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UTILIZATION OF MAIZE GERM CAKE AS A NUTRITIONAL AND FUNCTIONAL INGREDIENT IN PROCESSED CHEESE

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Abstract: *The present study was conducted to investigate the effect of partially incorporating maize germ cake flour (MGC) in the formula of processed cheese on the physicochemical, textural, microstructure, and sensory properties of the final product. The processed cheese was prepared with the addition of MGC at a ratio of 1, 2, 3, and 4%, and then stored at 4 °C for 60 days. The results found that the MGC contains a higher protein, starch, and dietary fiber, as well as higher antioxidant activity. The dry matter % (DM %), protein %, and ash% of processed cheese significantly increased with increasing MGC amount, while the fat % and pH value significantly decreased. The textural and microstructural properties of processed cheese were enhanced by the addition of maize germ cake. The best sensory evaluation was found with control samples followed by processed cheese samples containing 1 and 2% MGC, while the lowest sensory degrees were observed with 4% MGC. This study recommends the use of MGC as a low-cost, nutritional, and functional ingredient at a ratio of 1 and 2% in the preparation of processed cheese.*

Keywords*: Processed cheese; Maize germ; Microstructure; Texture; Antioxidants*

1. Introduction

Processed cheese is one of the most famous and widespread dairy products around the world. The process of making processed cheese involves combining non-dairy ingredients like emulsifying salts, sodium chloride, some natural colours and flavors, water, and mold inhibitors with some dairy ingredients like natural cheese, butter, milk protein concentrate (MPC), skim milk powder, whey powder, whey protein concentrate (WPC), and permeate. The mixture is then heated with continuous stirring to form a homogeneous final product with a long shelf life [1]. The stages of manufacturing processed cheese are divided into two basic parts: (1) selection of ingredients and formation of the cheese formula and (2) manufacturing and storage of cheese [2]. The first step involves choosing and shredding natural cheese, standardizing fat content, choosing suitable emulsifying salts and other ingredients, and blending the ingredients to achieve the desired gross chemical composition. The technological processing steps, such as mixing and cooking, packing, chilling, cartooning, and storing, are covered in the second stage [2]. Previous studies reported that the fortifying processed cheese with natural bioactive ingredients has increased significantly in the past few years, for example, the incorporation of soy bean flour, chickpea flour, medicinal herb extracts, essential oils, and curcumin nanoemulsions [3, 4, 5] into cheeses, which resulted in improved nutritional value and organoleptic properties, and

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extended the shelf life of cheese types. A wide range of processed cheeses with diverse textures and flavors can be produced thanks to the wide variety of ingredients that can be added to processed cheese blends. As a result, processed cheese can be eaten alone or used to make other dishes, such as snacks [6]. These characteristics and features make processed cheese among the most innovative products in the dairy sector. Therefore, the processed cheese market is always in need of more innovations aimed at improving the nutritional value and health benefits of the final product [6]. Maize (*Zea mays* L.) is one of the most important food crops in many countries around the world, and both the world's cultivated area and maize production have grown in recent years [7]. The maize germ represents approximately 5-14% of maize kernel weight depending on maize variety and grain size [8] and is an excellent source of numerous nutrients, including 18–41% fat. Maize germ cake (MGC) flour is a byproduct from the corn oil industry. In many countries, it is used for animal feed due to the low cost of this ingredient [7]. Maize germ cake is considered a rich source of protein, which represents about 20% of the dry matter. Maize germ cake protein consists mainly of globulin and albumin [9]. This protein is considered balanced in its content of essential amino acids, and the amino acid lysine represents about 5-6 % of total proteins, and this percentage is twice that of wheat flour [9]. In addition to nutritional considerations of MGC, the functional properties of MGC flour, such as oil and water absorption, solubility, emulsifying properties, and foaming capacity and stability, also significantly contribute to the final quality of the processed food products. It has been demonstrated that the protein in maize germ flour has an exceptional capacity for both fat and water binding, which stabilizes emulsions by absorbing or binding excess water and increases the yield of final products [10]. As a result, MGC's nutrient-rich composition suggests that it could be a useful addition or fortifier in a range of food products, including muffins, bread, and cookies. Despite the excellent nutritional quality of MGC, the available information in previous literature about its functional properties and applications in the food industry is very limited. Therefore, this study aimed to investigate the effect of supplementation with maize germ cake on processed cheese's physicochemical, microstructural, textural, and sensory characteristics during two months of storage in refrigerator at 4±1°C.

2. Material and Methods

Materials

Maize germ cake (MGC) was obtained from the National Company of Maize Products (NCMP), Egypt. Butter (82% fat), and Six months old Cheddar cheese (62.4% dry matter (DM), 34% fat, and 25% protein), were purchased from AlSakr Food Industries Company, Egypt. Skim milk powder with 34% protein was obtained from Fonterra Co., New Zealand. Egy Phos S20 emulsifying salt was purchased from EGY-Dairy Company, Egypt.

Chemical composition of MGC

The chemical composition of the MGC (total solids (TS %), protein %, ash %, and, fat %) was determined based on AOAC procedures [11].

Determination of antioxidant activity of MGC

a- Preparation of maize germ cake extract

The extract of MGC was prepared based on the method of Öztürk et al. [12].

b- Determination of total phenolic content

The total phenolic content (TPC) of the MGC extract was determined as mg gallic acid equivalents (GAE) /100 g, according to the method of Abirami et al. [13].

c- Determination of flavonoid content of MGC

The total flavonoid (TF) content of the extracts was determined as mg rutin equivalents (RE) /100 g according to the method of Barros et al. [14].

d- DPPH radical scavenging activity (%)

The scavenging activity of DPPH radicals was determined according to the method of Lim and Quah [15]. The scavenging activity of each extract was calculated using the following equation:

$$\text{DPPH scavenging activity \%} = (1-\text{Abs}_{sample}/\text{Abs}_{control}) \times 100$$

e- Ferric reducing antioxidant power

Ferric reducing antioxidant power (FRAP) was determined as mg gallic acid equivalents (GAE)/100 g based on the procedure of Oyaizu [16].

Preparation of processed cheese

Processed cheese was manufactured according to the method of Muira et al. [17] by mixing 16 % cheddar cheese, 8.62 % skimmed milk powder, 19.5 % butter (82% fat), 0.33 % salt, and 2 % emulsifying salts (control treatment or main formula). The other processed cheese treatments involved the addition of MGC to the previous formula (main formula) at ratios of 1, 2, 3, and 4% (treatments of MGC 1%, MGC 2%, MGC 3%, and MGC 4%, respectively). Individual mixtures were well mixed by Thermomix (GmbH Co., France) at 100 rpm for 15 minutes, and 100 g representative samples from each admixture were taken for RVA simulated manufacture of processed cheese. The rest of each admixture is continually manufactured into processed cheese. In about five minutes, the pre-blend temperature was raised to 80 °C and held at this temperature for a further five minutes. Throughout the heating and holding phases, the auger's speed was 140 rpm, and the samples were packed in 200 g aseptic plastic containers and stored in a refrigerator at 4.0±1.0 °C for 60 days.

Simulated manufacture of processed cheese by rapid visco analyzer (RVA)

The emulsification time, apparent viscosity and end viscosity of processed cheese treatments were measured using a rapid visco analyzer (RVA) based on the procedure of Kapoor and Metzger [18].

Physicochemical analysis of MGC-Processed Cheese

Physicochemical analysis of processed cheese (dray matter (DM %), protein %, fat % and ash %) was carried out according to AOAC procedures [11]. Using a pH meter (Jenway, UK), the pH of processed cheese samples was determined.

Microbiological evaluation of MGC-Processed Cheese

The microbiological quality of processed cheese samples was evaluated by determining the coliform count [19] and yeasts and molds count [20].

Texture analysis of processed cheese

The firmness, stickiness, work of sheer, and work of adhesion of processed cheese were measured using a texture analyzer (TA. XT_{Plus}, U.K).

Microstructure of MGC-Processed Cheese

Based on the method of Tahmasebi et al. [21], scanning electron microscopy was used to assess the microstructure of the processed cheese samples.

Sensory evaluation of MGC-processed cheese

Thirty-five panelists from the Dairy Technology Research Department, Food Technology Research Institute, assessed processed cheese samples for taste, color, odor, texture, appearance, and overall acceptability. A nine-point hedonic scale was used to determine the evaluation (1 being extremely disliked and 9 being extremely liked) [5].

Statistical analysis

Using SPSS 16.0, a one-way (ANOVA) analysis of the data was carried out. At a significance level of $P \leq 0.05$, the means of the treatments were compared using Duncan's test, and the correlation was computed using Pearson's correlation coefficient.

3. Results and Discussion

Chemical composition and antioxidant activity of MGC

The data presented in Table (1) show the chemical composition and antioxidant activity of MGC. The results showed that the MGC contained significant quantities of protein (27.57%), starch (28.84%), and fat (10.95%) as well as crud fiber (7.77%). Additionally, MGC are an excellent natural source of total phenolic (TP) and total flavonoids (TF). The antioxidant activity of MGC was evaluated using DPPH and FRAP assays. The MGC showed a higher DPPH scavenging activity (78.36%) and higher FRAP value (141.9%). The potential health benefits of total phenolic (TP) are related to their antioxidant, anti-radical, anti-carcinogenic, anti-inflammatory, and anti-mutagenic activities [22].

Table 1

Chemical composition and antioxidant activity of MGC

Chemical composition	
Total solids (%)	91.79±0.11
Protein (%)	27.57±1.01
Crud fiber (%)	7.77±0.48
Starch (%)	28.84±0.42
Fat (%)	10.95±0.53
Ash (%)	4.02±0.06
Antioxidant activity	
Total phenolic content (mg GAE/100g)	1688±12.34
Total flavonoids content (mg RE/100g)	7.489±0.14
DPPH scavenging activity (%)	78.36±1.92
FRAP (mg GA/100g)	141.9±3.78

Chemical composition of processed cheese

Table (2) shows the effect of MGC addition on the chemical composition of processed cheese during storage for 60 days at 4 °C. When MGC was added, the percentage of cheese DM increased in comparison to the control, and the increase was greater with MGC 4% treatment. Throughout the storage period, the DM% of all processed cheese samples increased significantly ($P<0.05$). By the end of storage, a higher DM % was found in the MGC 4% samples, while the control samples had the lowest DM %. The loss in the moisture of the control samples during storage was higher compared to MGC-cheese samples. This might be due to the water-binding properties of starch in MGC powder [23]. Additionally, the contents of protein (%) and ash (%) of processed cheese were significantly ($P<0.05$) increased with the addition of MGC, and higher protein and ash values were found with MGC 4% samples at all storage times. No significant changes were found in the protein and ash values of all samples during cold storage. In contrast, the fat content of processed cheese samples was significantly decreased with the addition of MGC compared to the control sample, and the lowest fat content was observed with the MGC 4% samples. The fat content in this study (approximately 20%) agrees with that recommended by Kapoor & Metzger [2]. No significant changes occurred in the fat content of all processed cheese samples during 2 months of cold storage. The decreased fat content of MGC-processed cheese samples compared with control samples was due to the low fat content in MGC powder. On the other hand, the salt content of processed cheese was not affected by the addition of MGC powder. At the end of storage (60^{th} day), the salt content of all MGC-processed cheeses was significantly lower than that of the control samples. Indeed, the increased salt content of control cheese is due to the decrease in moisture content of control samples compared with MGC-processed cheeses.

Table 2

Chemical composition of processed cheese supplemented with MGC during cold storage (60 days/4°C)

Parameter (%)	Storage Time (days)	Treatments				
		Control	**MGC 1%**	**MGC 2%**	**MGC 3%**	**MGC 4%**
DM	1	38.27 ± 0.13^{Eb}	38.87 ± 0.14^{Db}	39.46 ± 0.15^{Cb}	40.03 ± 0.27^{Bb}	40.60 ± 0.20^{Ab}
	30	38.49 ± 0.30^{Db}	39.01 ± 0.21^{Db}	39.63 ± 0.37^{Cab}	40.31 ± 0.21^{Bab}	40.87 ± 0.37^{Ab}
	60	39.06 ± 0.22^{Da}	39.73 ± 0.29^{Ca}	40.18 ± 0.34^{BCa}	40.66 ± 0.37^{Ba}	41.50 ± 0.29^{Aa}
Fat	1	19.30 ± 0.10^{Aa}	19.21 ± 0.09^{ABa}	19.13 ± 0.13^{ABCa}	19.04 ± 0.12^{BCa}	18.96 ± 0.16^{Ca}
	30	19.30 ± 0.11^{Aa}	19.25 ± 0.11^{ABa}	19.15 ± 0.15^{ABCa}	19.05 ± 0.13^{BCa}	19.00 ± 0.11^{Ca}
	60	19.35 ± 0.15^{Aa}	19.25 ± 0.15^{ABa}	19.15 ± 0.15^{ABa}	19.05 ± 0.14^{Ba}	19.00 ± 0.11^{Ba}
Protein	1	6.54 ± 0.16^{Ca}	6.67 ± 0.13^{BCa}	6.80 ± 0.11^{ABCa}	$6.93\pm0.19A^{Ba}$	7.05 ± 0.13^{Aa}
	30	6.63 ± 0.13^{Da}	6.71 ± 0.15^{CDa}	6.88 ± 0.13^{BCa}	6.99 ± 0.12^{ABa}	7.12 ± 0.13^{Aa}
	60	6.74 ± 0.16^{Da}	6.84 ± 0.17^{CDa}	6.95 ± 0.13^{ABCa}	7.06 ± 0.17^{ABa}	7.21 ± 0.12^{Aa}
Salt	1	0.650 ± 0.021^{Aa}	0.640 ± 0.011^{Aa}	0.637 ± 0.013^{Aa}	0.631 ± 0.021^{Aa}	0.625 ± 0.011^{Aa}
	30	0.656 ± 0.012^{Aa}	0.644 ± 0.022^{Aa}	0.640 ± 0.011^{Aa}	0.635 ± 0.011^{Aa}	0.630 ± 0.011^{Aa}
	60	0.660 ± 0.011^{Aa}	0.652 ± 0.010^{ABa}	0.645 ± 0.015^{ABa}	0.639 ± 0.013^{ABa}	0.634 ± 0.010^{Ba}
Ash	1	2.87 ± 0.08^{BCa}	2.84 ± 0.06^{Ca}	2.94 ± 0.06^{ABCa}	2.96 ± 0.07^{ABa}	2.99 ± 0.01^{Aa}
	30	$2.94\pm.06^{ABa}$	2.88 ± 0.10^{Ba}	2.97 ± 0.07^{ABa}	3.00 ± 0.06^{ABa}	3.04 ± 0.05^{Aa}
	60	2.99 ± 0.10^{ABa}	2.91 ± 0.06^{Ba}	3.01 ± 0.03^{ABa}	3.05 ± 0.07^{Aa}	3.08 ± 0.07^{Aa}

**Mean values ± SD with capital letters within treatments are significantly different at P < 0.05; means ± SD with different small letters within times are significantly different at P<0.05; MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake.*

Changes in pH during storage

Figure (1) shows the changes in pH values of processed cheese during storage at 4 °C for 60 days. The pH vales of processed cheese samples ranged from 5.71- 6.06. There was a significant (P<0.05) decrease in the pH values of all processed cheese samples during the storage period. Higher pH values (P<0.05) were observed with the control samples during all storage times, while, the lowest pH values were observed with the MGC 4% samples at all storage times. The pH values were significantly (P<0.05) influenced by the MGC addition levels. These results are in agreement with Rafiq and Ghosh [23], who found that the pH of processed cheese significantly decreased during storage.

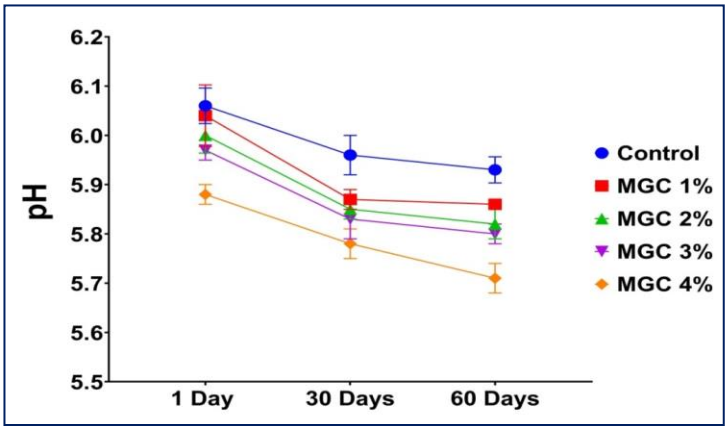

Fig. 1 Changes in pH of processed cheese samples during storage (60 days/4°C). MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake.

Microbiological quality of processed cheese

During 60 days of storage at 4 °C, molds, yeasts, and coliform bacteria were not discovered in all processed cheese samples. The absence of these microorganisms confirms that the processed cheese was safe to eat even after 60 days of refrigeration at 4 °C. This can be attributed to the highly hygienic conditions during manufacturing and storage that prevented postproduction contamination [5].

RVA-final manufacture viscosity of processed cheese

The functional properties of processed cheese are affected by various factors, such as the type and properties of natural cheese, supplemental ingredients, emulsifying conditions, moisture, pH, fat content, cooling, and ripening [25]. Using its own specially designed profiles for mixing, measuring heating, and cooling, the Rapid Visco Analyzer (RVA) is the most effective tool on the market for determining the cooked viscous properties of starch, grain, flour, and many other food products [26]. Therefore, the RVA is used to evaluate the melted textural properties of processed cheese and processed cheese spreads [18]. The time of emulsification, apparent viscosity (cP), and end viscosity (cP) of processed cheese prepared with/without MGC addition were determined using RVA (Fig. 2). There were no significant differences (P>0.05) in emulsification time among all treatments, and the emulsification time for all treatments took 5 min. This means that the addition of MGC did not affect the emulsification time of processed cheese. The apparent viscosity significantly (P<0.05) increased as the amount of MGC increased, and a higher apparent viscosity was observed with the MGC 3% and MGC 4% samples. Additionally, the results showed that the values of end viscosity followed the same trend as apparent viscosity, as the end viscosity values were significantly (P<0.05) increased by increasing the MGC amount in the processed cheese formula, and a higher end viscosity value (P<0.05) was observed with MGC 4% samples followed by MGC 3% samples. The lowest apparent viscosity and end viscosity values were found in the control samples (P<0.05). According to Prow [27], the RVA melting properties of the processed cheese samples (hot apparent viscosity and time at 5000 cP) exhibited a good correlation with the melt temperature as determined by dynamic stress rheometry (0.82 and 0.85, respectively).

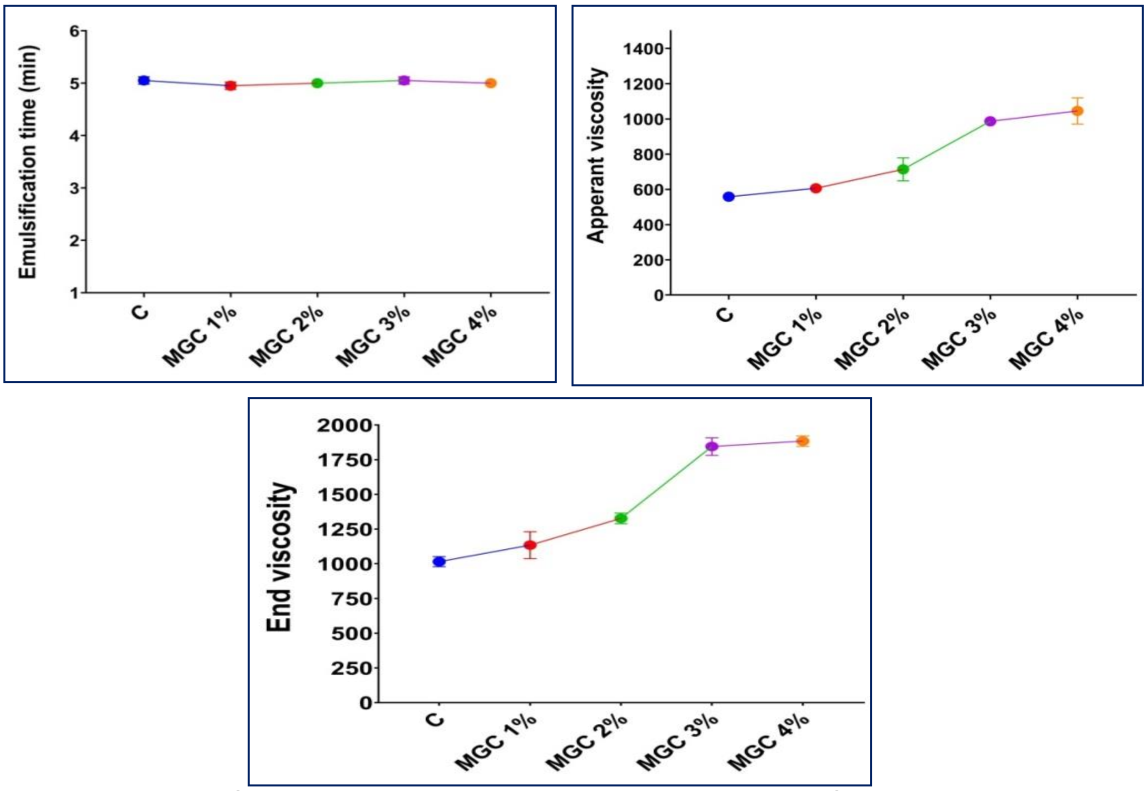

Fig. 2 RVA (emulsification time, apparent viscosity, and end viscosity) of processed cheese. C: control; MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake.

Texture analysis

The firmness, stickiness, work of sheer, and work of adhesion of all processed cheeses samples was conducted at zero, 30, and 60 days of cold storage at 4 °C (Figure 3). Firmness is the force required to compress a sample between the molars, and is one of the important factors in determining cheese texture and quality.

The findings demonstrated that as the amount of MGC increased, processed cheese's firmness significantly (P<0.05) increased, and a higher increase was found with MGC 4% treatment. Additionally, the firmness values of all treatments significantly (P<0.05) increased during the storage period (60 days/4 °C). By the end of the storage period, the higher firmness values were found with MGC treatments compared with the control. These findings concur with those of El-Sayed et al. [28], who discovered that 120 days of storage at 4 °C resulted in a significant (P<0.05) increase in the hardness of UHT-processed cheese.The increase in firmness of processed cheese is associated with a decrease in its moisture content. The penetration force is a direct function of firmness, while the work of shear is the opposite function of spreadability. Spreadability is an important aspect of the consumer acceptability of processed cheese spread. Solowiej [29] found that the hardness of cheese increased with increasing casein level. The data presented in Figure (3) show that the addition of MGC to processed cheese caused a significant (P<0.05) increase in the work of shear values, and a higher work shear value was observed with the MGC 4% samples. During the storage period, there was a significant (P<0.05) increase in the work shear values, and higher work shear values were observed on the 60th day of storage. In the same trend, the addition of MGC raised the stickiness and work of adhesion of processed cheese samples. The MGC 4% samples showed higher values of stickiness and work of adhesion. The stickiness and work of adhesion values of the control and all other treatments increased as the storage period advances. These results are in agreement with the observations of Cunha et al. [30], who found that the adhesiveness of processed cheese was significantly increased during storage. Cheese samples' functional and physical characteristics are significantly impacted by the composition of the processed cheese, which can change depending on differences in moisture content, pH, and protein content [31]. Very slight increases in moisture significantly reduce the firmness and increase the meltability of cheese [32]. Guinee and O'Callaghan [32] found that the firmness of processed cheese samples markedly increased with decreasing the fat content and increasing the protein levels.

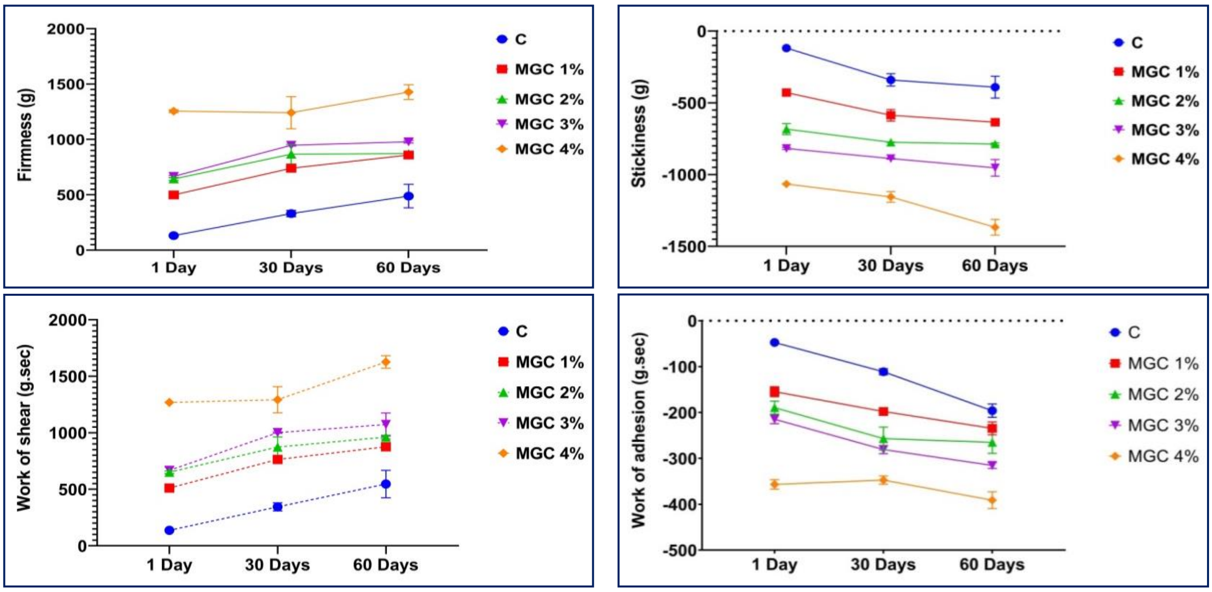

Fig. 3 Changes in texture characteristics of processed fortified with MGC during 2 months of cold storage (4°C) cheese. C: control; MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake.

Microstructure of processed cheese

Scanning electron micrographs (X2500, 20 kV, 10 μM) showed that fortifying processed cheeses with varying concentrations of MGC had an impact on their microstructure (Figure 4).The use of MGC as a nutritional ingredient makes a different casein network structure within processed cheese. In the control sample, it was observed that the protein network was homogeneous and the distribution of free fat globules was limited due to the occurrence of a link between protein and fat by the action of emulsifying salts, forming a homogeneous protein-fat network. In samples of MGC 1 % and MGC 2%, a noticeable change in the composition of the protein network was noticed, where small voids appeared within the protein network due to the entry of MGC protein, which differs in its characteristics and functional properties from milk protein; thus, the texture became more open, and this change appears in a clear manner in the case of MGC 2%. Additionally, the presence of a large amount of starch in MGC binds with water and thus increases the hardness of cheese. By increasing the amount of MGC (MGC 3% and MGC 4% treatments), swelling of the protein network occurred in a clear and homogeneous manner, and the number of free fat globules decreased. This change could be due to the increase in the association of MGC protein with milk protein, forming a new protein network that differs in its structure and properties from the control, or to the swelling of starch molecules as a result of their absorption of water, which led to an increase in the hardness of cheese. These findings are in line with those of Fu and Nakamura [25], who found that adding tapioca starch to processed cheese resulted in a more dispersed casein network structure and increased firmness, while adding potato starch caused the casein network structure to become more finely stranded and imparted the maximum firmness.

Sensory evaluation

Recently, Food products containing naturally occurring components that are beneficial to health, such as enzymes, antioxidants, probiotics and prebiotics, natural extracts, antimicrobials, and essential oils derived from plants, have demonstrated a preference among consumers [33]. For the determination of the sensory properties of processed cheese samples containing maize germ cake, the properties of color, taste, odor, texture, appearance, and overall acceptability of cheese were evaluated (Fig. 5). When compared to the control, it was found that the addition of MGC caused the processed cheese's color score to drop on the first day of storage ($P<0.05$), and the lowest score was found with MGC 4%. The color score of all MGC-cheese showed a significant ($P<0.05$) increase after the first month of storage, followed by another decrease on the 60th day. On the 1st day, higher taste scores were observed with the control and MGC 1% samples; however, the lowest taste scores were found with the MGC 3% and MGC 4% samples. On the 30th and 60th days of storage, higher taste scores were noted with MGC 1% and MGC 2%, respectively. By the end of the storage period, the taste values of all processed cheese samples were significantly ($P<0.05$) decreased. On the 1st day of storage, the processed cheese samples containing MGC showed a significant ($P<0.05$) decrease in texture scores, and the lowest score was found with the MGC 4% samples. Meanwhile, on the 30th and 60th days of storage, higher texture scores were observed with MGC 1% samples, while the lowest scores were found with treatment with MGC 4%. Moreover, the texture values of MGC 1%, MGC 2%, MGC 3%, and MGC 4% samples were significantly ($P<0.05$) increased after the first month of storage and then decreased at the end of storage, except for MGC 4%, which was not affected. The odor of the MGC-chesses samples was significantly (P<0.05) lower than that of the control samples on the 1st day of storage, but after 30 days of storage, there were no significant (P>0.05) differences between the MGC treatments and the control, except for MGC 4%, which was the lowest. All cheese treatments showed a significant increase in odor after 30 days of storage and a significant (P<0.05) decrease after 60 days. During the storage period, the control and MGC 1% samples had higher acceptability scores, and there were no significant (P>0.05) differences between them. Additionally, higher appearance scores were detected with the control followed by MGC 1%.

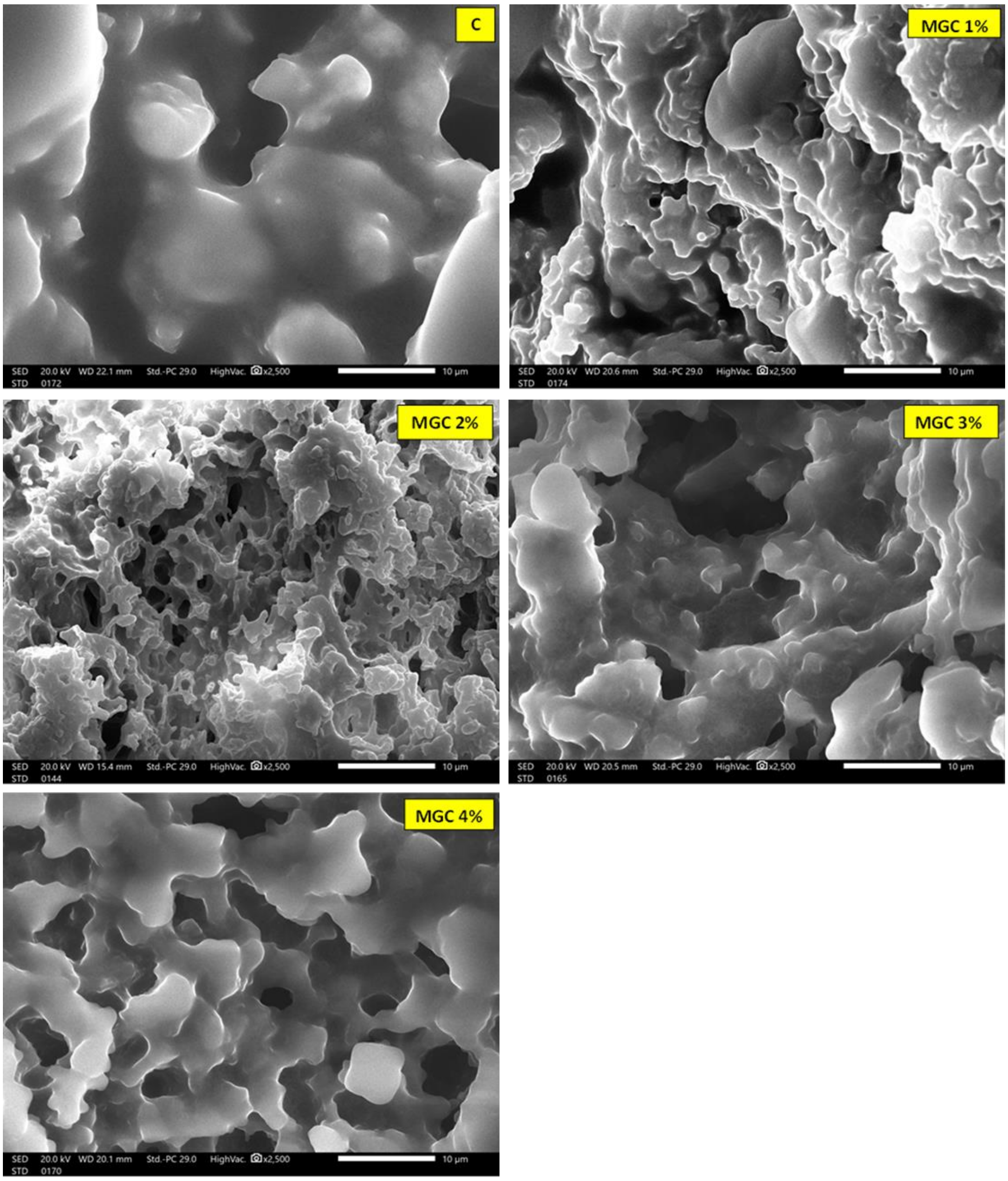

Fig. 4 Scanning electron micrograph (SEM) of processed cheese fortified with MGC. C: control; MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake. Magnitude 2500x; at 20 KV. Bar = 10 µm.

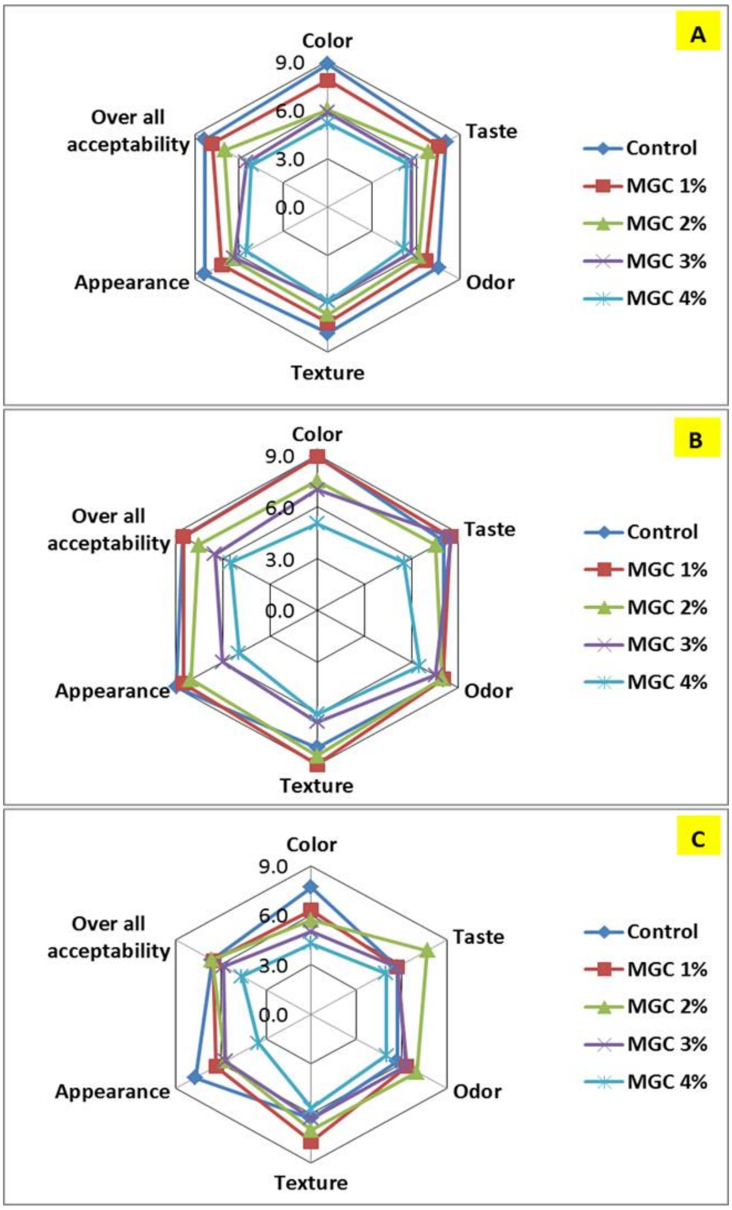

Fig. 5 Sensory evaluation of processed cheese fortified with MGC, (A) 1 day of storage; (B) 30 days of storage; (C): 60 days of storage. C: control: without MGC ; MGC 1%: processed cheese containing 1 % maize germ cake; MGC 2%: processed cheese containing 2% maize germ cake; MGC 3%: processed cheese containing 3 % maize germ cake; MGC 4%: processed cheese containing 4% maize germ cake.

4. Conclusion

This study aimed to investigate the effect of maize germ cake (MGC) on the physicochemical, textural, microstructure and organoleptic properties of processed cheese. The addition of MGC caused significant changes in the texture (firmness, work shear, stickiness, and work of adhesion) and microstructure properties of processed cheese. The MGC-cheese showed an increase in DM, protein, and ash contents compared to the control, while fat and pH were decreased. During storage, the control and MGC 1% samples showed higher acceptability values compared to all other treatments followed by the MGC 2% samples. The MGC 1% and MGC 2% samples had higher taste scores after 30 and 60 days of cold storage.

Therefore, this study recommends the use of MGC as a low-cost nutritional and functional ingredient at a ratio of 1 and 2% in the preparation of processed cheese.

5. Acknowledgements

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6. Declarations

Conflict of interest The authors declare no conflicts of interest.

Funding Not applicable.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

EKO preparation of processed cheese, cheese analysis. MIE methodology, cheese analysis, maize germ cake analysis, statistical analysis, and writing-review & editing. NAAE Cheese analysis, Data Curation.

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