Flaxseed as a functional food: A review

Raghuwanshi VP, Agrawal RS and Mane KA

Abstract
Flaxseed has recently gained attention as a functional food ingredient due to its rich potential health benefits associated with its biologically active components such as alpha-linolenic acid, lignans, and dietary fiber. Health benefits attributed to flaxseed include antioxidant, antidiabetic, anticancer properties etc. As a functional food ingredient, flaxseed 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 is an attempt to highlight the potential of flaxseed as functional food.

Keywords: Flaxseed, functional food, biologically active components, health benefits

Introduction
Flaxseed (Linum usitatissimum) also known as common flax or linseed belongs to the family Linaceae. In Indian languages it is also known as Alsi, Jawas, Aksebija. Flaxseed is one of the most important oilseed crops for food, feed, fiber and industrial purposes. Commercially, almost all parts of flaxseed plant are utilized directly or after processing. Flaxseed is crispy in texture and nutty in taste (Rubilar et al., 2010) [12]. The Latin name of flaxseed means “very useful” and it has two basic varieties: brown and yellow golden. Both have similar nutritional characteristics and equal numbers of short-chain ω-3 fatty acids. The exception is a type of yellow flaxseed called solin (trade name Linola), which has a completely different oil profile and is very low in ω-3 fatty acids (Dribenek et al., 2007) [13]. Flaxseed is gaining importance in the world’s food chain as a functional food due to growing interest of consumers for foods having more health benefits. Flaxseed has wonderful prospects as functional food due to its superb nutritional composition. The seeds are rich contents of ω-3 fatty acid: alpha-linolenic acid (ALA), short chain polyunsaturated fatty acids (PUFA), soluble and insoluble fibers, phytoestrogenic lignans, proteins and an array of antioxidants. (Kajla et al., 2015) [7]. Edible flaxseed products include the whole flaxseed, ground meal and extracted oil or mucilage. These products have been considered as nutritional additives in the preparation of various food products such as baked cereal products, ready to eat cereals, fiber bars, salad toppings, meat extenders, bread, muffins and spaghetti (Singh et al., 2011) [14].

Flaxseed as Food
As Ingredient
Flaxseed is utilized as a versatile ingredient in various types of food products. Flaxseed supplemented food products are gaining popularity because of its high content of polyunsaturated fatty acids, protein, soluble fiber and phytochemicals. Flaxseed can be used as whole, roasted or milled in batters, dough and other baked products. Flaxseed-water mixture acts as egg substitute in the diet of vegetarians especially in baked products pancakes, muffins and cookies. These baked products are slightly gummier and chewier, and have low loaf volume than normal. Flaxseed gum, prepares from flaxseed meal has many potential food and non-food applications (Kajla et al., 2015) [7]. Flaxseed can be supplemented in bread and other goods such as cookies and muffins including gluten free products. The incorporation into bread results in an improved texture and crumb texture. Healthy functional snack foods such as high protein energy bars can also be prepared with flaxseed as ingredient (Chishty and Bissu, 2016) [2].

Edible Oil
Flaxseeds produce a vegetable oil known as flaxseed oil or linseed oil, which is one of the oldest commercial oils. Flaxseed oil is obtained by expeller pressing and sometimes followed by solvent extraction. For many years, flaxseed was used mainly in the manufacturing of drying oil, paints, coating, and printing inks etc (Choo et al., 2007) [5]. But recently, there has been new beginning in the use of flaxseed oil for edible purposes owing to its nutraceutical...
values. Flaxseed contains high amount of alpha-linolenic acid and thus has multiple industrial applications. Plant breeders, food technologists and nutritionists are using conventional and molecular approaches for altering the fatty acid profile of flaxseed and create its competitive food market. In this respect, initiative was taken to reduce the alpha-linolenic acid of flaxseed oil, to less than 5%. Flax council has given the name solin for such cultivars containing less than 5% alpha-linolenic acid (Kajla et al., 2015) [7].

**Nutritional composition of Flaxseed**

According to its physico-chemical composition, flaxseed is a multicomponent system with bio-active plant substances such as oil, protein, dietary fiber, soluble polysaccharides, lignans, phenolic compounds, vitamins (A, C, F and E) and mineral (P, Mg, K, Na, Cu, Mn and Zn) (Bhatty, 1993) [1]. Flaxseed has potential health benefits besides the nutrition, due to mainly 3 reasons: first, due to its high content of ω-3 α-linolenic acid; second, being rich in dietary soluble and insoluble fibers; and third, due to its high content of lignans, acting as anti-oxidants and phytoestrogens. The chemical composition of flaxseed can vary with growing environment, genetics, method of analysis and processing conditions (Morris, 2007) [10].

**Omega-3-fatty acids**

Alpha-linolenic acid is the main functional component of flaxseed. It serves as an exclusive source of omega-3 fatty acid in the vegetarian diets (Riediger et al. 2009) [11]. Of all lipids in flaxseed (approximately 30%), 55% are α-linolenic acid (ALA), 17% linoleic acid (LA), 19% oleic acid, 3% stearic acid, and 5% palmitic acid, which provides an excellent n-6: n-3 fatty acid ratio of approximately 0.3:1 (Simopoulos, 2002) [13]. Fatty acid profiles of various oilseeds are reported in Table 1. It is evident from the data that flaxseed contains highest amount of linolenic acid followed by soybeans and mustard oil, while sunflower and safflower oils contain large amount of linoleic acid which may leads to various diseases.

**Table 1: Fatty acid profile of various oilseeds**

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Flaxseed</th>
<th>Mustard</th>
<th>Soybean</th>
<th>Rice Bran</th>
<th>Corn</th>
<th>Sesame</th>
<th>Safflower</th>
<th>Olive</th>
<th>Sunflower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated</td>
<td>10</td>
<td>8</td>
<td>15.7</td>
<td>21.3</td>
<td>14.8</td>
<td>15.7</td>
<td>9.1</td>
<td>15.3</td>
<td>12.8</td>
</tr>
<tr>
<td>Monounsaturated</td>
<td>18.5</td>
<td>62.4</td>
<td>24.2</td>
<td>42.4</td>
<td>28.1</td>
<td>40.1</td>
<td>13.9</td>
<td>73.8</td>
<td>22.4</td>
</tr>
<tr>
<td>Polysaturated</td>
<td>71.8</td>
<td>31.5</td>
<td>59.8</td>
<td>35.9</td>
<td>57.1</td>
<td>45.7</td>
<td>77.3</td>
<td>10</td>
<td>66</td>
</tr>
<tr>
<td>Linoleic acid (n6)</td>
<td>16.8</td>
<td>21.6</td>
<td>52.1</td>
<td>34.6</td>
<td>56.1</td>
<td>45.3</td>
<td>76.5</td>
<td>9.4</td>
<td>65.6</td>
</tr>
<tr>
<td>Linolenic acid (n3)</td>
<td>55</td>
<td>9.9</td>
<td>7.8</td>
<td>1.2</td>
<td>1</td>
<td>0.4</td>
<td>0.8</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>N6/n3</td>
<td>0.3</td>
<td>2.2</td>
<td>6.7</td>
<td>2</td>
<td>56</td>
<td>113</td>
<td>7.4</td>
<td>16</td>
<td>131</td>
</tr>
</tbody>
</table>

Dubois et al., 2007 [5].

A large number of clinical studies have recognized the tremendous potential of n-3 polyunsaturated fatty acids in the prevention of coronary heart diseases, atherosclerosis, rheumatoid arthritis and asthma (Kremer, 2000) [8]. Flaxseed and its oil reduce the growth of tumors at the later stage of carcinogenesis. The role of flaxseed oil in tumors prevention is attributed to its high alpha-linolenic acid.

**Lignans**

Flaxseed is considered as good source of plant lignans (Thompson et al., 1996) [15]. Lignans are phytostrogens that are abundantly available in fiber rich plants, cereals, legumes, vegetables, fruits and alcoholic beverages. Flaxseed contains about 75 to 800 times more lignans than cereal grains other legumes, fruits, vegetables or cereals (Mazur et al., 2000) [9]. The major lignan in flaxseed is called Secoisolariciresinol diglucoside (SDG). Flaxseed lignan is also a source of useful biologically active components found in plant foods, such as phytochemicals, and it is considered a functional food.

**Protein**

The average protein content of flaxseed varies from 20 to 30%, constituting approximately 80% globulins and 20% glutelin. Majority of the protein is concentrated in the cotyledons. (Hall et al., 2006) [6]. The amino acid pattern of flaxseed protein is similar to that of soybean protein and contains no gluten, which is seen as one of the most nutritious of the plant proteins. Flaxseed protein is rich in arginine, aspartic acid and glutamic acid, while lysine is limiting. High cysteine and methionine contents improve the antioxidant levels, thus helps in reducing risk of cancer. The processing conditions, dehusking and defatting affect the protein content. Flaxseed protein is effective in lowering plasma cholesterol and triglycerides compared to casein protein and soya protein (Singh et al., 2011) [14].

**Carbohydrate**

Flaxseed contains less carbohydrate (sugars and starches), providing only 1 gram (g) per 100 g. Due to this, flaxseed contributes little to total carbohydrate intake. Flaxseed polysaccharides composed of two major fraction:- Neutral arabinoxylan (75%) and an acidic Rhamnogalacturonan (25%).

**Lipids**

The lipid content of flaxseed varies from 37 to 45 g/100 g of the seed as reported by various scientists (Morris, 2007) [10]. Cotyledons are the major oil storage tissues, containing 75% of the seed oil. Flaxseed oil constitutes 98% triacylglycerol, phospholipids and 0.1% free fatty acids (Singh et al., 2011) [14].

**Dietary Fiber**

Flaxseeds serve as a good source of both soluble and insoluble dietary fiber. It contains 35–45% of fibre and two-third is insoluble and one third is soluble fiber. Insoluble fiber consists of cellulose, hemicellulose and lignin. Most of the soluble fiber of flaxseed appears to be the mucilage of seed coat. High water binding capacity of flaxseed is attributed due to the presence of polysaccharides in the seed coat (Morris, 2007) [10]. Flaxseed fibre plays an important role in lowering the blood glucose level.

**Minerals and vitamins**

Flaxseed contains good source of minerals especially, phosphorus, magnesium, calcium and has low amount of sodium. It also contains small amounts of water-soluble and fat-soluble vitamins. Vitamin E is present as γ-tocopherol, amounting to 39.5 mg/100 g. γ-tocopherol acts as an antioxidant preventing fat from oxidation Vitamin C is absent in flaxseed (Morris, 2007) [10].
**Value added flaxseed based food products**

A large number of nutritional attributes present in flaxseeds are attracting the health professionals and nutritionist to consider the flaxseed in the formulation of functional foods and in the choice of a healthy diet. Flaxseed is potentially utilized as a versatile ingredient in various types of food products. Flaxseed supplemented food products are gaining popularity due to its high content of polyunsaturated fatty acids, protein, soluble fiber and phytochemicals. Flaxseed has been valued in bakery sector for preparation of baked food products like bread, cookies, muffins etc. Various studies have been carried out on the composite flour technology with special reference to improve the wheat flour quality by blending it with other flours. Flaxseed-water mixture serve as egg substitute in the diet of vegetarians especially in baked products pancakes, muffins and cookies. Flaxseed gum can be used for stabilization of emulsion in case of salad dressings.

**Conclusion**

Flaxseed can contribute in improving the availability of healthy food choices, specifically with the improvement in nutrient profile of foods by reductions in the salt, sugar and saturated fat content; and by increasing the content of ω-3 fatty acids and other bioactive compounds. Various research studies revealed that the flaxseed constituents provide disease preventive and therapeutic benefits. This encourages development of new branded healthy and functional foods using flaxseeds, oil and cakes.

**References**