INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
09–014/RSM/2009/11–3–311–315
http://www.fspublishers.org

Full Length Article

Physical and Sensory Properties of Maize Germ Oil Fortified Cakes

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ABSTRACT

In this study oil was extracted from maize germ, refined and used in cake recipe for value-addition. Cakes were prepared from different blends of maize germ oil (MGO) and normal shortening; evaluated for physical and sensory attributes. The specific gravity of the MGO was 0.923±0.001, while the refractive index was 1.472±0.001 at room temperature. The iodine value, saponification value, acid value, peroxide value and free fatty acids of the MGO were recorded to be 113.67±1.53 g 100 g^{-1}, 192.67±2.08 mg KOH g^{-1}, 0.33±0.001 mg KOH g^{-1}, 1.69±0.03 meq kg^{-1} and 0.033±0.01 g 100 g^{-1}, respectively. Cake volume and specific volume increased, whereas crumb hardness of cake slices was not significantly affected with the addition of MGO in the formulation. Hunter color "b" values of cake crumb increased significantly with MGO fortification, representing an increased yellowish tint of the crumb. The MGO also resulted in momentous increase in chroma and hue angle values. Sensory scores for overall quality increased with the MGO augmentation in cakes and the highest score (12.6±0.8) was assigned to treatment with 60% MGO that differed non-momentously from 80% and 100% MGO fortified cakes. Overall, cakes were successfully prepared with all levels of MGO fortification with high acceptability.

Key Words: Maize germ oil; Fortified cakes; Sensory evaluation; Physical properties

INTRODUCTION

Maize germ constitutes 5-14% of the weight of kernel and is a good source of key nutrients especially 18-41% of oil (Johnston *et al.,* 2005; MPOC, 2008). Keeping in view the germ recovery from various maize hybrids in Pakistan, roughly 225 thousand tons of germs is obtainable annually for oil production.

Maize germ oil (MGO) is bestowed with the components of nutritional significance like tocopherols and polyunsaturated fatty acids (PUFA). MGO has gained wide popularity as a good source of essential fatty acids with 50-60% of polyunsaturated fatty acids (Lemcke-Norojarvi *et al.,* 2001). Presence of PUFA plays pivotal role in betterment of human health through maintaining the body homeostasis and regulating serum lipid profile (Ramaa *et al.,* 2006). Furthermore, MGO is amongst the richest sources of vitamin E as it contains appreciable amounts of α- and γ-tocopherols. The supply of these components through diet is of significant importance as they provide several health benefits especially in coronary cure. Presence of MGO allied antioxidants in diets improves serum tocopherols especially γ-tocopherol status. Improved antioxidant defense system has the ability to reduce the extent of LDL oxidation and subsequently improving cardiovascular health (Lemcke-Norojarvi *et al.,* 2001; Albertini *et al.,* 2002).

Edible oils are vital, serving as important ingredient of many foods by imparting characteristic flavor and texture to finished food products (Rudan-Tasic & Klofutar, 1999). Acquaintances with chemical and physical properties of edible oils are imperative as they tie up with processing functionality, storage stability and nutritional behavior. These properties depend primarily on variety, composition and origin of fats and oils. Technological properties of maize germ oil (MGO) proved it as stable vegetable oil that renders its extensive use as cooking medium, in margarines and salad dressings (CRA, 2006).

Product development is not only restricted to create distinctive food commodities but also includes product relocation, line extension and reformulating the existing items. Among different value added food systems, baked products provide an excellent opportunity to incorporate food-grade fractions from grains, legumes, or other non-traditional food sources (Siddiq *et al.,* 2009). Baked foods i.e., bread, cookies and cakes etc. are consumed worldwide relatively on large scale (Bakke & Vickers, 2007). Studies for successful incorporation of new ingredients in existing food systems for value-addition involves physico-chemical and sensory evaluation. The objective of present study was

To cite this paper: Nasir, M., M.S. Butt, F.M. Anjum, A. Jamil and I. Ahmad, 2009. Physical and sensory properties of maize germ oil fortified cakes. *Int. J. Agric. Biol.*, 11: 311–315

to determine the composition, physical and chemical characteristics of oil extracted through n-hexane to evaluate its nutritional quality and stability and to assess physical and sensory acceptability of cakes prepared from different levels of maize germ oil.

MATERIALS AND METHODS

Maize germ oil (MGO) extraction and refining. Germs were separated from the maize kernels using quick germ milling process according to the method described by Singh and Eckhoff (1996) at National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan during the year 2006-2007. Extraction of maize germ oil (MGO) was done through solvent extraction (*n*-hexane) technique with Soxklet system through continuous refluxing. The solvent from oil was removed by distillation through rotary vacuum evaporator (Model: SB-601, Eyela N-N Series, Tokyo Rikakikai Co. Ltd., Tokyo, Japan). The extracted MGO was kept in desicator over anhydrous calcium chloride for 24 h to ensure complete removal of moisture. MGO was then refined to remove unsaponifiable matter, pigments and to some extent the partial esters. The refining included the processes of dewaxing, degumming, neutralization, bleaching and deodorization.

Analysis of refined MGO. The refined MGO was analyzed for physical characteristics i.e., color (Cc 13j-97), flavor, odor, specific gravity (Cc 10a-25), refractive index (Cc 7-25) and chemical characteristics i.e., free fatty acids (Ca 5a-40), peroxide value (Cd 8-53), acid value (Cd 3d-63), saponification value (Cd 3-25), iodine value (Cd 1d-92) using their respective methodology (AOCS, 1998; AOAC, 2006).

Cake preparation. Normal shortening (NS) was replaced with refined MGO at 20, 40, 60, 80 and 100% levels. Cakes were prepared, from control and all the MGO-NS blends according to AACC (2000) method with some modifications. Creaming of shortening and sugar was done through Hobart Mixer (Model N-50, Hobart Corp. Troy, Ohio, USA). The rest of ingredients were added as per sequence and mixed to homogenous mass. The batter was put in greased pans and baked at 180°C for 45-50 min. The cakes were then cooled and packed for further analysis.

Physical analysis. Volume of sample cakes was determined by rapeseed displacement method (AACC, 2000; 10-10B) and weight was recorded by using 2-decimal digital weighing scale, while cake specific volume was calculated by dividing cake volume by weight. The color of the cake crumb was measured with Hunter Color Meter (Model: D25 L Optical Sensor, Hunter Associates Lab., Reston, Virginia, USA). The color values were recorded as "L" (0 black; 100 white), "a" (–a greenness; +a redness) and "b" (–b blueness; +b yellowness). The data thus obtained was used to calculate Chroma and Hue angle according to the method of Little (1975).

Textural analysis of cake; as force required to compress 50% of the original height of the cake slices of 25 mm thickness was done using a Stable Micro System (SMS) Texture Analyzer (Model: TA-XT2*i*, Texture Technologies Corp., Scarsdale, New York, USA). The individual cake slices were tested under the compression mode using 35-mm dia. compression probe. A crosshead speed of 100 mm min^{-1} was used to record the maximum force expressed as the firmness of the cake crumb in Newton (N).

Sensory evaluation. Cakes prepared with normal shortening and MGO blended shortening were subjected to sensory evaluation by a trained taste panel of 10 judges as described by (Meilgaard *et al.,* 2007). Evaluation was carried out by the panelists using 15-cm unstructured line for parameters of uniformity of cells, softness of texture, crumb color, aroma, taste and overall quality. All evaluations were conducted at room temperature on the same day in the National Institute of Food Science and Technology (NIFSAT), University of Agriculture, Faisalabad.

Cake slices were placed in transparent cups, labeled with 3-digit random codes. Panelists were provided with distilled water and unsalted crackers to clean their mouths between the samples. The cake samples were presented in random order and panelists were asked to rate their acceptance by marking a cross on the line for all the parameters. The data thus obtained was converted to numerical scores using metric scale and statistically analyzed to check the degree of significance and variance analysis using Co-Stat 2003 software.

RESULTS AND DISCUSSION

Characteristics of maize germ oil. Physical and chemical characteristics of MGO are shown in Table I. MGO showed agreeable flavor and pale yellow color. The specific gravity was noted to be 0.923±0.001 and the refractive index measured at room temperature was 1.472±0.001. The iodine value, saponification value, acid value, peroxide value and free fatty acids were found to be 113.67±1.53 g 100 g^{-1}, 192.67±2.08 mg KOH g^{-1}, 0.33±0.001 mg KOH g^{-1}, 1.69±0.03 meq kg^{-1} and 0.033±0.01 g 100 g^{-1}, respectively.

Color of oil reflects the degree of refining and is an important criterion for its intended use in food formulations. The flavor of the oil is also key property, which is subjective to temperature, moisture, air in contact, light and presence of antioxidants. Specific gravity is a good indicative of purity of oil. It is dependant on the number of double bonds and the chain length of the fatty acids. At any given temperature specific gravity increases as the mean molecular weight decreases (higher saponification value) with increase in degree of unsaturation (higher iodine value). Refractive index of oil increases with increase in the number of double bonds (iodine value). In general, the refractive indices of oils relate to the degree of unsaturation in a linear way (Rudan-Tasic & Klofutar, 1999).

Iodine value is used to assess degree of unsaturation of

Table I. Physical and chemical characteristics of maize germ oil

Characteristic	Value
Color	Pale yellow
Flavor	Agreeable
Specific gravity	0.923±0.001
Refractive index	1.472±0.001
Iodine value (g 100 g^{-1})	113.67±1.53
Saponification value (mg g^{-1})	192.67±2.08
Acid value (mg KOH g^{-1})	0.33±0.001
Peroxide value (meq kg^{-1})	1.69±0.03
Free fatty acids (g 100 g^{-1})	0.033±0.01

Table II. Physical parameters of maize germ oil (MGO) fortified cakes

MGO level in cakes (%)	Volume (mL)	Specific volume (mL g^{-1})	Weight (g)	Crumb hardness (N)
0	281.3±1.2c	3.29±0.02d	85.5±0.9a	21.45±2.13a
20	282.3±0.6c	3.31±0.05cd	85.2±1.5a	21.28±1.61a
40	284.0±1.7c	3.29±0.01d	86.3±0.6a	22.96±1.07a
60	292.3±4.5b	3.37±0.04bc	86.7±0.3a	24.00±1.03a
80	295.7±1.2b	3.42±0.06ab	86.6±1.2a	24.07±1.45a
100	300.7±1.2a	3.47±0.01a	86.7±0.6a	24.54±1.07a

Means sharing the same letter in a column are not significantly different

fatty acids and indicator of oxidative stability. The higher iodine value represents the greater degree of unsaturation. Saponification value gives the idea of molecular weight of fatty acids present in oil; higher value corresponds to lower molecular weight of fatty acids. Saponification value of the MGO depicted that fatty acids present in the MGO have more number of carbon atoms.

The acid value is an indirect measure of free fatty acid contents present in oil/fat and hence the index of freshness. Humidity and temperature result in increased acid value due to hydrolysis of glycerides. Higher acid value gives an idea about increased susceptibility of oils to rancidity. The oils intended for dietary purposes should not contain high free fatty acids. Presence of free fatty acids in oils/fat is not desirable, because they render unpleasant odor and deteriorate the quality of the product. Peroxide value is used to measure the oxidative rancidity of oil and is one of the most important parameters to evaluate the degree of deterioration of lipids. Peroxides and hydro-peroxides produced due to oxidation of oil/fat undergo break down to produce bad smelling aldehydes, ketones and acids. Fresh refined oils should have zero POV but for acceptable storage stability, the POV should be less than 5 mmol kg^{-1} of sample (Rudan-Tasic & Klofutar, 1999).

The results for specific gravity and refractive index are closely associated with those reported by Rudan-Tasic and Klofutar (1999) for maize germ oil. CRA (2006) also published typical values for physical parameters of MGO: color; pale yellow, specific gravity; 0.922-0.928, refractive index; 1.470-1.474 and flavor; slight corn, slight nutty/buttery.

Chemical characteristics of germ oil are in agreement with the published data for these indices. According to the list of primary specifications for corn oil laid down by the

Fig. 1. Hunter color "L", "a" and "b" values of MGO fortified cakes

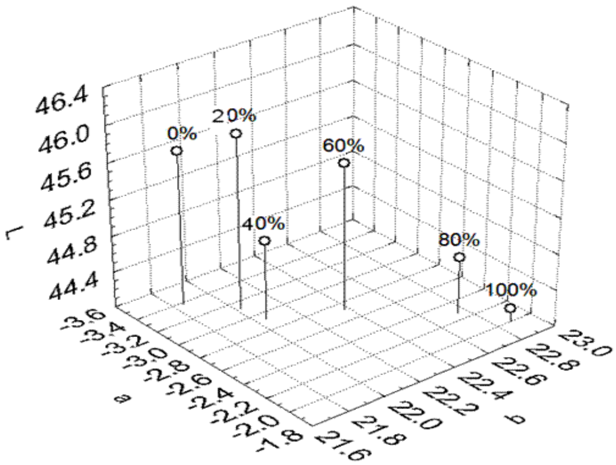
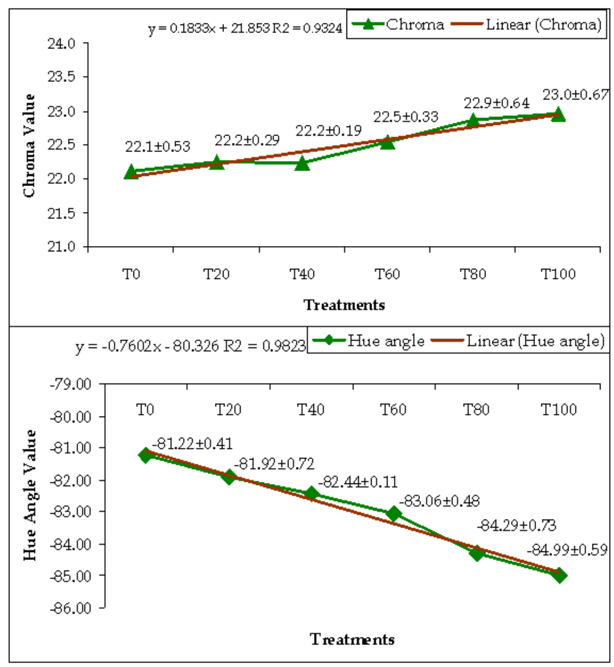


Fig. 2. Chroma and hue angle values of MGO fortified cakes



Committee on Food Chemicals Codex of the National Academy of Sciences/National Research Council, free fatty acids should not be more than 0.1% and POV not more than 10 meq kg^{-1} (FCC, 2003). Present results are in conformity with these specifications. The findings of present research are also within the ranges given by Corn Refiners Association for chemical and physical characteristics of corn oil (CRA, 2006). Leibovitz and Ruckenstein (1983) also reported that the iodine value of crude maize germ oil is 110-125 g 100 g^{-1}. They further showed that free fatty acids and POV values of refined maize oil samples ranged from 0.02-0.03% and 0.0-0.1 meq kg^{-1}, respectively. The findings of present investigation for POV, iodine value, acid value

Table III. Sensory scores of MGO fortified cakes

MGO level in cakes (%)	Crust color	Cells uniformity	Texture softness	Aroma	Taste	Overall quality
0	12.8±1.4	12.3±1.5	13.0±1.5a	11.5±1.4a	11.3±1.7	11.1±1.1c
20	12.4±1.6	12.0±1.5	12.0±1.8abc	12.0±1.5a	11.3±1.7	11.7±1.2bc
40	11.8±1.5	12.5±1.6	11.5±1.7bc	11.8±1.5a	11.8±1.9	11.8±1.0abc
60	12.3±1.3	10.9±2.4	12.8±1.4ab	12.3±1.3a	12.1±1.9	12.6±0.8a
80	12.3±1.1	11.1±2.6	11.6±1.2bc	12.8±1.5a	11.7±1.6	12.2±1.0ab
100	12.2±1.7	10.8±2.9	11.0±1.7c	12.5±1.9a	10.9±1.8	12.2±0.9ab

Means sharing the same letter in a column are not significantly different

and saponification value are also in line with the earlier results reported by Rudan-Tasic and Klofutar (1999).

Physical characteristics of cakes. Cake volume and specific volume were affected significantly, whereas treatment did not show any momentous effect on weight and crumb hardness. Means of cake physical characteristics are given in Table II. Cake volume increased gradually with the addition of maize germ oil (MGO) in formulation and highest volume was recorded for cakes prepared with 100% MGO. Cake volume was improved from 281.3±1.2 mL for normal shortening to 300.7±1.2 mL for 100% MGO fortified cakes. Maize germ oil showed positive effect on specific volume; increased from 3.29±0.02 to 3.47±0.01 mL g^{-1} as the MGO level was increased from 0 to 100%. Though, crumb hardness increased with increasing level of MGO, but the values were non-significant. Cake weights did not depict variations with MGO fortification. Ranges for weight and crumb hardness were 85.2±1.5 to 86.7±0.6 g and 21.28±1.61 to 24.54±1.07 N, respectively. Overall, cakes prepared from MGO addition exhibited increased volume, specific volume and crumb hardness.

The results for hardness and volume are also supported by the findings of Jacob and Leelavathi (2007) who studied effect of fat type on cookie quality. They reported that oil increased resistance during mixing as compared to bakers fat resulting in comparatively harder texture. The product prepared with oil addition also resulted in increased spread ratio. Fat is one of the basic components of cake formulation and acts as lubricant providing plasticity to the dough (Maache-Rezzoug *et al.,* 1998). Oil in shortening has a key role in adequate aeration (O'Brien, 2004) resulting increased volume.

Crumb color. Redness ("a"), hue angle, lightness ("L") and yellowness ("b") were significantly affected by MGO addition, whereas chroma was found to be non-significant. Mean values for color parameters i.e., "L", "a" and "b" are illustrated in Fig. 1, whereas chroma and hue angle is shown in Fig. 2. It is evident from results that MGO addition resulted in decreased greenness ("-a"), lightness ("L") and increased yellowish color ("b") of cake crumb. The normal shortening cake was lighter in color, as depicted by higher "L" value that decreased with MGO addition. Hunter color "b" values increased significantly with MGO addition in cake formulation, representing an increased yellowness of the cake crumb.

The values for chroma and hue angle also increased momentously by adding up of MGO in cakes' formulation. Chroma and hue angle values ranged from 22.1 to 23.0 and -81.22 to -84.99, respectively. The results clearly indicated that the addition of MGO significantly decreased lightness and increased yellowness of the crumb. The results are supported by the fact that MGO was pale yellow in color and the replacement of shortening with MGO imparted yellowish crumb color.

Sensory evaluation. Sensory scores for overall quality and texture softness depicted significant variation with that of treatments, while cells uniformity, color, flavor and taste showed non-significant differences with treatments (Table III). Overall quality increased with the level of MGO in cake formulation and significantly highest score (12.6±0.8) was recorded for cakes prepared with 60% MGO that non-significantly differed from 80% and 100% MGO fortified cakes. Lowest scores (11.1±1.1) for overall acceptability were assigned to control cakes; improved non-significantly up to 40% MGO addition. Scores for texture softness decreased with MGO blending levels from 13.0±1.5 to 11.0±1.7. The scores for texture softness are supported by the objective data for texture hardness, as there is an inverse correlation between these traits.

The ranges for crust color, cells uniformity, aroma and taste were 12.2±1.7 to 12.8±1.4, 10.8±2.9 to 12.3±1.5, 11.5±1.4 to 12.8±1.5 and 10.9±1.8 to 12.1±1.9, respectively. It can be noted that cakes with 60% MGO were awarded maximum scores for overall quality and taste, the two most important parameters. It is concluded that MGO blending with normal shortening in cake formulation improved the sensory and physical attributes of finished product. In some other studies normal shortening was also successfully replaced with oils to improve the nutritional quality of bakery products e.g., wheat germ oil, rice bran oil and sunflower oil (Sharif *et al.,* 2003; Jacob & Leelavathi, 2007).

Maize germ oil contains 30% monounsaturated fatty acids and 56% polyunsaturated fatty acids (EFSA, 2005); can play a vital role in the diet being a rich source of essential fatty acids that help to regulate cholesterol and blood pressure (Hauman, 1985; Dupont *et al.,* 1990). Consequently, maize germ oil incorporation in cake formulation potentially satisfies the requirements for essential fatty acids (CRA, 2006). Maize germ oil is amongst the rich sources of tocopherol; helpful in cholesterol lowering or preventing cardiovascular maladies and oxidative stress (Lloyd *et. al.,* 2000; Ricciarelli *et al.,* 2001; Birringer *et al.,* 2002).

CONCLUSION

Maize germ oil was found to possess good physical and chemical characteristics. Cakes were successfully prepared from all MGO-NS blends with good physical characteristics and high acceptable quality. Thus, MGO incorporation in cake recipe with potential health benefits can be helpful for the improvement of nutritional quality of end product.

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(Received 17 January 2009; Accepted 06 February 2009)