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Preparation of Sesame Flour Supplemented High Protein and Energy Food Bars

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Abstract. In this study, defatted sesame flour was mixed in different proportions (0, 25, 50, 75 and 100% and given names as T_0, T_1, T_2, T_3, T_4, respectively) with peanut flour and semolina to develop protein enriched sesame bars. These bars were analysed for physicochemical properties. Water activity, texture, calorific value, mineral profile, microbial examination and sensory evaluation were done at ambient temperature for 90 days. Results showed that water activity decreased from T_0-T_4 with mean values 0.6038-0.4308, respectively. Hardness decreased within treatments from T_0-T_4 with mean values ranges from 966.86 to 211.48 g while, factorability increased from 70.41 to 100.33 mm. Calorific value was also increased with maximum energy value found in T_4 (5355.5Kcal/g) and minimum in T_0 (3445.9Kcal/g). During storage, mold growth was increased from 3.2758CFU/g (T_0) to 3.6008CFU/g (T_4). Sensory evaluation results showed that T_2 gave overall best results having moisture content 4.5%, crude protein 35.73%, crude fat 0.61%, crude fibre 2.14%, total ash 2.44% and nitrogen free extract (NFE) 46.04.

Keywords: protein energy, malnutrition, sesame flour, supplemented flour, energy bars

Introduction

Developing countries are facing the challenges of nutritional problems, protein energy malnutrition and micronutrient deficiencies where fast growing population has resulted in limited supply of nutrients and poor sanitation conditions. The specific maladies such as Kwashiorkor and Marasmus are more prevalent in children characterised by odema, restrictions in protein intake, wasting of body tissues, particularly muscles and subcutaneous fat while in adults protein deficiency results in poor health and limited physical and mental stability (Shakeel *et al.,* 2009).

Sesame (*Sesamum indicium* L.) of the family Pedaliaceae also known as gingely, beniseed, sim-sim and till, is an important annual oilseed crop in tropical countries. It is an important potential candidate for protein supplementation in cereal based foods (Alobo, 2001). The world production of sesame is estimated about 3.66 million tonnes mainly from Asia (2.55 MT) and Africa (0.95 MT). Sesame seed is called "queen of the oil seed crops, due to the high production of edible oil. Most of the sesame seeds are used for extraction of oil (Gandhi and Taimini, 2009).

Peanuts (*Arachis hypogaea* L.), also called groundnuts or earthnuts, is known as "The king of oilseeds". It is mainly grown in tropical and the warmer regions of the temperate zone. It is believed to be the nature's blessing to mankind being highly nutritious, tasty and cheapest food as compared to other nuts i.e., walnuts, almonds, pistachio etc. In Pakistan, it is cultivated on an area of about 50,700 hectares, with 85% in Punjab province of Pakistan (Umar, 2006).

Semolina, a product obtained from wheat (*Triticum durum*) as a result of milling process in which bran and germ are removed. In Europe, finely ground semolina is used along with white flour in equal quantities to make quite dense but very flavourful bread (Palumbo *et al*., 2002). In Pakistan, it is usually used to make various types of sweet dishes. Pasta products, mostly consumed all over the world are conventionally manufactured from durum wheat named semolina, known to be the best raw material suitable for pasta production. It is rich source of carbohydrates (74-77%) and its importance is rising due to its nutritional properties, predominantly low glycemic index (GI). It also has proteins 11-15% but deficient in threonine and lysine (the first and second limiting amino acids), common to most cereals (Abdel-Aal *et al*., 2002). This provides an opportunity for the use of non-traditional raw materials to enhance the nutritional quality of pasta (Chillo *et al*., 2008).

Sesame flour is an innovative, economical and traditional ingredient for the preparation of value added products. Sesame bars will not only fulfill the nutritional require-

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ments of school going children, but also act as a healthy product for all age groups. The rising trends of nutritious meals and snacks has promoted food products that combine convenience and nutrition (Izzo and Niness, 2001).

Food products developed through supplementation of defatted sesame and peanut flour provides balanced amount of amino acids required for human body. The present study therefore, has been designed to develop high energy and nutritious bar as an alternative to conventional snacks using sesames indigenous sources. Sesame flour supplemented high protein and energy food bars were prepared and examined to find out their acceptability through physicochemical analysis and sensory evaluation.

Materials and Methods

Procurement and preparation of raw materials. Sesame cultivar (TH-6, White till) were procured from Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan while other materials required for the preparation of sesame bar e.g. peanut, suji (semolina), coconut, edible oil and sugar were procured from local market. All reagents (analytical) were procured from Merck (Merck KGaA, Darmstadt, Germany) and Sigma-Aldrich (Sigma Aldrich, Tokyo, Japan). Sesame seeds were partially defatted by using hydraulic press and ground to flour. Coconut were reduced in size by crushing. Peanuts were converted into peanut flour after roasting and grinding. All flours were packed in polyethylene bags and stored at room temperature for further analysis and utilization.

Analysis of raw materials. Sesame flour along with peanut flour and semolina were analysed in triplicate for moisture content, crude protein, crude fat, crude fibre, ash content and nitrogen free extract (NFE) by following respective methods as described in AACC (2000).

Mineral analysis. Raw materials (sesame flour, peanut flour and semolina) were analysed for mineral profile. Each treatment was analysed for Na, K, Ca, and Fe through flame photometer (Sherwood Scientific Ltd., Cambridge) and atomic absorption spectrophotometer (Varian AA240, Australia) by following procedure of AOAC (2006).

Preparation of sesame flour supplemented food bars. Roasted sesame flour, peanut flour, coconut flour, semolina, oil and sugar were mixed on mild heating for 20-30 mins to make a uniform blend. After cooling sheeting were done followed by cutting into bars maintaining a specific size, shape and thickness. Finally bars were baked at 175°C for 20-25 mins followed by packing in aluminium foil. Sesame flour was supplemented in different proportions (Table 1) with remaining ingredients like peanut flour, suji, coconut, sugar and oil kept constant and all compositions were utilized for the preparation of sesame flour supplemented bars.

Table 1: Experimental treatments used for sesame bars

Treatments	Supplementation of sesame flour (%)
T_0	0
T_1	25
T_2	50
T_3	75
T_4	100

Analysis and shelf life study of bars. Sesame flour supplemented bars prepared from all compositions were stored at room temperature (25-30 °C) and analysed for physicochemical, mineral profile, microbial examination, calorific value and sensory evaluation at 0, 30, 60, and 90 days storage interval and the results are summerized in Table 1-9.

Proximate analysis. Sesame flour supplemented food bars were analysed for moisture content, crude protein, crude fat, crude fibre, ash content and NFE according to respective methods given in AACC (2000).

Water activity. An electronic hygropalm water activity meter (Model Aw-Win, Rotronic, equipped with a Karl-Fast probe) was used for estimating the water activity of the sesame flour supplemented food bars at regular storage intervals. Hygropalm water activity meter was caliberated and sesame bars were analysed (AOAC, 1998).

Texture analysis. Texture of bars was determined at different storage intervals according to the method as described by Rehman and Al-Farsi (2005) with some modifications by using a texture analyser (Model TA-XT) plus Stable Microsystems (Surrey, UK) with 5 kg load cell.

Colour measurement. A hand held colorimeter tristimulus colorimeter (colour Test Meter II, Neohaus Neotec) was used to determine the colour of sesame flour supplemented food bars at regular storage intervals according to the method described by Rocha and Morais (2003).

Mineral profile. Samples of sesame bars were analysed for mineral profile according to the procedures given in AOAC (2006).

Mold growth. Mold growth was done according to the method as described in method 42-50 (AACC, 2000).

Calorific value. Calorific values of the bars were determined by using oxygen bomb calorimeter (IKA-WERKE, C2000 Basic) as described by Krishna and Ranjhan (1981).

Sensory evaluation. Sesame flour supplemented food bars were evaluated for sensory characteristics such as colour, flavour, texture, crispiness, chewability and overall acceptability at room temperature (i.e. 25-30°C) for a storage period of three months in a sensory evaluation laboratory by a panel of five judges on 9-point Hedonic scale (Meilgaard *et al.,* 2006).

Statistical analysis. The results obtained for each parameter were subjected to statistical analysis to determine the level of significance according to the methods described by Steel *et al.* (1997)

Results and Discussion

Raw materials analysis. *Proximate analysis.* Defatted sesame flour subjected to proximate composition (Table 2) indicated that it comprises of moisture 2.19 ± 0.02%, crude protein 51.5 ± 0.4%, crude fibre 3.45±0.03%, ash 6.14 ± 0.09%, crude fat 1.49 ± 0.03% and 45.56 ± 0.19 NFE. Onsaard *et al.* (2010) reported that defatted sesame flour contains moisture 2.19%, crude protein 50.45%, crude fibre 3.46%, ash 6.15%, crude fat 1.49% and NFE 45.56. These results were in conformity with the composition of defatted sesame flour assessed.

Peanuts (*Arachis hypogaea* L.) under proximate analysis showed moisture 4.5 ± 0.03%, crude fat 46.18 ± 0.13%, crude protein 30.59 ± 0.31%, crude fibre 3.87 ± 0.08%, ash 2.72 ± 0.21% and NFE 9.64 ± 0.27%. The earlier findings of Atasie *et al.* (2009) were found in accordance with the composition results who reported that peanut contains crude fat 45%, crude protein 36%, moisture 6.1%, crude fibre 3.25%, ash 2.9% and NFE 6.75%.

Chemical composition of semolina revealed that, it contains moisture 11.22 ± 0.06%, crude protein 13.86 ± 0.17%, crude fat 0.2 ± 0.01%, ash 0.82 ± 0.05%, crude fiber 0.7 ± 0.02% and NFE 73.2 ± 0.15%. The composition of semolina was found in concurrence with the earlier findings of Hussein *et al.* (2011), who reported that semolina contains moisture 12 %, crude protein 14%, crude fat 0.4%, ash 0.9%, crude fibre 0.6% and NFE 73.6%.

Mineral analysis. Defatted sesame flour subjected to mineral composition (Table 2) indicated that, it comprises of K (385 ± 0.3 mg/100g), Na (7.63 ± 0.9 mg/100g), Fe (6.19 ± 0.21 mg/100g) and Ca (20.3 ± 0.9 mg/ 100g). Hahm *et al*. (2009) reported that, defatted sesame flour contains K (382mg/100g), Na (7.60 mg/100g), Fe (6.17 mg/100g) and Ca (420 mg/ 100g). These results were in conformity with the composition of defatted sesame flour assessed.

Peanuts (*Arachis hypogaea* L.) under mineral analysis showed that, they contain K (38.5 ± 0.4 mg/100g), Na (22.6 ± 0.6 mg/100g), Fe (0.8 ± 0.03 mg/100g) and Ca (21.4 ± 0.72 mg/100g). Findings of Vincent *et al*. (2009) were in accordance with the composition results, who

Table 2: Proximate composition and mineral analysis of raw materials

Raw materials	Proximate composition (%)					
	Moisture	Protein	Fat	Fibre	Ash	NFE
Defatted sesame flour	2.19±0.02	51.5±0.4	1.49±0.03	3.46±0.03	6.15±0.09	45.56±0.19
Peanut flour	4.5±0.03	30.59±0.31	46.18±0.13	3.87±0.08	2.72±0.21	9.64±0.27
Semolina	11.22±0.06	13.86±0.17	0.2±0.01	0.7±0.02	0.82±0.05	73.2±0.15
Raw materials	Mineral profile (mg/100g)					
	Potassium (K)	Sodium (Na)	Iron (Fe)	Calcium (Ca)	-	-
Defatted Sesame flour	385±0.3	7.63±0.9	6.19±0.21	20.3±0.9	-	-
Peanut flour	38.5±0.4	22.6±0.6	0.8±0.03	21.4±0.72	-	-
Semolina	3.20±0.6	8.53±0.3	41.5±0.45	278±0.52	-	-

NFE = nitrogen free extract.

reported that peanut contains K (38.1 mg/100g), Na (22.0 mg/100g), Fe (0.78 mg/100g) and Ca (21.1 mg/ 100 g).

Mineral composition of semolina revealed that it contains, K (3.20 ± 0.6 mg/100g), Na (8.53 ± 0.3 mg/100g), Fe (41.5 ± 0.45 mg/100g) and Ca (278 ± 0.52 mg/ 100g). The mineral composition of semolina was found inaccordance with the earlier findings of Cubadda *et al*. (2009), accordance who reported that semolina contains K (3.18 mg/100g), Na (8.51 mg/100g), Fe (41.1 mg/100g) and Ca (276 mg/100g).

Moisture content. Moisture of the sesame bars was observed to be highly significant among the treatments. These formulations of sesame bars contained different concentrations of defatted sesame flours at regular storage intervals and ambient temperature were statistically analysed for moisture content ranging from 5.63 ± 0.02 to 3.65 ± 0.05% Table 3. The mean values for moisture content of various sesame bars treatments reveal the peak score for T_0 and the minimum score for T_4. During storage period, the moisture difference was significantly high as well. Having the highest moisture content at 0 day and gradually decreasing to 90 days where it was the lowest, the mean values for storage ranged from 4.73 ± 0.71 to 4.17 ± 0.56% (Table 4) similar to the results in water activity of the sesame bars. There was a steady decrease in moisture content with increasing concentration of defatted sesame flour in treatments. Decrease in the moisture of the sesame bars was vastly significant, possibly due to desertion of water from the products, as a result of two main factors i.e. increased temperature during the hot weather and exposure to the atmosphere at times. Analogous to the case in water activity, moisture content in the last two treatments T_3 and T_4 containing higher concentration of defatted sesame flour showed greater reduction in moisture as compared to treatments containing lower concentration of defatted sesame flour i.e. T_1 and T_2. It could be possible due to the presence of oil in T_3 and T_4 which does not have the tendency to hold water. Also there was highly significant effect of treatment and storage interaction on moisture contents of sesame bars. Outcomes of moisture fluctuations during storage for various treatments is in agreement with the results of Gandhi and Taimini (2009) that moisture content decreased significantly in cereal nut bars from 7.75-6.39% during storage of 30 days at ambient temperature. Results were contradictory to those of Estevez *et al*. (1998), who reported that moisture content remained similar i.e., 7.6-9.6% with no significant storage change in cereal nut bars during a storage period of 90 days at 18-20°C. Low temperature could be the possible reason for constant moisture content during the storage period.

Table 3: Effect of treatments on proximate composition and mineral profile of sesame bars

Treatments	Proximate analysis (%)					
	Moisture	Protein	Fat	Fibre	Ash	NFE
T_0	5.63±0.02 a	33.69± 0.12e	0.64±0.13 c	1.93±0.81 d	2.67±0.03 b	46.04±0.61 c
T_1	4.99±0.07 b	35.57±0.23d	0.61±0.08 d	1.86±0.71 e	2.13±0.08 e	44.85±0.53 e
T_2	4.53±0.04 c	35.73±0.15 c	0.61±0.09 d	2.14±0.07 c	2.44±0.03 d	46.04±0.43 c
T_3	3.73±0.09 d	35.90±0.17 b	0.77±0.11 b	2.34±0.21 b	2.62±0.09 c	46.93±0.27 b
T_4	3.65±0.05 d	36.19±0.23 a	0.97±0.05 a	2.54±0.31 a	3.43±0.11 a	49.17±0.21 a
	Mineral Profile (mg/100g)					
	Potassium	Sodium	Iron	Calcium		
T_0	384.48±9.21 d	46.46±0.52 c	10.22±0.04 a	61.59±2.34 b		
T_1	362.03±8.26 e	44.11±0.91 d	7.49±0.06 b	55.65±1.56 d		
T_2	486.75±5.41 c	38.20±0.74 e	7.90±0.06 b	52.86±3.56 e		
T_3	511.69±8.19 b	48.77±0.75 b	6.48±0.02 c	60.26±2.45 c		
T_4	555.96±6.53 a	51.28±0.48 a	5.35±0.08 d	67.27±1.78 a		

Means carrying same letters in a column for each factor do not differ significantly; NFC= nitrogen free extract; T_0= 0% supplementation of defatted sesame flour; T_1= 25% supplementation of defatted sesame flour; T_2= 50% supplementation of defatted sesame flour; T_3= 75% supplementation of defatted sesame flour; T_4= 100% supplemen-tation of defatted sesame flour.

Crude protein. Protein content differed significantly along the various treatments of the sesame bars according to the statistical results. Table 3 demonstrates the statistical analysis for protein content of different treatments of sesame bars containing assorted concentrations of defatted sesame flours at storage intervals (0, 30, 60 and 90 days). Mean values for protein contents of sesame bars samples ranged from 33.69 ± 0.12 to 36.19 ± 0.23 %, with T_0 having the least protein content and T_4 with the highest protein score. Gradual increase in protein contents with increasing concentrations of defatted sesame flour in treatments was evident from the results. The mean values for treatments also reveal that treatments T_3 and T_4 have significantly higher protein content due to increased quantity of defatted sesame flour used. A non significant effect of storage on protein contents of sesame bars was calculated by the mean values for storage ranged from 35.35 ± 0.65 to 35.48 ± 0.24 % during 90 days storage period as illustrated in Table 4. There were non-significant effect of treatment and storage interaction on protein contents of sesame bars.

Variation in protein content during storage for various treatments is in conformity with the findings of Khalil (1986), who reported that in sesame bars fortified with almonds, skim milk powder, soy protein isolate and single cell proteins, protein content was increased from 4.9-5.3% in the control to 10.7-12.1% in samples containing the high protein ingredients. These supplemented sesame bars not only increased protein content but also possess significantly higher chemical scores and essential amino acids. The protein content changed non-significantly in legume and vegetable based soup powder from 19.35%-19.45% according to Rokhshana *et al*. (2007) during storage of 6 months. Protein results obtained in the present study are compatible with these findings.

Crude fat. Different treatments of sesame bars containing varied concentrations of defatted sesame flour at regular storage intervals at ambient temperature were statistically analysed for fat content and are presented in Table 3. The results in the variation in fat content among different treatments are highly significant. Treatment T_4 had the maximum score where as T_0 having the least score was deducted by the mean values for treatments which ranged from 0.64 ± 0.13-0.97 ± 0.05 %. The mean value for fat contents of sesame bars samples have been presented in Table 3. Evidently from the results, it is affirmed that there was a gradual increase in fat contents with increasing concentration of defatted sesame flours in all the treatments but obviously T_3 and T_4 had more fat content due to the manual inclusion of fat in them used for frying. There was highly significant effect of storage days on fat contents of sesame bars where the mean values ranged from 0.63 ± 0.03 to 0.77 ± 0.03% in Table 4. There was highly significant effect of treatment and storage interaction on fat contents of sesame bars. Similar findings were obtained by Goni and Gamazo (2002) who reported that fat content increased from 1.81-2.60% in wheat pasta after incorporation of chickpea flour in it.

Table 4: Effect of storage on the proximate and mineral profile of sesame bars

Storage intervals	Proximate analysis (%)					
	Moisture	Protein	Fat	Fibre	Ash	NFE
S_0	4.73±0.71 a	35.35±0.65 d	0.63±0.03 d	2.09±0.92 d	2.49±0.72 d	46.01±3.12 d
S_{30}	4.63±0.67 ab	35.40±0.24 c	0.67±0.03 c	2.15±0.78 c	2.65±0.91 c	46.36±2.15 c
S_{60}	4.52±0.24 b	35.44±0.45 b	0.71±0.06 b	2.20±0.82 b	2.73±0.76 b	46.76±4.63 b
S_{90}	4.17±0.56 c	35.48±0.24a a	0.77±0.03 a	2.24±0.56 a	2.79±0.34 a	47.07±2.96 a
	Mineral Profile (mg/100g)					
	Potassium	Sodium	Iron	Calcium		
S_0	459.59±14.24 c	45.69±3.93 d	8.09±0.72 a	59.45±3.67 d		
S_{30}	459.74±18.96 c	45.74±1.46 c	8.01±0.56 a	59.50±1.95 c		
S_{60}	460.47±15.78 b	45.79±2.56 b	6.46±0.73 c	59.56±2.83 b		
S_{90}	460.93±17.93 a	45.85±3.72 a	7.42±0.92 b	59.62±1.57 a		

Means carrying same letters in a column for each factor do not differ significantly; NFE = nitrogen free extract; S_0 = 0 day; S_{30} = 30 days; S_{60} = 60 days; S_{90} = 90 days.

Crude fibre. Fibre content differentiation was highly significant among various treatments of the sesame bars according to the statistical results. Table 3 demonstrates the statistical analysis for fibre content of different treatments of sesame bars containing assorted concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days). The mean values of fibre contents for treatments, ranged from 1.93 ± 0.81 to 2.54 ± 0.31% having the lowest score for T_0 and the highest score in case of T_4. There was a gradual increase in fibre contents with increasing concentrations of defatted sesame flour in treatments according to the results. Treatments T_3 and T_4 (2.34 ± 0.21 and 2.54 ± 0.31%) due to increased quantity of defatted sesame flour, showed higher results of fibre percentage as compared to T_1 and T_2 (1.93 ± 0.81 and 1.86 ± 0.71). Higher dry matter in the sesame bars was seen by the mean values of fibre contents for storage periods ranged from 2.09 ± 0.92 to 2.24 ± 0.56% from 0 to 90 days in Table 4. There was significant effect of treatment and storage interaction on fibre content of sesame bars. The change of fibre during storage for various treatments is in conformity with the findings of Rokhsana *et al*. (2007) who reported that fibre content changed non-significantly in legume and vegetable based soup powder from 0.65-0.70% during storage of 6 months.

Ash content. The analysis of variance for ash contents of different treatments of sesame bars containing varied concentrations of defatted sesame flours at regular intervals showed that the difference in ash contents among different treatments is highly significant (Table 3). The mean values of ash contents for treatments ranged from 2.67 ± 0.03 to 3.43 ± 0.11% having the lowest ash contents for T_0 and the highest ash content in T_4. There was a gradual increase in ash contents with increasing concentrations of defatted sesame flour in treatments and results show that treatments T_3 and T_4, due to increased quantity of defatted sesame flour, showed higher results of ash percentage (2.62±0.03 to 3.43 ± 0.11%) as compared to T_1 and T_2 (2.13±0.08 to 2.44 ± 0.03%) as depicted in Table 3. This could also be due to higher dry matter in the sesame bars of T_3 and T_4. Regarding the dry matter i.e. defatted sesame flour in the sesame bars, ash content is directly related to the fibre content of the sesame bars. There was a highly significant effect of storage days on ash contents of sesame bars. The mean values of ash contents for storage period ranged from 2.49 ± 0.72 to 2.79 ± 0.34% for 0 to 90 days (Table 4). There was a highly significant effect of treatment and storage interaction on ash contents of sesame bars. Results are also in accordance with Gandhi and Taimini (2009) who reported that ash contents were not affected by storage conditions in sesame bars.

Nitrogen free extract (NFE). The data presented in Table 3 showed that NFE among treatments and during storage were highly significant. The interaction of treatment and storage was also highly significant. In Table 3 the mean values of NFE of different treatments showed that minimum NFE was found in T_0 that was 46.04 ± 0.61 and maximum was found in T_4 which was 49.17 ± 0.21. The mean values of NFE contents of supplemented flour showed in Table 4 at 0, 30, 60 and 90 days interval were 46.01 ± 3.12, 46.36 ± 2.15, 46.76 ± 4.63 and 47.07 ± 2.96. The interaction of storage period into treatments showed that the highest NFE value 49.17 ± 0.21 was found in T_4 and the lowest NFE value 46.04 ± 0.61 was observed in T_0 at 90 days of storage period. With the passage of time NFE increased significantly. This is due to increase in fat and protein content. The increasing trend in flours during storage is also observed by Gandhi and Taimini (2009).

Physical characteristics of sesame bars. ***Water activity.*** Water activity fluctuated significant during storage days, ranging the mean values from 0.53 ± 0.08 to 0.49 ± 0.67 for 0 to 90 days, respectively, in Table 7. Water activity among all the treatments naturally decreased due to the decrease in moisture content during storage, as a result of high temperature in the summer. Comparing the defatted sesame flour treatments T_3 and T_4 (0.46 and 0.43) with treatments T_0 and T_1 (0.60 and 0.55), possibly reveal that T_3 and T_4 have lower water activity because of inclusion of vegetable oil in the treatments which could be helpful in binding the water present in the sesame bars. There was a highly significant effect of treatment and storage interaction on water activity of defatted sesame flour bars.

During storage the variation of water activity in various treatments is in compliance with the findings of Estevez *et al*. (1998) in the cereal and nut bars, who informed that water activity significantly reduced in the bars from 0.71-0.52 during storage of 60 days. Similar results were obtained in Amaretti cookies by Piga *et al*. (2005) who reported water activity 0.54 at the start which progressively decreased to 0.40 after storage of 35 days at ambient temperature.

Texture. Two properties of texture were observed i.e., initially hardness of the bars which is described in terms of the maximum force (g) and fracturability in terms of distance (mm) necessary for the texture analyzer probe to travel through the bars. Reflecting significant differences in the hardness and fracturability of the various sesame bars, the statistical analysis of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) are given in Table 7. The mean values of hardness for treatments ranged from 966.86-211.48 g, having the lowest mark for T_0 and the maximum mark in case of T_4 (Table 7) and fracturability ranged from 70.41-100.33 mm having the least score for T_0 and the highest rank in case of T_4. Increasing concentrations of defatted sesame flour in various treatments apparently resulted in a gradual increase in hardness and fracturability. Hardness of sesame bars increased from 0-30 days progressively. This trend gradually decreased from 60-90 days thereby, decreasing hardness. On the other hand fracturability increased in smooth way from 0-90 days and a relationship with hardness was observed, concluding a highly significant effect of storage days on texture of sesame bars. In general, this might be due to the moisture loss to the atmosphere from the sesame bars but treatments T_3 and T_4 were harder in texture due to cooking treatment which hardened the texture due to excess moisture loss. Thereby, there was a highly significant effect of treatment and storage on hardness and fracturability of sesame bars. The variation of texture during storage for various treatments is in conformity with the hardness that significantly changed rather decreased in Amaretti cookies from 59-383 N during storage of 35 days (Piga *et al*., 2005).

Colour measurement. At regular storage intervals (0, 30, 60 and 90 days) under ambient temperature, the colour values of various treatments of sesame bars containing different concentrations of defatted sesame flour were statistically analysed and are given in Table 7. The observed results obviously reveal that the differences in colour values are highly significant amongst different treatments. The treatment T_0 having the lowest score and the highest score in case of T_4 were increased from the range of mean values of colour from 87.00-180.00 CTn in the treatments. The means for colour values of sesame bars samples have been presented in Table 7. Results apparently show that there was a continual increase in colour values with increased concentrations of defatted sesame flour addition in the bars i.e., greater the amount of defatted sesame flour, higher the colour value. The mean values for storage phase ranged from 125.60 ± 6.21 to 155.60 ± 7.23 CTn for 0-90 days, respectively, showing that there was a highly significant effect of storage on colour of sesame bars as shown in Table 7. The treatments T_3 and T_4 containing greater amounts of defatted sesame flour have significantly higher colour values 141.00-180.00 CTn as compared to T_0 and T_1 containing lesser amount of depatted sesame flour therefore, having lower colour values 87.00-143.00 CTn, which is due to the increase in the quantity of defatted sesame flour used in T_3 and T_4. The results of treatment and storage periods interaction on colour of sesame bars is non-significant. The colour of the bars during storage could be influenced by the Maillard reactions, leading to darken the sesame bars with the passage of time.

Comparing the results with the earlier deductions illustrate that the alteration of colour during storage for various treatments is in conformity with the findings of McMahon *et al*. (2002) who reported that during storage period of 42 days colour changed significantly in high whey protein nutritious bars from 54.73 to 70.30, as the bars became darken in colour during storage depending upon the Maillard reactants.

Mineral profile of sesame bars. *Potassium content.* Potassium is an important intracellular cation in the body that plays a vital role in the maintenance of energy metabolism, cell membrane potential and membrane transport of other ions. Because of its role in these processes, optimum potassium intake is vital for the contraction of muscle groups such as the heart.

Potassium content difference was highly significant amongst several treatments on statistical analysis for potassium content of the sesame bars treatments containing different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) as shown in Table 3. The mean values for treatments in Table 3 ranged from 384.48 ± 9.21 mg/100g having the least potassium content for T_0 to 555.96 ± 6.53 mg/100g the highest potassium content in case of T_4. Results reveal that there was a gradual increase in potassium content with increasing concentrations of defatted sesame flour among treatments and T_3 and T_4 have a greater potassium content score (511.69 ± 8.19 and 555.96 ± 6.53 mg/100g) as compared to T_0 and T_1 (384.48 ± 9.21 and 362.03 ± 8.26 mg/100g). A highly significant effect of storage on potassium content of sesame bars was observed by the mean values for storage ranged from 459.59 ± 14.24 to 460.93 ± 17.93 mg/100g from 0 to 90 days, respectively, in Table 4. Effect of treatment and storage interaction on potassium content of the sesame bars was non-significant, more likely due to its metabolizing disability, which in turn shows no alteration in the potassium content during storage. Change in potassium content during storage for various treatments is in conformity with the findings of (Ismail *et al*., 2008) who reported that potassium content changed non-significantly in cereal and nuts bars during 1 year storage period at room temperature.

Sodium content. Sodium content of different treatments of sesame bars when subjected to statistical analysis reveals a highly significant effect of these treatments on the sodium content of these bars containing different concentrations of defatted sesame flour at ambient temperature at regular storage intervals (0, 30, 60 and 90 days). It is elaborated in Table 3 along with the mean values of sodium content for treatments that the maximum marks 51.28 ± 0.48 mg/100g is in case of T_4 and the least score 46.46 ± 0.52 mg/100g is for T_0. Results reveal that with increasing concentrations of defatted sesame flour among treatments, there was a steady increase in sodium content. The mean values for storage ranging from 45.69 ± 3.93 to 45.84 ± 3.72 mg/100g from 0-90 days, respectively, showed highly significant effect of storage on sodium content of sesame bar in Table 4. Also the effect of treatment and storage interaction on sodium content of sesame bars was significant. The results are in accordance with Ismail *et al.* (2008) that treatments and storage interaction are highly significant.

Iron content. Iron is an essential element and its physiological losses must be compensated regularly (Yip and Dallman, 1996). Iron content difference was highly significant on statistical analysis of various treatments of sesame bars containing different concentrations of defatted sesame flour at storage intervals (0, 30. 60 and 90 days) at ambient temperature. Table 3 elaborates the mean values of iron content for treatments ranging from the highest score 10.22 ± 0.04 mg/100 g in case of T_0 and the lowest score 5.35 ± 0.08 mg/100 g for T_4. A highly significant effect of storage on iron content of sesame bars was observed by the mean values for storage ranging from 8.09 ± 0.72 to7.42 ± 0.92 mg/100 g at 0-90 days, respectively (Table 4). Effect of treatment and storage interaction on iron content was also highly significant. The iron content changed significantly in legume and vegetable based soup powder from 26.75-25.77 mg/100 g during 6 months storage period at room temperature in the findings of Rokhsana *et al*. (2007) which happen to be similar to the iron content variations in the sesame bars during storage.

Calcium content. Calcium content varied highly significant amongst the various treatments in conclusion to the statistical analysis different treatments of sesame bars containing varied concentrations of defatted sesame flour as illustrated in Table 3, at regular storage intervals (0, 30, 60 and 90 days). Table 3 presents the mean values of calcium content for treatments ranging from 61.59 ± 2.34 to 67.27 ± 1.78 mg/100 g, having the lowest calcium content for T_0 and the highest in case of T_4. A gradual increase in calcium content, owing to increasing concentrations of defatted sesame flour among treatments is evident from the results. The mean values for storage ranged from 59.45 ± 3.67 to 59.62 ± 1.57mg/100 g from 0-90 days, respectively, in Table 4. There was highly significant effect of storage and significant effect of treatment-storage interaction on calcium content of sesame bar. Calcium content changed during storage for sesame bars treatments is in conformity with the findings of Rokhsana *et al*. (2007) who reported that calcium content changed non-significantly in legume and vegetable based soup powder from 65.193-69.103mg/100g sample during 6 months storage at room temperature.

Mold growth. With reference to the statistical analysis in Table 5, results obviously demonstrate that highly significant differences were observed in the mold count of various treatments of sesame bars with different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) at room temperature. As presented in Table 5, the highest mean values of mold count was 7.63×10^2 ± 3.6 CFU/g for T_4 and the least was 3.275×10^2 ± 2.76 CFU/g for T_0. The results show that an increase in mold count was not related to increasing concentrations of defatted sesame flour in treatments T_3 and T_4 show higher mold growth (3.160 and 3.600×10^2) as compared to treatments T_0 and T_1 (3.275×10^2 ± 2.76 and 6.65×10^2 ± 2.99) . This can possibly be due to the cooking treatment in T_0 and T_1 which undoubtedly perishes the mold present up to an extent. Highly significant effect of storage and storage treatment interaction on mold count of sesame bars are deducted from the mean values for storage change periodically from $0.282\text{-}7.065\times10^2$ ± 0.02 CFU/g at 0 and 90 days, respectively. Thereby increased the mold growth significantly during storage for 3 months at ambient temperature but within tolerable limitations.

Table 5: Effect of treatments and storage on mold count (CFU/g) of sesame bars

Treatments	Mold count (CFU/g) storage intervals				Means
	S_0	S_{30}	S_{60}	S_{90}	
T_0	0.28±0.02	0.95±0.04	4.91±0.34	6.95±0.13	3.27±2.76 d
T_1	0.22±0.04	0.50±0.06	4.61±0.12	6.65±0.42	6.65±2.99 c
T_2	0.41±0.03	1.51±0.02	5.13±0.24	7.14±0.31	3.55±2.71 e
T_3	0.11±0.02	0.65±0.04	4.93±0.31	6.94±0.17	6.94±2.87 b
T_4	0.38±0.01	0.79±0.07	5.59±0.42	7.63±0.24	7.63±3.6 a
Means	0.28±0.11 c	0.88±0.35 c	5.03±0.32 b	7.06±0.32 a	

Means carrying same letters in the column do not differ significantly; Means carrying same letters in the row do not differ significantly; CFU = colony forming unit.

The varied increase in mold growth during storage for different treatments is in consistency with the findings of Al-Hooti *et al*. (1997b), who accounted that mold growth increased significantly in all treatments during 6 months storage ranging from 2.60-3.00×10^2 CFU/g of sesame bar samples.

Calorific value. With reference to the statistical analysis in Table 6, results obviously demonstrate that highly significant differences were observed in the calorific value of various treatments of sesame bars with different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) at room temperature. The highest mean value of gross energy was 5355.5 ± 336.9 Kcal/g for T_4 and the least was 3445.9±312.4 Kcal/g for T_0 (Table 6). The results gives the evidence that an increase in calorific value was not related to increasing concentrations of defatted sesame flour in treatments T_3 and T_4 (4488.2±207.6 Kcal/g and 5355.5±336.9 Kcal/g) show higher gross energy as compared to treatments T_0 and T_1 (3445.9±312.4 Kcal/g and 3602.4±291.3 Kcal/g). Highly significant effect of storage and storage-treatment interaction on gross energy of sesame bars are deducted from the mean values for storage change periodically from 3813.0±691.2 Kcal/g to 4484.7±725.6 Kcal/g at 0 and 90 days, respectively. Increase in gross energy, is thereby highly significant, during storage for 3 months at ambient temperature. Results are in accordance with Gandhi and Taimini (2009) who reported that gross energy increased in storage conditions in sesame bars.

Sensory evaluation of sesame bars. Sensory evaluation happens to be the most essential part of the product development and assessment, which reveals the consumer preferences at the initial stages of developing an innovative product like the defatted sesame flour supplemented food bars. It was carried out to evaluate the response of judges towards the product and their likings were recorded on a hedonic scale. Sesame bars were assessed for colour, flavour, texture, crispiness, chewability and overall acceptability during 90 days of storage periods after every 30 days interval.

Colour. Colour reveals the first impression of a food product before consumed. It is the first score of a likeable and disliked food commodity. Results depict that the

Table 6: Effect of treatments and storage on calorific value of sesame bars

Treatments	Energy value (Kcal/g) storage intervals				Means
	S_0	S_{30}	S_{60}	S_{90}	
T_0	3059.4±54.12	3265.6±38.72	3574.5±27.24	3884.3±30.67	3445.9±312.4 e
T_1	3221.7±36.85	3444.9±32.92	3760.1±29.86	3983.0±52.49	3602.4±291.3 d
T_2	3611.6±48.92	3732.8±29.85	3848.9±31.76	3990.1±42.24	3795.8±140.0 c
T_3	4243.2±62.06	4353.0±31.67	4573.7±41.34	4782.8±30.82	4488.2±207.6 b
T_4	4929.1±49.92	5143.5±29.34	5565.7±43.97	5783.6±28.78	5355.5±336.9 a
Means	3813±691.2 d	3988±685.6 c	4264.6±733.7 b	4484.7±725.6 a	

Means carrying same letters in the column do not differ significantly; Means carrying same letters in the row do not differ significantly.

colour score differed highly significant among different treatments. These treatments of sesame bars containing varied concentrations of defatted sesame flours at regular intervals of storage (0, 30, 60 and 90 days) at ambient temperature were statistically analysed for colour evaluation as shown in Table 8. The results pertaining to mean score for the sesame bars in Table 8 revealed that T_2 (7.85 ± 0.13) was most preferred by judges regarding colour followed by T_1 (6.32 ± 0.14). This could be due to the acceptable range of defatted sesame flour addition in the two treatments. Though remaining treatments got fewer score, yet they were acceptable having a reduced colour score in T_0 (5.63 ± 0.17) and T_4 (5.40 ± 0.12), a highly significant effect of storage on colour score of sesame bars. Communally, it was observed that sesame bars were more readily accepted having the maximum scores which were decreased from 5.92 ± 0.92 to 6.58 ± 0.35 after 90 days storage (Table 9). The decrease in colour score might possibly be due to non enzymatic browning within storage period. There was a highly significant effect of treatment and storage interaction on colour score of sesame bars. A decrease in colour score from 6.8-6.2 during storage of 6 months in sesame bars was recounted by Al-Hooti *et al.* (1997b), whose findings were in concurrence with the changes in colour of sesame bars during their storage period. The colour of sesame bars significantly affected by storage periods, according to Ahmed and Ramswamy (2005). They illustrated that colour score varied from 6.6-6.2 during storage of 6 months at ambient temperature.

Flavour. Flavour is combination of taste and aroma which as a matter of fact compiles the acceptability of food product under a single sensory attribute. Flavour differed highly significant amongst different treatments on their statistical analysis as shown in Table 8, containing different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days). The results concerning to mean score for the sesame bars presented in Table 8, revealed that T_2 (8.40 ± 0.47) was favoured by the panel of judges among the sesame bars treatments, followed by T_0 (6.25 ± 0.82) regarding flavour. This could be due to the satisfactory proportions of defatted sesame flour in the two treatments. Though remaining treatments got fewer score, yet they were acceptable having a reduced flavour score in T_1 (5.37 ± 0.72) and T_4 (5.4 ± 0.12). There was a highly significant effect of storage and significant effect of treatment-storage interaction on flavour of sesame bars. Collectively, the highest scores were observed in fresh sesame bars that gradually increased from 5.82 ± 0.53 to 6.56 ± 0.43 after 90 days storage presented in Table 9. A decrease in flavour from 6.8-6.3 storage of 6 months in sesame bars was observed by Al-Hooti *et al.* (1997b) which was in accordance to the change of flavour during

Table 7: Effect of storage on physical analysis of sesame bars

Storage intervals	Sensory evaluation parameters			
	Water activity (Aw)	Hardness (g)	Fracturability (mm)	Colour (CTn)
S_0	0.5363±0.08 a	645.17±15.58 a	76.707±3.21 d	125.60±6.21 d
S_{30}	0.5315±0.03 b	517.80±20.14 b	85.487±3.53 c	135.60±5.93 c
S_{60}	0.5013±0.75 c	407.74±18.93 c	89.765±6.21 b	145.60±2.56 b
S_{90}	0.4905±0.67 d	388.14±22.12 d	99.223±2.86 a	155.60±7.23 a

Means carrying same letters in a column for each factor do not differ significantly.

Table 8: Effect of treatments on sensory evaluation of sesame bars

Treatment	Sensory evaluation parameters					
	Colour	Flavour	Texture	Crispiness	Chewability	Overall acceptability
T_0	5.63±0.17 d	6.25±0.82 b	5.38±0.09 e	5.91±0.45 d	5.62±0.23 b	5.80±0.24 d
T_1	6.32±0.14 b	5.37±0.72 d	6.40±0.03 b	6.36±0.36 c	5.50 ±0.13cd	6.40±0.23 b
T_2	7.85 ±0.13a	8.40±0.47 a	7.67±0.05 a	7.92±0.25 a	8.42±0.72 a	7.93±0.12 a
T_3	6.07±0.18 c	5.60±0.13 c	5.50±0.07 d	6.55±0.43 b	5.45±0.23 d	5.95±0.82 c
T_4	5.40±0.12 e	5.37±0.09 d	5.65±0.04 c	5.70±0.28 e	5.57±0.23 bc	5.32±0.64 e

Means carrying same letters in a column for each factor do not differ significantly

Table 9: Effect of storage on sensory evaluation of sesame bars

Storage intervals	Sensory evaluation parameters					
	Colour	Flavour	Texture	Crispiness	Chewability	Overall acceptability
S_0	5.92±0.92 d	5.82±0.53 d	5.72±0.21 d	6.10±0.72 d	5.83±0.67 d	5.96±0.27 d
S_{30}	6.14±0.83 c	6.10±0.32 c	6.00±0.92 c	6.35±0.66 c	6.01±0.54 c	6.16±0.51 c
S_{60}	6.38±0.43 b	6.32±0.46 b	6.24±0.25 b	6.63±0.87 b	6.25±0.24 b	6.40±0.72 b
S_{90}	6.58±0.35 a	6.56±0.43 a	6.52±0.92 a	6.88±0.44 a	6.36±0.33 a	6.60±0.45 a

Means carrying same letters in a column for each factor do not differ significantly

storage of various sesame bars samples. (Ahmad and Ramaswany, 2005) reported that storage periods have significant effect on flavour of fruit bars. It was recorded that, flavour acceptability varied from 7.1-6.9 during storage at ambient temperature.

Texture. Texture of sesame bars when statistically analysed, showed highly significant difference amongst different treatments containing different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) at ambient temperature signified in (Table 8). The mean score findings for texture of the sesame bars given in Table 8 revealed that T_2 (7.67 ± 0.05) was favoured by the judges followed by T_1 (6.40 ± 0.03), which could probably be owing to increased amount of defatted sesame flour in a greater quantity in T_2 and T_1 has given a better compact texture to the sesame bars which may be due to lesser moisture content in the treatments as compared to the T_3 and T_4. Significant texture rating in T_3 (5.50 ± 0.07) and T_4 (5.65 ± 0.04) were collected but they were favourably within satisfactory confines. There was a highly significant effect of storage on texture of sesame bars as well. In general, the maximum scores observed have been presented in Table 9, fresh sesame bars but highly significant effect on storage thus gradually increased them from 5.72 ± 0.21 to 6.52 ± 0.92. There was non-significant effect of treatment and storage interaction on texture of sesame bars. A significant decrease in texture from 6.9-5.9 during storage of 6 months was reported by Al-Hooti *et al.,* (1997b) which happened to be in conformity with variations in the texture of the sesame bars.

Crispiness. Crispiness of sesame bars when statistically analysed showed highly significant difference amongst different treatments containing different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) at ambient temperature signified in Table 8. The mean score findings for texture of the sesame bars in Table 8 reveal that T_2 (7.92 ± 0.25) was favored by the judges followed by T_3 (6.55 ± 0.43), which could probably be owing to increased amount of defatted sesame flour in a greater quantity in T_2 and T_3 has given a better compact crispiness (7.92±0.25 and 6.55±0.43) to the sesame bars which may be due to lesser moisture content in the treatments as compared to the T_1 and T_4 (6.36 ± 0.36 and 5.70 ± 0.28). Significant crispiness rating in T_1 (6.36 ± 0.36) and T_4 (5.70 ± 0.28) were collected but they were favourably within satisfactory confines. There was a significant effect of storage on crispiness of sesame bars as well. In general, the maximum scores were observed in fresh sesame bars but highly significant effect on storage thus gradually increased them from 6.10±0.72 to 6.88±0.44 (Table 9). There was non-significant effect of treatment and storage interaction on crispiness of sesame bars. A significant increase in crispiness from 5.5-6.7 during storage of 6 months was reported by Al-Hooti *et al.* (1997b) which happened to be in conformity with variations in the crispiness of the sesame bars.

Chewability. Chewability of sesame bars when statistically analyzed showed highly significant difference amongst different treatments containing different concentrations of defatted sesame flour at storage intervals (0, 30, 60 and 90 days) at ambient temperature signified as in Table 8. The mean score findings for texture of the sesame bar in Table 8 reveal that, T_2 (8.42 ± 0.72) was favuored by the judges followed by T_0 (5.62 ± 0.23), which could probably be owing to increased amount of defatted sesame flour in T_2 and T_0 (8.42 ± 0.72 and 5.62±0.23) has resulted a compact chewability to the sesame bars due to lower moisture content in the treatments as compared to the T_1 and T_4 (5.50±0.13 and 5.57±0.23). Significant chewability rating in T_1 (5.50±0.13) and T_4 (5.57 ± 0.23) were collected but they were favourably within satisfactory confines. There was a highly significant effect of storage on chewability of sesame bars as well. In general, the maximum scores were observed in Table 9, fresh sesame bars but highly significant effect on storage resulted from 5.83 ± 0.67-6.36 ± 0.33. There was significant effect of treatment and storage interaction on overall acceptability of sesame bars.

The findings of Al-Hooti *et al.* (1997b), showed significant increases in chewability of sesame bars from 6.2-6.9 during storage of 6 month. The results are in accordance with the alteration of chewability during storage for various sesame bar treatments.

Overall acceptability of sesame bars. The quality scores obtained from the evaluation of colour, flavour, texture, crispiness, chewability and overall acceptability, whose statistical analysis at storage intervals (0, 30, 60 and 90 days) is illustrated in Table 8. Results reveal that the overall acceptability differed highly significant among different treatments. The results related to mean score for the sesame bar in Table 8 revealed that T_2 (7.93 ± 0.12) was preferred by the judges followed by T_1 (5.80 ± 0.24) regarding overall acceptability. This could be due to the acceptable range of defatted sesame flour addition in the two treatments. Though having a reduced score in T_3 (5.95 ± 0.82) and T_4 (5.32 ± 0.64) resulted in greater acceptability of the sesame bars. There was a highly significant effect of storage on overall acceptability of sesame bars. Collectively, the maximum scores were observed in Table 9 fresh bars that gradually increased from 5.96 ± 0.27 to 6.60 ± 0.45 after 90 days storage. There was non-significant effect of treatment and storage interaction on overall acceptability of the sesame bars. The findings of Al-Hooti *et al.* (1997a) who reported significant increase in overall acceptability of sesame bars from 6.9 to 7.9 during storage of 6 months are in accordance with the alteration of overall acceptability during storage for various sesame bars treatments.

Conclusion

Protein energy malnutrition can be overcomed by the provision of healthy, tasty, convenient and nutritious sesame snack bars. In the current scenario, development of nutritious bars is a good substitute to other junk foods. Sesame snack bars have great market potential to boost up energy and maintain performance by providing minerals, vitamins, fat, protein and carbohydrates. Sesame supplemented bar can be used for the school nutrition programmes to uplift the nutritional status of the school going children.

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