PAPER

EFFECT OF HYDROGENATED FAT REPLACEMENT WITH WHITE SESAME SEED OIL ON PHYSICAL, CHEMICAL AND NUTRITIONAL PROPERTIES OF COOKIES

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ABSTRACT

Sesame seed oil has known antioxidant properties that may improve both nutritional importance and shelf-life of the product. Three aims of the study were to: a) examine nutritional value and physicochemical properties of white sesame seed oil (WSSO) and hydrogenated vegetable fat (HVF) cookies, b) compare the antioxidant potential of the cookies and c) determine the effects of storage and treatment conditions on palatability of the cookies. Results showed that energy and fat% were significantly higher ($P < 0.05$) in WSSO than HVF cookies. At 60th day, mean moisture, peroxide value, and acidity were higher ($P < 0.05$) in HVF cookies. Over time, protein and fiber% decreased significantly ($p < 0.05$) in both cookies but remained higher ($P < 0.05$) in WSSO at 60 days. WSSO cookies had longer shelf life, greater palatability, improved physical properties and greater antioxidant potential.

Keywords: antioxidant potential, food product development, palatability, physicochemical properties, sesame oil

1. INTRODUCTION

Food industries are interested in developing plant products that provide both functional as well as nutritional value (JISHA *et al.*, 2009; OOMAH and MAZZA, 1998; TRIPATHY *et al.*, 2003). In addition, the increasing trend toward consuming "pre-packaged" "ready-to-eat" products have increased the need for improving the nutritional quality, palatability and shelf life of these food products (NANDITHA and PRABHASANKAR, 2009).

Along with proteins and carbohydrates, fats are a critical component of a healthful diet. Fats are important for improving both the taste and texture of food as well as stimulating neurological sensory signals of "fullness" after consumption (ROLLS, 1995). Some oil containing foods are rich in antioxidants, which may be able to decrease harmful inflammatory conditions resulting from oxidative stress. These same antioxidative properties may also be able to increase the shelf life of food products by reducing the undesirable progression of oxidation that causes rancidity (SIMS and FIORITI, 1977). Furthermore, increasing shelf life also influences the economic cost of the product by reducing the waste of discarding unused "out of date" products (REDDY *et al.*, 2005). Finally, there is an increasing need to replace partially hydrogenated fats that are now known to be unhealthy, with healthy replacements without affecting the physical and sensory properties of the end products (WANG *et al.*, 2016).

White sesame seed oil (WSSO) (*Sesamum indicum L.*) specifically has been recognized for its potential role in a healthful diet. The oil in sesame seeds contains appreciable amounts of bioactive components with powerful antioxidant properties identifying it as a promising nutraceutical in the treatment of chronic inflammatory conditions such as cardiovascular disease and diabetes (BHUVANESWARI and KRISHNAKUMARI, 2011; HEMALATHA and GHAFOORUNISSA, 2004; LATIF and ANWAR, 2011).

WSSO is readily cultivated in tropical and sub-tropical regions of the world and has been used in food preparation and baking and for centuries (RESHMA *et al.*, 2010). Sesame oil (SO) is considered as an extremely stable oil against oxidation because of the high proportion of natural antioxidants or lignans, such as sesamin and sesamolin (ANILKUMAR *et al.*, 2010). The presence of these antioxidants may also improve the oxidative stability of SO (EL-ADAWY, 1997; LATIF and ANWAR, 2011; RESHMA *et al.*, 2010). It is plausible that exchanging the fat source in cookies from standard hydrogenated vegetable fat with SO, would improve the antioxidant potential, shelf life and palatability of cookies. SOWMYA *et al.*, (2009) described the effect of fat replacement with SO, hydrocolloids and emulsifiers on changes in the fatty acid profile and microstructural qualities of cakes. They determined that a combination of 50% SO combined with hydroxypropylmethylcellulose and emulsifiers greatly improved the palatability of the product and provided better results than the control (vegetable fat) cake in all aspects. In fact, replacement of fat with SO also decreased the saturated fatty acid content of the cake (SOWMYA *et al.*, 2009). LIM and LEE (2015) described that that by incorporating black sesame powder into cookies, the functional properties of the cookies was improved without affecting the consumer acceptability. In addition, cookies in which butter was replaced with an oil emulsion, showed better fracture properties and higher consumer acceptability and potentially overall healthier properties (GIARNETTI *et al.*, 2015). Finally (RANGREJ *et al.*, 2015) noted that the replacement of hydrogenated fat with seed oil improved the physical, textural and sensory properties of cookies. To our knowledge, no previous studies have examined the effect of replacing the fat source in cookies with SO. It is currently unknown whether replacing the fat source in cookies would improve the nutritional, antioxidative or perhaps more importantly, the taste and palatability of the cookies. The purpose of this investigation was to study the differences in nutritional

properties as well as the palatability of cookies made with SO compared to cookies made with hydrogenated vegetable fat (HVF).
The specific aims of this study were three-fold: 1) to examine differences in nutritional value and physicochemical properties of cookies made with SO compared to HVF, 2) to compare the antioxidant potential of the cookies and 3) to determine the effects of time and oil type on palatability of the cookies.

2. MATERIAL AND METHODS

2.1. Materials

Two types of cookies were prepared, one with 100% hydrogenated vegetable fat (HVF) and other with 100% white sesame seed oil (WSSO). Vegetable fat (VF) was the hydrogenated fat and it was the blend of soybean, palm and canola vegetable oil. Cookies were prepared according to the method given by the American Association of Cereal Chemists (AACC, 2000) with modifications to fat replacement and baking time & temperature. Baking ingredients were procured from the local market. All ingredients were weighed as per their percentage in the recipe that included: fine (cake) flour (45%), whole wheat flour (10%), white sesame seed oil (33%) or vegetable fat (hydrogenated fat composed of soybean, palm and canola vegetable oil), salt (0.30%), egg (5%), stevia (0.15%), baking powder (5%), sugar (1.5%), and vanilla extract (0.05%). Cookies were prepared in a commercial bakery unit. The white sesame seed oil was extracted from seeds (PB-Till 90) that were procured from the Ayub Agriculture Research Institute Faisalabad, Pakistan. Sesame seed oil was extracted from seeds through solvent extraction method (LATIF and ANWAR, 2011) then this oil was used for the preparation of cookies.
Dry ingredients (flour, whole wheat flour, salt, sugar, stevia and baking powder) were placed in a mixer at low speed for 2-3 minutes to ensure thorough mixing. Next, eggs were added to the dry mixed ingredients during mixing. The fat source (either SO or HVF) was then added in small amount to facilitate thorough blending of fat with the ingredients and the mixer speed was increased up to 50-60 rpm (medium) and the ingredients were mixed for additional 4-5 minutes. Then vanilla extract was added. The whole mixing process was completed in approximately 10-15 minutes. Two batches of 15 kg each, one from SO and the other from HVF were made. Cost of recipe for both type of cookies was almost same and these was not much difference.
The mixture was dispersed onto a cookie sheet in 12-15 gm aliquots to produce a total of 950-970 cookies. Cookies were baked in a preheated commercial oven at 175°C for approximately 15-20 minutes until a golden color was achieved. Baked cookies were then allowed to cool on a rack and the weight of each cookie was noted. Cookies were then divided into 12 air-tight glass containers (6 with SO and 6 with HVF) holding 160-170 cookies each and placed in a cabinet in the laboratory at an ambient room temperature (25 ± 5°C) away from sunlight for a period of 60 days. One container of each type of cookie (SO and HVF); were opened and the cookies were analyzed at each data collection period (baseline, 30th and 60th day).

2.2. Methods

2.2.0. Proximate analysis of cookies

Proximate composition analyses followed the specific methodology as described by AACC, (2000). These analyses included, moisture (Method No. 44-15A), protein (Method

No. 46-30), fat (Method No. 30-25), fiber (Method 32-10), ash (Method No. 08-01). Energy (kcal) was estimated by calculating kcal per gram of the individual macronutrients.

2.2.1 Moisture

Moisture was determined by following the method (method no. 44-15A) AACC (2000). Air dried oven (Blodgett; CTB/CTBR, USA) was used to determine the moisture. The percentage of moisture was calculated according to the expression given below.

$$\text{Moisture (\%)} = \frac{W1 \times 100}{W}$$

Where,
W1 = Loss in gm of the material on drying
W = Weight in gm of the material taken for test

2.2.2 Protein

Protein content in each sample was estimated according to the Kjeldahl's method (method no. 46-30) as described in AACC, (2000).

2.2.3 Fat

Fat (%) content in each sample was determined by taking 5 gm dried sample and running through Soxhlet apparatus for 04 hours using n-hexane as a solvent by following the procedure described in AACC, (2000) method no. 30-25. The percentage of fat was calculated according to the expression given below.

$$\text{Fat (\%)} = \frac{\text{Wt. of fat}}{\text{Wt. of sample}} \times 100$$

2.2.4 Fiber

The crude fiber was estimated according to the procedure as outlined in AACC, (2000) method 32-10. Muffle furnace (Thermo scientific thermolyne F48010-33, USA) was used to determine the fiber. The percentage of fiber was calculated after igniting the samples according to the expression given below.

$$\text{Fiber (\%)} = \frac{\text{Weight loss}}{\text{Weight of sample}} \times 100$$

2.2.5 Ash

Ash was estimated according to the procedure as outlined in AACC, (2000) method no. 08-01. Ash content was determined by high temperature incineration in an electric muffle furnace (Thermo scientific thermolyne F48010-33, USA).

$$\text{Ash } (\%) = \frac{A-B}{C} \times 100$$

Where:
A = weight of crucible with sample (gm) B = weight of crucible with ash (gm) C = weight of sample (gm)

2.3. Antioxidant potential

Antioxidant potential was determined by measuring peroxide value, total acidity, energy, nitrogen free extract, and thiobarbituric acid value according to their respective methods described in AACC, (2000). Furthermore, the lignan content (sesamin, and sesamol) of the cookies were assessed following the method of SCHWERTNER and RIOS, (2010).

2.3.1 Peroxide value

Ash was estimated according to the procedure as outlined in AACC, (2000) method. Sample was melted and filtered through the filter paper to remove any impurities. A blank reading was taken under the similar conditions at the same time.
The peroxide value was calculated by using the relationship

$$\text{Peroxide value} = \frac{(B-A) \times N \times 1000}{W}$$

B = Vol. of $Na_2S_2O_3$ used for blank
A = Vol. of $Na_2S_2O_3$ used for sample
N = Normality of $Na_2S_2O_3$
W = Weight of the oil taken.

2.3.2 Total acidity

Total was estimated according to the procedure as outlined in AACC, (2000) method. Total acidity was calculated according to the expression given below.

Calculation:

Acid value = 56.1VN,
Where:
V = Volume in ml of standard KOH or NaOH used
N = Normality of the KOH solution or NaOH solution; and
W = Weight in gm of the sample

2.3.3 Nitrogen Free Extract (NFE)

The NFE was calculated by the following expression.
NFE% = 100 – (moisture% + ash%+ fat%+ fibre% + protein%)

2.3.4 Thiobarbituric Acid Value

TBA reagent (0.2883g/100mL of 90% glacial acetic acid), heated in water bath for 35 min with a blank sample. The tubes were cooled in water for 10 min and absorbance (D) against blank sample was taken by adjusting spectrophotometer (Cecil CE-7200, UK) on 538nm wavelength (AACC, 2000).
TBA no. was calculated by using the following expression:

TBA no. (mg malenaldehyde per Kg sample) = 7.8 x D

2.3.5 Lignans

Lignans (sesamin and sesamol) were analyzed by adopting the method of (SCHWERTNER and RIOS, (2010); SCHWINGSHACKL and HOFFMANN, (2012))with little modifications in it. A 2ml of sesame seed oil sample was taken in glass tubes and poured in it 20ml of methanol and vortex it for 30 minutes. The sample was then centrifuged at 2500 rpm for 30 minutes. After centrifugation, the upper layer was separated and again extraction was done by adding methanol again in it. The two extractions were combined and then evaporated under nitrogen. Then 2 ml of methanol was added to reconstitute it and vortex it. 20 µl of sample was injected into HPLC (Model: Perkin Elmer series 200 USA) equipped with C18 (4.6mm X 150 mm). The mobile phase was a mixture of methanol and water (70:30, v/v) and the flow rate was 1 ml/min. The UV detector was set at 288 nm. Sesamin, sesamolin and sesamol were quantified by comparing with standards.

2.4. Physical properties and palatability

To evaluate the palatability of cookies, taste tests were conducted using a sensory evaluation assessment tool described by MEILGAARD *et al.,* (2007). Briefly, 100 men and women were recruited from University student, faculty, and staff members, and the local community to participate in a series of consumer taste tests. The same individuals were asked to evaluate the cookies at each time period. Among these volunteers, 75 people completed the testing at all three-time points. Cookies were placed on a table in small cups coded by type. Both researchers and panelists were blinded to the coding scheme. Panelists were provided water to neutralize the taste after chewing and between tasting each cookie. Each panelist was asked to taste 3 cookies of each type and asked to evaluate the cookies for colour, flavor, taste, texture, crispness and overall acceptability using a 9-point (1= extremely poor to 9 = excellent), hedonic scale (MEILGAARD *et al.,* 2007). The physical properties such as cookie size and diameter, thickness, and spread factor were determined by investigators on three cookies from each group at the three time points (AACC, 2000).

2.5. Statistical Analyses

Data was expressed as mean ± SE. For composition analyses and physical properties, a total of 3 cookies from each group (HVF or SO) were evaluated at each time point. For palatability studies, evaluation data from 75 subjects was compared for each variable at each time point. All data were analyzed by repeated measures ANOVA. Where significant effects occurred, Tukey post-hoc analyses were performed. A p-value of ≤ 0.05 was considered statistically significant.

3. RESULTS AND DISCUSSIONS

3.1. Proximate analysis and antioxidant potential of cookies

As previously described, two types of cookies were prepared, one with 100% SO and other with 100% HVF and both were stored for up to 60 days in an air tight container. A description of the proximate composition of each of the cookies type for each time period is shown in Table 1. At baseline, both SO and HVF cookies had similar properties of moisture, fiber and ash. Compared to HVF, SO had significantly higher initial percentages of protein (6%), fat (8.5%), and energy kcal/100gm (15.4%).
By the end of the 60 days of storage time, moisture content in SO cookies increased approximately 34% ($p < 0.05$), while other components decreased significantly ($p < 0.05$) over time; (protein: -0.2%, fat: -3%, fiber: -5.5%, and ash: -7.9%). In HVF cookies, a similar trend was observed. In HVF cookies, moisture increased by about 52% ($p < 0.05$), while other components decreased ($p < 0.05$); (protein: -2.5 %, fat: -3.4 %, fiber: -6.9 %, and ash: -16.4 %) from baseline to 60 days of storage. Energy (kcal/100gm) did not change over time in either cookie group.

Table 1. Cookies proximate analysis.

Component	Day 0	Day 30	Day 60
Moisture (%)			
SSO	2.49 ± 0.04 (2.63)	3.19 ± 0.05 (2.87)[a]	3.35 ± 0.05 (2.60)[a,b,c]
HVF	2.41±0.02 (1.66)	3.08±0.03 (1.49)[a]	3.66±0.06 (2.96)[a,]
Protein (%)			
SSO	9.11±0.02 (0.33)[c]	9.05±0.04 (0.83)[c]	9.00±0.03 (0.62)[a,c]
HVF	8.57±0.02 (0.40)	8.43±0.03 (0.54)[a]	8.36±0.02 (0.43)[a]
Fat (%)			
SSO	39.62±0.59 (2.57)[c]	38.92±0.04 (0.18)[c]	38.41±0.31 (1.40)[c]
HVF	36.51±0.39 (1.83)	35.82±0.07 (0.33)	35.31±0.05 (0.22)
Fiber (%)			
SSO	2.09±0.02 (1.27)	2.01±0.02 (1.32)[a,c]	1.98±0.03 (2.31)[a,c]
HVF	2.01±0.02 (1.99)	1.92±0.03 (2.90)[a]	1.88±0.04 (3.72)[a]
Ash (%)			
SSO	0.95±0.01 (2.11)	0.93±0.02 (2.84)[c]	0.88±0.02 (4.10)[a,c]
HVF	0.92±0.02 (3.92)	0.83±0.03 (5.52)	0.79±0.03 (6.70)
Energy (Kcal/100gm)			
SSO	535.67±2.97 (0.96)[c]	535.58±0.24 (0.08)[c]	534.42±2.59 (0.84)[c]
HVF	464.33±2.96 (1.11)	463.89±2.77 (1.03)	463.12±2.82 (1.06)

Mean±SE (%Coefficient of Variance); the values are replicate of at least three.
Sig. [a]p<0.05 from Day 0;
Sig. [b]p<0.05 from Day 30;
Sig. [c]p<0.05 sesame seed oil cookies vs vegetable fat cookies.
At 60 days there were significant ($p < 0.05$) differences between groups. Moisture was significantly higher in HVF verses SO, whereas all other components were significantly ($p < 0.05$) lower in HVF group compared to SO group; (protein: -7.6%, fat: -9%, fiber: -5% and ash: -11 %).

Table 2 shows antioxidant potential of both SO and HVF cookies. At baseline, both SO and HVF had similar properties of nitrogen free extract and thiobarbituric acid value. Compared to SO, HVF had significantly higher initial percentages of peroxide value (37.5%) and acidity (20%). Lignans with antioxidant potential were detected in SO but were absent in HVF. Over time, from baseline to 60 days, peroxide value increased approximately 252% in SO cookies. Additionally, in SO, acidity, nitrogen free extract, and thiobarbituric acid values increased (35%, 3%, 54% respectively), while bioactive components, sesamin and sesamol, decreased significantly ($p < 0.05$) over time (i.e., -0.22% and -1.2% respectively). A similar trend was observed in HVF cookies. In HVF cookies significant ($p < 0.05$) increases were observed in peroxide (+182.5%), acidity (+24%), nitrogen free extract (+5%) and thiobarbituric acid (+ 53%) from baseline. There were no bioactive components detected in HVF cookies.

Table 2. Antioxidant potential of cookies.

Component	Day 0	Day 30	Day 60
Peroxide value (meq/kg)			
SSO	0.133±0.01 (17.3)[c]	0.341±0.00 (1.83)[a,c]	0.469±0.00 (0.93)[a,b,c]
HVF	0.183±0.01 (8.67)	0.428±0.00 (0.62)[a]	0.517±0.00 (1.02)[a,b]
Acidity (%)			
SSO	0.142±0.01 (11.3)[c]	0.188±0.01 (4.88)[a]	0.192±0.00 (4.26)[a,c]
HVF	0.171±0.00 (0.58)	0.198±0.00 (1.34)[a,b]	0.212±0.00 (1.70)[a]
Nitrogen free extract (%)			
SSO	41.27±1.01 (4.23)	42.21±1.24 (5.10)	42.57±1.21 (4.93)
HVF	41.87±0.51 (2.11)	42.45±0.70 (2.84)	43.94±0.58 (2.29)
Thiobarbituric acid value (mg malonaldehyde/kg-oil**)**			
SSO	0.046±0.00 (8.70)	0.068±0.01 (14.0)[a]	0.071±0.01 (18.3)[a]
HVF	0.055±0.00 (6.56)	0.062±0.00 (8.98)	0.084±0.00 (3.15)[a,b]
Sesamin (mg/kg)			
SSO	8.093±0.00 (0.01)	8.077±0.00 (0.09)[a]	8.075±0.00 (0.09)[a]
HVF	NA	NA	NA
Sesamol (mg/kg)			
SSO	18.64±0.05 (0.46)	18.48±0.02 (0.20)[a]	18.42±0.02 (0.20)[a]
HVF	NA	NA	NA

Mean±SE (%CV) the values are replicate of at least three
Sig. [a]$p<0.05$ vs Day 0; [b]$p<0.05$ vs Day 30; [c]$p<0.05$ vs HVF

The moisture content of both the cookies increased over the 60 days of storage period in both cookies. However, it increased significantly more in the HVF cookies. During storage, the rise in moisture content in cookies and cakes has been well documented by studies conducted by (LEELAVATHI and RAO, 1993; NAGI *et al.*, 2012; ROBERTSON, 1993). The hygroscopic nature of the dry ingredients of cookies is known to influence moisture content during storage. Additionally, this rise in moisture can influence the shelf life of the products by increasing peroxide value, acidity, nitrogen free extract, and thiobarbituric acid value; while decreasing protein, fat, fiber and ash content. Ash helps with the overall absorption of moisture. Thus a reduction of ash results in a corresponding increase in moisture. This storage phenomenon whereby a decrease in ash results in increasing moisture, has been well documented (PASHA *et al.*, 2002; REDDY *et al.*, 2005; SHARIF *et al.*, 2003; WAHEED *et al.*, 2010). When compared with other vegetable oil; sesame seed oil has high degree of monounsaturated and polyunsaturated fatty acids *i.e.*, is approximately 39% and 46% respectively that collectively makes almost 85% of unsaturated oil and low saturated fatty acids *i.e.*, is approximately 14% (SCHWINGSHACKL and HOFFMANN, 2012). Replacement of normal shortening in cookies with vegetable oils showed significant effect on moisture, fat content and NFE during storage, while change in fiber and ash content was not significant (SHARIF *et al.*, 2005). Bioactive components (i.e., sesamin, sesamolin, and sesamol) in the SO, were also affected during the storage period. High temperature (160-250°C) does not affect the bioactive components of sesame seed oil especially lignans and their concentration almost remains the same that is the reason behind the strong antioxidant potential of sesame seed oil even at high temperature it sustain its properties (YOSHIDA and TAKAGI, 1997). Nutritional improvement is not in a sense that it increases anything, but here it's in a context that it increases the stability of WSSO cookies against oxidation during study period due to antioxidant potential of white sesame seed oil. Antioxidant potential is evident from the results. Storage in polythene bags showed a significant change in moisture, peroxide value and overall acceptability of cookies (RANGREJ *et al.*, 2015). As the moisture increased with storage time, the antioxidant properties decreased. However, although moisture increased in both groups of cookies, because SO cookies had greater antioxidant potential to begin with, the SO cookies showed more stability than HVF cookies. NANDITHA and PRABHASANKAR, (2009) presented in their studies that natural antioxidants are very effective in enhancing the shelf life of bakery products. SHARIF *et al.*, (2003) made cookies from oil extracted from natural source that has functional properties and natural antioxidants, which increased the shelf life of cookies by enhancing their antioxidant potential. Similar to our findings various studies reported that SO cookies are not only more stable in their proximate composition analysis but also in the antioxidants available by day 60 (QUILEZ *et al.*, 2006; REDDY *et al.*, 2005).

3.3. Sensory evaluation

A total of 75 people completed the study at all three time periods. Before sensory evaluation, training and instructions were given to the all participants so that they can evaluate the products for sensory evaluation in the right way. The mean rating scores of the 9 points (low to high) sensory evaluation scale of colour, flavour, taste, crispness and overall acceptability are shown in Table 3. Table 3 indicates that at baseline, SO cookies had significantly ($p < 0.05$) higher evaluation for colour (16%), flavour (10%), taste (5%), texture (9%), crispness (9%) and overall acceptability (12%) compared to HVF cookies.

Over the period from baseline to 60 days, the mean rating on each attribute decreased significantly ($p < 0.05$) for each cookie type. For SO cookies, colour decreased by about -5.5%, flavour -8%, taste -16%, texture -11.6%, crispness -8% and overall acceptability by -14%. A similar trend was observed in HVF cookies. In HVF cookies, the mean rating for colour decreased -9%, flavour decreased by -11%, taste decreased by -11%, texture decreased by -12%, crispness decreased by -7% and overall acceptability decreased by -5.5%.

By day 60, there were significant ($p < 0.05$) differences in the sensory rating between groups. Compared to the HVF group, colour, flavor, texture and crispness were rated higher in the SO group (range 8-20%). Taste and overall acceptability were lower than baseline but were not significantly different between groups by day 60.

Table 3. Palatability of cookies.

Characteristic	Day 0	Day 30	Day 60
Color			
SSO	8.51±0.07 (6.80)^{c}	8.21±0.05 (5.02)^{a,c}	8.05±0.03 (2.81)^{a,c}
Vegetable oil	7.35±0.10 (12.2)	6.91±0.09 (10.7)^{a}	6.71±0.09 (11.4)^{a}
Flavor			
SSO	7.51±0.06 (6.71)^{c}	7.11±0.09 (11.0)^{a,c}	6.93±0.08 (9.58)^{a,c}
Vegetable oil	6.80±0.09 (11.1)	6.43±0.08 (10.6)^{a}	6.12±0.05 (7.09)^{a,b}
Taste			
SSO	8.00±0.09 (9.86)^{c}	7.15±0.09 (11.2)^{a}	6.87±0.07 (8.74)^{a,b}
Vegetable oil	7.65±0.09 (10.2)	7.15±0.08 (10.2)^{a}	6.92±0.09 (11.6)^{a}
Texture			
SSO	7.49±0.09 (9.90)^{c}	6.95±0.10 (12.5)^{a,c}	6.72±0.08 (9.96)^{a,b,c}
Vegetable oil	6.89±0.09 (11.1)	6.25±0.05 (7.48)^{a}	6.17±0.05 (6.72)^{a}
Crispness			
SSO	7.40±0.10 (11.5)^{c}	7.05±0.09 (11.4)^{a,c}	6.84±0.07 (9.00)^{a,b,c}
Vegetable oil	6.79±0.08 (9.78)	6.45±0.06 (8.17)^{a}	6.33±0.06 (7.93)^{a}
Overall Acceptability			
SSO	8.00±0.06 (6.82)^{c}	7.40±0.09 (10.4)^{a,c}	7.03±0.07 (9.05)^{a,b,c}
Vegetable oil	7.12±0.08 (9.51)	6.97±0.08 (10.5)	6.75±0.06 (7.35)^{a}

Scale 1= low; 9 = high
Mean±SE (%CV) the values are replicate of at least three
^{a}p<0.05 vs Day 0; ^{b}p<0.05 vs Day 30; ^{c}p<0.05 vs. vegetable oil cookies

At each time period, both SO and HVF cookies had similar physical properties as shown in table 4. By 60 days, the diameter in HVF cookies increased significantly ($p < 0.05$) by about 3% from baseline. In both groups, the rating for colour and flavor decreased over time. During storage, a common oxidation process that is stimulated by an increase in moisture known as maillard reactions, stimulates increased oxidation of the fat and increases in free fatty acids which could affect colour and flavor of the cookie. TBARS is an important indicator for the quality of stored food (BUTT *et al.*, 2007; WADA, 1998). Slow increase in moisture of WSSO cookies caused the sustainability of total acidity and peroxide value that is directly related to antioxidant potential of WSSO cookies. As noted previously, the increase in moisture with storage resulted in increased peroxide and acidity which will negatively affect most of the sensory attributes. In fact, several authors (BENDER, 1996; SHARIF *et al.*, 2003; WAHEED *et al.*, 2010), have reported a similar trend between increasing moisture with decreasing palatability with storage. Previous research has also indicated that the addition of sesame flour improved the aroma, taste and overall acceptability of cookies and there were no significant differences from the control cookies (OLAGUNJU and IFESAN, 2013). Also, LIM and LEE reported that the addition of sesame powder did not affect the overall acceptance of cookies (LIM and LEE, 2015). Further, when bioactive components like phytosterol, α tocopherol and β phytosterol were added, there were no changes in the sensory and chemical properties of cookies (QUILEZ *et al.*, 2006). Lastly, extra moisture is known to change the diameter, thickness, and spread factor of the cookie. During storage, the amount of moisture absorbed will increase the diameter of cookies and decrease their thickness. Physical properties are also directly related to composition of cookies. As in composition of both cookies the main difference was the WSSO and hydrogenated vegetable fat that creates the difference during storage.

Table 4. Physical properties of cookies.

Characteristic	Day 0	Day 30	Day 60
Diameter			
SSO	63.25±0.26 (0.70)^{c}	63.02±0.04 (0.11)^{c}	62.96±0.06 (0.16)^{c}
HVF	62.08±0.14 (0.38)	62.01±0.10 (0.27)	63.93±0.03 (0.08)^{a,b}
Thickness			
SSO	9.80±0.03 (0.51)	9.76±0.01 (0.20)	9.71±0.03 (0.47)
HVF	9.75±0.01 (0.21)	9.72±0.03 (0.45)	9.69±0.06 (1.00)
Spread factor			
SSO	64.54±0.42 (1.13)^{c}	64.56±0.05 (0.12)	64.84±0.08 (0.20)^{c}
HVF	63.67±0.08 (0.21)	63.79±0.23 (0.64)	63.91±0.40 (1.08)

Mean±SE (%CV) the values are replicate of at least three
$^{a}p<0.05$ vs Day 0; $^{b}p<0.05$ vs Day 60; $^{c}p<0.05$ vs. HVF cookies

5. CONCLUSIONS

The results of this study indicate that exchanging the fat source used in a cookie significantly affects its physiochemical properties, antioxidant potential, palatability, and physical properties. Although, following 60 days of storage, the overall properties of both types of cookies decreased, the cookies made with white sesame seed oil had better organoleptic properties and were found to be more palatable than the HVF cookies. Furthermore, since SO cookies have greater antioxidant potential than cookies made with HVF, they may be a healthier cookie choice. The results of this study indicate that WSSO improved the overall functional importance of SO cookies in terms of their physicochemical properties and bioactive components. The enhanced stability of WSSO cookies against oxidation and their improved antioxidant potential may be particularly important for food industries that are interested in developing cookies with functional value. By replacing the fat source with sesame oil, cookie manufacturers may be able to meet high standards for nutritional potential without sacrificing palatability or shelf life of the cookies.

ABBREVATIONS

White sesame seed oil (WSSO), Sesame seed oil (SSO), Hydrogenated vegetable fat (HVF).

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