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Review On "Dietary Fiber Incorporated Dairy Foods: A Healthy Trend"

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ABSTRACT
Dietary fiber is not a 'nutrient', it is nevertheless an important component of our diets. The fact that it passes through the body without being absorbed is the main reason why fiber is so important. Dietary fiber or 'roughage' comprises the edible parts of plant that cannot be digested or absorbed in the small intestine and passes into the large intestine in an intact form and which is also resistant to enzymatic digestion that includes cellulose, non-cellulosic polysaccharides such as hemicellulose, pectic substances, gums, mucilages and a non-carbohydrate component (i.e. lignin). Based on their solubility fibers are classified into soluble and insoluble fibers. The soluble fibre enriched diets have a positive effect on human health as their consumption has been known to help in preventing constipation, possible colon & rectal cancer,lowers total cholesterol, calories and alsoregulate variance in the blood sugar levels. Soluble dietary fibre enriched dairy products may serve as functional foods. Fiberfortification also helps to improve sensory characteristics, shelf life and structural properties (i.e. viscosity, texture, water & oil holding capacity) of dairy foods.This reviewbriefs about the various soluble dietary fibers available and their potential functional role in human health as well as food additives in dairy foods.

Key words: Dietary fiber, Fortification, Nutrients, Soluble and Insoluble fibers, Dairy products.

I. INTRODUCTION:

Dietary fiber (DF) is the indigestible portion of food which helps in fighting against several diseases mainly associated with the modern life-style. However, milk is a concentrated source of life-sustaining nutrients with high digestibility and is purely devoid of DF. These dietary fibers can be added in milk and milk products either for health or for technological benefits or for sensory reasons. Dietary fiber (DF) was originally defined in 1972 by Trowell as 'that portion of food which is derived from cellular walls of plants which are digested very poorly by human. The processing of dietary food over the past few years is increasing which leads to decrease its fibre content (Kendall *et al.* 2010). Intake of fiber through various foods such as nuts, whole-grain flour, fruits, and vegetables is now associated with decreased low-density lipoprotein (LDL)-cholesterol, lower insulin demand, increased stool bulk, softening of fecal contents, and improved laxative properties (Park *et al.* 2005). Epidemiological studies have correlated high consumption of DF with lower incidence of certain diseases such as cardiovascular and cancer of colon and rectum. Such findings boosted searches for DF. Several conditions such as diabetes, atherosclerosis, breast cancer, diverticulitis, hemorrhoids have been connected to a low intake of fiber (Gutkoski*et al.* 2007). Fiber of various sources is added to dairy products because of its water-holding capacity, reduce the lipid retention, improve textural properties and reduce caloric content by acting as a bulking agent to increase its product yield. Consumption of products containing high fiber may decrease hypertension, hypercholesterolemia, obesity, gastrointestinal disorders, coronary heart disease, diabetes, and cancer. Therefore, in this paper the recently innovated dairy products that are developed using varied sources of DF have been reviewed.

There is growing interest among consumers about the nutritional and therapeutic aspects of the food they eat. This has led to new inquiries about the linkage between food and health. The basic tendency of human beings has always been to procure and consume "natural foods". However, the fast pace of modern life has placed a great burden on such past activities and consequently canned, packaged, and ready-to-eat foods have now moved into a central position and onto the tables of modern consumers. Many of them have become aware that they are being deprived of some food components, which may be of immense importance to health. Milling of grain to white flour, ready-made squeezed juices, and many canned vegetables have clearly cut down the supply of fiber from the diet. Fiber not only increases the bulk of the food and moves it through the gastrointestinal tract more rapidly, but also helps in preventing constipation and possible colon and rectal cancer (Chawla*et al.*, 2010).Cereals,

fruits, vegetables, as well as algae are sources of abundant dietary fibre. TheseFibre rich products can fortify dairy foods, increase their dietary fibre content and result inhealthy products, low in calories, cholesterol and fat. They may also serve as functionalingredients to improve physical and structural properties of hydration, oil holding capacity, viscosity, texture, sensory characteristics, and shelf life (Mohamed *et al*. 2011).

II. HISTORYAND DEFINITION OF DIETARY FIBER (DF):

Prior to 1965, fiber was referred to as roughage, bulk, or ballast, and was measured as crude fiber. It is only in the past 25 to 30 years that fiber, now termed dietary fiber (DF), has been accorded the scientific importance it deserves. (Chawla*et al.*, 2010). Useful knowledge about DF dates back to 1953 when Hipsley (1953) first discussed the meaning of DF. Accordingly, DF is a shorthand term for non-digestible constituents making up the plant cell wall. Since then, many definitions of DF have been advanced by several workers, including Asp and Johansson (1981) who developed methodology directed at quantifying food components. In 1985, Health and Welfare Canada defined DF as "the endogenous components of plant material in the diet which are resistant to digestion by enzymes produced by humans.

They are predominantly nonstarch polysaccharides (NSPs) and lignin and may include, in addition, associated substances". A committee of the American Assn. of Cereal Chemists (AACC 1998) was charged to review and develop a definition of DF. Subsequently, in 2000, AACC defined DF as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine (Tungland and Meyer 2002).

Definition of Dietary Fiber (DF)

The Codex Alimentarius Commission adopted a new definition of fiber in July 2009, designed to harmonize the use of the term around the world. It describes fiber as elements not hydrolysed by endogenous enzymes in the small intestine (indigestibility) as well as having physiological effects beneficial to health. Dietary fibers are carbohydrate polymers with ten or more monomeric units and belonging to one of three categories of carbohydrates Dietary Fiber and Availability of Nutrients: A Case Study on Yoghurt as a Food Model 457 polymers: edible carbohydrate polymers naturally occurring in food, carbohydrate polymers which have been obtained from raw food material by physical, enzymatic, or chemical means, and synthetic carbohydrate polymers (Marina *et al*., 2012).

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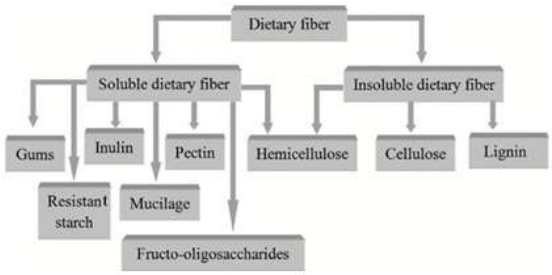
III. CLASSIFICATION OF DIETARY FIBERS:

DF can be classified by many possible ways such as on the basis of source that can be further categorized into plant polysaccharides, animal polysaccharides, and polysaccharides derived from native or synthetic sources. On the basis of structure, polysaccharides can be categorized into polysaccharides having linear or nonlinear molecular structure. On the basis of solubility they are soluble or non-soluble. Other basic groupings are by properties, their applications, and on the basis of polysaccharide chemistry



(BeMiller2001).

Table 1. Classification of food-ingredient polysaccharides based on solubility

S.NO	CLASS	EXAMPLES
1	Insoluble	Cellulose
2.	Soluble only in hot Water	Agars, algins (in the presence of Ca^{2+}),amyloses, kappa-type carrageenans(in the presence of K^+ or Ca^{2+}), lambda-type carrageenans (in the presence of Ca^{2+}), furcellarans (in the presence of K^+ or Ca^{2+}), gelan,konjac, nattoun, locust bean gum,low-methoxyl (LM) pectins (in the presence of Ca^{2+}), granular starches, and starch derivatives
3.	Soluble in room temperature water, insoluble in hot water	Curdlan,hydroxypropylcelluloses,hydroxypropylmethylcelluloses,methylcelluloses
4.	Soluble in room temperature and hot water	Alginates (as Na^+ salt), amylopectins, carboxymethylcelluloses, kappa-type carrageenans (as Na^+ salt), lambda-type carrageenans (as Na^+ salt), dextrins, iota-type carrageenans, dextrins, furcellarans (as Na^+ salt), guar gum, gum arabic, gum tragacanth, high-methoxyl (HM) pectins, LM pectins (as Na^+ salt), polydextrose, xanthan

IV. COMPONENTS OF DIETARY FIBER (G/D):

DF can be divided into 4 main categories: total NSPs, which make up 11.8 to 16.4 g/d of total dietary fiber (TDF) intake. This part predominantly comes from cereals and vegetables, which contribute approximately 40% to 50% of the DF. Total NSPs can further be categorized into insoluble NSPs and soluble NSPs, which account for 6.5% to 7.0% and 5.3% to 8.7%, respectively. Apart from total NSPs, other different components

are inulin and fructo-oligosaccharides (FOSs), resistant starch (RS), and lignin, which contribute 2% to 12%, 1.5% to 15%, and 1.0% to 1.4%, respectively, to our total intake of DF (approximately 16.3 to 43.4 g/d). The energy provided by fiber varies in value from source to source, but the generally accepted and most frequently used value is 2 kcal/g (Chawla*et al.*, 2010).

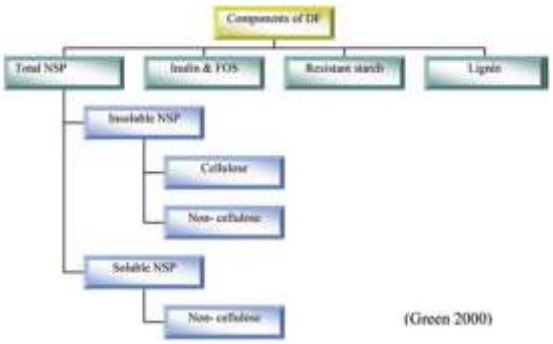


Figure1 components of dietary fiber

V. HEALTH BENEFITS OF SOLUBLE DIETARY FIBER:

The beneficial properties of SDFs have been associated with their significant role in human physiological function. Foods rich in fibre contain a broad spectrum of compounds that may prevent different types of cancer. Also, several fibres have demonstrated, in vitro, and in vivo, their capacity for adsorbing carcinogenic agents, so it is recommended to consume plant foods with lignified or suberized cell walls that are the most effective for linking hydrophobic carcinogenic agents (Filiz, Y. 2013).

Brown *et al.(*1999) reported that soluble fibers such as oats, psyllium, pectin, and guar gum, and some other fibers lower total and LDL cholesterol . Water insoluble wheat fiber and cellulose have no effect unless they displace foods supplying saturated fats and cholesterol.

Filiz, Y. (2013) reviewed that the ingestion of suitable quantities of food fiber produces many beneficial effects on the digestive tract, such as the regulation of the intestinal function, improvement of the tolerance to glucose in diabetics or prevention of chronic diseases as colon cancer.

Soluble fiber not only performs certain important physiological functions but also builds up important microflora by acting as a substrate food for beneficial microorganisms; therefore, it acts as a prebiotic and improves host health. A prebiotic aims selectively to feed probiotic organisms indigenous to the human colon(Chawla*et al*., 2010)

Table2. Functions and benefits of dietary fibre on human health

Functions	Benefits
• Adds bulk to the diet, making food full faster • Attracts water and turns to gel during digestion, trapping carbohydrates and slowing absorption of glucose • Lowers total and LDL cholesterol • Regulates blood pressure • Speeds the passage of foods through the digestive system Facilitates regularity • Adds bulk to stool • Balances intestinal pH and stimulates intestinal fermentation production of short-chain fatty acids	• May reduce appetite • Lowers variances in blood sugar levels • Reduces risk of heart disease • May reduce onset risk or symptoms of metabolic syndrome and diabetes • Facilitates regularity • Alleviates constipation • May reduce risk of colorectal cancers

Source: Devinder*et al.* (2012)

VI. APPLICATIONS OF SOLUBLE FIBERS IN DAIRY INDUSTRY

6.1 Inulin and Oligofructose:

Inulin-type fructans [*β*-(2,1)-fructans] extracted from chicory (*Cichoriumintybus*) roots are prebiotic food ingredients, which in the gut human are fermented to lactic acid and SCFAs. Physically, inulin is colourless, odourless, and has a pleasant, slightly sweet taste with moderate solubility in water, dependent on temperature.Also, inulin comes under both soluble as well as insoluble fiber categories depending on the degree of polymerization (DP). Inulin and short-chain FOS are compounds with unique D-fructofuranose polymers linked by a *β*2→1 bond at the anomeric C2 (Figure 1), and are accumulated in the tissues of many plant species (Delzenne 2003).

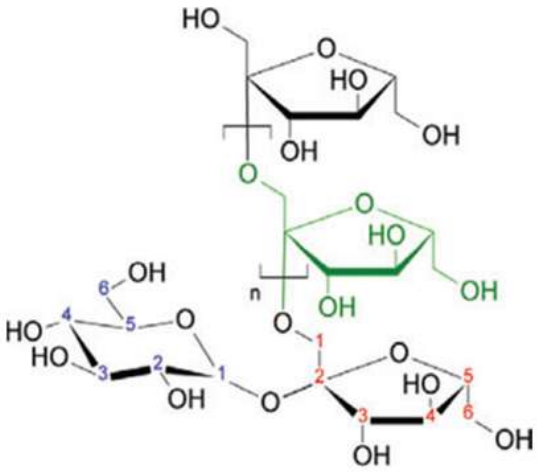


Figure 2. Structure of inulin

Human data largely confirm reduction in blood triglycerides and cholesterol after administration of inulin and FOS. In an experiment employing response surface methodology (RSM) (RSM is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes), it has been shown that cholesterol can be successfully removed in the presence of mannitol, inulin, and FOS using *Lactobacillus acidophilus*(Liong*et al*., 2005).

Filiz, Y. (2013) reported that inulin introduces numerous improvements into dairy products. It improves body and mouth feel in

cheese analogues or ice cream, and reduces Synerisys in yoghurt and other fermented milk products.

Inulin products containing mainly long-chain molecules are used for fat replacement because in the presence of water they are able to form a particulate gel, thus modifying the product texture and giving rise to a fat like mouthfeel (Arica *et al*., 2011).

6.2 Oat Fiber (*β*-glucans):

Structurally *β*-glucans are comprised of *β*-(1,3) and *β*-(1,4) linkages (Figure 2), exhibiting distinct structural and physicochemical features . They are mainly present in oats, barley, wheat, the cell wall of baker's yeast, certain types of fungi, and many kinds of mushrooms and bacteria. However, the highest values have been recorded in barley- and oat-based products.

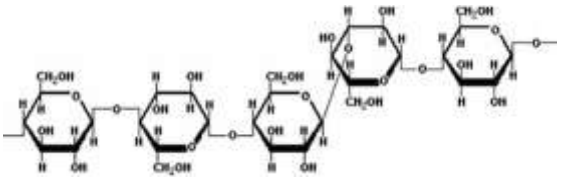


Figure 3. Stucure of *β*-glucan

Oat bran contains some insoluble fiber plus a larger amount of soluble fiber, both of which produce laxative effects. Oat fiber has also been shown to reduce postprandial glucose and insulin requirements.Overweight subjects require consumption of at least 2 g *β*-glucan per meal to reduce glycemic response, and a greater amount of *β*-glucan per meal may be required to achieve substantial effects in overweight subjects(Chawla*et al*., 2010).

Fernandez-Garcia et al. (1998) prepared Calorie-reduced yogurts that were fortified with 1.32% oat fiber were prepared from lactosehydrolyzed milk, alone and supplemented with 2 and 4% sucrose. They compared treated unsweetened yogurt with sweetened yogurt with 2, 4, and 6% sucrose and found that Fiber addition decreases overall flavour quality but improved the body and texture of unsweetened yogurts.

6.3 Polyfructan:

A water-soluble fiber, synthesized from sucrose by the action of *Aspergillussydowi conidia*, is a good source of SDF having much less viscosity than other polysaccharides. Polyfructan can be used in various bakery and dairy goods, in which it acts as a low-calorie bulking agent when used in conjunction with aspartame or other artificial sweeteners, or used as a fat substitute, such as in ice cream (Harada *et al*., 1993).

6.4Alginate:

Alginate, a polyuronic saccharide (a hydrocolloid), can be isolated from the cell walls of number of brown seaweed species. It is also produced extracellularly by certain bacteria (Stokke*et al.,* 2000).

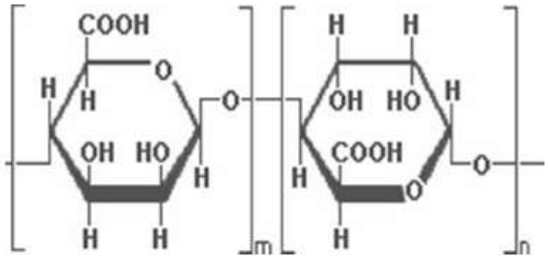


Figure4. Structure of Alginate

Alginates add a type of body and texture to ice cream that other gums don't easily duplicate. Extracted from ocean kelp, this natural gum dissolves best at 155° to 160°F. Combined with sodium or phosphate salts, it forms gels at levels from 0.18% to 0.25%. Because it binds calcium, it will reduce the amount of free calcium in the mix. Precipitation of sodium alginate will occur at high calcium levels, making it difficult to hydrate without adding sequesterant(Naresh*et al.,* 2006).

6.5 Carrageenan

Carrageenan is a generic term for several polysaccharides also extracted from seaweed. Carrageenan is also used for thickening, suspending, and gelling food products. Gums including carrageenan can be used as a source of soluble fiber. They act as thickening or gelling agent and as a binder. Carrageenan is approved as a food additive in the EU with an ADI value of 75 mg/kg body weight and by The Food and Agriculture Organization (FAO)/World Health Organization (WHO) with a status of "not specified" (Nayak*et al*., 2000).

The hydrophilic colloid, carrageenan, stabilizes α-casein against precipitation by calcium ions by an interaction between α-casein and a component which may be present in both K- and λ-carrageenan. This component occurs predominantly in the K-fraction. The resulting complex resembles the alpha-casein complex, but it is not acted upon by rennin (Hansen 1967).

Quality of sandesh from buffalo milk could be improved through incorporation of stabilizers such as sodium alginate, carrageenan or CMC into milk prior to manufacture. Among stabilizers, carrageenan proved to be most suitable. A level of 0.1% carrageenan produced better results in textural and sensory properties of buffalo milk Sandesh compared to control and the levels of

0.075 and 0.125% of carrageenan (Sanyal*et al.*, 2011).

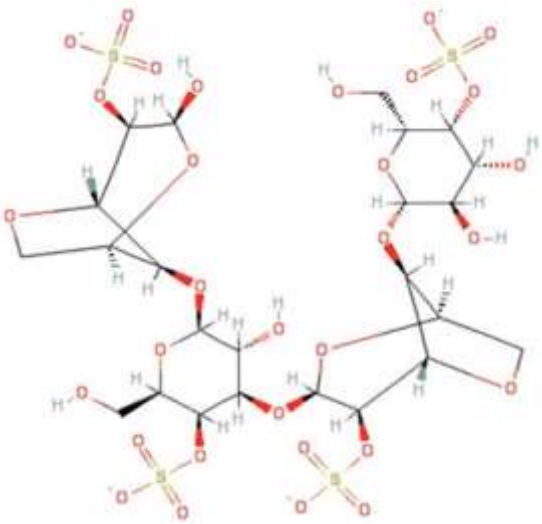


Figure5. Structure of carrageenan

6.6 Gum acacia

Gum acacia is a product derived from the exudates of acacia trees. It is a natural DF that is fermented in the large intestine and possesses water-soluble property along with benefits of its applications in emulsification and encapsulation. Diesol is a soluble fiber blend derived from several species of acacia trees. It is a light brown, free-flowing powder which provides a viscosity of 10 cps in a 5% solution that can be successfully added in high and light fiber drinks, soups, sauces, ice cream and other frozen desserts, dairy products such as yogurt, confectionery items such as snacks, bars, cheese cake, and more. Its fermentation has a prebiotic effect and produces SCFAs, which may promote several metabolic effects such as lowering of cholesterol (Kravtchenko 1997).

6.7 Xanthan gum:

A product of bacterial fermentation, this giant glucomannan polymer (2 million daltons) makes an excellent emulsion/stabilizer because its suspending properties keep emulsions dispersed. It's a popular ingredient in low fat compositions**.**

It can be dispersed by blending with skim milk, corn syrups or nonfat milk solids. Xanthan is cold water soluble, hydrates quickly once dispersed and provides water binding. It is always used in combination with other gums. It is synergistic with locust bean gum, which reduces the levels of locust bean gum and guar required. Xanthan gum is heat and pH resistant and also has a cleaner flavor when compared to other gums. It possesses pseudoplastic properties and exhibit shear thinning, a useful property for pumping and extrusion in soft serve ice creams. Overuse can cause excessive gelation, an overly viscous mix, and a chewy ice cream. Usage levels range from 0.015 to 0.040%. However, its cost limits its usage (Nareshet *al.*, 2006).

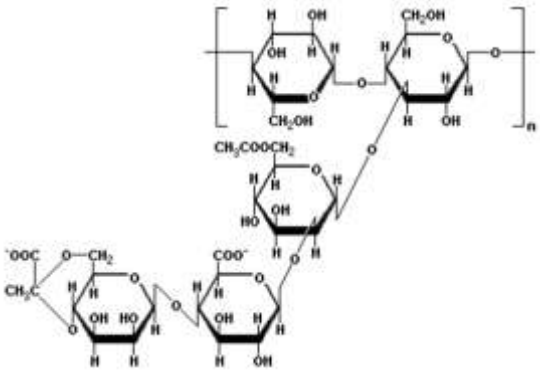


Figure6.chemical structure of xanthan gum

6.8 Guar gum

Guar gum, a plant polysaccharide (made of the sugars galactose and mannose) and non ionicgalactomannan, is isolated from the shrub *Cyamopsistetragonolobus*that is traditionally cultivated for livestock feed.This well-established gum is widely used in a variety of products, but suffers from off-flavor defect. To eliminate this existing problem, a newer technology (a proprietary manufacturing processthat deodorizes guar gum without the use of organic solvents) has been developed by TIC Gums Inc. permitting its use in a range of specialty products and as an excellent source ofSDF and being odourless, this guar gum can be easily and profusely used in food materials . Guar gum powder can also be used as an emulsifier and can be added to sauces and salad dressings as a thickening additive, and to ice cream as an agent to prevent ice crystal formation. It can also be used as fat substitute that adds the typical fat-rich "mouthfeel" to various products.

Table 3. Maximum permitted level of guar gum in various food products.

Product	Maximum level Product permitted (%)
Baked goods/baking mixes	0.35
Breakfast cereals, gravies, and sauces	1.2
Cheese	0.8
Dairy product analogs	1
Fats and oils	2
Jam and jellies	1
Milk products	0.6
Processed vegetables and processed juices	2
Soup and soup mixes Sweet sauces, toppings	0.8
syrups	1
All other food categories	0.5

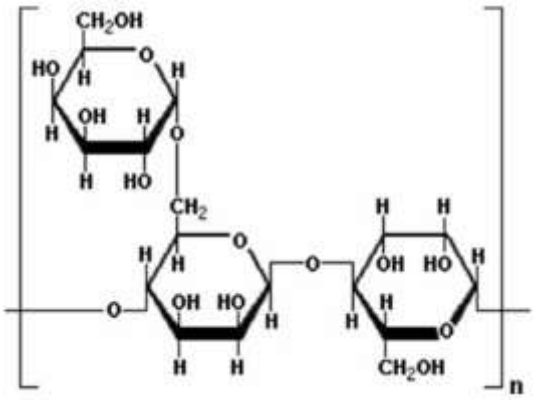


Figure7. Structure of Guar gum

6.9 Pectin

Pectin is a polysaccharide that acts as a cementing material in the cell walls of all plant tissues.In a study carried out by Singh and others (2005) various hydrocolloids like carrageenan, carboxymethyl cellulose (CMC), pectin, and guar gum at 0.1% and 0.25% were used to improve the thermal stability and aesthetic quality of whey protein in whey-based beverage systems. The stabilizing effects of the stabilizer showed a progressive increase with an increase in the level of its addition from 0.1% to 0.2%, but among CMC, guar gum, carrageenan, and pectin, at 0.25% carrageenan and pectin showed maximum stability.

Pectin, as a food ingredient, can be used as a gelling agent, thickening agent and stabilizer in food applications. Pectin is used in diverse applications such as yogurt, confectionery and acid milk drinks. Pectin has the image of a natural product and has acknowledged nutritional benefits. Pectin is also used to optimize the mouthfeel of fruit-based beverages and as a protein stabilizer in acidified dairy products (Chawla*et al*., 2010).

6.10 Lignin

Lignin is, next to cellulose, the most abundant renewable resource and worldwide about 50 million tons of lignin is being produced annually as residue in paper production processes. Lignin is the only substance which is a noncarbohydratetype of DF.Lignin is consumed in small quantities because of its association with spiral and annular bands in xylem conducting vessels. Also, as the woody tissues are not frequently consumed, its comparative consumption is less (Chawla et al., 2010). Lignin is abundantly present in "whole" preparations and also in fruits that contain edible seeds and mature vegetables such as carrots and other root vegetables (Salvin 1987).

Lignin is thought to act as a physical barrier to microbes, limiting their capacity to fermentation.Dietary lignin has also been reported as a precursor of mammalian lignans, which are phytoestrogens and may contribute to the prevention of breast cancer and coronary heart disease(Begum *et al.,* 2004).Lignins on their positive side have also been reported to have a role in the anticancer treatment as it induces apoptosis via production of an ascorbyl radical in the presence of vitamin C along with their beneficial role in lipid balance (Chawla*et al.*, 2010).

VII. RECOMMENDED DIETARY ALLOWANCES (RDA) AND INTAKES

The recommendations regarding the intake of DF are not the same in all countries. The United Kingdom proposes 18 g/d of DF expressed as NSPs, while an amount of 30 g/d has been proposed by Germany, and in the United States the specified intake should be 38 g/d for men and 26 g/d for women (Be- Miller 2004). The DF intake ranges between 30 and 38 g/d for males whereas a value of 21 to 26 g/d has been proposed for females by Natl. Academy of Sciences, Food and Nutrition Board, U.S.A (Nayak*et al*., 2000).

Adequate Intake for Total Fiber (RDA)

LIFE STAGE	AGE	MALE (g/day)	FEMALE (g/day)
Infants	0-6 months	Not Determined	Not determined
Infants	7-12 months	Not Determined	19
Children	1-3 yrs	19	25
Children	4-8 yrs	25	26
Children	9-13 yrs	31	26
Adolescents	14-18 yrs	38	25
Adults	19-50 yrs	38	21
Adults	51 yrs and older	30	28

VIII. CONCLUSION

Consumers have been different expectations to be relevance changing world situation and developing technologies. Human had to give more importance to their health and nutritional situation with increasing environmental pollution and stress in their life. So, recently it is watched that there has been increasing demand to dairy foods that has low calories, low fat and low cholesterol content and functional foods. Functional foods can be defined as foods that have positiveeffects on the health. An important development in this regard has been in dietary fiber mixed products. The enrichment of dairy foods with dietary fibres is an effective way to enhance nutritional and physiological aspects and to promote functionality by influencing rheological and thermal properties of the final product. It is needed to work on better understanding both for users and producers of dietary fibre values.

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