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Evaluation of new Egyptian flaxseed genotypes and pasta fortified with flaxseeds

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ABSTRACT. The present investigation was conducted to study yield, yield components and chemical composition of some flax genotypes (Sakha 3, 5 and 6, Giza 11, 12 and Strain 651). New flax strain 651 (S.651) recorded the highest value in technical length, while flax Giza 12 and 11 achieved the highest straw yields per plant and per hectare. Flax Giza 11 variety had the highest value of seed yield per hectare. With respect to chemical composition of flaxseed genotypes, flaxseed Sakha 5 variety had the lowest moisture content followed by Sakha 3, Sakha 6, Giza 12 and Giza 11. On the other hand, flaxseed S.651 genotype had the highest moisture and fiber contents. Flaxseed Sakha 5 had the highest oil content whereas; flaxseed Sakha 3 had the lowest oil content. Flaxseed Sakha 3 had the highest protein content followed by flaxseed S.651 and flaxseed Giza 12. Extracted oils from all genotypes had low values of physicochemical parameters. Main fatty acids of extracted flaxseed oil were linolenic, oleic, linoleic, stearic and palmitic fatty acids. Pasta was fortified with flaxseed at levels 5, 10 and 15% w w^{-1} to enhance the nutritional quality. Pasta samples were assessed for proximate analyses, minerals, cooking quality and sensory evaluation. Chemical composition of pasta fortified with flaxseed meal was reflective of the innate composition of flaxseed meal. There was no significant variance between control and flaxseed 5% in optimum cooking time. Sensory evaluation of pasta (control and flaxseed 5%) revealed no significant difference in terms of taste, color and overall acceptability.

Keywords: Flaxseed Sakha 5; fortification; α-linolenic acid; cooking quality; pasta sensory evaluation.

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Introduction

Flax (*Linum ustatissimum L.*) is one of the well-known ancient crops grown for its fiber and oil. There are two basic varieties of flaxseeds: brown; and golden or yellow. Flax production dates back to ancient history where ancient Egyptians made fine linens from the fiber. Flax fiber is being blended with certain types of plastic resins to produce automotive components. Europe produces most of the high-quality long-fiber flax used for linens, rugs, and other textiles. Seeds from flax are crushed to produce linseed oil and linseed meal. Linseed oil is a major ingredient in many fine paints, varnishes, and stains that are used to preserve, protect, and beautify wooden surfaces. Due to high quantities of omega-3 fatty acid, its cultivation and consumption is increasing as a healthy oil resource (Charlton & Ehrensing, 2001). The maximum productivity of crop plant depends on variety. Several investigations were carried out on yield components and chemical characters such as Bakry, Tawfik, Mekki, and Zeidan (2012) and El-Borhamy, Mohamed, and Al-Sadek (2017). The Egyptian production for flax fiber and flaxseed were 7525 and 10000 tons, respectively and the world production were 1085734 and 3068254 tons, respectively during season 2019. The area harvested in the world for flax fiber and flaxseed were 259424 and 3223531 hectare during season 2019 (Food and Agriculture Organization of the United Nations [FAO], 2021).

Flaxseed was used in human nutrition because of its nutritional and health values. Flaxseed flour is used in bakery and pasta products that have properties of functional foods. Flaxseed is considered a favorable source of important substances such as vitamins A, B, and E, magnesium, calcium, zinc, phosphorus, fiber, ω-3 fatty acids (essential fatty acid) and lignan (phytoestrogens with antioxidant effects). Furthermore, flaxseed has health benefits such as reduction in the risk of occurrence of cancer, cardiovascular diseases, diabetes, osteoporosis and blood pressure (Filipović, Ivkov, Košutić, & Filipović, 2016). Flaxseed was used for medical intend in ancient Egypt and Greece, mainly to relieve stomach pains and furthermore as a source of power (Bernacchia, Preti, & Vinci, 2014).

Pasta is one of the most popular food products in the world for simple preparation, low price, and long shelf life. Pasta consumption had increased all over the world therefore; produce new types of pasta, for example fortified with non-conventional components (Teterycz, Sobota, Zarzycki, & Latoch, 2019). The U.S. Food and Drug Administration allow the inclusion of up to 12% (by weight) of flaxseed in food (Goyal, Sharma, Upadhyay, Gill, & Sihag, 2014).

This study was carried out to evaluate yield and chemical composition of some new Egyptian flaxseed genotypes (Flaxseed Sakha 3, 5 and 6, Flaxseed Giza 11, 12 and Flaxseed Strain 651) and to investigate the possibility of using ground flaxseed as ingredient in paste (spaghetti) and its effect on quality.

Material and methods

Materials

The present investigation was conducted at Sakha Agricultural Research station, Kafr El-Sheikh Governorate, during seasons 2018/2019 and 2019/2020 to study yield components and chemical composition of some flax genotypes (Sakha 3, Sakha 5, Sakha 6, Giza 11, Giza12 and S.651). The flax varieties were sown in 15^{th} and 10^{th} November in both seasons, respectively.

Semolina (55% extraction) was brought from Egypt Food Company. Wheat flour (72 % extraction) was obtained from the North Delta Mills company, Egypt.

The experimental design used was randomized complete block design with three replications. The plot size was $12m^2$ (3x4m), seeds were planted with broadcast method. All agronomic practices were done and 100 kg calcium super phosphate (15.5% P_2O_5) was applied to all plots as recommended and 107 kg N $hectare^{-1}$ was applied before first and second irrigation. The normal cultural practices used in flax production were applied. At harvest ten individual guarded plants were taken in random for each plot to study yield per plant and its component:

Technical length (cm)
Main stem diameter (mm)
Straw yield $plant^{-1}$ (g)
Fruiting Zone length (cm)
Number of capsules $plant^{-1}$
Seed index
Seed yield $plant^{-1}$ (g)
Straw yield $hectare^{-1}$ (ton)
Seed yield $hectare^{-1}$ (kg)

To study straw yield per hectare, all plants from plot were harvested then total weight of air dried straw yield per plot after removing capsules were estimated as well as seed yield/hectare. Both straw and seed yields were calculated on whole plot area basis. Table 1 consists of the source of different genotypes.

Table 1. The source of different flax genotypes.

No.	Genotypes	Classifications [a]	Source
1	Sakha 3	F	Belinka × I 2096
2	Sakha 5	O	I.370 × I 2561
3	Sakha 6	D	S.420 × Bombay
4	Giza 11	D	Giza 8 × S.2419/1
5	Giza12	D	S.2419/1 × S.148
6	S.651	F	S.420/4/2/14 X Belinka

[a] D, dual purpose types, F, fiber purpose type and O, oil purpose type.

Chemical analysis

Moisture, crude protein, crude oil, crude fibers and ash were determined according to Association of Official Analytical Chemists (AOAC, 2007) methods (2007). Total carbohydrates were determined by difference.

Extraction of flaxseed oil

Flaxseeds were pressed using laboratory hydraulic press (Carver) at room temperature 22°C (Ustun, Kent, Çekin, & Civelekoglu, 1990). The resultant oil was filtered, kept in amber bottles and stored in deep freezer at -18°C until analysis.

Physical and chemical parameters of flaxseed oils

Refractive index (RI), free fatty acids (FFA), peroxide value (PV), conjugated dienes (CD), conjugated trienes (CT), saponification value (SV) and unsaponifiable matter of the extracted oils were determined according to Association of official analytical chemists AOAC (2007), and thiobarbituric acid (TBA) value was determined according to Allen and Hamilton (1989).

Fatty acids composition of flaxseed oils:

Methylation of fatty acids

An aliquot of fatty acids after saponification and acidification of flaxseed oil, about 10 mg, was dissolved in 2mL hexane and then 0.4 mL of 2N KOH in anhydrous methanol was added (Cossignani, Simonetti, & Damiani, 2005), after 3 min., 3 mL water was added. The organic layer, separated by centrifugation, was dried over anhydrous sodium sulfate, and then concentrated, with a N_2 stream to around 0.5 mL for GC analysis of fatty acids methyl esters (FAME) as described below.

Gas chomatography (GC) analysis of FAME

Agilent 6890 series GC apparatus provided with a DB-23 column (60 m × 0.32 mm × 0.25 μm) was used. Oven temperatures were 150°C ramped to 195°C at 5°C $min.^{-1}$, ramped to 220°C at 10°C $min.^{-1}$ and flow rate was 1.5 $min.^{-1}$. Fatty acids results after the previous procedures steps were transformed into methyl esters and directly injected into the GC. A reference containing FAME standards was used for identification and quantification of the fatty acids.

Technological methods

Preparation of flaxseed whole meal

Flaxseed Sakha 5 were dry cleaned to remove dust and undesirable materials, then seeds were roasted in oven at 40°C for 30 min. After that seeds were ground, sieved to fine powder and mixed with semolina and wheat flour to produce pasta.

Formulation of paste

Ground flaxseed meal was added at different ratios (0, 5, 10 and 15%) to semolina (70%) and wheat flour (30, 25, 20, 15%), respectively to produce pasta as illustrated in Table (2).

Table 2. Formulations of whole flaxseed meal with semolina and wheat flour.

	Formulations
Control	700 g semolina+ 300 g wheat flour (control)
Flaxseed 5%	700 g semolina+ 50 g flaxseed meal +250 g wheat flour
Flaxseed 10%	700 g semolina+ 100 g flaxseed meal +200 g wheat flour
Flaxseed 15%	700 g semolina+ 150 g flaxseed meal+150 g wheat flour

Pasta processing

The pasta samples were processed according to Walsh, Ebeling, and Dick (1971) in Home Economic Department, Faculty of Specific Education, Kafrelsheikh University., using pasta Matic 1000 Simac Machine Corporation, Milano, Italy. Wheat flour was mixed with 0, 5, 10 and 15% of flaxseed meal, respectively, and then added 70% semolina and water (446, 370, 345 and 332 mL, respectively). Water absorption is the amount of water required to develop dough to a standard strength (American Association of Cereal Chemists [AACC], 2000). Pasta was hydrated under atmospheric air for 60 min., and then dried in a cabinet dryer at 40°C for 2h. The samples were cooled enough at room temperature 22°C, then packed in polyethylene pouches and stored at room temperature until analysis.

Proximate composition of pasta

Proximate composition of pasta fortified with flaxseed meal was determined according to AOAC (2007).

Minerals profile of pasta

Minerals including, calcium, magnesium, zinc, manganese, sodium and potassium were determined using an Atomic Absorption Spectrometry (GBC Avanta E, Victoria, Australia) according to AOAC (2007).

Optimal cooking time

Optimal cooking time (OCT) is the time necessary to achieve a complete gelatinization of starch (Tudorica, Kuri, & Brennan, 2002). Optimal cooking time was determined by compressing the pasta strand between two glass slides in 30 s intervals. The optimal cooking time was reached when the white center of ungelatinized starch had just disappeard according to the approved method cooking time (AACC, 2000).

Cooking quality

Cooking loss, water absorption and volume increase were evaluated according to Özyurt et al. (2015).

Sensory evaluation of pasta

Sensory evaluation was performed by 10 panelists of staff members in Home Economic Department., Faculty of Specific Education, Kafrelsheikh University, Egypt. Panelists were asked to score appearance, taste, color, odor and overall acceptability of pasta using the nine-point hedonic scale (Larmond, 1997).

Statistical analysis

Statistical analyses were conducted using SPSS program version 16.0. Treatment means were compared with Duncan's Multiple Range Test at probability P - of 5% level as indicated by Duncan (1955).

Results and discussion

Straw yield and its related parameters:

Data in Table 3 showed that flax genotypes were significantly differed in technical length, main stem diameter, straw yield plant^{-1} as well as straw yield/hectare. The new flax strain 651 (S. 651) achieved the highest value in technical length, but it achieved the lowest value in main stem diameter. On other hand, flax Giza 12, flax Giza11 were achieved the highest straw yield plant^{-1} as well as straw yield/hectare. It must be mentioned that the differences between the two flax varieties flax Giza11 and flax Giza 12 in relation to technical length, main stem diameter and straw yield plant^{-1} as well as per hectare did not reach the level of significance in both seasons. The differences among flax varieties and new flax strain could be due to the genetic factor. These results agreed with those noticed by Bakry et al. (2012); Butorac, Brunsek, Agusttinovic, Pospisil, and Andrassy (2014) and El-Borhamy et al. (2017).

Seed yield and its components

Data in Table 4 indicated that fruiting zone length, number of capsule plant^{-1} and seed yield plant^{-1} were only significant affected by flax genotypes. Flax Giza 12 and flax Giza11 varieties had the highest averages in fruiting zone length, seed yield plant^{-1} while both of flax Sakha 3 and flax S. 651 had the lowest averages in the previous characters. On the other side, the differences among flax genotypes were highly significant in seed index and seed yield hectare^{-1}. Moreover, flax Giza 11 variety had higher seed yield in both seasons followed by flax Giza 12 and flax Sakha 6 while the lowest seed yield hectare^{-1} was obtained with flax Sakha 3 and flax S. 651 as well as seed index. These results are harmony with those obtained by Kineber et al. (2015) and El-Borhamy et al. (2017).

Approximate chemical composition of flaxseed cultivars

Chemical composition of flaxseed cultivars are shown in Table 5. There were significant differences of characteristics among flaxseed varieties. Data showed that flaxseed Sakha 5 variety had the lowest moisture content (6.53%) followed by flaxseed Sakha 3 (6.61%). On the other hand, flaxseed S.651 genotype had the highest moisture content (7.00%). The obtained results were lower than observed by

Amin and Thakur (2014) and Eggie (2010). Also, results revealed that oil content was significantly affected by the variety with the highest value recorded for flaxseed Sakha 5 (38.87%) whereas flaxseed Sakha 3 had the lowest oil content (28.61%). The composition of flaxseed can vary with growing environment, seed processing, genetics and method of analysis (Daun, Barthet, Chornick, Duguid, & Cunnane, 2003).

Table 3. Mean values of straw yield and its components.

Genotypes	Technical length (cm)	Main stem diameter (mm)	Straw yield plant^{-1} (g)	Straw yield hectare^{-1} (ton)
		2018/2019 season		
Sakha 3	83.0^{b}	1.8^{c}	0.945^{cd}	8.014^{b}
Sakha 5	62.6^{c}	2.2^{b}	0.818^{d}	6.895^{c}
Sakha 6	86.0^{ab}	2.9^{a}	1.48^{b}	8.390^{b}
Giza 11	89.0^{ab}	3.0^{a}	2.14^{a}	9.929^{a}
Giza 12	84.0^{ab}	3.0^{a}	2.23a	9.940^{a}
S. 651	89.6^{a}	1.2^{c}	1.06^{c}	8.450^{b}
F- test	*	**	*	**
Standard deviation	3.47	0.24	0.12	0.41
		2019-2020 season		
Sakha 3	87.0^{a}	1.7^{c}	0.935^{c}	8.14^{b}
Sakha 5	64.6^{b}	2.2^{b}	0.808^{c}	7.01^{c}
Sakha 6	84.0^{a}	3.2^{a}	1.38^{b}	8.17^{b}
Giza 11	88.0^{a}	3.3^{a}	2.09^{a}	9.79^{a}
Giza 12	84.0^{a}	3.1^{a}	2.17^{a}	9.92^{a}
S. 651	87.6^{a}	1.4^{c}	1.01^{c}	8.16^{b}
F- test	*	**	*	**
Standard deviation	4.15	0.19	0.13	0.39

* and ** indicate p < 0.05, < 0.01, in order. Means of each treatment followed by the same letter are not significantly differ at 5% level, as indicated by Duncan's multiple range test.

Table 4. Means values of seed yield and its components.

Genotypes	Fruiting zone length (cm)	No. of capsules plant^{-1}	Seed yield plant^{-1} (g)	Seed index (g)	Seed yield hectare^{-1} (kg)
			2018/2019 season		
Sakha 3	10.9^{d}	8.0^{d}	0.543^{e}	4.62^{d}	1165.08^{b}
Sakha 5	22.8^{bc}	18.3^{c}	0.846^{d}	7.15^{c}	1700.79^{a}
Sakha 6	24.5^{ab}	23.0^{b}	0.986^{c}	10.20^{b}	1726.19^{a}
Giza 11	25.8^{a}	29.3^{a}	1.328^{a}	11.19^{a}	1773.80^{a}
Giza 12	21.7^{c}	23.0^{b}	1.142^{b}	9.93^{b}	1559.52^{a}
S. 651	7.13^{e}	6.3^{d}	0.457^{e}	3.51^{e}	1158.73b
F- test	*	*	*	**	**
Standard deviation	1.47	2.11	0.07	0.18	121.99
			2019/ 2020 season		
Sakha 3	11.7^{c}	11.0^{c}	0.578^{c}	4.51^{e}	1150.79^{c}
Sakha 5	20.7^{a}	20.0^{b}	0.860^{b}	7.15^{d}	1688.88^{ab}
Sakha 6	23.9^{a}	25.6^{b}	1.013^{ab}	10.19^{b}	1670.64^{ab}
Giza 11	25.7^{a}	35.0^{a}	1.200^{a}	11.21^{a}	1785.71^{a}
Giza 12	23.7^{a}	25.0^{b}	1.210^{a}	9.93^{c}	1617.46^{b}
S. 651	6.1^{d}	6.0^{c}	0.570^{c}	3.30^{f}	1103.17^{c}
F- test	*	*	*	**	**
Standard deviation	1.42	3.16	0.12	0.12	79.79

* and ** indicate p < 0.05, < 0.01, in order. Means of each treatment followed by the same letter are not significantly differ at 5% level, as indicated by Duncan's multiple range test.

Table 5. Approximate chemical composition (% on dry weight basis) of flaxseed cultivars.*

Characteristics	Sakha 3	Sakha 5	Sakha 6	Giza 11	Giza 12	S.651
Moisture	6.61±0.20^{a}	6.53±0.13^{a}	6.71±0.11^{ab}	6.95±0.05^{bc}	6.74±0.23^{abc}	7.00±0.10^{c}
Crude oil	28.61±0.24^{a}	38.87±0.18^{e}	32.95±0.27^{d}	32.93±0.15^{d}	31.57±0.17^{c}	29.46±0.24^{b}
Crude Protein	25.86±0.41^{e}	16.82±0.67^{a}	19.30±0.77^{b}	20.92±1.08^{c}	21.70±1.30^{c}	23.58±0.37^{d}
Crude fibers	13.26±0.27^{c}	11.41±0.22^{a}	12.31±0.40^{b}	13.12±0.28^{c}	12.92±0.71^{bc}	13.35±0.15^{c}
Ash	4.47±0.15^{c}	3.31±0.15^{a}	4.09±0.15^{b}	4.28±0.12^{bc}	4.15±0.13^{b}	4.49±0.19^{c}
Total carbohydrates	41.06±0.79^{a}	41.00±0.99^{a}	43.66±1.19^{b}	41.87±1.36^{ab}	42.59±1.60^{ab}	42.47±0.78^{ab}

*different superscripts indicate significant differences (p < 0.05).

It is clear that flaxseed Sakha 3 showed the highest protein content (25.86%) (Table 5). Oomah and Mazza (1993) reported that protein content in flaxseed was ranged from 10.5 to 31%. Also, flaxseed Sakha 5 had the lowest protein content (16.82%) and the highest oil content (38.87%). As general, results showed that protein content was negatively correlated with oil content confirming previous findings (Saastamoinen et al., 2013; Tavarini, Angelini, Casadei, Spugnoli, & Lazzeri, 2016). Data showed also that flaxseed S.651 had the highest content of crude fibers (13.35%) and flaxseed Sakha 5 had the lowest content (11.41%).

Ash ranged from 3.31 to 4.49% (Table 5). This agreed with Amin and Thakur (2014) who found that ash content of flaxseeds was 3.8 and was close to the value of 3.3% reported by Eggie (2010).

Some physical and chemical parameters of flaxseed oils

Physicochemical parameters are quite important on oils quality evaluation. There was significant difference observed in case of refractive index (RI) of flaxseed oils (Table 6). The highest RI was 1.4749 for Sakha 5 flaxseed oil. On the other hand, RI of Sakha 3 flaxseed oil was 1.4720. Refractive Indexes of all studied flaxseed oil were within the range fixed by Codex (1999). The refractive index of oils depends on molecular weight, fatty acids chain length, degree of unsaturation and degree of conjugation (Andhale, Syed, Bhavsar, & Dagadkhair, 2017). Free fatty acids (FFA) ranged from 0.22 to 0.39% (as oleic acid). All samples of flaxseed oils had low values and were in accordance with Codex (1999).

Table 6. Some physical and chemical parameters of extracted oils form flaxseed cultivars.*

Characteristics	Sakha 3	Sakha 5	Sakha 6	Giza 11	Giza 12	S.651
Refractive index (at 20°C)	1.4720±0.0004^{a}	1.4749±0.0001^{d}	1.4745±0.0002^{ed}	1.4740±0.0004^{c}	1.4732±0.0002^{b}	1.4725±0.0004^{a}
FFA % (as oleic acid)	0.39±0.01^{e}	0.22±0.02^{a}	0.28±0.01^{b}	0.31±0.02^{bc}	0.34±0.03^{cd}	0.36±0.03^{de}
Peroxide value (meqO_2 kg oil^{-1})	2.13±0.06^{e}	1.74±0.04^{a}	1.84±0.02^{b}	1.92±0.02^{c}	1.95±0.01^{c}	2.05±0.05^{d}
Conjugated dienes (CD) ^{232nm}	1.86±0.02^{e}	1.69±0.03^{a}	1.72±0.02^{ab}	1.75±0.04^{bc}	1.79±0.02^{cd}	1.82±0.02^{de}
Conjugated trienes (CT) ^{268nm}	0.26±0.02^{d}	0.18±0.01^{a}	0.20±0.02^{ab}	0.22±0.01^{bc}	0.24±0.01^{cd}	0.25±0.01^{d}
TBA value (mg malonaldehyde kg oil^{-1})	0.65±0.02^{e}	0.36±0.01^{a}	0.43±0.01^{b}	0.48±0.03^{c}	0.56±0.01^{d}	0.63±0.04^{e}
Saponification value (mg KOH g^{-1})	197.00±1.00^{e}	186.33±1.53^{a}	190.33±1.53^{b}	192.00±1.00^{b}	194.67±1.15^{c}	195.00±1.00^{ce}
Unsaponifiable matter (%)	0.86±0.02^{a}	1.24±0.03^{d}	1.20±0.03^{d}	1.10±0.01^{c}	1.06±0.02^{bc}	1.04±0.04^{b}

*different superscripts indicate significant differences ($p < 0.05$).

The peroxide value (PV) is a measure of primary oxidation process. Results in Table 6 revealed that Sakha 3 flaxseed oil had the highest PV (2.13 meqO_2 kg oil^{-1}). On the other hand, Sakha 5 flaxseed oil had the lowest PV (1.74 meqO_2 kg oil^{-1}). All flaxseed oil samples were in accordance with Codex (1999). Low values of PV reflected a good quality of flaxseed oil due to the fresh extraction of flaxseed oil.

Conjugated diene (CD) and conjugated triene (CT) are considered important parameter for the investigation of primary oxidative deterioration of the oils (Yoon, Kim, Shin, & Kim, 1985) and thus a good indicator of the extracted flaxseed oil quality. Results in Table 6 revealed that Sakha 5 flaxseed oil had the lowest values of CD (1.69) and CT (0.18). Sakha 3 flaxseed oil had the highest values of CD (1.86) and CT (0.26).

Also, results in Table 6 showed that Sakha 3 flaxseed oil had the highest value of Thiobarbituric acid (TBA) value (0.65 mg malonaldehyde kg oil^{-1}) compared to other flaxseed oils. The TBA test measures a secondary product of lipid oxidation. Saponification value (SV) of flaxseed oils ranged from 186.33 to 197 (mg KOH g^{-1}). The SV of the flaxseed oils agreed with Codex (1999). Waxes, sterols and hydrocarbons in oils are generally determined as unsaponifiable matter (Stauffer, 1996). Unsaponifiable matter of studied flaxseed oils were ≤20 in according with Codex (1999). In flax grains, lipids are protected against oxidation by various mechanisms, for example, the presence of antioxidants such as lignans and phenols (Kitts, Yuan, Wijewickreme, & Thompson, 1999).

Fatty acids composition

Fatty acids composition of the flaxseed oils reported in Table 7. The main constitutes of fatty acids were linolenic ($C_{18:3}$) (49–57%), oleic ($C_{18:1}$) (15–19%), linoleic ($C_{18:2}$) (16–19%), stearic ($C_{18:0}$) (2–4%), and palmitic ($C_{16:0}$) (5–9%) fatty acids, which together comprised about 99% of the total fatty acids. These results agreed with Codex standards (1999) and also were similar to that reported by Choo, Birch, and Dufour (2007). Flaxseed oil extracted from Sakha 5 cultivar had the highest contents of $C_{18:3}$, $C_{18:2}$ and the lowest content of $C_{18:1}$. On the other side, Sakha 3 flaxseed oil had the highest content of $C_{18:1}$ and the lowest contents of $C_{18:3}$, $C_{18:2}$. Bhatty (1995) reported that with an increase in $C_{18:3}$ in flaxseed oil, there was a corresponding decrease in $C_{18:1}$ fatty acid.

Table 7. Fatty acids composition of extracted oils form flaxseed cultivars.*

Characteristics	Sakha 3	Sakha 5	Sakha 6	Giza 11	Giza 12	S.651
$C_{16:0}$	9.50±0.20 e	5.49±0.30 a	6.65±0.15 b	6.87±0.06 b	7.71±0.06 c	8.17±0.07 d
$C_{16:1}$	0.12±0.01 a	0.25±0.02 c	0.23±0.03 c	0.22±0.02 c	0.18±0.01 b	0.17±0.02 b
$C_{18:0}$	4.76±0.20 d	2.20±0.10 a	2.61±0.11 b	2.68±0.10 b	3.16±0.10 c	3.26±0.06 c
$C_{18:1}$	19.07±0.12 d	15.59±0.34 a	16.62±0.12 b	17.00±0.20 b	18.37±0.22 c	18.57±0.45 c
$C_{18:2}$	16.32±0.07 a	19.10±0.10 e	18.50±0.2 d	18.31±0.07 d	17.85±0.13 c	17.29±0.08 b
$C_{18:3}$	49.98±0.63 a	57.12±0.90 d	55.12±0.65 c	54.65±0.47 c	52.43±0.55 b	52.27±0.74 b
$C_{20:0}$	0.15±0.02 b	0.10±0.01 a	0.12±0.02 a b	0.12±0.01 a b	0.14±0.01 a b	0.14±0.04 a b
$C_{20:1}$	0.10±0.01 a	0.15±0.03 b	0.15±0.02 b	0.14±0.01 b	0.14±0.02 b	0.13±0.02 a b
Σ SFA **	14.41±0.42 e	7.78±0.41 a	9.38±0.28 b	9.67±0.17 b	11.01±0.17 c	11.57±0.17 d
Σ USFA ***	85.59±0.42 a	92.21±0.41 e	90.62±0.28 d	90.33±0.17 d	88.98±0.17 c	88.43±0.17 b
MUSFA ****	19.29±0.14 d	15.99±0.38 a	17.00±0.17 b	17.36±0.23 b	18.70±0.24 c	18.87±0.49 c d
PUSFA *****	66.30±0.56 a	76.22±0.80 d	73.62±0.45 c	72.97±0.40 c	70.28±0.42 b	69.56±0.66 b
$C_{18:1}$/ $C_{18:2}$	1.16±0.01 f	0.81±0.01 a	0.89±0.01 b	0.92±0.01 c	1.02±0.01 d	1.07±0.02 e
$C_{18:3}$/ $C_{18:2}$	3.06±0.05 b	2.99±0.06 a b	2.97±0.06 a b	2.98±0.04 a b	2.93±0.04 a	3.02±0.06 a b
USFA / SFA	5.94±0.20 a	11.86±0.68 d	9.66±0.31 c	9.34±0.18 c	8.07±0.14 b	7.64±0.13 b

*different superscripts indicate significant differences ($p < 0.05$) **SFA: saturated fatty acids. ***USFA: unsaturated fatty acids. **** MUSFA: monounsaturated fatty acids. *****PUSFA: polyunsaturated fatty acids.

Also, results in Table 7 revealed that Sakha 3 flaxseed oil had the highest ratios of $C_{18:3}$/ $C_{18:2}$ and $C_{18:1}$/ $C_{18:2}$. The high ratio of $C_{18:3}$/ $C_{18:2}$ is very important for prostaglandins metabolism which in turn pivotal in the regulation of inflammation, hormone synthesis, and steroid production (Jakubowica, 1983).

Technological application

Figure 1 showed pasta fortified with different levels of flaxseed meal.

Proximate chemical composition of pasta

Proximate analyses of pasta fortified with different levels of flaxseed meal are shown in Table 8. Flaxseed meal contained substantially more protein, lipid and ash than semolina and wheat flour. Moisture content was minimum in flaxseed meal and maximum in semolina. There was significant difference between pasta (control) and fortified pasta with flaxseed. The protein, lipid and ash contents for pasta fortified with flaxseed meal (Sakha 5) were reflective of the innate composition of flaxseed meal. Regarding chemical composition and caloric value of pasta fortified with 5, 10 and 15% of flaxseed meal, it could be noticed that as the level of flaxseed meal increase, caloric value and all chemical composition were increased except total carbohydrate.

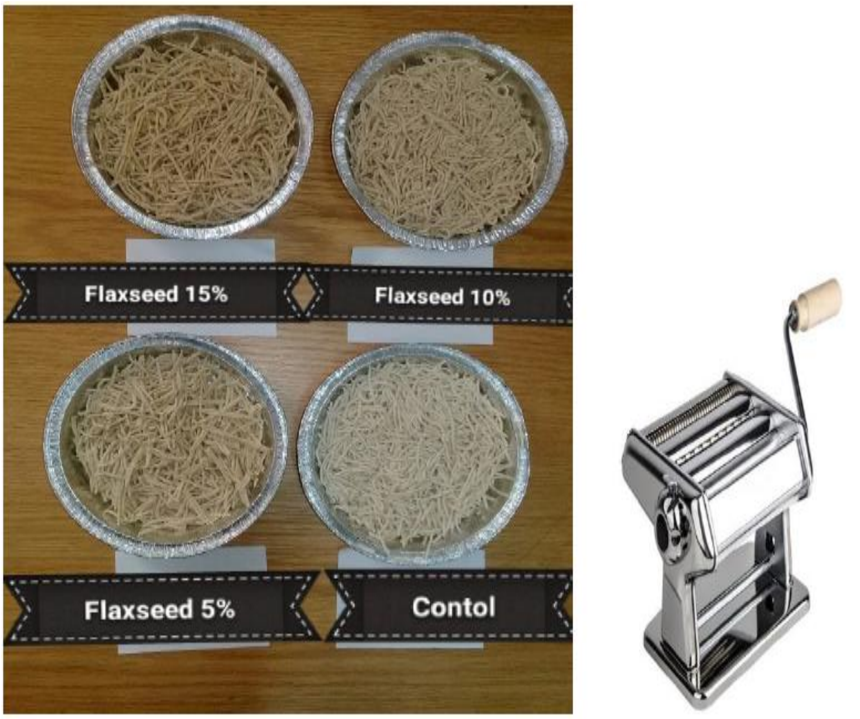

Figure 1. Pasta fortified with different levels of flaxseed meal.

Table 8. Proximate analyses (% on dry weight basis) and minerals of wheat pasta fortified with different levels of flaxseed meal**.

Characteristics		Flaxseed meal	Semolina flour	Wheat flour	Pasta formulation			
					Control	Flaxseed 5%	Flaxseed 10%	Flaxseed 15%
Moisture		6.53±0.13	14.75	14.48	10.66^{a}	9.01^{b}	9.12^{b}	8.95^{b}
Crude protein		16.82±0.67	10.25	9.94	10.15^{a}	10.44^{ab}	10.53^{b}	12.02^{c}
Crude oil		38.87±0.18	0.43	0.52	1.45a	2.24^{b}	3.03^{c}	4.82^{d}
Crude fiber		11.41±0.22	0.36	0.24	0.32^{a}	0.84^{b}	1.16^{b}	1.68^{c}
Ash		3.31±0.15	0.67	0.66	0.66^{a}	0.98^{b}	1.21^{c}	2.03^{d}
Total carbohydrates		41.00±0.99	88.65	88.88	87.72	86.32	85.22	81.12
Caloric value*					416.16	418.78	421.78	427.48
Macro-minerals	P	4523.60	462.88	483.92	469.19^{a}	671.15^{b}	880.10^{c}	1070.06^{d}
	Na	962.50	70.00	12.50	105.00^{a}	119.25^{a}	129.75^{ab}	149.25^{b}
	Ca	1012.00	235.00	228.50	233.05^{a}	252.23^{a}	331.40^{b}	390.58^{c}
	Mg	6385.00	263.50	347.75	288.78^{d}	530.64^{c}	862.50^{b}	999.36^{a}
	K	771.00	978.75	1330.00	3684.13^{a}	3056.18^{b}	2128.23^{c}	1800.28^{d}
Micro-minerals	Fe	112.00	12.50	15.00	13.25^{a}	19.10^{b}	25.95^{c}	31.80^{d}
	Zn	49.10	7.50	8.75	7.88^{a}	11.89b	15.91^{c}	18.93^{d}

*Energy value (kcal 100g^{-1}) = (protein content x 4.27) + (fat content x 9.02) + (carbohydrate content x 4.10) **different superscripts indicate significant differences ($p < 0.05$).

Minerals composition

The minerals composition of pasta fortified with flaxseed meal were illustrated in Table 8. Flaxseed meal had the highest content of minerals compared with semolina and wheat flour, with exception of potassium (K) was higher in wheat flour. Flaxseeds are a source of minerals as calcium, magnesium and phosphorus. Magnesium (Mg) was the most abundant element (6385.00 mg kg^{-1}) in flaxseed meal approximately 46% of total mineral content determined in flaxseed meal. This value was higher than (29.92– 42.14%) that observed by Kaur, Kaur, and Gill (2017). Also this value was higher than that observed by Daun et al. (2003) (3.2-4.1 mg g^{-1}). Phosphorus (P) was the second abundant element in flaxseed meal followed by calcium (Ca) that recorded 4523.60 and 1012.00 mg kg^{-1}, respectively. Iron (Fe) was the most abundant micro-minerals followed by zinc (Zn) that recorded 112 and 49.10 mg kg^{-1}, respectively in flaxseed meal. The deficiency of Fe is frequently associated with anemia as it plays an important role in blood formation. The contents of Fe (36.7–1664.4 mg kg^{-1}) and Zn (38.2–93.6 mg kg^{-1}) in flaxseed have been reported by Daun et al. (2003). Mineral contents of pasta fortified with flaxseed meal were reflective of the innate composition of flaxseed meal. The higher fortified with flaxseed meal, the higher P, Na, Ca, Mg, Fe and Zn content were.

Cooking quality evaluation

The optimal cooking time of fortified pasta varied from 4.24 to 11.32 min (Table 9). The fortified pasta with 15% flaxseed meal increased the optimal cooking time comparing with control. The reduction in cooking time was accompanied by a higher water uptake. Also, results indicated that when flaxseed meal increased, cooking time was increased, but there were no significance differences between cooking times of control and flaxseed meal 5%. There was the same trend observed between 10% and 15% treatments but with significant difference. On the other hand, the cooking loss of fortified pasta was increased with increasing level of flaxseed meal compared with pasta control. Low amount of residue indicates high pasta cooking quality (Del Nobile, Baianoa, Contea, & Moccic, 2005). Cooking loss could be attributed to weak protein-starch interaction and destroyed protein matrix (Izydorczyk, Lagassé, Hatcher, Dexter, & Rossnagel, 2005). High cooking loss of pasta fortified with flaxseed meal compared to control may result from presence of high water-soluble protein fraction and minerals in flaxseed meal. Moreover, the decreased amount of cooking loss in control could be attributed to the lowest in the fat content. These are in the agreement with those reported by Matsuo, Dexter, Boudreau, and Daun (1986) who mentioned that lipids exert a marked influence on pasta cooking quality, the presents of lipids lead to less exudation of amylose during gelatinization because of lipid amylase complexing.

Table 9. Cooking quality evaluation of pasta fortified with flaxseed meal compared with control.*

Formulations	Optimum cooking time (min.)	Cooking loss (%)	Volume increase (%)	Water absorption (%)
Control	4.24^{c}	6.15^{b}	200.62^{a}	190.5^{a}
Flaxseed 5%	4.45^{c}	6.91^{a}	210.21^{ab}	181.3^{b}
Flaxseed 10%	7.55^{b}	7.09^{a}	190.85^{b}	169.9^{c}
Flaxseed 15%	11.32^{a}	7.21^{a}	181.16^{c}	151.2^{d}

*different superscripts indicate significant differences ($p < 0.05$).

Data in Table 9 showed that cooked volume pasta control decreased by the increase of flaxseed meal as a trend but it become significantly from 10% flaxseed meal. Moreover, pasta water absorption was affected by flaxseed meal addition. Pasta control was higher than that of fortified pasta while pasta 15% flaxseed meal showed the lowest water absorption. These results could be attributed to difference in protein quantity. As the protein concentration increased, the water absorption of cooked pasta decreased. Pasta cooking quality affected by protein quantity and quality (Matsuo & Irvine, 1970).

Sensory evaluation

Appearance, taste, odor, color and overall acceptability are the important attributes for food item acceptability. Data in Table 10 revealed that pasta control had the best scores for all studied attributes followed by pasta fortified with 5, 10 and 15% flaxseed meal, respectively. Sensory evaluation of pasta (control and flaxseed 5%) revealed no significant difference in terms of taste, color and overall acceptability.

Table 10. Sensory evaluation of pasta fortified with flaxseed meal.*

Formulations	Appearance	Taste	Odor	Color	Overall acceptability
Control	9.12^{a}	9.91^{a}	9.59^{a}	9.26^{a}	9.12^{a}
Flaxseed 5%	8.86^{b}	9.59^{a}	8.81^{b}	8.96^{a}	8.86^{ab}
Flaxseed 10%	8.53^{b}	8.63^{b}	8.69^{bc}	8.53^{b}	8.61^{b}
Flaxseed 15%	8.01^{c}	8.13^{c}	8.12^{c}	8.11^{c}	8.34^{c}

*different superscripts indicate significant differences ($p < 0.05$)

Conclusion

The differences in yield per plant and its components among flax genotypes could be due to the genetic factor. Flaxseed Sakha 5 had the highest oil content whereas, flaxseed Sakha 3 had the highest protein content. All physical and chemical parameters and fatty acids composition of flaxseed oils extracted from genotypes agreed with Codex.). Flaxseed oil extracted from Sakha 5 had the highest contents of $C_{18:3}$, $C_{18:2}$ and the lowest content of $C_{18:1.}$ Pasta fortified with flaxseed meal 5% was enhanced the nutritional quality. As the protein concentration increased, the water absorption of cooked pasta decreased.

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