Functional flaxseed in baking

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Received: 18 September 2012 / Accepted: 3 May 2013

REVIEW PAPER

Abstract

The use of flaxseed as a functional food has gained in popularity in recent years. It has been grown since ancient times for food and other uses. Flaxseed is an excellent source of nutrients including protein, soluble and insoluble dietary fibre as well as omega-3 fatty acids. The flaxseed can be used as a whole or it can be incorporated in other foods including bakery products. The flaxseed proteins can enhance the biological parameters of bread and unleavened flat bread (chapattis). The addition of flaxseed to wheat flour can also contribute towards several health benefits and can serve as a low-cost treatment for many diseases, e.g. diabetes, hypercholesterolemia and cardiovascular complications. The current review will focus on the health benefits of flaxseed and the potential of these seeds to be incorporated into breads and chapattis which are staple foods for a large segment of the population.

Keywords: bread, chapattis, flaxseed, functional foods

1. Flaxseed: general perspectives and composition

Functional foods are considered to play a key role in disease prevention and the maintenance of good health. Many common foods, especially modified/developed new food products, are referred to as 'functional foods', e.g. green tea, soy, flaxseed, garlic, fish, fruits, vegetables, grains and legumes (Arai, 1996). The flax (*Linum usitatissimum*) is a blue flowering rabi crop and is a member of the *Linaceae* family, commonly known as 'Alsi' in the Gujrati, Hindi and Punjabi languages (Gowda, 2013). Flaxseed and linseed are the other names which are often used interchangeably. In North America flax is called 'flaxseed' when eaten by humans, and 'linseed' when used for linoleum flooring. However, Europeans use the term flaxseed to explain the varieties grown for the manufacture of linen (BeMiller *et al.*, 1993). The history of flaxseed cultivation goes back as far as 3000 B.C. World production of flaxseed during 2011 was 1,602,047 tons (FAOSTAT, 2011). The prospective health benefits of oil seeds such as flaxseed, especially in relation to cancer and cardiovascular disease, have received more attention from nutrition experts and food scientists. Many researchers are conducting studies on its role in the cure and prevention of several diseases (Jenkins *et al.*, 1999). Due to the health-promoting properties and excellent nutrient profile of flaxseed, it has been becoming a popular candidate for incorporation in the human diet. Flaxseed is being used extensively for the development of functional foods. The components of flaxseed that have been identified as exhibiting health benefits are fibre, lignans and linolenic acid (omega-3 fatty acid). Moreover, flaxseed is a good source of high quality protein, soluble fibres and phenolic compounds (Oomah, 2001).

Flaxseed is the best source of lignans. It is also present in most whole grains (oats, millets, barley and buckwheat), vegetables (carrots, cauliflower, broccoli and spinach) and soybean. Phytochemicals have the ability to bind oestrogen receptors in the body and act as an anti-carcinogenic agent. These help to prevent prostate, breast and endometrium cancers. People who consume more lignans are least prone to these cancers (Setchell *et al.*, 1980; Toure and Xueming, 2010). Flaxseed is also an excellent source (about 28%) of dietary fibre. About two thirds of the total fibre in flaxseed is insoluble which increases the bulk in the digestive system, thus helping digestion and preventing constipation. These properties of fibre provide great protection against cancers. Furthermore, the remaining fibre portion of the flaxseed is soluble and has the ability to lower cholesterol levels in the body. The soluble fibres also optimise blood sugar concentrations (Institute of Medicine of the National Academics, 2002).

The flaxseed is also a rich source of polyunsaturated fatty acids consisting of about 80% of total oil with a high ratio of omega-3 to omega-6, both of which are essential and eaten as a part of the diet since the body does not manufacture them from other sources (Anonymous, 2006). Flaxseed oil contains one of the essential fatty acids, i.e. alpha-linolenic acid (ALA). It is one of three omega-3 fatty acids; the other two are eicosapentaenoic and decosahexenoic from fish sources. Omega-3 fatty acids play a role in reducing the risk of cardiovascular diseases. All the omega-3 fatty acids regulate cholesterol, triglycerides and blood pressure, whereas ALA is particularly helpful in promoting proper growth in infants (Horrobin and Manku 1990; Morris, 2004).

The incorporation of flaxseed into the diet can improve taste in regularly consumed dishes. The reddish brown flaxseed grains have a pleasant flavour and taste resembling nuts, and they are easily incorporated in different products. It can be spread over soups, salads, cereals or yoghurt. The baked products can be supplemented with whole flaxseed grains to achieve an attractive and appealing form which enhances the texture of the final product. The grinding of flaxseed before its addition to products can be more beneficial to obtain the prospective health benefits from its active components like dietary fibre, lignans and omega-3 fatty acids. Several researchers has found that wheat flour can be replaced by ground flaxseed or whole flaxseed grains in the production of pancake, muffins, breads and cookies. Several food products containing flaxseed are available in the market. Energy bars, pasta, bagels, muffins and pancakes are some examples of products with added flaxseed either whole or in its ground form (Manthey *et al.*, 2002b; Muir and Westcott, 2000). The average nutritional information about flaxseed grain is presented in Table 1.

2. Dietary fibre and alpha-linolenic acid

Dietary fibre is a common term used to describe a variety of plant substances that are not easily digested by the enzymes responsible for digestion in humans (Eastwood and Passmore, 1983). It is advised to consume an adequate amount of dietary fibre from a variety of plant foods (American Dietetic Association, 2008). An adequate intake of dietary fibre can provide a multitude of health benefits. The adequate recommend daily intake for different age groups from all sources (fruits and vegetables) is presented in Table 2.

There are two types of dietary fibre: soluble and insoluble. Soluble fibres like psyllium, guar gum and oats are responsible for a reduction in total cholesterol and low density lipoprotein (LDL) cholesterol (Glore *et al.*, 1994). Several studies on the health-promoting role of dietary fibre have been published. Table 3 is a summary of the health benefits associated with the use of dietary fibre based on the recent review of Hauner *et al.*, (2012).

There are two groups of omega fats; omega-3 and omega-6 fatty acids. Linolenic acid, eicosapentaenoic acid, and docosahexaenoic acid are the three types of omega-3 fatty acids and are nutritionally important. All three fatty acids have been shown to reduce the risk of cardiovascular disease. Linolenic acid is naturally present in canola, flaxseed, and walnuts whereas the other two types of omega fats are mainly present in fish like salmon, mackerel and herring (Hurteau, 2004). ALA (18:3n-3) is mainly derived from plants and is the main n-3 (ω3) fatty acid in the human diet. It is the principal precursor for long chain polyunsaturated fatty acids, of which eicosapentaenoic (20:5n-3) and docosahexaenoic acid (22:6n-3) are the most prevalent (Thomas, 2002). Intake of alpha-linolenic for a period of weeks to months results in an increase in the proportion of eicosapentaenoic acid (20:5n-3) in plasma lipids, in erythrocytes, leukocytes, platelets. These are required for maintaining optimal tissue function. Capacity to up-regulate ALA conversion in women may be important for meeting the demands of the foetus and neonate (Brena *et al.*, 2009; Burdge and Calder, 2005).

3. Health benefits of flaxseed

Some of the studies showing the health benefits of whole flaxseed, defatted flaxseed meal, flaxseed oil and individual flaxseed components are reviewed in this section. Flaxseed fibre is also believed to reduce blood glucose and cholesterol levels by delaying and reducing their absorption in the body (Shen *et al.*, 1998). Studies by Jenkins *et al.* (1999) showed a 5 and 8% reduction, respectively, in serum total and LDL cholesterol levels in subjects fed partially defatted flaxseed. These researchers attributed the LDL reduction to the soluble fibre component of the flaxseed. Cunnane *et al.* (1995a) reported that blood glucose levels fell by about 27% when bread containing flaxseed was consumed.

Ground flaxseed is high in omega-3-fatty acids, which have been shown to reduce hypertension, cholesterol and triglyceride level (Oomah and Mazza, 1998). Flaxseed is a good food for lowering cholesterol and improving heart function due to the eicosanoids derived from omega-3-fatty acids (Simopoulos, 1999). Many studies reveal that monounsaturated and polyunsaturated fatty acids are responsible for lowering total cholesterol in the diet (Zambon *et al.*, 2000). ALA from flaxseed exerts positive effects on blood lipids. The dietary ALA was found to be

Table 1. Nutritional composition of flaxseed (per 100 g) according to USDA (2012) and Flax Council of Canada (2007).

Nutrients	USDA	Flax Council of Canada
Moisture (g)	6.96	8.75
Energy (kcal)	534	492
Crude protein (g)	18.29	19.50
Crude fat (g)	42.16	34.0
Ash (g)	3.72	3.50
Nitrogen free extract (g)	28.88	34.25
Total dietary fibre (g)	27.3	27.9
Minerals		
Calcium (mg)	255	199
Iron (mg)	5.73	6.22
Magnesium (mg)	392	362
Phosphorus (mg)	642	498
Potassium (mg)	813	681
Sodium (mg)	30	34
Zinc (mg)	4.34	4.17
Copper (mg)	1.22	1.04
Manganese (mg)	2.48	3.28
Selenium (µg)	25.4	5.50
Vitamins		
Vitamin C, total ascorbic acid (mg)	0.6	0.50
Thiamin (mg)	1.64	0.53
Riboflavin (mg)	0.161	0.23
Niacin (mg)	3.08	3.21
Pantothenic acid (mg)	0.99	0.57
Vitamin B-6 (mg)	0.47	0.92
Vitamin E (alpha-tocopherol) (mg)	0.31	-
Tocopherol, gamma (mg)	19.95	-
Tocopherol, delta (mg)	0.35	-
Vitamin K (phylloquinone) (µg)	4.3	-
Lipids		
Fatty acids, total saturated (g)	3.663	3.196
4:0 (g)	0	0
6:0 (g)	0	0
8:0 (g)	0	0
10:0 (g)	0	0
12:0 (g)	0	0
14:0 (g)	0.008	0
16:0 (g)	2.165	1.802
18:0 (g)	1.330	-
20:0 (g)	0.052	-

Nutrients	USDA	Flax Council of Canada
22:0 (g)	0.052	-
24:0 (g)	0.031	-
Fatty acids, total monounsaturated (g)	7.527	-
16:1 undifferentiated (g)	0.024	-
18:1 undifferentiated (g)	7.359	-
20:1 (g)	0.067	-
22:1 undifferentiated (g)	0.013	-
24:1 c (g)	0.064	-
Fatty acids, total polyunsaturated (g)	28.730	-
18:2 undifferentiated (g)	5.903	-
18:3 undifferentiated (g)	22.813	-
18:4 (g)	0	-
20:2 n-6 c,c (g)	0.007	-
20:4 undifferentiated (g)	0	-
20:5 n-3 (g)	0	-
22:5 n-3 (g)	0	-
22:6 n-3 (g)	0	-
Amino acids		
Tryptophan (g)	0.297	-
Threonine (g)	0.766	-
Isoleucine (g)	0.896	-
Leucine (g)	1.235	-
Lysine (g)	0.862	-
Methionine (g)	0.370	-
Cystine (g)	0.340	-
Phenylalanine (g)	0.957	-
Tyrosine (g)	0.493	-
Valine (g)	1.072	-
Arginine (g)	1.925	-
Histidine (g)	0.472	-
Alanine (g)	0.925	-
Aspartic acid (g)	2.046	-
Glutamic acid (g)	4.039	-
Glycine (g)	1.248	-
Proline (g)	0.806	-
Serine (g)	0.970	-
Hydroxyproline (g)	0.175	-

- = no data available.

as effective as oleic (18:1n-9) and linoleic acid (18:2n-6) in the reduction of plasma total cholesterol, low density lipoprotein cholesterol and very low density lipoprotein cholesterol in 20-34 year-old healthy men (Chan *et al.*, 1991). In another study, 12 g ALA was taken three times a day by a group of healthy young women in the form of flaxseed oil capsules and compared with other group given the flaxseed flour supplemented products. An impressive reduction in blood lipids was observed in both cases (Cunnane *et al.*, 1993). A full-fat flaxseed meal enhanced the cholesterol-lowering effect of diets containing flaxseed oil (Ranhotra *et al.*, 1993). The flaxseed protein was also found to be effective in lowering plasma cholesterol and triacylglycerides (Bhathena *et al.*, 2002). Cunnane *et al.* (1995a) stated that an 8% reduction in LDL protein and a 30% increase in bowel movement were observed in adults

Table 2. Adequate recommended daily intake of dietary fibre (Institute of Medicine of the National Academics, 2002).

Age (years)	Adequate intake (g/day)	
	Male	Female
1-3	19	19
4-8	25	25
9-13	31	26
14-18	38	26
19-50	38	25
≥51	30	21
Pregnancy		28
Lactation		29

Table 4. Adequate recommended daily intake of alpha-linolenic acid (Institute of Medicine of the National Academics, 2002).

Age	Adequate intake (g/day)	
	Male	Female
0-6 months	0.5	0.5
7-12 months	0.5	0.5
1-3 years	0.7	0.7
4-8 years	0.9	0.9
9-13 years	1.2	1.0
≥14 years	1.6	1.1
Pregnancy		1.4
Lactation		1.3

Table 3. Summary of relationships between dietary fibre intake and some nutrition-related diseases (review by Hauner *et al.*, 2012).

Disease	Possible evidence, risk reducing	Probable evidence, risk reducing	Convincing evidence, risk reducing	Possible evidence, no association	Probable evidence, no association	Convincing evidence, no association
Obesity (children)	-	-	-	yes	-	-
Obesity (adult)	-	yes	-	-	-	-
Type II diabetes mellitus	-	-	-	-	yes	-
Total cholesterol	yes	-	-	-	-	-
LDL cholesterol	yes	-	-	-	-	-
HDL cholesterol	-	-	-	-	yes	-
Triglycerides	-	-	-	-	-	yes
Hypertension	-	yes	-	-	-	-
Metabolic syndrome	-	-	-	yes	-	-
Cardiac heart disease	-	yes	-	-	-	-

consuming 50 g flaxseed per day for 4 weeks. Hasler *et al*. (2000) observed a 6.9% reduction in total cholesterol of women fed on bread and muffins supplemented with 38 g of flaxseed for a period of six weeks. Lemay *et al.* (2002) noticed small changes in the cholesterol levels of 25 hypercholesterolaemic women fed on a diet containing 40 g flaxseed/day.

Arjmandi *et al.* (1998) reported that thirty-eight women with mild, moderate or severe hypercholesterolaemia were provided with 38 g of flaxseed incorporated into bread or muffins as part of their daily diet for six weeks. The total cholesterol, LDL cholesterol and lipoprotein concentrations fell significantly, possibly due to the activity of linolenic or linoleic acids, fibre and non-protein constituents present in this seed. In a clinical study by Lucas *et al*. (2002), 40 g of either ground flaxseed or a wheat-based comparative control regimen was fed to postmenopausal women on a daily basis for three months. The flaxseed supplementation resulted in a 6% reduction in both serum total and high density lipoprotein (HDL) cholesterol, whereas no effect was observed due to the use of a control regimen. The flaxseed regimen reduced the serum levels of both LDL and HDL cholesterol by 4.7% and triglyceride by 12.8%. Dodin *et al.* (2005) reported that the intake of flaxseed reduced serum total (-0.20±0.51 mmol/l) and HDL cholesterol (-0.08±0.24 mmol/l) concentrations of menopausal women who consumed 40 g flaxseed per day.

4. Storage and cooking stability of flaxseed

Oxidative rancidity is a major cause of the development of bad odour and flavour in foods containing higher oil contents. Free radical formation is responsible for that process. The by-product of this process is the development of peroxides. The measurement of peroxide value helps to determine the degree of rancidity present (Martin, 2004). Addis and Warner (1991) found that in higher oil-containing functional foods, lipid per oxidation results in the deterioration of their nutritive value and stability. The flavour and taste of such foods or the foods to which these oils are added are also affected (Barlow, 1990). The flaxseed meal or oil can easily be incorporated into common food products such as breads, rolls, cereals, muffins, margarines, and salad dressings (Fitzpatrick, 2006). Flaxseed oil is a source of essential fatty acids, such as linoleic acid and linolenic acid (LNA, 18:3n-3), required in the diet for normal health (Dobson, 2002; Lee and Lip, 2003). The level of LNA in flaxseed oil is generally higher than 50% of the total fatty acids. LNA has been reported to play an important role in the prevention of immune disorders, cardiovascular diseases and certain type of cancers (Kris-Etherton *et al.*, 2002). However, there is great concern about the use of flaxseed oil as a nutraceutical supplement, owing to its high content of LNA which is prone to rapid oxidation, resulting in quality deterioration. The study by Hauman (1998) indicated that flaxseed oil is high in unsaturated fatty acids, mainly in ALA, which is about 52% of the total fatty acid content of flaxseed oil. The instability of flaxseed oil as regards oxidation is the limiting factor for its incorporation in food products. (Kolodziejczyk and Fedec, 1995) reported that the stability of oil can be extended by suitable storage which is vital for improving the oxidative stability of flaxseed oils. ALA in a remote form or as a part of an extracted oil is generally considered susceptible to oxidation as it is highly unsaturated and oxidation in oils is encouraged by both heat (auto-oxidation) and light (photo-oxidation). However, ALA in the intact seed of flax has proven particularly resistant to oxidation.

The storage stability of flaxseed is of major importance before using it in any food product. Due to its high oil content, proper cooking and storage assures better stability of high oil-containing flaxseeds in different products. Several researchers have worked on the storage and cooking stability of flaxseed. Macaroni fortified with ground flaxseed at levels of 10 and 20% was dried at 40, 70 and 90 °C. In dried macaroni after storage for 32 weeks, conjugated diene values indicated no significant increase while ALA levels in the fortified macaroni remained unchanged during the whole storage period (Hall *et al.*, 2005). The study conducted by Lee *et al.* (2000) concluded that macaroni containing 20% ground flaxseed flour showed significant storage stability. ALA content and storage stability of the spaghetti were not affected by the processing method. Fatty acid profile of the pasta remained consistent during the storage. Conjugated dienes and headspace analysis also indicated non-significant variations.

Both the whole and coarsely ground flaxseed showed long-term storage stability at room temperature. No changes in the peroxide values were observed after 308 days of storage at a temperature of 22 °C. The percentage of ALA in fat extracted from the stored flaxseed samples also remained unchanged (Ratnayake *et al.*, 1992). The roasting of flaxseed significantly affected the peroxide value (POV). Roasted samples showed a lower peroxide value as compared to the non-roasted flaxseed samples. The storage time significantly affected the peroxide value; it increased after the 4-week storage period, which ultimately resulted in a decrease in the stability of the flaxseed. Storage temperatures also affected the peroxide value. Samples stored at 30 °C had a higher POV than those stored at 25 °C. Non-roasted samples had statistically (P<0.05) higher free fatty acid levels than roasted samples. The fatty acid profile showed low variation, indicating insignificant changes in terms of linolenic acid content (Scott *et al.*, 2004).

Flaxseed can be stored in different materials that affect its stability. The peroxide values were relatively unchanged and the ALA content was not affected in flaxseed packaged in loosely packed plastic bags and protected from light when stored at room temperature for 20 months in warehouse conditions (Daun, 2001). Flaxseed spread out in trays showed ample deterioration (high peroxide levels) after 14 weeks of storage. Flaxseed stored in bags showed very little increase in peroxide levels and fatty acids remained unaffected during storage period (Wiesenborn *et al.*, 2004).

Flaxseed samples milled and stored at 22.7 °C for 4 months in paper bags with plastic liners were tested after 0, 33, 66, 96 and 128 days of storage intervals. A slight increase in peroxide values and changes in ALA content was observed. There was no difference in odour or taste of fresh and stored samples of flaxseed tested by a sensory panel (Malcolmson *et al.*, 2000). Negligible changes in chemical parameters of oxidation like peroxide value and free fatty acids were observed. No difference was observed in the aroma intensity of the water slurries of fresh and stored samples (Malcolmson *et al.*, 1998). Similarly, flaxseed samples stored in a glass tube remained unchanged regarding their ALA content and showed stability in heat and light for 280 days during storage at room temperature. Few changes in head space oxygen were recorded during the said period (Chen *et al.*, 1994).

Research conducted by Cunnane *et al.* (1995b) showed no significant reduction during the baking process in the thiobarbituric acid-reactive substances and alpha-linolenate content of muffins supplemented with 25 g of flaxseed. Malcolmson (1997) reported that 36 consumers could not tell the difference between the taste of yeast bread baked with either fresh or stored milled flaxseed at 11% of the flour weight in the recipe. In another study, Manthey *et al.* (2002a) concluded that processing and cooking of spaghetti did not significantly affect ALA contents.

During baking, a minimal loss of ALA from flaxseed was observed, which is helpful for the incorporation of flaxseed in different food products (Chen *et al.*, 1994). No changes in peroxide values and fatty acid composition were observed when whole and milled flaxseed was heated for 60 minutes at either 100 or 350 °C (Ratnayake *et al.*, 1992). Macaroni was fortified with 20% (by weight) ground flaxseed, stored for 20 weeks and cooked in boiling water for 12 minutes. The ALA content remained the same during the whole storage process and after cooking (Manthey *et al.*, 2002b).

5. Potential of flaxseed use in different food products

The flaxseed grain is oval and flat, slightly larger than a sesame seed and about 2.5×5.0×1.5 mm in size. The colour of flaxseed ranges from reddish brown to a light yellow (Freeman, 1995). The texture of flaxseed is crisp and chewy and it has a pleasant nutty taste (Carter, 1996).

The approximate composition of flaxseed is 30% protein, 35% lipids and 35% fibre; though it varies depending upon the seed variety, cropping year, cropping location and environmental conditions. The protein content in flaxseed has been reported to range from 10.5 to 31% depending on environment and growing conditions (Bajpai *et al.*, 1985). Flaxseed is not a good source of starch. The soluble fibre represents approximately a quarter of the total fibre present in flaxseed. Mucilaginous gum is the major component of the soluble fibre in flaxseed and its composition varies from 7-10 g per 100 g (Carter, 1993). ALA, which is an omega-3 fatty acid, forms the mass composition of polyunsaturated fatty acids in flaxseed. It makes up about 50% of the total fatty acids (Daun and Przybyliski, 2000). ALA cannot be synthesised by the human body from any other substance therefore it is considered as an essential fatty acid. The essential fatty acid requirements for the human body can be fulfilled by consuming flaxseed products (Morris, 2004). 100 g of flaxseed provides 100% of the recommended daily allowance (RDA) of manganese and potassium, 57-65% of the RDA of phosphorus and iron, and 13-35% of zinc, calcium and copper while its recommended daily intake is 25 to 50 g (Stitt, 1986). Specialty grains (bulgar wheat, barley, flax seed, sprouted grains and rice extract) are used in breakfast cereals to add novel textures, flavours and colours in these products (Kuntz, 1998). Al-Dmoor (2012) reviewed the importance of the fortification of flaxseed flour in flat breads. Hussain *et al.* (2012) reported that the level of soluble, insoluble and total dietary fibre and essential amino acids in flaxseed supplemented unleavened flat breads was higher. It was noticed that the net protein utilisation, biological value, protein efficiency ratio and true digestibility improved significantly ($P \leq 0.05$) when diets containing flaxseed supplemented unleavened flat breads were fed to rats.

Similarly, chapattis containing 20% or lower levels of the full fat flaxseed flour were found acceptable by the panellists with respect to their sensory attributes. The mineral contents of the chapattis increased significantly as the levels of the full fat flaxseed flour were increased in the wheat flour (Hussain, 2004). The breads containing 10 and 13% levels of linseeds were characterised by higher amounts of protein, fat, dietary fibre, macro and microelements in comparison to standard bread. There was a significant increase in iron, zinc and manganese content of the bread with the increasing level of flaxseed flour in the wheat flour (Gambus *et al.*, 2004; Naz, 2000). The ground flaxseed used at 30 to 50% has been found to be acceptable in muffins and quick breads (Alpers and Morse, 1996). The cookies prepared from wheat flour containing 20% whole flax grains, partially defatted flaxseed flour and full fat flaxseed flour were found acceptable with respect to their sensory attributes (Hussain *et al.*, 2006).

Gambus *et al.* (2003) investigated the quality of two bakery products (cookies and muffins) containing brown and yellow flaxseed flour at 11 and 9%, respectively. These levels of replacement did not affect the sensory properties of flax hermit cookies and flax muffins. The increased linseed content improved the dietary and nutritional values of both types of bakery products due to the increased total protein and dietary fibre contents. The study conducted by Zaib-un-Nisa (2000) showed that the protein content of biscuits made from composite flour containing 15% ground flaxseed increased from 6.50 to 8.52%, fat content increased from 26.13 to 31.45%, fibre content increased from 0.15 to 3.78% and ash content increased from 0.26 to 1.00%. The supplementation of flaxseed flour up to 15% showed no deleterious effect on the sensory attributes of biscuits. Minerals like iron, zinc and manganese contents increased significantly with 15% supplementation of flaxseed flour. According to Gambus *et al.* (2004), a 3% increase in linseed in the recipe for flax hermit cookies and a 5% rise of linseed in flax muffins resulted in an increase in the amounts of proteins, dietary fibre, micro and macro minerals. Frank and Sarah (2006) also studied the effect of combining flaxseed meal (15%) and soy flour (5 and 10%) on the product quality in the production of yeast bread. The addition of flax and soy flour resulted in the reduction of bread volume. The sensory attributes like crust and crumb colour were also affected due to the addition of soy/flaxseed flours and a darker colour was observed in both products. No significant differences in moisture in the flax and soy/flax breads were recorded as compared to control breads prepared from wheat flour alone.

Kocka and Anil (2007) reported that the addition of flaxseed to wheat flour at 15 and 20% levels resulted in a decrease in dough stability, lower crust and crumb scores as compared to the control breads prepared from 100% wheat flour. In another study, conducted by Pohjanheimo *et al.* (2006), the effect of the addition of flaxseed to bread rolls and cinnamon rolls on their sensory profile and chemical composition was studied. At 0 and 6 days of storage, no significant changes were observed in their sensory attributes. Higher contents of saturated fatty acids were observed in the cinnamon rolls. Both bakery products were found to be higher in ALA contents. The fibre content of the bread rolls also increased.

The wheat grown in Pakistan and in some other parts of Asia is mainly used for the preparation of unleavened flat breads, which are known locally as chapatti or roti. The chapattis are unleavened and are prepared from whole-wheat flour or atta (95% extracted flour). Wheat is a basic raw material for the preparation of chapattis and its other variants like rotis and naans. The quality of chapattis is influenced by the wheat quality (Haridas *et al.*, 1986; Prabhasankar, 2002). The most important parameters of chapatti quality are flavour and texture and are evaluated as soft texture, greater pliability, light creamy brown colour with small brown spots, slight chewiness, fully puffed, and baked wheaty aroma (Haridas *et al.*, 1986; Shaikh *et al.*, 2007). The composite flours can be prepared and used to improve the nutritional and technological properties of the chapattis. Gandhi *et al.* (1983) demonstrated that chapattis made from wheat flour containing 10-15% soy flour were judged to be of satisfactory flavour, texture, appearance and overall acceptability by a trained sensory panel, although flavour and texture were significantly different from the all-wheat-flour chapattis. Khan *et al.* (2005) and Anjum *et al.* (2006) observed a significant improvement in the mineral content (iron, zinc, calcium, magnesium and copper) of chapattis supplemented with soy flour /hulls and found that soy flour and hulls can be replaced up to 24 and 4.5% levels, respectively, to produce organoleptically acceptable chapattis. The chapattis prepared from the composite flour containing 15 g roasted flaxseed powders, 0.05 g oil and 80 g of whole wheat flour provided 29.9 g carbohydrates, 6.3 g protein, 5.9 g fat and 198 Kcalories (Soniya *et al.*, 2004). The texture of chapattis became progressively harder when stored at both room and refrigerated temperatures. A decrease in sensory quality and acceptability of the chapattis was observed with storage. The rate at which the chapattis went stale was lower at refrigerated temperature than at room temperature (Shaikh *et al.*, 2007).

6. Rheological characteristics of composite flours containing flaxseed

The mechanical and rheological properties of the dough exert a promising effect on the overall quality of baked products (Blokshma and Bushuk, 1988). The arrangement and interaction of constituents (especially proteins) and the structure of materials are the factors that affect the rheological properties (Bushuk, 1985). The final product quality depends upon the dough rheology taking place during the processing of the constituents (Lindahl, 1990). The nature of ingredients, their proportions, mixing time and beating conditions are responsible for the quality of batter which finally determines the baked product quality (Baixauli *et al.*, 2007). The dough rheological properties are influenced by the structure of the aggregates and their tendency to interact with each other. The quality and quantity of the proteins affect the water absorption capacity of the dough (Finney, 1984). The farinograph or mixograph are the two most common methods used for measuring the rheological properties of dough during mixing (Mani *et al.*, 1992). The mixing of flours results in hydration which leads to the formation of a gluten matrix. During the mixing process, air is also incorporated into the dough system (Bushuk, 1985). The mixograph provides an indication of the mixing requirements of flour (Hoseney and Finney, 1974). The peak height depends on the gluten content of the wheat flour. The wheat variety Barani-83 of Pakistan showed higher gluten levels which resulted in the increase of peak height (Anjum and Walker, 2000). The rheological properties of the composite flours are significantly affected as the level of replacement of wheat flour by cottonseed flour was increased (Bajwa, 1997). Similarly 10% replacement of wheat flour by defatted peanut flour altered the water absorption capacity and extensibility of the dough mix (Rao and Vakil, 1980), while no significant effect on the peak height and mixing time was observed with the 10% addition of cottonseed flour in the two different types of wheat flours (Rasool, 2004). More water absorption with sticky dough is observed, as the fibre content of chapattis was increased and the mixing time of the dough was decreased (Ahluwalia and Kuar, 2001). The addition of cottonseed, peanut, safflower and soy flour to wheat reduced the mixing tolerance while an increase in the water absorption is observed (Mathews, 1972). The water absorption of composite flour containing 10% chickpea flour decreased significantly from 68.40% at (0 day) to 66.5% (60 days) as a function of storage time (Shahzadi, 2004).

Flaxseed mucilage is composed mainly of polymeric carbohydrates while galacturonic acid, rhamnose, galactose, fructose, glucose are also present in small quantities. It can help to improve the water absorption characteristics of the dough (Fedeniuk and Biliaderis, 1989). Flaxseed may function as a natural additive that retards the staling of the bread (Pohjanheimo *et al.*, 2006) as its gum possesses excellent water-binding capacities and technological benefits (Konecsni *et al.*, 2005). The farinographic studies of bread prepared from wheat flour replaced with flaxseed flour at 5, 10, 15, and 20% showed that water absorption, dough development time and mixing tolerance index increased as the amount of flaxseed flour increased, while dough stability decreased at 10, 15 and 20% of flaxseed flour supplementation. The addition of 15 and 20% levels of flaxseed flour showed a decrease in the dough extensibility. The doughs containing 10, 15 and 20%

flaxseed flour exhibited resistance to extension comparable to that of control dough containing no flaxseed flour (Koca and Anil, 2007).

The quality of breads based on sensory attributes is described by appearance, aroma, texture and flavour (Lawless and Heyman, 1999; Meilgard *et al.*, 2007). Wang *et al.* (2002) reported that the addition of or increase in dietary fibre in breads results in a decrease in loaf volume, increase in crumb firmness and darker crumb appearance of bread. Filipovic *et al.* (2007) also found that incorporation of fibres (modified and unmodified) showed a decrease in scores assigned to volume and crumb quality of bread. The sensory scores for appearance, texture and flavour of breads have been reported to be decreased by the incorporation of non-wheat flours in wheat flours (Shittu *et al.*, 2007). Frank and Sarah (2006) found that addition of 15% flaxseed meal to bread negatively affected the volume, crust colour and crumb colour of breads. Koca and Anil (2007) showed that crumb darkness increased by increasing the level of flaxseed flours levels. A significant decrease in scores for all the sensory attributes has also been supported by the study conducted by Naz (2000) who observed that breads exceeding 15% flaxseed supplementation in wheat flour resulted in lower scores for texture, crumb colour, grain, and volume and crust colours. The first limiting amino acid in wheat flour is lysine, but its quantity in flaxseed flour is 6.8 mg/100 g of protein (Dev and Quensel, 1986) which is higher than soy flour, i.e. 5.8 mg/100 g of protein (Friedman and Levin, 1989), and wheat flour. Thus the addition of flaxseed flour to chapattis and bread can be helpful in improving the biological parameters of these products.

7. Conclusions

Flaxseed grains are a good source of nutrients and also provide health benefits. The storage stability of flaxseed for about 2 months makes it suitable for blending with wheat flour. The flaxseed proteins can enhance the quality parameters of bread and chapattis. The addition of flaxseed to wheat flour can also contribute towards the several health benefits and can offer a low-cost treatment for many diseases, e.g. diabetes, hypercholesterolemia and cardiovascular complications. Flaxseed should be included in a daily diet plan through its incorporation into wheat flour used for the production of breads and other bakery products. The baking industry should focus on the fortification of bakery products with flaxseed flour. Flaxseed supplemented chapattis and breads should be advised for diabetic and heart patients. Lignans of flaxseed should be explored for their anticancer effects. Flaxseed should be used in various other products based on dairy and beverages. Active ingredients from flaxseed should be extracted and used as nutraceuticals in different food products including chapattis and other traditional products.

Acknowledgements

This project was financially supported by King Saud University, Deanship of Scientific Research, College of Food & Agricultural Sciences, Research Center.

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