a flavoring agent in different cheeses in Iran. So, it is a good case for masking the fishy flavor of fortified cheeses with fish oil and fish oil powder Ye et al. (2009) fortified processed cheese with fish oil and concluded that a fish oil emulsion made with a milk protein complex is a useful carrier for elevating the fortification level of omega-3 LC PUFA in this dairy product. Aryana (2007) substituted Omega-Pure (a commercial oil rich in n-3 fatty acids) with 100, 50, 25, and 0 % of the milk fat in different cheeses and found a significant difference between the cheese flavors fortified with n-3 fatty acids compared with the control cheeses (0 % DHA).

2- Oilseeds : Among oilseeds, flaxseed is the most abundant source of α-linolenic acid (ALA). Its content in flaxseeds accounts for 53% of total FA (Bloedon and Szapary 2004). Moreover, fatty acid profile of flaxseed is characterised by an excellent ratio of ω 6:ω 3 FA. The excess of short- and medium-chain saturated FA and low level of unsaturated ω 3 FA in human diet are a common pattern observed in the Western countries. It is also considered as an atherogenic factor and the primary cause of cardiovascular diseases (Adkins and Kelley 2010). Therefore, the boost in consumer interest in food products with increased concentration of mono- and polyunsaturated fatty acids was observed. The research carried out indicated that flaxseed is a good source of energy and protein for lactating dairy cows and it can affect milk FA profile (Petit 2010; Oeffner et al. 2013).

Kuhn et al 2012 evaluated the stability of flaxseed oil - whey protein isolate emulsions.High-pressure homogenization (80 MPa) and an increase in the number of homogenization cycles, led to the formation of high molecular weight aggregates (>200 kDa), which favored an increase in viscosity of the emulsions. The increase in homogenization pressure also increased the formation of primary oxidation products, which could be explained by the increase in temperature and in the surface area of the droplets.

Ankit Goyaet al 2014 reported that Flaxseed is emerging as an important functional food ingredient because of its rich contents of α-linolenic acid (ALA, omega-3 fatty acid), lignans, and fiber. Flaxseed oil, fibers and flax lignans have potential health benefits such as in reduction of cardiovascular disease, atherosclerosis, diabetes, cancer, arthritis, osteoporosis, autoimmune and neurological disorders. Flax protein helps in the prevention and treatment of heart disease and in supporting the immune system. As a functional food ingredient, flax or flaxseed oil has been incorporated into baked foods, juices, milk and dairy products, muffins, dry pasta products, macaroni and meat products. The present review focuses on the evidences of the potential health benefits of flaxseed through human and animals' recent studies and commercial use in various food products.

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