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CHEMICAL AND TECHNOLOGICAL STUDIES ON FLAXSEED (*Linum usitatissimum*) AND ITS APPLICATION IN SOME FUNCTIONAL FOODS

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ABSTRACT

Flaxseed was analyzed and characterized in terms of physical properties, chemical composition, functional properties, oil composition and its characteristics. Flaxseed flour was found to be a good source of crude oil and protein being 39.18 and 22.04%, respectively. It contains a high proportion of dietary fibre and could be considered as a good source of minerals e.g. K, P and Mg. α- linolenic acid was the major fatty acid and constituted about 57.25% of the total fatty acids. In addition, flaxseed contained minor amounts of ascorbic acid, phenolic compounds and tocopherols. These compounds appear to have anticancer and antioxidant effects in human body. The studied functional properties of flaxseed flour indicated good advantages for preparing different baked and meat products such as biscuits, cookies, crackers, cake, pizza, meat loaf and beef burger. These products can be used as functional foods.

Keywords: Flaxseed, Physical properties, Chemical composition, Oil characteristics, Functional properties, Application of flaxseed.

INTRODUCTION

The flaxseed (*Linum usitatissimum*) of the family Linaceae has been used in the diets of humans for thousands of years. The Babylonians cultivated flaxseed as early as 3,000 B.C., and millennia later, in 650 B.C., Hippocrates used flaxseed for the relief of intestinal discomfort. Flaxseed was so important for the health of his subjects that the 8th century king Charlemagne, passed laws and regulation governing its consumption (Bhatty, 1995).

Today, consumers are turning to flaxseed for its many health benefits and pleasant, nutty flavour – a distinctive addition to baked products (Cunnane, 1996)

Flaxseed is rich in protein, fat and dietary fibre, each contributing to its overall value in the diet. In addition, flaxseed contains two components that favourably affect the immune system: alpha – linolenic acid (ALA), an essential omega–3 fatty acid, and lignans, a type of phytoestrogen. These components affect the immune cells and the mediators of the immune response such as eicosanoids and cytokines. ALA suppresses the proliferation of peripheral blood mononuclear lymphocytes and delayed hypersensitivity response to certain antigens (Kelley *et. al.*, 1993). In addition, ALA and lignans in flaxseed modulate the immune response and may play a beneficial role in the clinical management of autoimmune disease (Raper, *et. al.*, 1992).

Also, ALA is the parent compound of the omega–3 fatty acid family. ALA is a precursor to the long–chain fatty acids eicosapentaenoice acid (EPA) and docosahexaenoic acid (DHA) and is an essential fatty acid for humans because it cannot be synthesized from dietary precursors (Cunnan and Anderson, 1997).

It has been reported that flaxseed contains high level of the plant lignan precursor, seciosolariciresinol diglycoside (SDG). This precursor is a phenolic substance associated with the plant fibre and have shown antioxidant effects *in vitro* and or *in vivo* (Kirkman *et. al.*, 1995 and El-Shimi *et. al.*, 2011).

It has been reported that ALA and lignans have been found stable under common baking conditions (Chen *et. al.*, 1994).

According to the auther's best knowledge, little attention has been directed toward the utilization of whole and ground flaxseeds after certain treatment such as soaking, boiling, autoclaving, roasting, fermentation and demucilaging in preparing certain baked products such as baladi bread, biscuits, petit four and flaxseed beverage (Khattab, 2004).

The aim of the present study is to utilize whole flaxseed and its flour in preparing some common food products. Physical characteristics of seeds, proximate analysis, chemical composition, technological procedures as well as the sensory evaluation of the products were covered during this study.

MATERIALS AND METHODS

Materials:

Five kg of Egyptian flaxseed, (***Linum usitatissimum***) Sakha – 1 variety were obtained from Fibre Crops Institute, Agricultural Research Center, Egypt (Season 2010/2011). Flaxseeds were transferred to the laboratory of Food Science and Technology Department, Faculty of Agriculture, Alexandria University, Alexandria, Egypt. The seeds were cleaned, packed in polyethylene bags and stored in a refrigerator at 4°C until used.

All ingredients mentioned in our work were purchased from the local market of Alexandria, Egypt.

Methods:

Preparation of flaxseed samples:

Cleaned flaxseeds were divided into two portions. The first portion was taken as whole seeds to study their physical properties and to utilize it in preparing some food products. The other portion was milled using an electric miller (model Braun 500) to pass through 80 mesh sieve to obtain flaxseed flour (FSF). The obtained flour was packed in airtight Kilner jar and stored in a refrigerator (4°C) until used.

Incorporation of whole flaxseeds (WFS) and flaxseed flour (FSF) into some food products:

Aniseed biscuits:

Aniseed biscuits were prepared from the following ingredients: 250.0 g wheat flour (72% extraction), 75.0 g sunflower oil, 100.0 g powdered sugar, 2 whole egg, 0.5 g sodium bicarbonate, 8.0 g baking powder, 5.0 g vanilla and 1.0 g salt. Effect of replacing 5.0, 10.0 and 15.0% WFS based on the weight of wheat flour on the biscuit quality was studied.

All ingredients were mixed in the Hobart dough mixer (Model N – 50 G, 470 rpm Hz 50) for 7 min. at 470 rpm. The dough was flattened using sheeting roll machine and shaped. Baking was performed at 150°C for 15 min (Askar, 1991). Biscuits were allowed to cool and stored in polyethylene bags at room temperature.

Chocolate chip cookies:

Chocolate chip cookies were prepared from the following ingredients: 250.0 g wheat flour (72% extraction), 125.0 g shortening, 125.0 g brown sugar, 62.5 g white granulated sugar, 2.5 g vanilla, 1.0 whole beaten egg, 2.5 g baking soda, 1.0 g salt and 125.0 g chocolate chips. Effect of replacing 10% FSF based on the weight of wheat flour on the cookies quality was studied. The shortening and the sugar were firstly creamed, then beaten egg and vanilla were added. Flour, baking soda, salt, chocolate chips and FSF were combined all together and added to the creamed mixture. The mixture was dropped by teaspoonful onto a cookie sheet, leaving 5 cm between cookies. Cookies were baked at 180°C for 10 to 12 min until golden. Cookies were removed from sheet and left to cool before packaging in polyethylene bags and kept at room temperature.

Farmland flax cookies:

Farmland flax cookies were prepared from the following ingredients: 325.0 g butter, 300.0 g granulated sugar, 375.0 g brown sugar, 3 whole eggs, 7.0 g vanilla, 825.0 g wheat flour (72% extraction), 15.0 g baking soda, 750.0 g oatmeal and 575.0 g FSF. Cream butter, sugars and flaxseed were added all together. Eggs and vanilla were beated together and then were combined with flax mixture. The flour and soda were sifted together then were mixed in oat meal and combined with other ingredients. The dough was formed into 4 cm round logs, placed in the freezer and chilled, then, the dough was sliced into 0.5 cm medallions. The slices were placed on baking sheet leaving about 5 cm between each cookies. Cookies were baked for 13 to 15 min in an oven at 180°C. The baked cookies were removed from sheet and cooled before packaging in polyethylene bags and kept at room temperature.

Flaxseed crackers:

Flaxseed crackers were prepared from the following ingredients: 375.0 wheat flour (72% extraction), 20.0 g shortening, 2.0 g baking powder, 2.0 g salt, 125.0 g skim milk, 50.0 g WFS (13.3%) and 50.0 g FSF (13.3%). Flour, baking powder, salt and shortening were combined all together in a bowl of a stand-up mixer. With the paddle attachment, the mixture was mixed at low speed until it resembles a coarse meal. The above mixture was stirred using milk and mixed until the mixture forms a soft dough. The dough was wrapped in plastic wrap and chilled for 10 min, then divided into quarters, turned out onto a lightly floured board, rolled out very thin in a rectangle shape of 2 mm thick, cutted into 6 cm squares, transferred to an ungreased baking sheets, repeated with remainder of the dough, and then baked in a preheated oven at 160°C for 20 min until crisp and golden. Crackers were cooled before packaging in polyethylene bags and kept at room temperature.

Two-hour buns:

Two-hour buns were prepared from the following ingredients: 250.0 g wheat flour (72% extraction), 16.0 granulated sugar, 1 whole egg, 0.5 g salt, 0.35 g fast rising instant yeast, 100 ml water and 25.0 g FSF.

The yeast and half the flour were mixed in a bowl. Sugar, egg and salt were beated in a large bowl. Water was added and stirred. Flour mixture was added to the liquid and was beaten until it is well blended. The remaining flour was added, kneaded and let to rise for 15 min. The dough was punched down and let to rise again for 15 min, then punched down and formed into buns. Buns were placed on a greased baking sheet allowing 5 cm between buns and then let to rise for 1 hr. Buns were baked in a preheated oven at 180 °C for 20 min. Buns were removed and cooled on a rack before packaging in polyethylene bags and kept at room temperature.

Pizza:

Pizza was prepared from the following ingredients: 250.0 g wheat flour (72% extraction), 7.0 g baking powder, 12.5 g sunflower oil, 125.0 g skim milk, 1 whole egg, salt (1.0 g), 35.0 g shredded mozzarella cheese, 25.0 g diced green pepper, 25.0 g diced tomato, small little amount of tomato paste, 35.0 g diced pickled olive 35.0 g sliced pastarami and 60.0 g(FSF). Wheat flour, granulated sugar, baking powder, salt and FSF were combined in a bowl. In another bowl, milk, oil and egg were whisked together. Liquid was poured into dry ingredients, stirred just until dry ingredients were moistened. The mixture was poured into a well greased pan. Tomatoes, green pepper, olive, pastarami and mozzarella cheese were sprinkled on the top of the batter and baked in a preheated oven at 180°C for 55 to 60 min.

Meat loaf:

Meat loaf was prepared from the following ingredients: 1.0 kg lean ground beef, 250.0 g skim milk, 125.0 g dry bread crumbs, 125.0 g chopped onion, 1 beaten egg, 15.0 g Worcestershire sauce, 5.0 g black pepper, 5.0 g garlic powder, 5.0 g dry mustard, 2.0 g celery, 1.0 g salt, 1.0 g ground thyme, 50.0 g ketchup and 125.0 g FSF. Meat, milk, crumbs, onion, egg, Worcestershire sauce, pepper, garlic, mustard, celery salt and thyme were combined and well mixed in a large bowl. The mixture was patted into a 22 × 13 × 8 cm loaf pan. Ketchup was spreaded over the loaf. The loaf was baked at 180 °C for 1 to 1½ hrs until no pink remains. The baked loaf was removed from the oven and left to stand for 5 min. The baked loaf was removed from the pan and placed on the platter before subjecting to organoleptic test.

All the previous products (cookies, crackers, two – hour buns, pizza and meat loaf) were prepared according to the procedures mentioned in family favourites (recipes and healthful tips) developed by the Flax council of Canada).

Cake:

The cake were prepared according to the basic formula described by El–Abasy (2011). The formula included 100.0 g wheat flour (72% extraction), 120.0 g white sugar, 50.0 g whole egg, 60.0 g liquid milk, 30.0 g butter, 3.0 g baking powder and 1.0 g vanilla. The effect of replacing 5, 10 and 15% FSF based on the weight of wheat flour, on the quality of the cake was studied. Sugar was creamed with homogenized whole egg and butter containing vanilla for 25 min using stand mixer (M. K. 2010 N Matsushita. electric trading Co., Ltd, Japan). Wheat flour and baking powder were added in small portions and mixed for 5 min. The batter was poured in baking pan and baking was carried out at 180 °C for 25 min. The cake after cooling was cut into slices, and kept at room temperature (25 °C), before assessed organoleptially.

Menain:

The menain was processed according to the traditional procedures application in the backer's shop and prepared from the following ingredients: 250.0 g wheat flour (72% extraction), 100.0 g corn oil, 2.5 g roasted sesame, 5.0 g dry yeast, 2.5 g aniseeds, 2.5 g fennel, 5.0 g dry yeast and 125.0 g warm water. The effect of replacing 5, 10 and 15% FSF based on the weight of wheat flour, on the quality of menain was studied. The menain dough was prepared by employing the straight dough method, which involved mixing all the ingredients at one step. After 15 min hard mixing to optimum consistency, the resulting smooth dough was covered with sack cloth and allowed to ferment at ambient temperature for 90 min. At the end of the fermentation time, the dough was moulded, and then divided into round pieces. The pieces were rounded by hand into cylinderical shape of about 3 cm in diameter, slightly flattened by fingers and then were cutted into equal parts. The obtained shaped dough parts were further fermented for 45 min at ambient temperature, then backed at 190°C for 25 min. The menain was allowed to cool and kept in polyethylene bags at room temperature until used for analysis.

Batti, Mahleb and Patton salé:

Batti, Mahleb and Patton sale were processed according to the traditional procedures application in the backer's shop. The formula was as follows:

	Amounts (g)		
	Batti	**Mahleb**	**Patton Salé**
Wheat flour (72% extraction)	300	300	300
Corn oil	25	50	75
Shortening	100	-	
Water	100	100	100
Sodium chloride	6	6	7
Sugar	3	3	3
Dry yeast	15	15	15
Aniseeds	-	-	25
Mahleb	-	20	-
Flaxseeds	15	20	25
Egg	One (whole)	-	-

The dough in each product was prepared by employing the straight dough method which involved mixing all the ingredients at one step. The obtained dough was allowed to ferment at room temperature for 1 hr, then shaped and baked at 160°C for 20 min. The obtained products were allowed to cool and kept in polyethylene bags at room temperature until used for analysis.

Beef burger preparation:

Beef burger was prepared from the following ingredients:
250.0 g minced beef meat, 50.0 g soy protein, 5.0 g spices mixture, 2.5 g black pepper powder, 5.0 g sodium chloride, 50.0 grated fresh onion, 0.25 g polyphosphate salt and 50.0 g water. The effect of replacing 5 , 10 , 15 and 20% FSF based on the weight of minced beef meat, on quality of beef burger patties was studied. Minced beef meat was mixed with the other ingredients until a homogeneous mixture was obtained. Beef burger patties were formed in around forms with 10 cm diameters, ½ cm. thickness and $\simeq$ 50 g weights. Each piece was surrounded with two pieces of butter paper before packing in polyethylene bags. Each bag was electronic sealed before storing at -18 °C in deep freezer (Waffaa and Samia, 2008) until used. The beef burger patties were shallow fried in small amount of corn oil at 180 °C for 3 min (both sides) before subjecting to sensorial analysis. Weight loss% and shrinkage loss% were calculated according to the following equations as described by Moharram *et. al.* (1987).

$$\text{Weight loss\%} = \frac{\text{Weight(g) before frying} - \text{Weight (g)after frying}}{\text{Weight (g)before frying}} \times 100$$

$$\text{Shrinkage loss\%} = \frac{\text{Diameter (cm) before frying} - \text{Diameter (cm) after frying}}{\text{Diameter (cm) before frying}} \times 100$$

Physical properties of whole flaxseed (WFS)

Seed dimensions:

Thickness and diameter of flaxseed samples were measured using a micrometer (Athol, U.S.A.) according to Askar (1991).

Seed index:

Random sample of 1000 seeds were weighed using high accuracy balance (Fisher Scientific U.S.A.). The average of three replicates was recorded as the weight of 1000 seeds (Askar, 1991)..

Relative density:

Relative density of flaxseeds was determined according to Youssef (1978) by measuring the increase in volume of 200 ml distilled water placed in a measuring cylinder after immersing 1000 seeds of a known weight. Relative density was calculated from the following equation:

$$\text{Relative density (g/ ml)} = \frac{\text{The weight of the seeds (g)}}{\text{The volume of the seeds (ml)}}$$

Colour:

Colour was measured using a Lovibond Tintometer (Model E, U. K)according to Ranganna(1977) .

Chemical composition of flaxseed flour (FSF):

Proximate analysis of FSF including moisture, crude protein (NX 6.25), crude ether extract, total ash and crude fibre were carried out according to the AOAC (2003) procedures unless otherwise stated. Nitrogen free extract was calculated by difference. Ascorbic acid was determined according to the AOAC (2003) procedure using 2 , 6 dichlorophenol, indophenols dye. Phenolic compounds as % chlorogenic acid were determined by Folin- Ciocaltu reagent as described by Ranganna (1977) after extraction with 70% ethanol according to Naczk and Shahidi (1989). Dietary fibre content was determined according to the enzymatic gravimetric method as described by Prosky *et. al.* (1985). Total tocopherols were determined colorimetrically according to the procedure of Tsen (1961).

Minerals including Fe, Cu, Mg, Ca, Mn, Zn, Cd and Pb were measured using Perkin Elmer Atomic Absorption Spectrophotometer (Model 2380, U.K.). On the other hand, Na and K were determined using flame photometer (Model PEP7, U.K.). Total phosphorus was assayed colorimetrically at 630 nm using a spectrophotometer (Spectronic 20, USA) as described in the AOAC(2003).

Lipid profile of flaxseed oil:

The total lipids were extracted using choloroform: methanol (2 : 1 v/v) as mentioned by Folch *et. al.* (1957). The total lipid extract was fractionated into different classes using a TLC technique according to the method of Mangold and Malins (1960) on glass plates (20 × 20 cm) precoated with 0.25 mm silica gel, G-60. The developing solvent system used was petroleum ether: diethyl ether: glacial acetic acid (70 ; 30 : 2 , v/ v/ v). After running, the plate was air dried and the separated spots were visualized by iodine vapour. Lipid classes were identified by their R_F values according to Rahma and Abd El–Aal (1988).

Fatty acid composition:

Preparation of fatty acid methyl esters was performed according to the procedure of Radwan (1978) using 1% sulphuric acid in absolute methanol. Gas chromatographic analysis was carried out using ACME model 6100 GC (Young LIN Instrument Co., Korea) fitted with a split/ splitless injector and FID detector. Nitrogen was used as a carrier gas with a flow rate of 0.5 ml/ min. The components were separated on a 30–m Sp-2380 fused-silica capillary colum with a 0.25 mm i.d. and 0.2 µm film thickness (Supelco. Bellefonte, PA). The detector temperature was set at 260 °C. The injector temperature was set at 220 °C and in split mode (split ratio 80:1). The column was initially maintained at 140 °C for 5 min. and the temperature was subsequently increased to 240 °C at a rate of 4 °C/ min, (total program time 30 min).

Identity characteristics of flaxseed oil:

Identity characteristics of flaxseed oil including refractive index at 25 °C, iodine value, saponification value, peroxide value (as meq O_2/ kg oil), free fatty acids (as % oleic acid) and unsaponifiable matter content were determined as described in the AOCS (1983) procedures. Colour was measured using a Lovibond Tintometer (Model E U.K.), as described in the AOCS (1983) procedure using 2½ inch cell.

Amino acid composition and functional properties of FSF:

The amino acids were determined according to the method described by Spackman *et .al.* (1958) using a Beckman model 119CL amino acid analyzer (USA). Ninhydrin was used as a detective compound. Tryptophan was determined colorimetrically in the alkaline hydrolyzate according to the method described by Blauth e*l. al.* (1963). Amino acid score (AAS) was calculated from the essential amino acid (EAA) content to the total EAA content in 1 g sample protein divided by the same EAA content in the reference FAO/WHO (1985) Pattern. From the AAS, the limiting AA in FSF which had the lowest values of AAS could be established (FAO/WHO, 1985). Functional properties including water and fat absorptions, foam capacity, flour dispersibility and emulsion stability of FSF were determined according to the methods described by Chau and Cheung (1998) and Mora-Escobedo *et. al.* (1991), Del Rosario and Flores (1981)

Sensory evaluation of flaxseed products:

Colour, taste, texture, odour and overall acceptability of different products containing WFS and FSF including chocolate chip cookies, farmland flax cookies, flaxseed crackers, two-hour buns, pizza, meat loaf, aniseed biscuits, menain, cake, beef burger, batti, mahleb and batton salé were assessed by 15 panelists from Food Science and Technology Department, Faculty of Agriculture, Alexandria University. The panelists were asked to score the above attributes according to a standard hedonic rating scale from 9 (like extremely) to 1 (dislike extremely) according to Kramer and Twigg (1973).

Statistical analysis:

Data were statistically analyzed using t. test and randomized complete block design (R.C.B.D.). Least significant difference method (L.S.D at 5% probability level) was used to compare treatment means according to Steel and Torrie (1980). Before analysis data were transformed using square root of value ($\sqrt{X}$).

RESULTS AND DISCUSSION

Physical characteristics of whole flaxseeds(WFS):

Table (1) shows the physical characteristic of WFS. The data showed that flaxseed dimensions (length, width and thickness) were 5.01 , 2.45 and 0.85 mm, respectively. The value of seed index (weight of 1000 seeds) of WFS was 6.25 g. These results agreed well with those reported by El-Nakhlawy (1987), Oomah and Kenaschuk (1995), Carter, (1996), El – Kady (2000), and Khattab (2004).

As shown in Table (1), relative density of WFS was 0.67 g/ ml. These results were compatible with those obtained by El-Kady (2000) and Khattab (2004).

Because flaxseeds has a shiny reddish-brown colour, the colour dimensions of the seeds were 9.3 (Y), 8.63 (R) and 7.58 (B).

Table 1: Physical properties of whole flaxseeds(WFS)

Property	**Value**
Seed dimensions (mm)	
Length	5.01 ± 0.12
Width	2.45 ± 0.08
Thickness	0.85 ± 0.03
Seed index (g)	6.25 ± 0.23
Relative density (g/ ml)	0.67 ± 0.02
Coulor	
Yellow	9.30 ± 0.63
Red	8.63 ± 0.20
Blue	7.58 ± 0.43

Results are means of three replicates ± SD.

Chemical composition of flaxseed flour (FSF):

Table (2) shows that the moisture content of FSF was 5.82%. The moisture content agreed well with those reported by Pryde (1982), Susheelamma (1987), EL- Kady (1995), El- Kady *et. al.* (2001), Malcolmson *et. al.* (2001) and Khattab et al (2012). Crude ether extract of FSF was (39.18). The oil content of flaxseed was affected by genetic, environmental and growing conditions as well as analytical procedures (Oomah and Kenaschuk, 1995). The results obtained here are in conformity with those reported by El-Nakhlawy (1987), El-Kady *et. al.* (2001) and Khattab (2004). They reported that the crude oil content of different varieties of flaxseed varied between 36 and 44%. The data in Table (2) also shows that the protein content was 22.04% (on dry weight basis). The obtained result agreed well with those reported by Afify *et. al.* (1994), El- Kady *et. al.* (2001) and Khattab, (2004). They found that protein content of flaxseed ranged between 19.46 and 23.45%. The total ash content of flaxseed was 5.66% (Table 2). This value was slightly lower than that reported by Afify *et. al.* (1994), El-Kady *et. al.* (2001) and Khattab (2004).They found that the ash content varied between 5.38 and 5.61%. The crude fibre content of flaxseed was 5.5%. This value agreed well with the results obtained by Pryde (1982), Madhusudhan and Singh (1983) and Khattab (2004), They found that flaxseed varieties contained from 4.8 to 9.0% crude fibre. The results in Table (2) also reveals that flaxseed is low in carbohydrates and N-free extract. For this reason, flaxseed contributes little to total carbohydrate intake. The results obtained here are in a good agreement with those reported by Pryde (1982), Madhusudhan and Singh (1983), Fahmy *et. al.* (1996), El-Kably *et. al.* (2001) and Khattab (2004). They found that flaxseed varieties contained from 22.87 to 24.12% N-free extract.

The energy value calculated and expressed as K cal/ 100 g flaxseed flour was 549.98. The energy content of flaxseed is generally high due to the high content of oil and protein. It has been reported that the energy content in flaxseed varied between 518 to 560 K cal/ 100 g (Vaisey-Genser and Morris, 1994).

The results presented in Table (2) show that the total dietary fibre content of flaxseed was 27.9%. The results obtained here agreed well with those reported by (Vaisey-Genser, and Morris 1994). In general, flaxseed is a very good source of dietary fibre. It has been reported that two – thirds of flaxseed fibre is water insoluble and consists of non-starch polysaccharides such as cellulose and lignin (Vaisey-Genser and Morris, 1994). This type of fibre helps to improve laxation and prevent constipation, mainly by increasing fecal bulk and reducing bowel transit time. More fibre – rich foods like flaxseeds appear to offer protection against certain types of cancer, particularly hormone – dependent cancers such as breast, endometrium and prostate cancers (Vaisey–Genser and Morris, 1994).

Flaxseeds contain minor amount of ascorbic acid (0.56 mg/ 100 g). On the other hand, flaxseeds contain 10.26 mg/ g total phonolic compounds expressed as chlorogenic acid. It has been reported that flaxseeds contain at least three types of phenolics: Phenolic acids, flavonoids and lignans. These compounds appear to have anticancer and antioxidant effects in human body (Vaisey-Genser and Morris, 1994 and Khattab *et. al.* 2012). The results obtained in the present study are in accordance with those reported by Drabowsi and Sosulski, (1984) and khattab *et. al.* (2012).

The results in Table (2) also shows that the total tocopherol content of flaxseeds was 575.0 mg/ kg. It has been reported that tocopherols are present in flaxseeds primarily as gamma- tocopherols. Gamma-tocopherol is an antioxidant that protects all proteins and fats from oxidation, promotes sodium excretion in the urine, which may help lower blood pressure; and helps lower the risk of heart disease, some types of cancer and Alzheimer disease (Harris and Hagerty, 1993). The tocopherol content of flaxseeds is affected by the variety, maturity of the seeds, growing region, growing conditions and methods of extraction (Bhatty, 1995). The results obtained here agreed well with those reported by Cunnane (1996). The point of interest is that even at a low concentration of tocopherol in flaxseeds, it is still highly resistable against oxidation, thus flaxseed flour could be stored for 28 months at ambient temperatures without measurable changes in oxidation products. This can be attributed to the presence of antioxidants other than tocopherols in the seeds (Przybylski, 2005).

Table 2: Chemical composition of flaxseed flour(FSF)

Constituent	**Value***
Moisture (%)	5.82 ± 0.44
Crude protein (%)	22.04 ± 0.37
Crude ether extract (%)	39.18 ± 0.47
Total ash (%)	5.66 ± 0.11
Crude fibre (%)	5.50 ± 0.04
N-Free extract (%)**	21.80 ± 0.86
Energy value (k cal/ 100 g)	549.98 ± 2.69
Total dietary fibre (%)	27.9 ± 0.46
Ascorbic acid (mg/ 100 g)	0.56 ± 0.01
Phenolic substances (mg/ g as chlorogenic acid)	10.26 ± 0.02
Total tocopherols (mg/ kg)	575.0 ± 4.06

*** Results are means of three replicates ± SD on dry weight basis**
**** By difference**

Mineral Contant of flaxseed flour (FSF):

The mineral content of FSF are presented in Table (3). The data revealed that the macro-elements of FSF can be ranked in the following descending order: K , P , Mg , and Na. On the other hand, the micro-elements can be arranged in a descending order as follows: Fe, Zn, Mn and Cu.

Generally, it could be concluded that FSF is a very good source of minerals especially K, P and Mg as shown in Table (3). These results are in agreement with those reported by Vaisey-Genser and Morris, (1994), and Khattab *et. al*. (2012).

Table 3: Mineral Content of flaxseed flour (FSF)

Element	Value* PPm
K	8309 ± 6.25
P	6322 ± 5.46
Mg	4316 ± 4.16
Na	279 ± 2.33
Zn	52 ± 0.51
Fe	53 ± 0.46
Cu	10 ± 0.12
Mn	32 ± 0.23
Cd	0.25 ± 0.01
Pb	0.17 ± 0.01

*** Results are means of three replicates ± SD on dry weight basis**

Amino acid Pattern of FSF:

The amino acid pattern of flaxseed protein is shown in Table (4). The essential amino acids in flaxseeds were valine (5.0), histidine (2.19), isoleucine (4.13); phenylalanine (4.89), threonine (3.43) and tryptophan (1.98). On the other hand, the major non-essential amino acids were glutamic acid (21.37), arginine (10.06) and asparatic acid (9.18). The amino acid pattern of flaxseed protein is quite similar to that of soybean protein which is viewed as one of the most nutritious of the plant proteins (Vaisey-Genser and Morris, 1994). The present results agreed well with those obtained by El-Kady(2000), and Khattab *et. al.* (2012). As indicated from Table (4), the total amount of essential amino acids in FSF was 34.62 g/ 100 g protein. The essential amino acid profile revealed that the protein of FSF are deficient in methionine, lysine and leucine as compared with FAO/ WHO requirements patterns (Table 4).

Table 4: Amino acid composition and chemical score of flaxseed flour (FSF)

Amino acids (g/ 100 g protein)*	FSF	FAO/ WHO Pattern**	Chemical score***
Aspartic acid	9.18 ± 0.20		
Threonine	3.43 ± 0.10	3.40	100.88
Serine	4.21 ± 0.12		
Glutamic acid	21.37 ± 0.34		
Proline	3.76 ± 0.20		
Glycine	6.42 ± 0.17		
Alanine	4.85 ± 0.23		
Cystine	1.26 ± 0.12		
Methionine	1.61 ± 0.08	2.50	64.4+
Cystine + Methionine	2.67 ± 0.21		
Valine	5.00 ± 0.31	3.50	142.86
Isoleucine	4.13 ± 0.24	2.80	147.50
Leucine	5.53 ± 0.18	6.60	83.79+
Tyrosine	2.07 ± 0.07		
Phenylalanine	4.89 ± 0.19		
Tyrosine + Phenylalanine	6.96 ± 0.23	6.30	110.48
Tryptophan	1.98 ± 0.09	1.10	180
Histidine	2.19 ± 0.08	1.90	115.26
Lysine	3.79 ± 0.21	5.80	65.34+
Arginine	10.06 ± 0.43		
Total EAA	34.62	33.90	

*** Mean of two replicates ± SD.**
**** Pattern for 2 – 3 years old child**
***** g of EAA in 100 g protein of the sample divided by the g of the same EAA in 100 g protein of the FAO/ WHO standard pattern × 100**
*** The first limiting amino acid.**

Functional properties of flaxseed flour (FSF):

The data in Table (5) shows that water absorption and oil absorption of FSF were 1.28 and 2.41 g/ g sample, respectively. The value obtained here indicated a good ability of FSF to adsorb water and bind oil which are advantages of the flour for preparing several baked products such as biscuits, cookies, crackers, cakes and Pizza.

The FSF dispersibility which is defined as the volume of the suspended particles after stirring and resting for 30 min showed that 59% of FSF was still suspended after 30 min of resting time. The results indicated that the dispersibility of FSF was significantly high which may be due to its high protein content on dry weight basis (Khattab, 2004).

Foam capacity of FSF was about 15%. This value is mainly due to the high protein content and good quality. The value obtainal is useful in food systems that require aeration for textural and/ or leavening purposes. It has been reported that viscosity and foaming capacity increase with high protein concentration (Oomah and Mazza, 1993). The results in Table (5) show that FSF had high foam stability after up to 20 min. The potential of flaxseed proteins as foaming agents in foods has yet to be exploited commercially (Oomah *et. al.*, 1994).

The studied functional properties of FSF in the present study agreed well with those reported by Khattab *et. al.*, (2012).

Table (5): Functional properties of flaxseed flour (FSF)

Parameters	Value*
Water absorption g/ g sample	1.28
Oil absorption g/ g sample	2.41
Flour dispersibility (vol cm^3 after 30 min)	59.00
Foam capacity (%)	15.00
Foam stability (%)	
5 min	60
10 min	60
15 min	40
20 min	40
25 min	30
30 min	20
35 min	10
40 min	5
50 min	Zero

Means of three replicates ± SD

Physicochemical properties of flaxseed oil:

Some physicochemical properties of flaxseed oil are presented in Table (6). The higher specific gravity of 0.931 observed for flaxseed oil than other vegetable oils can be directly attributed to the high contribution of lionlenic acid. It is in line with the specific density of fatty acids that increases from 0.895 to 0.909 and to 0.914 for oleic, linoleic and linolenic acids, respectively (Przybylski, 2005).

Unsaponifiable matter content, saponification value and iodine values are characteristic for a high contribution of polyunsaturated fatty acids in the flaxseed oil. The content of unsaponifiable matter in faxseed oil (1.25%) is quite similar to other vegetable oils (El-Nakhlawy, 1987 and Przybylski, 2005).

Free fatty acid (FFA%) and peroxide value (mEq O_2/ kg oil) were 1.45 and 1.47, respectively. These low values indicate high stability of flaxseed oil to oxidation. The colour of the extracted flaxseed oil had 35 yellow, 3.8 red and 0.8 blue, respectively.

Table 6: Physicochemical Properties of flaxseed oil

Property	Value*
Refractive index (25/ 25 °C)	1.4748 ± 0.01
Specific gravity (25 °C)	0.931 ± 0.01
Free fatty acids (as % oleic acid)	1.450 ± 0.12
Acid value	2.870 ± 0.26
Peroxide value (meq O_2/ kg oil)	1.470 ± 0.20
Iodine value	193 ± 1.23
Saponification value	191 ± 1.06
Unsaponifiable matter (%)	1.250 ± 0.08
Colour	
Yellow	35 ± 0.01
Red	3.8 ± 0.02
Blue	0.8 ± 0.01

Results are means of three replicates ± SD

Faty acid composition of flaxseed oil

As shown in Table (7), flaxseed oil is naturally low in saturated fatty acids (10.38%). Approximately 89.62% of the fatty acids in flaxseed oil are polyunsaturated. Flaxseed oil contained 5.37% palmitic acid, 4.83% stearic acid, 15.16% oleic acid. Because of its high alpha-linelenic acid (ALA), an omega – 3 fatty acid; flaxseed oil has an omega – 6/ omega – 3 fatty acid ratio of 0.29 : 1 and has an omega – 3/ omega – 6 fatty acid ratio of 3.43 : 1 and has U/ S ratio of 8.63. Omega – 3 fatty acids have been shown to regulate gene transcription and expression, thus altering enzyme synthesis and to modify several risk factors for coronary heart disease, including reducing serum triacylgylerols and blood pressure (Schmidt *et. al.*, 1995). They also protect against thrombosis and certain types of cancer and modify immune and inflammatory reactions (Nair *et. al.*, 1997). The results obtained here agreed well with those reported by Khattab (2004) and Przybylski (2005).

Table 7: Fatty acid composition of flaxseed oil

Fatty acids	%*
C 16 : 0	5.37 ± 0.16
C 16 : 1 n 9 c	0.14 ± 0.21
C 18 : 0	4.83 ± 0.08
C 18 : 1 n 9 c	15.16 ± 0.20
C 18 : 2 n 6 c	16.68 ± 0.03
C 20 : 1	0.23 ± 0.01
C 18 : 3 n 3	57.25 ± 0.43
C 22 : 0	0.18 ± 0.01
C 22 : 1 n 9	0.16 ± 0.01
TSFA (S)**	10.38
TUFA (U)***	89.62
U/ S ratio	8.63

*** Expressed as mean of three replicates ± SD**
**** Total saturated fatty acids**
***** Total unsaturated fatty acids**

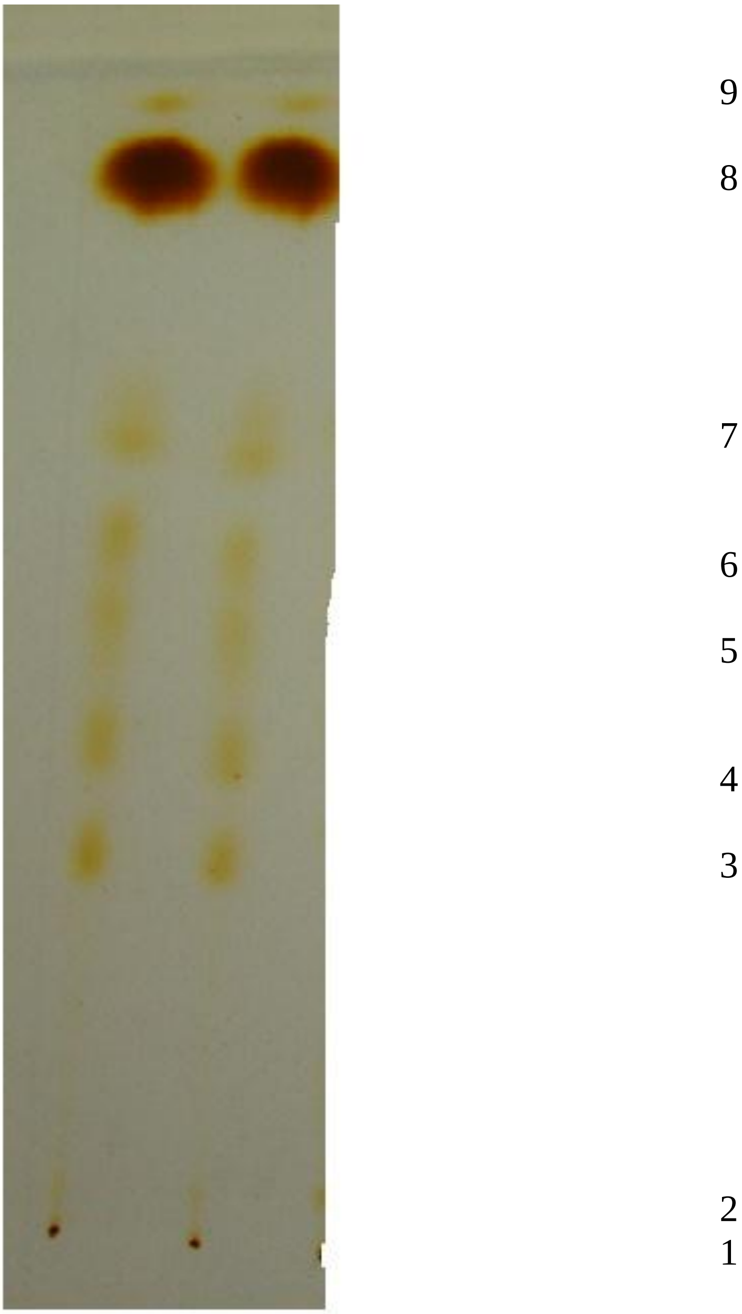

Fig 1: Thin layer chromatogram of total lipids of flaxseed oil

1- Polar lipids
2- Monoacylglycerols
3- 1 , 2 diacylglycerols
4- Sterols

5- 1 , 3 and 2 , 3 diacylglycerols
6- Unknown
7- Free fatty acids
8- Triacylglycerols
9- Hydrocarbons and Sterolesters

Total Lipid classes of flaxseed oil :-

The results of the fractionation of the total lipid classes of flaxseed oil are shown in Fig. (1). The total lipids of flaxseed oil consisted mainly of 8 fractions of acylglycerols and non acylglycerol components in addition to the polar lipid class located on the base line. Triacylglycerols were found to be the major fraction of flaxseed oil. On the other hand, the other classes can be arranged, based on their R_F, as follows: monoacylglycerols, 1 , 2 diacylglycerols, sterols, 1 , 2 , and 2 , 3 diacylglycerols, unknown, free fatty acids, triacylglycerols, hydrocarbons and sterolesters based on the front line. These results are in accordance with those reported by Bhatty (1995), Khattab (2004) and Przybylski (2005).

Sensory evaluation of some food products containing WFS and FSF:-

The general appearance of some food products containing WFS and FSF are presented in Fig. (2 and 3).

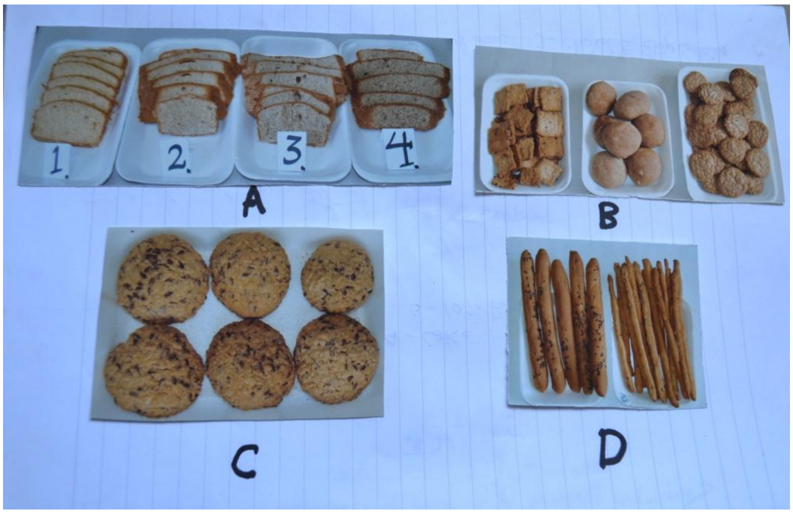

Fig 2: The general appearance of some food products containing WFS and FSF

A: Cake
1- Control 2- 5.0% FSF 3- 10.0% FSF 4- 15.0% FSF
B: 1- Flaxseed crackers 2- 2-hour buns 3- Chocolate chip cookies
C: Farmland cookies
D: 1- Mahleb 2- Patton salé

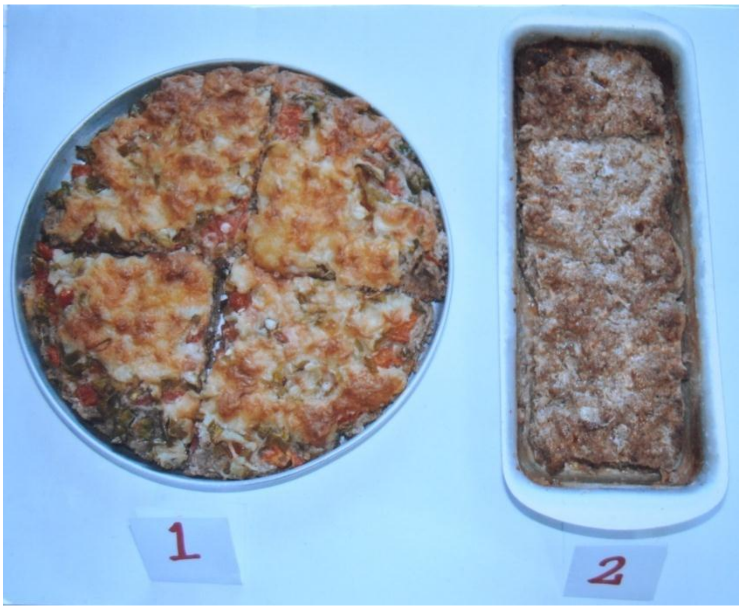

Fig 3: The general appearance of some meat products containing FSF
1- Pizza 2- Meat loaf

The organoleptic properties of some baked and meat products containing WFS and FSF are given in Table (8).

The organoleptic attributes of chocolate chip cookies, farmland flaxseed cookies, flaxseed crackers, two-hour buns, pizza and meat loaf including colour, taste, odour, texture and overall acceptability were over the numerical value of 7.0 (like moderately). These results indicated that all the characters studied were very well accepted by the panelists. Also, the results indicated that no significant differences were noticed in the organoleptic attributes for each product.

Table 8: Organoleptic evaluation of some food products containing FSF

Character	Products*						L.S.D
	1	2	3	4	5	6	0.05
Colour	8.05^{ab}	8.25^{a}	7.65^{b}	7.45^{b}	7.10^{b}	7.90^{b}	0.49
Taste	8.20^{a}	8.45^{a}	7.85^{b}	7.45^{b}	7.60^{b}	7.30^{b}	0.50
Odour	8.40^{a}	8.35^{a}	7.80^{b}	7.40^{b}	7.80^{b}	7.80^{b}	0.53
Texture	8.60^{a}	8.15^{a}	7.45^{b}	7.55^{b}	7.70^{b}	7.30^{b}	0.49
Overall acceptability	8.40^{a}	8.40^{a}	7.55^{b}	7.55^{b}	7.50^{b}	7.40^{b}	0.49

Means in a row not sharing the same letter are signficantly different at P ≤ 0.05

1 **Chocolate chip cookies**
2 **Farmland flax cookies**
3 **Flaxseed Crackers**
4 **Two – hour buns**
5 **Pizza**
6 **Meat Loaf**

Aniseed biscuits:

In the light of the obtained data presented in Table (9), it was obvious that panelists accepted this product and the overall acceptability varied between 7.80 in control biscuit sample and to 8.05 in biscuit contained up to 15% FSF. The data also revealed that no significant differences were noticed in the organoleptic characters between the control sample and those contained up to 15% FSF.

Table 9: Organoleptic evaluation of aniseed biscuits containing 5%,10% and15% of FSF

Character*	Treatments				L.S.D 0.05
	Control	5.0%	10.0%	15.0%	
Colour	8.00[a]	7.50[a]	7.75[a]	7.40[a]	n. s**
Taste	7.50[a]	7.60[a]	7.60[a]	7.80[a]	n. s
Odour	7.70[a]	7.25[a]	7.75[a]	7.55[a]	n. s
Texture	7.75[a]	7.35[a]	7.75[a]	7.55[a]	n. s
Overall acceptability	7.80[a]	7.85[a]	7.85[a]	8.05[a]	n. s

***Means in a row not sharing the same letter are signficantly different at $P \leq 0.05$**

**** Not Significant**

Menain:

The organoleptic characteristics of menain containing FSF are given in Table (10).

Table 10: Organoleptic evaluation of menain containing 5%,10% and 15% of FSF

Character*	Treatments				L.S.D 0.05
	Control	5.0%	10.0%	15.0%	
Colour	7.45[a]	7.20[a]	7.25[a]	7.40[a]	n. s**
Taste	6.65[b]	7.45[a]	7.50[a]	7.95[a]	0.58
Odour	6.65[b]	6.95[b]	7.30[b]	7.80[a]	0.64
Texture	6.85[b]	6.95[b]	7.35[b]	7.70[a]	0.60
Overall acceptability	6.85[b]	7.35[b]	7.50[b]	7.85[a]	0.59

***Means in a row not sharing the same letter are signficantly different at $P \leq 0.05$**

**** Not Significant**

The results indicated that menain containing 15% FSF was more acceptable in comparison with the control as well as those containing 5 and 10% FSF. Except the taste, odour, texture and overall acceptability of the control sample as well as the odour and texture of menain sample containing 5% FSF, all the four samples of menain were more acceptable by the panelists because all the attributes values were over the numerical value of 7.0.

Cake:

According to the obtained data in Table (11), the organoleptic attributes of cake containing FSF decreased with increasing the level of FSF. Except the colour of cake containing 15% FSF, all the organoleptic attributes were over the numerical value of 7.0 (like moderately). These results indicated that all the characters studied were very well accepted by the panelists. The results also revealed that there were slight significant differences in the organoleptic characters between the three cake samples containing 5, 10 and 15% FSF.

Table 11: Organoleptic evaluation of cake containing 5%,10% and 15% of FSF

Character*	Treatments				L.S.D 0.05
	Control	5.0%	10.0%	15.0%	
Colour	8.50[a]	7.55[b]	7.05[bc]	6.75[c]	0.64
Taste	8.45[a]	7.75[b]	7.30[b]	7.45[b]	0.60
Odour	8.35[a]	7.60[b]	7.45[b]	7.15[b]	0.60
Texture	8.35[a]	8.0[b]	7.55[b]	7.65[b]	0.52
Overall acceptability	8.60[a]	7.75[b]	7.50[b]	7.40[b]	0.60

***Means in a row not sharing the same letter are signficantly different at $P \leq 0.05$**

Beef burger:

The results of the organoleptic properties of beef burger containing FSF revealed that the organoleptic attributes of beef burger decreased with increasing the level of FSF (Table 12). Also, it can be concluded that slight and moderate significant differences were noticed between the control sample and those containing different concentrations of FSF. It can be concluded that 10% FSF is the maximum substitution level after which the sensory attributes were significantly declined.

Table 12: Organoleptic evaluation of beef burger containing 5%,10%,15% and20% of FSF

Character*	Treatments					L.S.D 0.05
	Control	5.0%	10.0%	15.0%	20.0%	
Colour	7.50[a]	7.75[a]	7.35[a]	6.90[ab]	6.45[b]	0.66
Taste	7.20[a]	6.70[b]	6.55[b]	6.25[b]	6.05[b]	0.64
Odour	7.85[a]	6.95[bc]	7.05[b]	6.35[c]	6.20[b]	0.61
Texture	7.50[a]	7.30[a]	7.00[b]	6.15[b]	6.20[b]	0.55
Overall acceptability	7.55[a]	7.10[ab]	6.90[ab]	6.30[b]	6.30[b]	0.61

***Means in a row not sharing the same letter are signficantly different at $P \leq 0.05$**

Weight loss and shrinkage of beef burger

Weight loss and shrinkage of beef burger containing FSF are shown in Table (13). The results indicated that weight loss (%) of beef burger decreased while shrinkage (%) increased with increasing the level of FSF. These findings may be due to the loss of water and fats during the frying process. These results agreed well with the sensory attributes which decrease with increasing the level of FSF subsitution as mentioned previously.

Table 13: Weight loss and shrinkage of beef burger containing 5%,10%,15% and 20% of FSF

Treatments	Weight loss (%)	Shrinkage (%)
0 %	29.71 ± 1.89	10.83 ± 1.34
5 %	21.09 ± 2.05	15.22 ± 1.21
10 %	21.79 ± 1.24	15.55 ± 1.14
15 %	17.48 ± 1.61	16.66 ± 1.23
20 %	15.65 ± 1.22	21.13 ± 1.17

*** Means of three replicates ± SD.**

Batte, Mahleb and batton salé:

According to the obtained data in Table (14), the organoleptic characteristics attributes of these three baked products were highly accepted by the panelists in comparison with the control samples containing no WFS. The organoleptic attribertes of batte, mahleb and buton salé which contain WFS including colour, taste, odour, texture and overall acceptability were over the numerical value of 8. These results indicated that all the organoleptic characters studied were very well accepted by the panelists.

Table 14: Organoleptic evaluation of batte,mahleb and batton sale containing FSF

Treatments	Character				
	Colour	Taste	Odour	Texture	Overall acceptability
			Batte		
A	8.09±0.77	7.76±0.70	7.76±0.83	7.90±1.0	8.05±0.50
B	8.57±0.60	8.33±0.66	8.48±0.87	8.38±0.74	8.61±0.59
t	4.27**	5.17**	5.33**	4.72**	4.40**
Mahleb					
A	7.95±0.92	7.86±0.73	7.62±0.80	7.52±0.43	7.81±0.75
B	8.61±0.67	8.43±0.81	8.24±0.89	8.38±0.42	8.52±0.81
t	5.33**	5.34**	3.43**	3.71**	4.18**
Batton salé					
A	7.57±0.75	7.62±0.86	7.62±0.47	7.57±0.93	7.81±0.81
B	8.48±0.51	8.42±0.81	8.24±0.78	8.48±0.84	8.67±0.66
t	6.65**	5.42**	6.35**	4.56**	7.29**

** Significant at 0.01 probability level
A: Control
B: Containing WFS

Comparing with the results obtained here, Navickis and Nelsen (1992) found that a 20% replacement of wheat flour by weight with milled flaxsed appears to be a reasonable limit in preparing yeast bread and muffins. On the other hand Khattab *et. al.*, (2012) indicated that the addition of up to 15% substituted level of defatted flaxseed flour into the formule of pita bread and similar bakery products improve its sensorial properties as well as their funtional properties.

From the aforementioned data, it can be concluded that the addition of WFS as well as FSF can improve the nutritional value, functional propertis as well as organoleptic characteristics of some food products with regard to alpha-linolenic acid, dietary fibre, lignans, protein and some minerals. Thus, consumers can increase their flaxseed intake by adding it to homemade baked goods; sprinkling flaxseeds on yogurt, cereal and salad. Flaxseeds may be used as a food ingredient in the form of whole or milled seeds. It can be used successfully in baked products such as bisccuits, cookies, crackers, cakes, pizza and some meat products such as meat loaf and beef burger by replacing from 10 to 20% of the weight of wheat flour or beef meat. Certainly, People who include flaxseeds in their daily eating patterns can enjoy its good taste and bring their diets in line with current dietary recommendations to help reduce the risk of chronic diseases.

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الخصائص الكيماوية والتكنولوجية لبذور الكتان وتطبيقاتها فى إنتاج بعض الأغذية الوظيفية

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تم دراسة الصفات الطبيعية والتركيب الكيماوى والخصائص الوظيفية وتركيب وصفات زيت بذور الكتان. وجد أن بذور الكتان تعتبر مصدراً جيداً لكل من الزيت والبروتين حيث أحتوت البذور على ٣٩,١٨% زيت خام، ٢٢,٠٤% بروتين. كما أحتوت البذور على نسبة عالية من الألياف الغذائية. ويمكن اعتبارها أيضاً مصدراً جيداً لبعض العناصر المعدنية مثل البوتاسيوم والفوسفور والماغنسيوم.

أظهرت الدراسة أن حامض ألفا لينولنيك هو الحامض الدهنى السائد فى زيت بذور الكتان ويمثل حوالى ٥٧,٢٥% من الأحماض الدهنية الكلية. بالإضافة إلى ذلك احتوت بذور الكتان على كميات صغيرة من حامض الأسكوربيك، المركبات الفينولية والتوكوفيرولات والتى يعتقد أن لها تأثيرات مانعة للأورام ومضادة للأكسدة فى جسم الإنسان.

أوضحت نتائج الخصائص الوظيفية التى تم دراستها أنه يمكن استخدام بذور الكتان سواء فى صورتها الكاملة أو المطحونة فى إعداد العديد من منتجات الخبيز واللحوم مثل البسكويت، الكوكيز والمقرمشات، الكيك، البيتزا، ورغيف اللحم والبيف برجر. وهذه المنتجات يمكن استخدامها كأغذية وظيفية.

قام بتحكيم البحث

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