Characterization of peanut seed oil of selected varieties and its application in the cereal-based product

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Abstract Peanut (*Arachis hypogaea*) is an important oil-seed crop of the world. Peanut seed oil (PSO) contains linolenic acid, oleic acid, also a good source of omega-6 fatty acids and omega-3 fatty acids. It contains an abundant amount of vitamin E which also act as an antioxidant. The research work was carried out to estimate the suitability of utilization of peanut oil from different available peanut varieties, i.e., Bari 2001, Bari 2011 in cereal-based products. The main objective of the study is the characterization of peanut seed oil acquired from Bari 2001 and 2011

variety, and explored its application in cookies and shelf life of the product. The purpose of the study is to determine the oil contents and characterization, its application in cookies and shelf life of the product. The data thus collected was analyzed by applying standard statistical procedures. Peroxide, saponification, and free fatty acids in Bari 2001 and Bari 2011 were 1.51 ± 0.09 meq O₂/kg and 1.47 ± 0.07 meq O₂/kg, 195.81 ± 2.47 mgKOH/g and 191.60 ± 2.66 mgKOH/g and $0.96 \pm 0.07\%$ and $0.91 \pm 0.04\%$ respectively. Cookies were prepared by incorporating PSO oil (Bari 2011) at concentrations of 5% (FC₁), 10% (FC₂), 15% (FC₃), 20% (FC₄), 25% (FC₅) and along with control (FC₀). Storage study (60 days) assessed the quality, sensory evaluation and oxidative stability of products in order of most suitable to least accepted as FC₃ > FC₄ > FC₅ > FC₁ > FC₂ > FC₀. The cookies produced by 15% replacement peanut seed oil resulted in an acceptable product.

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Introduction

Peanut (*Arachis hypogaea*), a leguminous crop, belongs to a family (Fabaceae). It's also known as the many other local names such as earthnuts, groundnuts, goober, monkey nuts, peas and pygmy nuts (Seijo et al. 2007). Peanut seeds also contain 44–56% oil and 22–30% protein on dry seed basis (Hassan and Ahmed 2012). It's predominantly perceived as a valuable source in relation to edible-oil along with protein source as left-over peanut meal or peanut cake so therefore considered to be vastly beneficial and nutritious in the human and animal diet. It is also a good source

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of antioxidants, such as p-coumaric acid, that contributed to health gain (Talcott et al. 2005; Duncan et al. 2006).

Peanut is also the most attractive and impressive oilseed crop throughout the world, possess different bio-constituents. Among this protein, oil (linoleic acid and oleic acid, also a valuable source of omega-6 fatty acids and vital amount of omega-3 fatty acids) and vitamin E (α -tocopherol) are the most important. Because they act as an antioxidant to delay the ageing process. Peanut oil contains tocopherol (α , β , γ , δ , etc. tocopherol) and pantothenate. The alpha-tocopherol, biologically and chemically the most effective type of vitamin E and the dominant lipid-soluble antioxidant (Adewale et al. 2016).

Fats and oils from the vegetable origin are generally used for the edible purpose and also used for animal feed and medicinal purpose. These are affluent energy source; having fatty acids, antioxidants-, antifoaming and anti-surfactant agents. Vegetable oils exhibit vital functionality and sensorial significance among food products by acting as a transportation medium for fat-soluble vitamins (A, D, E and K) (Adewale et al. 2016). Also, the aim for extending the shelf life of food items, supplementation of antioxidants in food products, especially in fat products is commonly approved technique.

Peanut seeds, besides being a low-cost product, are an excellent source of nutrients, since it contains a very high proportion of mono and polyunsaturated fatty acids. Peanut seed contains oleic acid (C18:1), linolenic acid (C18:2), proteins, carbohydrates, minerals, vitamins and many of the bioactive compounds that occur in peanuts are present with the oil fraction. It contains tocopherols, phytosterols and may different flavonoids including quercetin. Peanut is a good source of bioactive compounds with allied health benefits (Firestone 2013). Fatty acids are very important for a healthy human life, such as transporting the oxygen in the body, important for the development of cell membranes prevent cholesterol blockage in the arteries, prevent the early ageing process and keep the skin healthy (Mzimhiri et al. 2014).

Edible oils from vegetable or plant sources become more prevalent in various food and application industries. They provide attribute like flavor and texture to the food (Odoemelam 2005). The distinct taste and flavor of foods containing peanut are important in acceptance for different food preparations (Asibuo et al. 2008). Peanuts and tree nuts consumption was analyzed by clinical studies and verified useful effects on lipoproteins and lipids as they decrease the level of total cholesterol and cholesterol of low-density lipoprotein as well as triglycerides. Presence of essential fatty acids, bioactive compounds and other nutrients in peanut reflects its health benefits and importance in the diet (Griel et al. 2004).

Recent advancements in the field of food and nutrition focus on the consumption of functional foods as it has already become the largest eating adaptation of twenty-first century (Gibson et al. 2004; Schwager et al. 2008; Suh et al. 2013). The health-boosting and preventive disease aspects of these foods are mainly related due to their non-nutritive components. These bioactive components of different foods include essential oils, catechins, flavonoids, polyphenols, anthocyanin and fibers etc. (Hanf and Gonder 2005). Since peanut has the potential for health benefits and its use has increased in the developing countries. It is important to develop peanut processing into other valuable and consumable products.

Keeping in view the consideration, this study is intended to characterize the peanut seed oil of selected peanut varieties and evaluate its antioxidant properties to enhance the shelf stability and sensory attributes of prepared cookies and also examine consumer acceptability and storage stability of prepared cookies.

Materials and methods

Raw material

The two varieties of peanut seeds BARI 2001 and BARI 2011 were procured. While chemicals and standards used for the proposed study were purchased from Sigma-Aldrich Co (St. Louis, MO, USA). Ingredients for the preparation of cookies (flour, sugar and eggs etc) and packaging material were purchased from the local market.

Sample preparation

Peanut seeds were obtained after removing the shells. Peanut seeds were dried and converted into powder form to facilitate the oil extraction process by Soxhlet extraction. The powder was stored in polyethylene bags at 4 °C for further study. While whole peanut seeds were used for mechanical oil extraction (pressing method).

Oil extraction

Peanut oil was extracted by pressing method and Soxhlet extraction technique as described in (AOCS DFJA 1998). The oil was extracted by using the pressing technique and solvent extraction technique by using hexane. Peanut oil was heated at 60 °C to remove the complete solvent. The crude oil recovered, was placed in desiccators for the 24 h, through this moisture (if present) could be removed. Also, compare the percentage recovery of oil by both extraction methods, i.e., pressing method and soxhlet extraction method. The extracted oil was put in amber glass bottles,

airtight the bottle and stored in a freezer (-18°C) to be used for characterization and development of cookies. The percentage recovery of oil was calculated by the following formula:

$$\text{PSO yield (\%)} = \frac{\text{weight of oil} \times 100}{\text{weight of peanut seed power sample}} \quad (1)$$

Analysis of peanut seed oil (PSO)

Specific gravity

The specific gravity of the PSO was estimated at standard temperature (25°C) by using pycnometer (Sigma-Aldrich) having bored capillary stopper using the method no. Cc 10a-25 outlined in (AOCS DFJA 1998). The specific gravity was calculated by following the formula given as under:

$$\text{Specific gravity (g/mL)} = \frac{W_2 - W_1}{V} \quad (2)$$

where W_1 = Weight (g) of empty pycnometer, W_2 = Weight (g) of pycnometer filled with the test sample and V = Volume (mL) of pycnometer at temperature.

Free fatty acids content

The free fatty acids percentage (as oleic) in oil sample was calculated by titrating the oil in neutralized ethanol (95%) against NaOH solution according to the method no. Ca 5a-40, as outlined in AOCS (1998). 10 g of sample was taken into a clean, dry conical flask along with 25 mL (neutralized 95% ethanol). It was appropriately mixed so that the sample dissolved in ethanol. Added 1–2 drops of phenolphthalein indicator and then the contents were titrated against 0.1 N KOH solution, constantly shaking until pink color persisted for at least 30 s. The free fatty acids % was calculated as follows:

$$\text{Free fatty acids \% (as oleic)} = \frac{\text{Alkali used (mL)} \times N \times 28.2}{\text{Weight of oil sample (g)}} \quad (3)$$

whereas N = Normality of alkali used.

Iodine value

The Iodine value (I.V) is the measure of the degree of unsaturation and expressed in terms of a number of grams of iodine absorbed by 100 g of fat or oil. The I.V of the oil was determined by using method no. Cd 1d-92 as described in (AOCS DFJA 1998). The oil sample 5 g was dissolved in 5 mL carbon tetrachloride (CCl_4) in a glass bottle with

a stopper and 25 mL of Wij's solution was added into it. The bottle was allowed to stand for half an hour in a dark place before distilling with 20 mL (10% potassium iodide solution) and 20 mL of distilled water. The contents of the bottle were titrated against sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$) solution starch solution used as an indicator. Blank reading was also taken.

$$\text{I.V} = \frac{(B - S) \times 12.69 \times N}{\text{Weight of oil sample (g)}} \quad (4)$$

whereas B = Volume of $\text{Na}_2\text{S}_2\text{O}_3$ used for blank, S = Volume of $\text{Na}_2\text{S}_2\text{O}_3$ used for sample and N = Normality of $\text{Na}_2\text{S}_2\text{O}_3$ solution.

Saponification value

The saponification value is a number of milligrams of KOH required for the complete saponification of 1-g sample (fat or oil). It was measured by using method No. Cd 3-25 as described in AOCS (1998). 10 g of peanut seed oil sample was taken in a flask and refluxed with 25 mL of 0.5 N alcoholic potash in a water bath for 30 min. The sample was cooled to room temperature and titrated against 0.5 N HCL solution using phenolphthalein as an indicator. A blank reading was taken in identical fashion without the addition of oil. The saponification value was calculated as:

$$\text{Saponification value (mgKOH/g)} = \frac{(B - S) \times 28.2}{\text{Weight of oil sample (g)}} \quad (5)$$

whereas B = Volume of $\text{Na}_2\text{S}_2\text{O}_3$ used for blank and S = Volume of $\text{Na}_2\text{S}_2\text{O}_3$ used for the sample.

Peroxide value

It is expressed as milliequivalent of peroxides combined with one kg of fat/oil. The peroxide value of the oil sample was calculated according to method no. Cd 8-53 as described in AOCS (1998). 5 g of oil sample was taken in a 250 mL Erlenmeyer flask and 30 mL of glacial acetic acid-chloroform (3:2 v/v) mixture was added. The flask was swirled for 1 min so that the oil was completely dissolved in the solvent mixture. Then added freshly prepared saturated potassium iodide solution (0.5 mL) to the flask and stirred. Then 5 mL of the starch solution was added and the blue color appeared. Then the contents were titrated against 0.01 N standard sodium thiosulphate solution with constant shaking unless the blue color just disappeared. A blank reading was taken in an identical fashion.

The peroxide value was calculated by using the following expression:

$$\text{Peroxide value (meqO}_2\text{/kg)} = \frac{(B - S) \times N \times 1000}{\text{Weight of oil sample (g)}} \quad (6)$$

whereas S = Volume of Na₂S₂O₃ solution used for a sample, N = Normality of Na₂S₂O₃ solution and B = Volume of Na₂S₂O₃ solution used for blank.

Antioxidant potential of PSO

2-diphenyl-1-picrylhydrazyl (DPPH) estimation DPPH free radical scavenging activity of PSO was measured according to the method of Brand-Williams (Brand-Williams et al. 1995). For the blank probe, the 100 µL of PSO was replaced with 100 µL of absolute methanol. Radical scavenging activity was calculated by the following formula.

$$\text{Reduction of absorbance (\%)} = \frac{(AB - AA) \times 100}{AB} \quad (7)$$

where AB = absorbance of blank sample (t = 0 min) and AA = absorbance of tested oil solution (t = 15 min).

Thiobarbituric acid reactive substances (TBARS) assay

The thiobarbituric acid value of the peanut oil samples was determined by the AOCS Method no. Cd 19-90 (AOCS DFJA 1998). Peanut seed oil sample (150 mg) dissolved in 1-butanol mixed with 0.2% TBA in 1-butanol were incubated 2 h in a 95 °C water bath and cooled for 10 min under tap water (TBARS reaction). The absorbance was measured at 532 nm against a corresponding blank sample. The results were expressed as mg malonaldehyde/kg of oil. Also, blank reading was calculated.

Product development

The cookies were prepared in which butter was partially replaced with PSO. Cookies were prepared according to the procedure given in AACC (2000) with slight modifications. The normal shortening in cookies formulation was replaced with PSO in different concentrations, as described in Table 1.

Table 1 Treatment plan of the developed functional cookies

Treatments	Concentration of PSO (%)	Concentration of butter (%)
FC ₀	0	100
FC ₁	05	95
FC ₂	10	90
FC ₃	15	85
FC ₄	20	80
FC ₅	25	75

FC functional cookies

Analysis of cookies

Proximate composition

Proximate composition (moisture, ash, crude fiber, crude fat, crude protein and NFE) of prepared cookies containing PSO were determined.

Physico-chemical analysis of cookies

The cookies were subjected to analysis like caloric value, color, spread factor and texture properties on regular storage intervals as 0, 15th, 30th, 45th, 60th days.

Gross energy

Gross energy (Cal/g) was calculated by combusting the sample using the Oxygen Bomb Calorimeter (C-2000, IKA WERKE). Initially, 0.5 g of the prepared cookies sample were fed to the calorimetric buckets, after complete burned the cookies sample in the presence of high pressure and energy and reading was displayed on the automatic screen of the Oxygen Bomb Calorimeter (Krishna and Ranjhan 1981).

Texture characteristics

The texture of cookies was measured through texture analyzer (model TA. XT plus, Texture Technologies Corp.) equipped with three-point bend attachment (TA-92), a heavy-duty platform (TA-90) and stainless-steel blade (TA-92). The resistance of the cookies to fracture was measured. Three cookies were selected randomly and applied to the base of the analyzer. The internal gap adjustment of the base was set to place the cookie properly. A gap of base and distance of blade was kept constant for all samples. The data was obtained in the form of the force–deformation curve, indicating force, rupture distance, and gradient. Settings included pretest speed of 5 mm/s, the test speed of 3 mm/s, posttest speed 10 mm/s, distance 20 mm and trigger force 50 g (Piga et al. 2005).

Thiobarbituric acid reactive substances (TBARS) of product

The thiobarbituric acid value of the cookies samples was determined by the AOCS method no. Cd 19-90. A 5 g sample of cookies was dissolved in 1-butanol mixed with 0.2% TBA in 1-butanol were incubated 2 h in a 95 °C water bath and cooled for 10 min under tap water (TBARS reaction). The results were expressed as mg of malonaldehyde/kg of sample.

DPPH assay of cookies

DPPH radical scavenging activity of cookies was done by following the method of Brand-Williams (Brand-Williams et al. 1995). The antioxidant activities of the product were determined as a measurement of radical scavenging using the DPPH radical. The free radical scavenging activity was calculated by using the following formula.

$$\text{Reduction of absorbance (\%)} = \frac{(AB - AA) \times 100}{AB} \quad (8)$$

whereas AB = absorbance of blank sample (t = 0 min) and AA = absorbance of tested oil solution (t = 15 min).

Microbial analysis of cookies

Total viable bacterial counts were carried out on the cookies samples to determine the bacterial load of the cookies as described by the American Public Health Association (Easley et al. 2001). Cookies samples were ready by crushing and mixing in peptone water. Subsamples were diluted decimally and 0.1 mL aliquots were spread plated on nutrient agar (NA) for the enumeration of aerobic bacteria in samples and the plates were incubated at 37 °C for 24–48 h. The developed colonies were counted by colony counter and expressed as colony-forming units per gram (CFU/g).

Sensory analysis of cookies

Sensory evaluation of cookies for various attributes like flavor, crispiness and overall acceptability was carried out on a fortnightly basis for 2 months using nine-point hedonic scale system (Appendix I) by following the instructions of (Meilgaard et al. 1999). The cookies were presented to trained taste panel in transparent plates and implicated randomly to avoid biases. The judges were requested for mouth wash prior to each sample with warm water to avoid any after taste of different samples. The panelists rated the product for their strongly liking to strongly disliking by giving scores from 9 to 1, respectively.

Statistical analysis

The data obtained for all parameters were analyzed by using the statistical technique. Analysis of variance technique was applied and results were interpreted according to LSD at 5% probability level by using Statistics (version 8.1, Tallahassee, USA) software (Hines et al. 2008).

Results and discussion

Oil extraction and oil recovery

Extraction of oil from the peanut seed is an important operation. The quantity of oil is generally calculated in terms of percentage. At the present study, the oil is obtained from different two varieties of peanut seeds, i.e., Bari 2001 and Bari 2011 by solvent extraction and mechanical extraction method. Screw pressing is used in mechanical extraction. Screw pressing is commonly used for those seeds having greater oil contents. Various factors affect the oil recovery, including the method of oil extraction, extraction pressure, duration of extraction procedure used etc. For solvent extraction, 5–6 washings of samples are enough for general recommendations for research samples.

Specific gravity

The specific gravity of a substance can be defined as a comparison of its density to that of water at any specific temperature. It is the most significant physical property of a substance. In the present work higher, specific gravity value of PSO in comparison to other vegetable and cereal oils indicated the presence of more unsaturated fatty acids.

Free fatty acid

The free fatty acids are calculated as oleic acid. Free fatty acids are produced by the breakdown of Triglycerides. The quantity of liberated fatty acids found helps us to check the purity and quality of oils. The low amount of free fatty acid is due to the presence of a high concentration of natural antioxidants tocopherols which provide more stability to oil and resist enzymatic degradation.

Iodine value

Iodine value reflects the degree of unsaturation of fatty acids. It's explained as the number of grams of iodine absorbed by 100 g of fat, thus the degree of unsaturation of fatty acids help of iodine value. The more iodine content, greater, will be the degree of unsaturation. Thus, iodine value helps to identify the type of fatty acids existing in fats and oils (saturated or unsaturated). Temperature is measured as the most significant factor which also affects the iodine value.

In this research maximum iodine value of Bari 2001 is $(94.44 \pm 1.66 \text{ gI}_2/100 \text{ g})$ while in Bari 2011, iodine value was $(89.99 \pm 1.47 \text{ gI}_2/100 \text{ g})$. This result was similar to

Sher and Hussain observed iodine value of oil was 98.4 gI₂/100 g (Sher and Hussain 2009).

Saponification value

Saponification value predicts the carbon atoms number of fatty acids present in the oil. Higher the saponification value higher will be the carbon atoms number of fatty acids of oil. We determine the saponification value of Bari 2001 and Bari 2011 was 195.81 ± 2.66 mgKOH/g, 191.60 ± 2.47 mgKOH/g respectively.

Peroxide value

Peroxide value determines the degree of oxidation of the oil. Lower the peroxide value lower will be the oxidation tendency and vice versa. Peroxide value increases as the storage time and temperature increases and should be zero in case of freshly deodorized oil. Lower peroxide value revealed the good quality of the oil. We determine the peroxide value of Bari 2001 and Bari 2011 and presented in Table 2.

2,2-diphenyl-1-picrylhydrazyl (DPPH) estimation of PSO

The DPPH (2,2-diphenyl-1-picrylhydrazyl) analysis is a procedure to examine the antioxidant potential of test materials (peanut seed oil). This test also used to determine the antioxidant activity in fats and oils and related products. DPPH is organic free radical, which shows adsorption at 517 nm during using a spectrophotometer and presented in Table 2.

Thiobarbituric acid reactive substances (TBARS) assay of PSO

TBA value measures the level of secondary oxidation products, e.g., aldehydes and carbonyls, because these compounds create the off flavor and dark color in fats and

oils during the storage period. It is obvious that TBA value increases as storage time increases due to the production of secondary oxidation products. Storage period has a direct relation with TBA value. Longer the storage period higher will be the amount of TBA value (Aqil et al. 2006).

Selection of best variety

From the two varieties, Bari 2011 showed better yield and antioxidant potential. The oil stability test was performed (free fatty acid, Iodine value and peroxide value) and the antioxidant test was also performed. So, Bari 2011 was used in cookies.

Product development

Cookies were prepared according to the method given in AACC (2000) with some modifications. Commercially available flour was used with the substitution of normal shortening with oil of peanut variety Bari 2011 in the ratio given in (Table 1).

Proximate composition of prepared cookies

Prepared cookies were examined for moisture content, ash, protein, fat, fiber and nitrogen-free extract (NFE).

Storage study

Storage study (60 days) assessed the quality, sensory evaluation, oxidative stability, gross energy and texture of prepared cookies in order of most suitable to least accepted as $FC_3 > FC_4 > FC_5 > FC_1 > FC_2 > FC_0$. The functional cookies developed using 15% peanut seed oil resulted in a satisfactory product.

Table 2 Chemical composition of peanut seed oil

Parameters	Bari 2001	Bari 2011
Comparing oil yield by mechanical extraction (%)	40.20 ± 0.32	41.70 ± 0.29
Comparing oil yield by solvent extraction (%)	41.05 ± 0.37	42.30 ± 0.39
Specific gravity	0.912 ± 0.031	0.914 ± 0.029
Free fatty acid (%)	0.96 ± 0.07	0.94 ± 0.04
Iodine value (gI ₂ /100 g)	94.44 ± 1.66	89.99 ± 1.47
Saponification value (mgKOH/g)	195.81 ± 2.66	194.60 ± 2.47
Peroxide value (meq O ₂ /kg)	1.51 ± 0.09	1.47 ± 0.07
DPPH value	55.64 ± 0.36	50.53 ± 0.27
TBARS value	0.300 ± 0.006	0.288 ± 0.002

TBARS thiobarbituric acid reactive substances, DPPH 2,2-diphenyl-1-picrylhydrazyl

Gross energy

The maximum value of gross energy is (517.67 ± 0.32 kcal/100 g) that increased gradually with increasing the amount of PSO and the minimum value was observed in FC₀ (412.53 ± 0.33 kcal/100 g). However, the gross energy in cookies was noticed to differ non-significantly during storage time (Table 3). The increase in gross energy among the treatments may be due to the progressive increase of PSO, resulting in increased polyunsaturated fatty acids. According to (Waheed et al. 2010) the addition of fat regardless of source resulted in the increase in the calorific value of the cookies. Similarly, (Arshad et al. 2008) reported that the addition of oil in the cookies resulted in higher energy in the cookies.

Texture

Statistically, texture analysis expressed in terms of hardness was not significantly affected due to treatments, but storage has a highly significant influence. Means for hardness ranged between 74.59 ± 0.29 – 74.96 ± 0.36 among the treatments. Means for the hardness of cookies during storage explained the minimum value 74.42 ± 0.29 g at the start of the study that decreased consequently during storage and the highest value 74.62 ± 0.36 g was noted on the 60th day.

This indicates that FC₀ had less hardness and it's gradually increasing. The PSO does not affect this; thus, there is no significant difference in treatments. Current results are similar to the findings of (Waheed et al. 2010; Arshad et al. 2008) explained that the substitution of fat does not considerably affect the hardness of the cookies.

Thiobarbituric acid reactive substances (TBARS) of cookies enriched with PSO

The means for TBARS value steady increase; minimum value for this trait was noted (0.47 ± 0.003 mg malonaldehyde/kg) in FC₀ (control), whilst maximum TBARS

(0.95 ± 0.019 mg malonaldehyde/kg) was observed in FC₅ (25% PSO). During 60 day's storage, progressive increase in TBARS values was observed, i.e., 0.71 ± 0.003 to 0.74 ± 0.005 mg malonaldehyde/kg, respectively in PSO based cookies. TBARS values were significantly increased with additional increments of PSO. Results of the current study can be linked with the research findings of (Gouveia et al. 2006; Paradiso et al. 2008) who observed better oxidative constancy of the respective foodstuffs with the addition of polyphenol-rich vegetable ingredients, *Chlorella vulgaris* and *haematococcus pluvialis* biomass and antioxidant-rich oils.

2,2-diphenyl-1-picrylhydrazyl (DPPH) of cookies enriched with PSO

The means for DPPH value (Table 4) showed that gradual increase in PSO resulted in a clear decrease; the lowest value for this attribute was recorded (27.06 ± 0.21 g oil/g [DPPH[•]]) in FC₅ (25% PSO), whilst maximum DPPH (33.90 ± 0.23 g oil/g [DPPH[•]]) was detected in FC₀ (control). During 60 days' storage, progressive decrease in DPPH values was observed, i.e., 30.21 ± 0.21 to 29.52 ± 0.23 g oil/g [DPPH[•]], respectively in PSO based cookies. DPPH (2,2-diphenyl-1-picrylhydrazyl) analysis conducted for PSO cookies showed that the antioxidant potential of test materials inhibited DPPH radical formation. The DPPH[•] scavenging action indicates that the PSO cookies contain antioxidant compounds that react directly with DPPH[•] and suggests that the oil extracted from peanut seeds can bring benefits if used in feeding, fighting free radicals.

Total viable count (TVC) of cookies enriched with PSO

The results showed a significant effect of treatments and storage on the total viable counts of bacteria in cookies enriched with PSO. The bacterial count was increased as the storage proceeded. In freshly baked cookies, no

Table 3 Means for the proximate composition of cookies enriched with PSO

Treatments	Moisture	Ash	Protein	Fat	Fiber	NFE
FC ₀	3.36 ± 0.29^a	0.55 ± 0.01^a	6.75 ± 0.57^c	21.65 ± 0.34^b	0.45 ± 0.03^a	67.24 ± 1.24^a
FC ₁	3.14 ± 0.15^{ab}	0.54 ± 0.05^b	6.64 ± 0.34^a	22.08 ± 0.36^c	0.44 ± 0.02^a	67.16 ± 0.92^b
FC ₂	3.08 ± 0.19^c	0.51 ± 0.07^a	6.41 ± 0.24^b	22.57 ± 0.32^d	0.43 ± 0.05^b	67.00 ± 0.87^b
FC ₃	3.01 ± 0.14^a	0.49 ± 0.02^{ab}	6.83 ± 0.53^c	22.94 ± 0.38^c	0.46 ± 0.01^{bc}	66.27 ± 1.08^a
FC ₄	2.94 ± 0.25^b	0.51 ± 0.03^a	7.02 ± 0.43^{bc}	23.22 ± 0.36^d	0.48 ± 0.02^c	65.83 ± 1.09^c
FC ₅	2.80 ± 0.12^a	0.48 ± 0.04^a	7.09 ± 0.48^a	23.84 ± 0.34^b	0.52 ± 0.08^c	65.27 ± 1.06^c

NFE nitrogen free extract, FC₀ Cookies contain 0% peanut seed oil, FC₁ Cookies contain 5% peanut seed oil, FC₂ Cookies contain 10% peanut seed oil, FC₃ Cookies contain 15% peanut seed oil, FC₄ Cookies contain 20% peanut seed oil, FC₅ Cookies contain 25% peanut seed oil

Table 4 Effect of treatments on gross energy, texture, TBARS, DPPH and TVC value of functional cookies

Treatments	Gross energy	Texture	TBARS	DPPH	TVC
FC ₀	412.53 ± 0.76 ^a	74.40 ± 0.29 ^b	0.47 ± 0.003 ^a	33.90 ± 0.23 ^c	4.25 ± 0.138 ^a
FC ₁	435.13 ± 0.71 ^c	74.27 ± 0.34 ^{bc}	0.52 ± 0.004 ^b	30.69 ± 0.24 ^{bc}	3.39 ± 0.074 ^b
FC ₂	448.60 ± 0.83 ^b	73.12 ± 0.31 ^c	0.55 ± 0.006 ^b	29.77 ± 0.41 ^c	3.19 ± 0.070 ^c
FC ₃	472.60 ± 0.84 ^c	72.62 ± 0.33 ^c	0.63 ± 0.010 ^a	28.02 ± 0.19 ^a	3.17 ± 0.084 ^a
FC ₄	495.73 ± 0.91 ^a	74.84 ± 0.37 ^{bc}	0.80 ± 0.016 ^{ab}	28.46 ± 0.17 ^b	3.15 ± 0.087 ^c
FC ₅	517.67 ± 0.85 ^a	74.96 ± 0.36 ^a	0.95 ± 0.019 ^{ab}	27.06 ± 0.21 ^c	3.07 ± 0.089 ^b

Gross energy (kcal/100 g), texture (g), TBARS (mg malonaldehyde/kg) and TVC (log10CFU/g)

Data are the means ± standard deviation. Mean having same subscript are non-significance

detection of bacteria was seen. A vigorous increase in bacterial counts was observed after storage of the cookies at 15th day, i.e., 3.31 log10CFU/g which gradually increased to 3.68 log10CFU/g at the 30th day, 3.93 log10CFU/g at 45th day and a maximum of 4.11 log10CFU/g at 60th day. While FC₀ showed the highest mean value of 4.25 log10CFU/g and FC₅ the lowest 3.07 log10CFU/g. Total viable count reflects the circumstances in which the food was formed, abused or stored with skill; this sum can be used to predict the shelf life or keeping quality of the product. The decomposition of several foodstuffs may be imminent when the total viable count ranges of 10–100 million per gram of the produce. This indicates that the product was safe for human consumption (Ijah et al. 2014).

Sensory evaluation of cookies

The statistical results regarding the color of cookies prepared by substitution of PSO at different levels indicated significant effects of both treatments and storage intervals on the color of cookies. The interaction between treatments and storage intervals also possessed a significant effect on this sensory attribute of cookies (Fig. 1). Storage intervals also negatively affect the color of cookies. The scores regarding the color of cookies reduced as the storage interval increased. The cookies having highest scores 6.98 ± 0.07 at zero-day storage periods which decreased significantly to 6.85 ± 0.09 for cookies evaluated at the end of storage study. The lowest point for the cookies as a concentration of oil increased may be due to the darkening of the cookies. These changes become more evident when the PSO concentration increased above 15%, which cause a significant decrease in points assigned to the cookies prepared by 20% and 25% PSO. The darker color of the cookies might be due to the presence of high concentration of pigmented bodies of PSO (Table 5).

The statistical results regarding the flavor of cookies prepared by the substitution of PSO at different levels indicated significant effects of both treatments and storage intervals on the flavor of cookies. The interaction between treatments and storage intervals also possessed a significant

effect on this sensory attribute of cookies. These results were also confirmed by the (Arshad et al. 2008) for wheat germ oil-based cookies. The mean Table for the flavor scores assigned to the cookies. The results indicated that the cookies prepared by 15% PSO substitution (FC₃) with normal shortening got the highest scores 6.62 ± 0.06 for flavor followed by the FC₀ (100% normal shortening) which got 6.16 ± 0.09 points. Similar scores 6.24 ± 0.07 were assigned to the FC₁ prepared by 5% PSO substitution, but less than that was assigned to the FC₀.

However, the scores assigned to the cookies prepared by replacing the PSO with normal shortening at a level above than 15%, i.e., FC₄ (6.52 ± 0.08) and FC₅ (6.14 ± 0.06) got fewer scores. The results indicated that the flavor of those cookies was found acceptable, which were prepared up to 15% oil substitution. Among the treatments, FC₃ was found the best treatment in terms of flavor, which was close to the FC₀. The lower scores for the flavor as a concentration of PSO increased in the cookies might be due to the presence of peanut flavor of peanut seed oil. Similar results were found by the (Bilgiçli et al. 2006) who found that supplementation of wheat germ up to a certain limit gives the best results for consumer acceptance. It's reported that more than 15% wheat germ substitution in the macaronies did not affect its acceptability (Pinarlı et al. 2004).

The results regarding the crispiness of cookies showed that both treatments and storage interval has a significant effect on cookies crispiness. The crispiness of cookies prepared by the different levels of PSO was obtained different scores. Cookies of control treatment contained 100% normal shortening got scores (5.98 ± 0.09) followed by 6.55 FC₄ (20% PSO), while the cookies prepared by 5% (FC₁), 10% (FC₂), 15% (FC₃) and 25% (FC₅) PSO substitution acquired significantly fewer points, i.e., 6.11 ± 0.08 , 6.15 ± 0.09 , 6.40 ± 0.07 and 5.90 ± 0.08 respectively. As the concentration of PSO increases the crispiness of the cookies decreases due to less ability of the oil to incorporate the air during creaming process and dough did not properly set back in comparison to when shortening is used. The less ability of the oil to shorten the gluten structure resulted in reduced scores for cookies prepared by substituting the normal shortening with PSO.

Fig. 1 Sensory evaluation of cookies during storage study **Table 5** Effect of storage on gross energy, texture, TBARS, DPPH and TVC value of functional cookies

Storage days	Gross energy	Texture	TBARS	DPPH	TVC
0	498.89 ± 0.80 ^a	74.42 ± 0.31 ^a	0.61 ± 0.006 ^a	31.21 ± 0.17 ^c	2.82 ± 0.058 ^a
15	486.61 ± 0.85 ^b	74.17 ± 0.29 ^b	0.63 ± 0.004 ^a	30.97 ± 0.14 ^b	3.31 ± 0.069 ^{ab}
30	464.22 ± 0.94 ^b	74.23 ± 0.37 ^c	0.66 ± 0.006 ^b	30.73 ± 0.26 ^b	3.68 ± 0.078 ^b
45	457.88 ± 0.88 ^c	74.24 ± 0.33 ^c	0.71 ± 0.003 ^b	30.21 ± 0.21 ^b	3.93 ± 0.79 ^{ab}
60	448.71 ± 0.82 ^c	74.62 ± 0.35 ^b	0.74 ± 0.005 ^b	29.52 ± 0.23 ^a	4.11 ± 0.083 ^c

Gross energy (kcal/100 g), texture (g), TBARS (mg malonaldehyde/kg) and TVC (log10CFU/g)

Data are the means ± standard deviation. Mean having same subscript are non-significance

Normal shortening relaxes the gluten structure and more proper development of gluten network and causes proper aeration of the dough which produced the crispier cookies as compared to the PSO.

Storage intervals showed a pronounced effect on the crispiness of cookies. The cookies got a fewer score as the storage time increases. The freshly prepared cookies obtained the highest scores for crispiness 6.55 ± 0.09 , which was decreased to 6.45 ± 0.09 at the end of storing time. As storage time increased chemical composition of the cookies also altered. The decrease in the crispiness of the cookies might be due to the increase in the moisture content. As the moisture content increases the cookies became soggy and mealy, which results in reduced crispiness.

The results for the overall acceptability of the cookies prepared from different levels of PSO indicated that there were significant differences between treatments as well as storage intervals with respect to the overall acceptability of cookies. However, the interaction between treatments and storage intervals was found to be significant for the overall acceptability of the cookies. The results demonstrated that the cookies prepared by the 15% PSO replacement obtained the top place with respect to the overall acceptability. The addition of PSO has a significant effect on the overall

acceptability of the cookies. The most acceptable cookies on the basis of assigned scores were found FC₃ which were prepared by the replacement of 15% PSO and FC₀, which contained 100% normal shortening. The difference between both the treatments was found significant.

The results showed the following decreasing order of overall acceptability: FC₃ > FC₄ > FC₅ > FC₁ > FC₂ > FC₀, which revealed that the acceptable limit for the substitution of PSO was 25%. Overall acceptability of the cookies prepared from different levels of PSO was significantly influenced by the storage intervals. The freshly prepared cookies of FC₃ obtained the maximum overall, acceptability score (6.55 ± 0.07) at 0 day. The flavor is the main factor which determines the overall acceptability of the PSO based cookies. Higher oil concentration more than 15% results in after taste and peanut flavor.

Conclusion

In the present research peanut seed oil influenced the caloric value of prepared cookies, with the increase in peanut seed oil concentration during the storage not effected for influenced the caloric value of prepared cookies during storage. The addition of peanut seed oil

influenced caloric value also increased as the peanut seed oil concentration increased, but it was not observed during storage. During research work, it was found that FC₃ cookies prepared by the 15% PSO replacement obtained the top place in sensory evaluation and also show best results against oxidation while FC₅ is having 25% PSO replacement shows excellent potential against oxidation but secure fewer marks during the sensory evaluation as compare to FC₃. In the baked products, rancidity is the major problem that renders the product not consumable, but the addition of the functional and nutraceutical ingredients improved the antioxidant extent of that product. The same trend was observed in cookies after addition of peanut seed oil. A substantial accentuation is given on the improvement of the food processing industries that are rich. Photochemistry finds its application in diet-based therapies.

Conclusively, based on the above analysis, it could be highlighted that the peanut seed oil could be used as a potential cradle for functional food ingredients, antimicrobial compounds, natural antioxidants, and cosmetics. In addition, it could be further added to therapeutic functional food products. This proposes that the peanut seed should be further worked into different economic products. This will give good healthy and stable products. This product is good for all age of peoples and equally important to the people who are allergic to the peanut protein.

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