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Effect of sesame seed proteins supplementation on the nutritional, physical, chemical and sensory properties of wheat flour bread

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Abstract. Sesame products (sesame meal, roasted and autoclaved sesame meal, sesame protein isolate and concentrate) were added to Red wheat flour to produce blends at protein levels of 14, 16, 18 and 20 percent. Dough properties were studied using a Brabender Farinograph. Loaves were prepared from the various blends using the straight dough procedure and then evaluated for volume, crust and crumb colour, crumb texture, flavour and overall quality. The water absorption, development time and dough weakening were increased ($p < 0.05$) as the protein level increased in all blends; however, dough stability decreased. Sesame products could be added to wheat flour up to 18 percent protein level (sesame protein isolate) and up to 16 percent protein level (other sesame products) without any observed detrimental effect on bread sensory properties. No significant differences ($p > 0.05$) were recorded in loaf volume between control and breads containing sesame protein isolate (up to 18 percent protein level) and either autoclaved sesame meal or sesame protein concentrate (up to 14 percent protein level). Addition of sesame products increased the content not only of protein but also minerals and total essential amino acids, especially lysine. The addition also improved in-vitro protein digestibility.

Introduction

The major nutritional problem in most of the developing world is protein-calorie malnutrition. This acute problem is due to factors such as high birth rates, an insufficiencies of agricultural products and a limited supply of high quality proteins. Therefore, identification of inexpensive high protein materials is an important task in these countries. Such materials would be able to improve and upgrade the nutritional quality of the diets and the health of the people.

In Egypt wheat flour bread represents the main staple food for most of the people. Increasing the protein of the wheat flour by the addition of a good quality oil seed flour will markedly improve its nutritional value, with only a slight increase in production cost [5, 11, 24, 25]. Soybean meal, as one of the suggested materials, complements the amino acid profile of wheat flour by increasing its lysine content, whereas sesame meal is high in sulfur-containing amino acids. On the other hand, Rooney et al. [24] compared the baking qualities of several oilseed (cottonseed, peanut, sunflower and sesame)-wheat flour mixtures and found that oilseeds had varying effects on dough mixing and loaf volume characteristics. Heating enhanced the bread making characteristics of cottonseed and sunflower proteins but was detrimental to these properties of peanut and sesame proteins.

The objectives of this research were to study the effects of the addition of sesame products (sesame meal, roasted sesame meal, autoclaved sesame meal, sesame protein isolate and sesame protein concentrate) to wheat flour on the rheological, physical, sensory, chemical and nutritional properties of breads.

Materials and methods

Preparation of sesame products. Dehulled sesame seeds (*Sesumum indicum*) were obtained from the local market (Shibin El-Kom, Egypt) during the winter season of 1994. Wrinkled and mouldy seeds and foreign materials were removed. The sesame products (sesame meal, roasted sesame meal, autoclaved sesame meal, protein isolate and protein concentrate) were prepared as shown in Figure 1. After preparation, sesame products were reground and rescreened to pass through a 80-mesh sieve (Brith Standard Screen), then packed in air tight kilner jars and kept at 4 °C until used.

Preparation of sesame products-wheat flour blends. The flour used was derived from American Soft Red (ASR) wheat obtained from the Middle and West Delta Milling Company, Shibin El-Kom, Egypt. The extraction ratio of the wheat flour was 72 percent. Sesame products replaced wheat flour to produce blends with 14 percent, 16 percent, 18 percent and 20 percent protein levels (dry matter basis).

Determination of the dough physical properties. Water absorption, development time, stability time and dough weakening of the blends were determined with a Barbender Farinograph according to the constant flour method 54-21 of AACC [1]. Ten grams of flour were mixed at the optimum water absorption level and the farinograph curve was centered on the 500 BU line. Physical properties of dough were determined in triplicate.

Preparation of pan bread. Straight dough procedure, viz. 3-hr of fermentation, 55 min of proofing at 30 °C and 25 min baking at 220 °C was used. The baking formula, based on flour weight, was as follows: 50 g flour, 0.5 g sugar, 0.75 g salt, 0.5 g active dry yeast and 0.5 g shortening, with the water addition determined from a farinograph absorption test [9].

Loaf volume and sensory evaluation of baked bread. Loaf volume was measured immediately after baking by rapeseed displacement. Each treatment was done

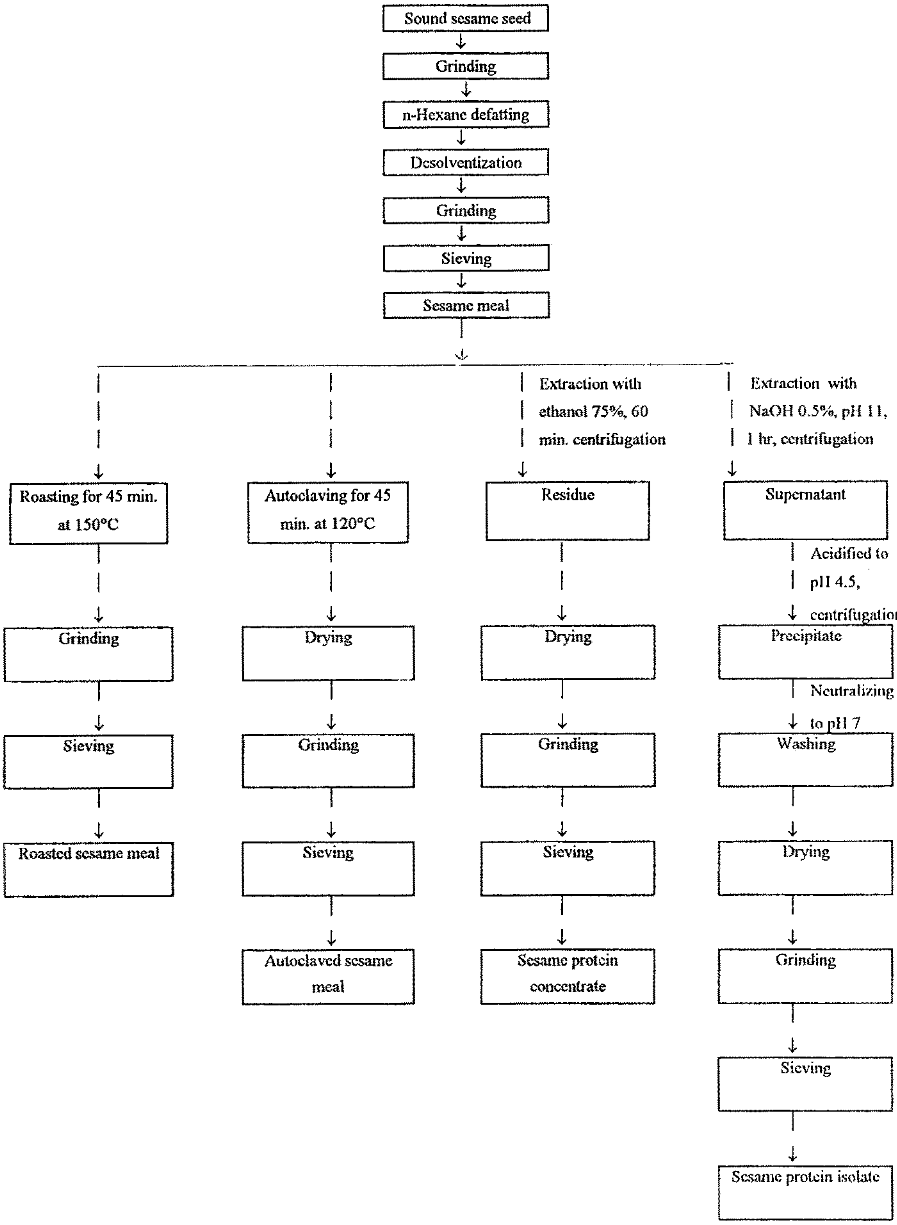

Fig. 1. Preparation diagrams of sesame seed products.

in triplicate and the average was calculated. Sensory evaluation was performed using a 9-member panel (trained) to measure crust colour, crumb colour, crumb texture, flavour and overall quality. A hendonic scale of 1 to 7 was used; 1 = poor and 7 = excellent.

Chemical composition. The proximate composition of sesame products, wheat flour and bread was determined using the following AOAC [3] methods: moisture (14.004), crude lipid (14.018), ash (14.006), crude fibre (14.020) and nitrogen (14.026). The conversion factors of nitrogen to protein were 5.7 for wheat flour and bread and 6.25 for sesame products. All the experiments were conducted in triplicate.

Amino acids were determined using a Mikrotechna AAA 881 automatic amino acid analyzer according to method of Moore and Stein [19]. Hydrolysis of the samples were performed in the presence of 6 M HCl at 110 °C for 24 hour under a nitrogen atmosphere. Sulfur-containing amino acids were determined after performic acid oxidation. Tryptophan was chemically determined by the method of Miller [18].

Minerals were determined after wet ashing with concentrated nitric acid and perchloric acid (1:1 v/v). Na, K and Ca were determined by flame photometry (Corning 410), while Mg, Mn, Zn, Fe and Cu were determined using an atomic absorption spectrophotometer (Perkin-Elmer Instrument Model 2380). Phosphorus was estimated photometrically via the phosphorus molybdate complex as described by Taussky & Shorr [29]. The mineral contents were determined in duplicate.

In-vitro protein digestibility. It was determined as described by Salgó et al. [26] by measuring the change in the sample solution pH after incubation at 37 °C with a trypsin-pancreatin enzyme mixture for 10 min. In-vitro protein digestibility was determined in triplicate.

Biological values. Biological values of breads were determined on the basis of amino acid profile. Chemical score of amino acids was calculated using the FAO/WHO [10] reference pattern. Essential Amino Acid Index was calculated according to Oser [21], using the amino acid composition of whole egg protein published by Hidvégi and Békés [15].

Statistical analysis. Physical properties, chemical composition, in-vitro protein digestibility and sensory properties data of sesame products and bread were statistically analyzed using analysis of variance and least significant difference [27]. Significant differences were determined at the $p < 0.05$ level.

Results and discussion

Chemical composition of sesame products and wheat flour. The chemical analysis data of the used raw materials are presented in Table 1. It is clear neither heat treatment (roasting and autoclaving) had any significant effect on ($p < 0.05$) total protein, ether extract and N-free extract. The changes in proximate composition due to heat treatments were quite minor. Rooney et al. [24] studied the effect of autoclaving on the protein content of some oilseed flours

Table 1. Chemical composition of wheat flour and sesame products (on dry weight basis)

Products	Moisture %	Crude protein %	Ether extract %	Crude fibre %	Ash %	N-free extract* %
Sesame meal	9.20 b	55.69 c	1.64 ab	3.41 c	9.83 b	29.43 b
Roasted sesame meal	8.76 b	57.12 c	1.73 a	4.01 b	9.02 c	28.12 b
Autoclaved sesame meal	9.31 b	54.83 c	1.80 a	4.21 ab	10.16 b	29.00 b
Sesame protein isolate	6.61 c	87.01 a	1.10 b	0.91 e	4.68 d	6.30 d
Sesame protein concentrate	7.21 c	62.32 b	1.20 b	4.36 a	10.97 a	21.15 c
Wheat flour	12.68 a	12.31 d	1.42 ab	1.30 d	1.18 e	83.79 a

*Calculated by differences.
Means in the same column with no common letters are significantly different ($p < 0.05$).
Means of three determinations.

and found that the heated and non heated flour did not differ in protein content. Sesame protein isolate had a significant higher ($p<0.05$) protein content than wheat flour and other sesame products. Also, sesame protein concentrate and autoclaved sesame meal had a significantly higher ($p<0.05$) level of crude fibre than wheat flour and other sesame products. Consequently addition of sesame products to wheat flour should increase both protein and ash contents of the bread. Crude fibre and ether extract contents of the sesame protein isolate were quite low (0.91 percent and 1.10 percent respectively).

Physical properties of dough. Farinograph data of wheat flour (control) and of flour supplemented with sesame products to give protein levels of 14, 16, 18 and 20 percent are shown in Table 2. The water absorption was increased significantly ($p<0.05$) due to the addition of sesame products at all protein levels except for sesame meal at 14 percent and 16 percent protein levels. Generally, wheat flours blended with sesame protein isolate, concentrate, autoclaved sesame meal and roasted sesame meal had greater water absorption than those blended with sesame meal. Wheat flour-sesame protein isolate blends appeared to have the highest water absorption compared to the other blends over all the ratios of blending. The increase in water absorption observed in all wheat flour blends may have been due to an increased hydration capacity of sesame products, especially protein isolate. Generally, these results agree well with those reported by Rasco et al. [23], Gonzalez-Galan et al. [13] and Yue et al. [30]. They found that water absorption increased substantially by 5–15 percent addition of native sunflower protein concentrate and isolate to wheat flour.

Dough development time was also increased for all wheat flour-sesame products blends. All blends had significantly higher ($p<0.05$) dough development times. However, dough development time was decreased with increasing the level of sesame products, but still higher than that of the control. Generally, the increase in dough development time may be due to the differences in the physicochemical properties of sesame products and that of wheat flour as previously detected by Morad et al. [20].

Dough stability time (a major index for dough strength) indicated that addition of sesame products lowered stability periods for all blends. Also, dough stability time was decreased with increasing the level of sesame products. These results agree well with those reported by Anjum et al. [2] and Yue et al. [30], which indicate that the high level of substitution of sunflower protein concentrate and isolate may have been responsible for decreasing dough stability time.

Sesame products substitution increased significantly ($p<0.05$) dough weakening, except sesame protein concentrate-wheat flour blend at 14 percent protein level. Also, dough weakening was increased with increasing the level of sesame products. This weakening of dough, could be due to; (a) the presence of sulphohydral groups in sesame products which cause the dough softening [8], (b) a decrease in wheat gluten content (dilution effect), and (c)

Table 2. Farinograph properties of sesame products-wheat flour blends

Products	Blend composition air-dry basis (%)		Protein level DM basis (%)	Water absorption (%)	Development time (min)	Stability time (min)	Weakening (BU)
	Product	Wheat flour					
Wheat flour (control)	0.00	100	12.31	58.9 h	1.5 e	4.5 a	80 f
Sesame meal	3.9	96.1	14	59.7 gh	3.5 b	2.5 e	110 de
	8.5	91.5	16	60.3 fgh	3.5 b	2.5 e	130 bcd
	13.2	86.8	18	61.5 def	3.0 c	2.0 f	140 ab
	17.8	82.2	20	61.9 cdef	3.0 c	2.0 f	160 a
Roasted sesame meal	3.8	96.2	14	61.5 def	3.5 b	3.0 d	120 cd
	8.3	91.7	16	62.2 cde	3.5 b	2.5 e	120 cd
	12.7	87.3	18	62.9 bcd	3.0 c	2.0 f	140 ab
	17.2	82.8	20	62.9 bcd	3.0 c	2.0 f	150 ab
Autoclaved sesame meal	4.0	96.0	14	60.6 efg	3.5 b	3.0 d	110 de
	8.7	91.3	16	61.5 def	3.5 b	3.0 d	120 cd
	13.4	86.6	18	62.7 bcd	3.0 c	2.5 e	150 ab
	18.1	81.9	20	63.5 abc	2.5 d	2.5 e	150 ab
Sesame protein isolate	2.3	97.7	14	62.7 bcd	3.5 b	3.5 c	130 bcd
	4.9	95.1	16	63.5 abc	3.0 c	3.5 c	130 bcd
	7.6	92.4	18	64.1 ab	3.0 c	3.5 c	150 ab
	10.3	89.7	20	64.9 a	3.0c	3.0 d	160 a
Sesame protein concentrate	3.4	96.6	14	61.9 cdef	4.0 a	4.0 b	90 ef
	7.4	92.6	16	62.5 bcd	3.5 b	4.0 b	120 cd
	11.4	88.6	18	63.1 bcd	3.5 b	3.5 c	130 bcd
	15.4	84.6	20	63.9 ab	3.0 c	3.5 c	140 ab

Means in the same column with no common letters are significantly different ($p < 0.05$).
Means of three determinations.

competition between proteins of sesame products and wheat flour for water [6].

Bread baking properties. Loaf volume and sensory properties data are presented in Table 3. The loaf volume was decreased with increasing levels of the different sesame product proteins. Loaf volume in the control bread was significantly higher ($p < 0.05$) than those baked with sesame meal or roasted sesame meal (all protein levels), autoclaved sesame meal (16 percent, 18 percent and 20 percent protein levels), sesame protein isolate (20 percent protein level) and sesame protein concentrate (16 percent, 18 percent and 20 percent protein levels). However, there was no significant depression in loaf volume for breads containing sesame protein isolate up to an 18 percent protein level. Also, the same trend was observed for breads contained autoclaved sesame meal and sesame protein concentrate at the 14 pecent protein level. These results are in a good agreement with those reported by Tally et al. [28] who found that 17 percent and 30 percent substitution by sunflower meal of wheat flour produced dense, compact loaves, although, 3 percent enrichment gave an attractive loaf. There was no significant difference ($p > 0.05$) in crust colour, among all breads up to 18 percent protein level of sesame products. Also, the differences were not significant ($p > 0.05$) for crumb colour, crumb texture, flavour and overall quality between control and breads prepared with sesame meal, roasted sesame meal, autoclaved sesame meal, sesame protein concentrate (up to 16 percent protein level) and sesame protein isolate (up to 18 percent protein level). Matthews et al. [17] mentioned that substituting high levels of sunflower flour resulted in deterioration of crumb colour and grain and the texture of the bread.

Therefore, the rest of this study was conducted on breads containing sesame meal, roasted sesame meal, autoclaved sesame meal, sesame protein concentrate at a 16 percent protein level, and sesame protein isolate at a 18 percent level.

Chemical composition of breads. Data in Table 4 show the changes in proximate composition of breads as a result of adding sesame products at a 16 percent level, and sesame protein isolate at an 18 percent level. Addition of sesame products to wheat flour increased protein content significantly. No significant differences ($p > 0.05$) in fat content were observed between wheat flour bread and sesame products breads with the exception of sesame protein isolate bread which had a lower fat content than those of the others. The crude fibre of sesame products breads was significantly higher ($p < 0.05$) than that of the control, except for the sesame protein isolate bread. Also, the addition of sesame products to wheat flour should an increase in ash content. These results are in agreement with those reported by Khan et al. [16]; Hansmeyer et al. [14]; Rasco et al. [22] and Salama et al. [25].

Mineral content of breads. Data presented in Table 5 show the minerals

Table 3. Loaf volume and sensory evaluation of bread fortified with sesame products

Bread products	Protein level, DM basis (%)	Loaf volume[1] (ml)	Crust colour[2]	Crumb colour[2]	Crumb texture[2]	Flavour[2]	Overall quality[2]
Control	12.31	250 a	6.3 a	5.9 a	5.7 a	5.4 a	5.8 a
Sesame meal	14	220 cd	6.0 a	5.7 a	5.6 a	5.2 a	5.6 a
	16	210 de	5.7 a	5.6 a	5.5 a	5.1 a	5.5 a
	18	190 h	5.7 a	4.9 b	4.9 b	4.8 b	5.0 b
	20	190 h	4.7 b	4.6 c	4.5 b	4.5 b	4.5 b
Roasted sesame meal	14	230 bc	5.9 a	5.7 a	5.5 a	5.1 a	5.6 a
	16	211 ef	5.8 a	5.6 a	5.5 a	5.0 a	5.5 a
	18	202 fg	5.7 a	4.7 b	4.6 b	4.2 b	4.6 b
	20	190 h	4.7 b	4.3 c	4.0 c	3.8 c	4.1 c
Autoclaved sesame meal	14	240 ab	6.1 a	5.6 a	5.6 a	5.2 a	5.6 a
	16	225 bc	5.9 a	5.5 a	5.4 a	5.1 a	5.5 a
	18	206 ef	5.7 a	5.0 b	5.0 b	4.8 b	4.9 b
	20	195 gh	5.0 b	5.0 b	4.6 b	4.8 b	4.9 b
Sesame protein isolate	14	249 a	6.2 a	5.8 a	5.8 a	5.4 a	5.8 a
	16	240 ab	6.2 a	5.6 a	5.6 a	5.2 a	5.7 a
	18	233 ab	5.9 a	5.5 a	5.4 a	5.1 a	5.5 a
	20	225 bc	5.2 b	4.8 b	4.7 b	4.5 b	4.8 b
Sesame protein concentrate	14	240 ab	5.9 a	5.7 a	5.5 a	5.1 a	5.6 a
	16	232 bc	5.7 a	5.5 a	5.4 a	5.0 a	5.4 a
	18	221 cd	5.7 a	4.7 b	4.5 b	4.2 b	4.7 b
	20	210 ef	4.8 b	4.3 c	4.0 c	4.0 b	4.3 c

Means in the same column with no common and letters are significantly different ($p<0.05$).
[1] Means of three determinations.
[2] Means of nine panelist scores.

Table 4. Chemical composition of bread fortified with sesame products (on dry weight basis)

Bread sample	Crude protein %	Ether extract %	Crude fibre %	Ash %	N-free extract* %
Control	12.63 c	1.38 ab	1.26 b	1.25 d	83.48 a
Sesame meal[1]	16.21 b	1.52 a	1.73 a	2.43 b	78.11 b
Roasted sesame meal[1]	16.25 b	1.59 a	1.80 a	2.20 b	78.16 b
Autoclaved sesame meal[1]	16.19 b	1.63 a	1.86 a	2.83 a	77.49 b
Sesame protein isolate[2]	18.42 a	0.94 b	1.02 b	1.84 c	77.78 b
Sesame protein concentrate[1]	16.23 b	1.11 ab	1.92 a	2.90 a	77.84 b

*Calculated by differences.
Means in the same column with no common and letters are significantly different ($p < 0.05$).
Means of three determinations.
[1] 16% protein level.
[2] 18% protein level.

Table 5. Mineral content of bread fortified with sesame products (on dry weight basis)*

Bread sample	Micro-elements (mg/100 gm)			
	Cu	Zn	Fe	Mn
Control	0.42	2.06	3.12	1.27
Sesame meal[1]	1.73	6.33	4.41	1.73
Roasted sesame meal[1]	1.52	6.51	4.53	1.62
Autoclaved sesame meal[1]	1.85	5.62	4.36	1.60
Sesame protein isolate[2]	0.93	2.43	3.91	1.31
Sesame protein concentrate[1]	2.10	6.82	4.92	1.80

Bread sample	Macro-elements (mg/100 gm)				
	Mg	Na	Ca	K	P
Control	66.27	460.60	98.41	100.31	120.32
Sesame meal[1]	190.31	420.00	121.30	140.20	139.80
Roasted sesame meal[1]	210.00	440.12	118.00	150.12	136.71
Autoclaved sesame meal[1]	200.15	430.17	130.61	145.10	140.91
Sesame protein isolate[2]	120.07	560.63	90.21	80.71	109.20
Sesame protein concentrate[1]	220.16	480.10	142.40	150.31	165.30

*Average of two determination.
[1] 16% protein level.
[2] 18% protein level.

content of different sesame products bread. The results revealed that there was marked increase in all minerals in the final bread. Breads baked with sesame protein concentrate had a higher content of micro and macro elements than those of other sesame products breads. On the other hand, sesame protein isolate-wheat flour bread had lower content of minerals than those of other sesame products breads. Generally, the same trend was reported by Salama et al. [25].

Amino acids profile of breads. Data presented in Table 6 show the amino acids composition of breads. The addition of sesame products to bread increased the concentration of the essential amino acids, valine, lysine, leucine (except sesame meal bread) and total sulphur amino acid (except sesame meal and autoclaved sesame meal breads). Lysine content of sesame products breads was increased by 80–125 percent compared to control. These results agree well with those reported by Hansmeyer et al. [14] and Salama et al. [25]. In the comparison of the amino acids composition of sesame products breads to the FAO/WHO [10] pattern, it can be seen that sesame products breads contained similar or higher essential amino acids levels than the standard except for a modest deficiency in some essential amino acid. The deficiency of these amino acids was not the result of sesame products addition.

In-vitro digestibility and biological value of breads. In-vitro digestibility and biological values of bread are given in Table 7. Bread containing sesame products had a significantly higher ($p < 0.05$) in-vitro protein digestibility with the exception of sesame meal bread. Digestibility of bread containing autoclaved sesame meal, sesame protein concentrate and sesame protein isolate was much better than that of other flour-sesame products. These results agree well with those reported by Gonzalez-Agramon and Serna-Saldivar [12], who found that soybean isolate fortified tortillas had a higher digestibility than 100 percent wheat flour and soybean meal fortified tortillas. Generally, addition of sesame products to bread improved the protein digestibility. Bookwalter et al. [4] reported that fortification of sorghum with 15 percent soy meal increased the digestibility from 75 percent to 84.4 percent. The low protein digestibility of wheat could be improved by mixing with highly digestible protein such as those of sesame products. Addition of sesame products to wheat flour improved the essential amino acid index and chemical score, especially sesame protein isolate and concentrate bread was superior. Although, lysine was the first limiting amino acid for the bread control, it was the second for sesame products, except for autoclaved sesame meal bread. Generally, these results agree well with those reported by El-Adawy [7], who showed that supplementation of wheat flour with detoxified apricot kernel meal improved chemical score and essential amino acid index.

Table 6. Amino acids composition of bread fortified with sesame products (gm amino acid/16 gm nitrogen)

Amino acid	Control	Sesame meal[1]	Roasted sesame meal[1]	Autoclaved sesame meal[1]	Sesame protein isolate[2]	Sesame protein concentrate[1]	FAO/WHO (1973)
Threonine	3.06	2.70	3.20	3.29	2.99	2.87	4.00
Cystine	1.75	1.86	2.33	1.52	1.45	1.44	—
Methionine	1.29	1.15	1.59	1.10	1.70	1.65	—
Total sulpher amino acid	3.04	3.01	3.92	2.62	3.15	3.09	3.50
Tyrosine	4.44	4.61	2.67	4.02	3.76	3.81	—
Phenyalanine	5.26	5.04	5.31	5.21	5.32	5.13	—
Total aromatic amino acid	9.70	9.65	7.98	9.23	9.08	8.94	6.00
Isoleucine	4.08	3.92	4.06	4.16	4.11	4.14	4.00
Leucine	7.46	7.37	7.68	7.46	7.71	7.86	7.00
Lysine	1.88	3.75	3.38	4.23	4.16	3.99	5.50
Valine	4.95	4.95	5.35	5.47	5.54	5.55	5.00
Tryptophan	0.98	0.70	0.60	0.70	0.80	0.92	1.00
Total essential amino acid	35.15	36.05	36.17	37.16	37.54	37.36	36.00
Aspartic acid	4.50	5.42	5.37	5.97	5.64	6.03	—
Glutamic acid	29.53	25.79	25.82	24.51	23.17	22.92	—
Proline	12.27	10.76	10.67	9.38	10.21	8.93	—
Serine	5.29	5.14	5.47	4.81	4.62	6.07	—
Glycine	4.11	4.63	4.49	4.95	4.88	5.12	—
Alanine	3.43	4.00	3.93	4.54	4.43	4.84	—
Arginine	3.83	5.20	5.61	5.47	6.63	5.93	—
Histidine	1.89	3.01	2.47	3.31	2.88	2.80	—
Total non-essential amino acid	64.85	63.95	63.83	62.84	62.46	62.64	—

[1] 16% protein level.
[2] 18% protein level.

Table 7. In-vitro protein digestibility and biological value of bread fortified with sesame products

Bread sample	In-vitro protein digestibility*	Essential amino acid index (EAAI) %	Chemical score (CS) %	First limiting amino acid	Second limiting amino acid
Control	71.19 d	60.77	34.18	Lys (34.18)	Thre (76.50)
Sesame meal[1]	74.68 cd	62.59	67.50	Thre (67.50)	Lys (68.18)
Roasted sesame meal[1]	75.96 bc	63.58	60.00	Try (60.00)	Lys (61.45)
Autoclaved sesame meal[1]	77.81 ab	64.76	70.00	Try (70.00)	Cys + Met (74.86)
Sesame protein isolate[2]	80.64 a	66.39	74.75	Thre (74.75)	Lys (75.64)
Sesame protein concentrate[1]	78.52 ab	66.76	71.75	Thre (71.75)	Lys (72.55)

*Means in the same column with no common and letters are significantly different ($p < 0.05$).
Means of three determinations.
[1] 16% protein level.
[2] 18% protein level.

General conclusion

The addition of sesame products (sesame meal, roasted and autoclaved sesame meal, sesame protein isolate and protein concentrate) to wheat flour let to increase ($p < 0.05$) the water absorption, development time and dough weakening as the protein level increased in all blends; however, dough stability decreased. Sesame protein isolate and other sesame products could be added to wheat flour up to 18 percent and 16 percent protein level respectively, without any observed detrimental effect on bread sensory properties. Also, addition of sesame products increased the content of protein, minerals, and total essential amino acids, especially lysine, also improved in-vitro protein digestibility.

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