155 *Egypt. J. Chem.* **Vol. 64,** No. 4 pp. 1687 - 1700 (2021)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Dielectric and Physico-chemical Techniques to Evaluate the Nutritional and Quality Characteristics of Fino Bread Fortified with Sunflower Meal

Ahmed S. Hussein,[a] Ayman A. Mahammad,[a] Salwa L. Abd-El-Messieh,[b] Shimaa F. Hamieda.[b] Fathy M. Mehaya[a]*

[a] *Food Technology Dept., National Research Centre, El-Buhouth St., Dokki, Egypt*

[b] *Microwave Physics and Dielectrics Dept., National Research Centre, El-Buhouth St., Dokki, Egypt*

Abstract

The fortification of fino bread with sunflower meal (SFM), as a source of protein and bioactive compounds, at the levels of 5, 10, 15, and 20% was investigated. The chemical composition, amino acid, phenolic profiles, and fiber fractions of SFM were determined. The prepared flour blends and fino bread samples were subjected to physico-chemical, dielectric, rheological, and organoleptic analyses. The obtained results showed that SFM is rich in amino acids, fibers and phenolic compounds. The rheological tests indicated that the fortification of wheat flour with SFM weakened the dough and reduced its elasticity and extensibility. Also, dielectric properties (DPs) gradually decreased as the SFM level increased. Fortified bread samples had a dense structure and dark brown color compared to the control sample. Photomicrographs of tested bread showed that SFM ruptured the gluten network and allowed starch granules to leach out. Bread samples were acceptable overall the organoleptic properties. These findings revealed the potential applications of SFM as a low-cost, and nutritious food ingredient to improve the nutritional value of bakery products. It also demonstrated the close dependencies between the physico-chemical and dielectric properties of raw materials and the quality characteristics of the final products.

"Keywords: sunflower meal, dielectric properties, fino bread, physico-chemical properties, scanning electron microscope."

1. Introduction

Recently, the Global awareness of consumers with the benefits of healthy food led to an increased demand for the fortified non-conventional food products [1]. Therefore, several investigations, concerned with improving the nutritional value, were carried out to fulfill the new trends in dietary habits. In this concern, bakery products, particularly bread and cookies, are utilized as the main vehicle for proteins, phytochemicals, vitamins, minerals, and prebiotics supplementation [2, 3]. The refined wheat flour lacks in many macro and micro-nutrients, consequently, the related products do not meet the nutritional requirements [4]. Moreover, lysine, threonine, and valine represent the limiting amino acids in wheat proteins [5]. Thus, the ongoing trials to improve the nutritional value of wheat flour, alongside maintaining its technological properties, are progressing day by day.

The potential use of vegetable oil production by-products, especially sunflower meal (SFM), as dietary supplements is gaining the consumer's acceptance worldwide. Sunflower meal is a nutritious good source of proteins, vitamins, fibers, minerals, and phytochemicals [6]. Furthermore, SFM provides many characteristics as low cost, high protein content, limited anti-nutritional factors, vegan source, absence of allergens, high phenolic content and essential amino acids which make it an appealing perspective foods ingredient [7, 8]. However, chlorogenic acid and black hulls of sunflower meal represent the main obstacles to its implementation in food products. Beside the dark color, the fibers were found to hinder the dry matter digestibility by decreasing its intestinal transit time [9]. While, oxidized chlorogenic acid-protein interactions led to the formation of green complexes, associated with the

*Corresponding author e-mail: dr_fathy_nrc@yahoo.com.; (F. M. Mehaya).
Receive Date: 29 November 2020, Revise Date: 14 December 2020, Accept Date: 23 December 2020
DOI: 10.21608/EJCHEM.2020.50954.3050

dark color development during food processing [8, 10].

Despite its adverse effects on the color of backed products, chlorogenic acid posses several health benefits like antioxidant and anti-inflammatory activities [11]. Thus, with the increased consumer awareness of such benefits and the successful methods to remove sunflower hulls, the SFM may find a wide future uses in human diets. Hence, the incorporation of sunflower meal in bakery products is of great interest, this inclusion will lead to considerable modifications of dough rheology and the quality characteristics of the final baked product. Therefore, to ensure the success inclusions, these modifications as well as the consumers acceptability should be investigated [12].

Since the wheat dough is mainly composed of starch and gluten. Starch gelatinization and gluten network development and the mechanisms that govern their dynamics during processing remains indispensable [13]. Alongside the conventional method, the dielectric technique can be implemented to explore the mechanisms of the molecular dynamics that takes place during the interphase of crystalline and amorphous transformations [14]. Dielectric properties (DPs) of food constituents generally expressed as dielectric constant (ε′) and dielectric loss factor (ε″), which refer to its ability to store and dissipate the electric energy, respectively [15]. The electrical responses of foods, as heterogeneous mixtures, are influenced by the contribution of polar, electronic, atomic, and Maxwell-Wagner mechanisms [16].

Although the DPs of grain were early published by Nelson et al. [17], limited investigations studied the DPs of baked products and their correlation with the quality parameters [18]. Among them, Keskin et al [19] and Sakiyan et al [20] investigated the DPs of bread and cake during the baking process, respectively. While Alifaki and Sakiyan [18] found a correlation between dielectric properties and quality parameters of cake samples fortified with chickpea. Similarly, Łuczycka et al [21] studied the correlation between DPs, chemical and technological properties of wheat and oat flour blends. But there has been no description of the DPs of wheat flour-SFM mixtures in the available literature. Thus, this study aimed to fortification of fino bread with SFM and application of dielectric and physico-chemical techniques to evaluate the quality parameters of the processed bread.

2. Experimental

Materials

Refined wheat flour (11.90% moisture, 12.05% protein, 1.12% fat, 0.70% ash, 0.45% fiber and 85.68% carbohydrate contents) was obtained from the North Cairo Flour Mills Company, Egypt. Sunflower seeds were purchased from the local market, Cairo, Egypt. Phenolic compound standards and Folin-Ciocalteau’s reagent were obtained from Sigma-Aldrich Chemical Co. (St. Louis, MO, US) and Supelco Co. (Bellefonte, PA, US) respectively. Other chemical and solvents were of analytical or chromatographic grade.

Methods

2.1.1. Oil extraction

Sunflower seeds were cleaned, crushed and defatted using laboratory oil expeller with a maximum pressure of 3500 psi for 1 hour at room temperature according to the method of Üstun et al [22].

2.1.2. Preparation of sunflower meal

Roller milling and sieving technique was used to separate the seed coat and prepare higher protein meal according to Murru and Calvo [23] with some modification. The sunflower cake was dried at 60 C in an oven for 4 hours. Then, the dried sunflower meal was milled using Quadrumat Junior flour mill (Model MLV-202, Switzerland). The obtained flour was sieved through 60 mesh screen.

2.1.3. Preparation of flour mixtures

Wheat flour was fortified with sunflower seed meal (SFM) at the levels of 5, 10, 15 and 20% on mass basis to prepare 4 individual mixtures. Wheat flour was used as a control sample.

2.1.4. Rheological properties

Rheological properties of dough were evaluated using Farinograph and Extensograph according to AACC [24].

2.1.5. Water binding capacity

The water binding capacities (WBC) of different samples were measured according to the method of

Keskin et al [19]. Dry ingredient (2.5g) was mixed with 37.5 mL demonized water in a tarred 50 mL centrifuge tube. The tube was capped and agitated using an incubator shaker for 1h, then centrifuged for 10 min at 2200×g. The water was decanted and the tube tipped up and allowed to drain for 10 min. The tube was then weighed and the amount of bound water by the sample was determined by subtracting the initial weight of the sample from the weight of 'treated' sample. The water binding capacity was calculated from the following equation:

$$WBC = \frac{\text{(weight of treated sample – Initial weight of sample)}}{\text{Initial weight of sample)}}$$

2.1.6. Fino bread preparation

Fino bread samples were processed using the prepared mixtures according to Kamel et al. [25] with some modifications. Firstly, active dry yeast (1.5g) was activated in warm water (as reported in Farinograph test) containing 2g sugar. The dry ingredients (flour mixture (100g), NaCl (1.5g), bread improver (1g)) were added and the mixture was kneaded, then shortening (1g) was mixed with the dough. The dough was fermented at 30 °C for 30 min in a fermentation cabinet under 80-85% relative humidity. After which dough was rolled, divided into 80g pieces, placed in the trays and proofed under the same conditions for 45 min. Bread dough loaves were baked at 325 °C for 10-15 min following steaming for 10s. Baked loaves were let to cool at room temperature for 60 min.

2.1.7. Dielectric measurement of flour and bread samples

An LCR meter type AG-411 B (Ando Electric, Japan) was used to measure the dielectric parameters over the frequency range 100 Hz–100 kHz. The capacitance C, the loss tangent tan δ and the resistance R were obtained directly from the bridges from which the dielectric constant ε', dielectric loss ε"and electrical conductivity σ were calculated. The samples were in the form of discs (5 cm diameter and 1.2 mm thickness). A guard ring capacitor (type NFM/5T Wiss Tech. Werkstatten GMBH, Germany) was used as a measuring cell. The cell was calibrated with standard materials, and the experimental errors of ε' and ε" were ± 3 and ± 5%, respectively.

2.1.8. Proximate analysis

Moisture, ash, fiber, protein and fat of raw materials and fino bread samples were determined according to AOAC [26]. Total phenolic content of SFM was determined using Folin-Ciocalteu method according to Zilic et al. [27].

2.1.9. Determination of amino acids profile of sunflower meal

Amino acids of sunflower seeds powder were determined according to AOAC [26]. The samples were acid hydrolyzed and determined using amino acid analyzer (Eppendorf LC3000, Germany). EZ Chrom Manual Software (2004) was used for data acquisition and processing.

2.1.10. Determination of phenolic acids profile of sunflower meal

Sunflower seeds meal (2g) was alkaline hydrolyzed by 40 mL of 2 M NaOH and stirred for 4 h at room temperature (25°C). The solution was then acidified to pH 2 with 6M HCl, and extracted three times with diethyl ether and ethyl acetate (1:1). The organic layers were combined and evaporated to dryness using a rotary evaporator at 40 °C and reconstituted in 2 mL methanol. Samples were filtered through a 0.45 µm Acrodisc syringe filter (Gelman Laboratory, MI) and injected to HPLC (Agilent Technologies 1100 series) equipped with an auto sampler and a diode-array detector. Phenolic acids were separated on an Agilent Eclipse XDB C18 column (150 x4.6 µm; 5 µm) using acetonitrile and 2% acetic acid in water (v/v) as a mobile phase at 0.8 $mL.min^{-1}$ flow rate for a total run time of 70 min according to Kim et al. [28].

2.1.11. Determination of fiber fractions of sunflower seeds meal

FIWE Raw Fiber Extractor (VELP) unit was used to determine hemicellulose, cellulose, neutral detergent fiber (NDF), acid detergent fibre (ADF) and lignin (ADL) according to the method of Van Soest and Robertson [29].

2.1.12. Baking quality of fino bread

Weight, volume and specific volume of fino bread were determined as described by AACC [24].

2.1.13. Color attributes of fino bread

Changes in Hunter color parameter (L, a &b) of fino bread samples were followed up using Tristimulus Color Analyzer (Hunter, Lab Scan XE, Reston, Virginia) with standard white tile [30].

2.1.14. Organoleptic properties of fino bread

Fino bread samples were evaluated for taste (20), aroma (20), mouth feel (10) crumb texture (15), crumb color (10), break & shred (10), crust color (10), and symmetry shape (5) according to the method described in AACC [24].

2.1.15. Freshness of bread

The freshness of bread samples was tested at 1, 3 and 5 days of storage at room temperature by alkaline water retention capacity (AWRC) according to method of Sidhu et al. [31].

2.1.16. Scanning electron microscope (SEM)

MODEL-163-JSM-T20 JEOL, Japan, was used to characterize the morphology of the prepared bread samples. The samples were coated with a very thin layer of gold to avoid electrostatic charging during the examination.

2.1.17. Statistical analysis

Data analysis was statistically performed using SAS (1987) software. Analysis of variance was used to test for differences between the groups. Least Significant Differences (LSD) test was used to determine significant differences ranking among the mean values at $P< 0.05$.

3. Results and Discussion

3.1. Nutritional profile of sunflower meal

The results of the proximate composition indicated that the SFM contained 7.45g moisture, 35.02g protein, 10.08g fat, 6.14g ash, 13.27g crude fiber, 35.49g total carbohydrate and 1.22g phenolic compounds per 100g (Fig. 1A). Regarding the proximate composition of wheat flour, SFM showed higher protein, fat, ash and fiber contents. The obtained results are in agreement with those reported by Rosa et al. [32] and Aishwarya and Anisha [33]. They mentioned that the protein and fiber contents of defatted sunflower meal varied from 28.4 to 36.2 and from 15 to 27%, respectively. Furthermore, the phenolic content of SFM is comparable to those reported by Dabrowski and Sosulski [34] and Grasso et al.[6] being 10 and 16.54 g GAE/kg, respectively.

The protein of SFM showed good amino acids content (Fig. 1B). Glutamic and aspartic acids dominated the amino acids profile of SFM with the concentrations of 18.66 and 13.08 g/100g sample, respectively. Among the essential amino acids, that represented 28% of the total amino acids, hisitidine recorded the highest value (5.41 g/100g sample). Sulphur-containing amino acids, cystine and methionine were found to be the first and the second limiting amino acids with the concentrations of 0.71 and 2.20 g/100g sample, respectively. These results indicate that the SFM proteins have good amount of essential amino acids and could be used as a good supplement to bakery products. Similar amino acid profile of sunflower meal was previously reported by Stringhini et al. [35] and Rosa et al. [32] with slight variations.

Results of fiber fractions of SFM (on dry weight basis) are shown in Fig 1C. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were found to be 39.14, 27.46 and 9.02%, respectively. Lignin, cellulose and hemicelluloses represented 5.13, 19.49 and 11.67% of SFM, respectively. ADF measures lignin and cellulose whereas NDF measures also hemicelluloses content [29]. Higher ADF and NDF values (31.68 and 42.15%, respectively) were reported by Stringhini et al. [35] for defatted dehulled sunflower seeds. While, Singh et al. [36] reported that ADF and lignin contents of defatted sunflower meal (with hull) ranged between 27-32% and 9-13.6%, respectively.

Concerning the phenolic profile of SFM (Fig 1D), chlorogenic acid was the predominant phenolic acid with a concentration of 635.99 mg/100g, representing 93.4% of the total identified phenolic compounds. Among the identified phenolic compounds, p-

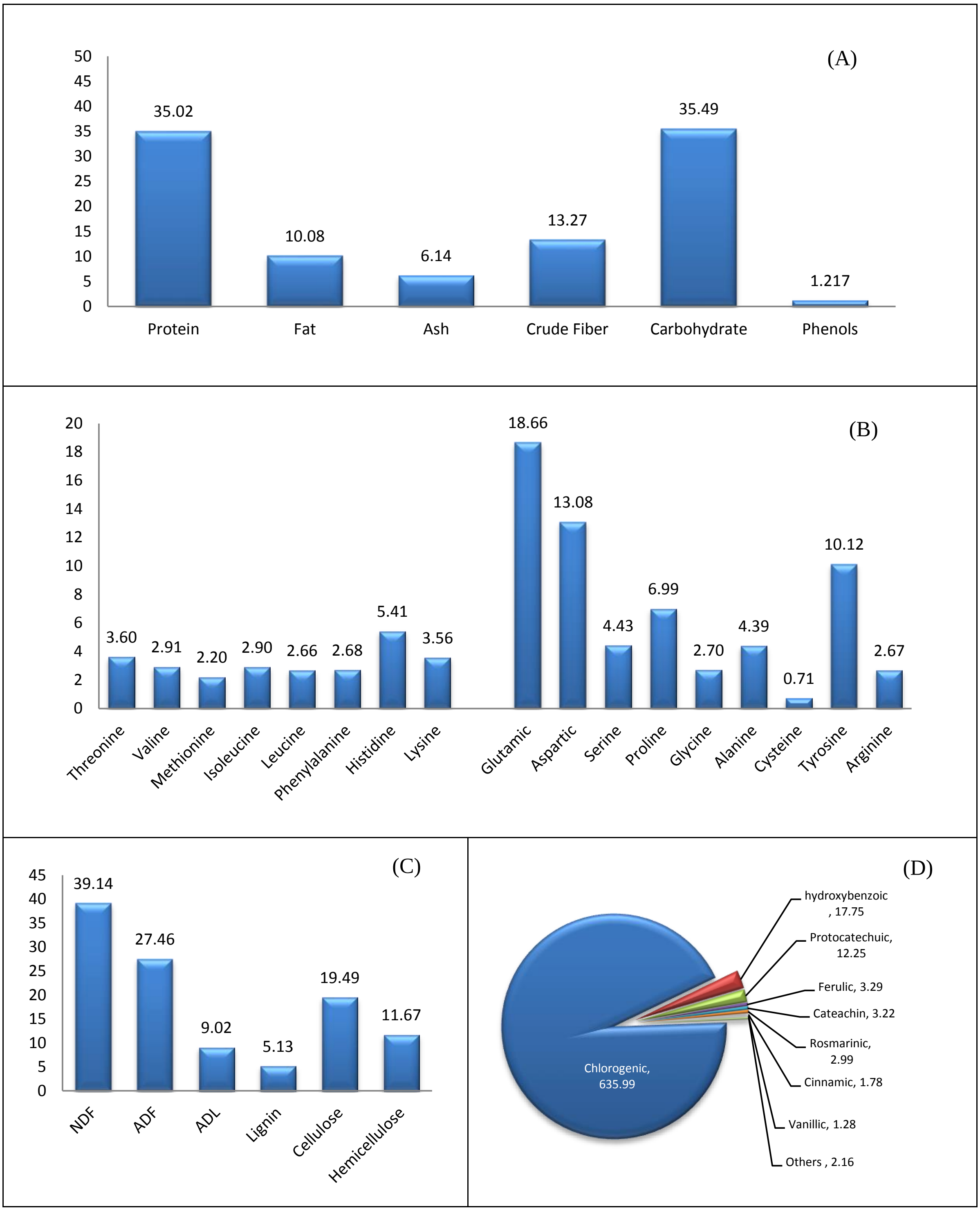

Fig. 1. Nutritional profile of sunflower seeds meal: A = proximate analysis (%), B = amino acids profile (g/100g sample), C = fiber fractions (%) and D = phenolic profile (mg/100g)

hydroxybenzoic and protocatechuic acid represented 17.75 and 12.25 mg/100g, respectively. Ferulic acid, catechin, and rosmarinic acids ranged in a narrow range between 3.29 and 2.99 mg/100g. Cinnamic, vanillic, and p-coumaric acids were found in lower concentrations being 1.78, 1.28, and 0.95 mg/100g, respectively. Other phenolic compounds (syringic, sinapic, quercetin, kaempferol, and chrysin) were detected as traces. Several studies investigated the phenolic profile of sunflower seeds and reported that chlorogenic, caffeic, and ferulic acids are the major phenolic compounds [37, 38].

3.2. Rheological properties of flour blends

Rheological parameters of wheat flour and the prepared blends, determined using Farinograph and Extinsograph, are shown in Table (1). All Farinograph parameters (water absorption, arrival time, dough development time, dough stability, dough weakening, and mixing tolerance index) increased by increasing the level of SFM compared to the control sample. The increasing in water absorption may be attributed to increment in fiber content in SFM, which elevates the water-binding ability of SFM. The longer dough development time and dough stability indicate that the inclusion of SFM into wheat flour requires more mixing efforts to produce consistent dough. Such results were in agreement with those obtained by Hadnađev et al. [39].

Extensograph parameters, presented in Table (1), explain the viscoelastic behavior of dough during the fermentation process. Data showed that extensibility, elasticity, and dough energy decreased by increasing SFM level. Wheat flour dough showed 350 BU, 140 mm, and 110 Cm^2 for elasticity, extensibility, and dough energy, respectively. Mixing wheat flour with SFM decreased these values between 310–220 BU, 130–80 mm, and 90–50 Cm^2, respectively. It is well known that the viscoelastic properties of wheat dough depend on both gluten quality and quantity. So these decrements may be due to the reduction of gluten content in dough containing SFM.

Table 1 Rheological parameters of wheat flour and sunflower meal composites

Parameter	Control (WF)	Wheat flour containing sunflower meal (%)			
		5	10	15	20
Farinograph parameters					
Water absorption (%)	59.8	61	62.5	64.5	65
Arrival time(min)	1.5	2	2.5	3.0	3.5
Development time (min)	3.0	4.0	4.5	5.0	5.0
Stability (min)	8.0	10	12	13	15
Weakening (BU)	70	80	100	110	130
Mixing tolerance index (BU)	40	45	55	60	70
Extinsograph parameters					
Extensibility (E)(mm)	140	130	115	90	80
Elasticity (BU)	350	310	280	240	220
Ratio (R /E)	2.5	2.38	2.43	2.67	2.75
Energy (Cm^2)	110	90	80	65	50

3.3. Dielectric measurement of flour blends

The permittivity (ε′) and dielectric loss (ε") of wheat flour as influenced by SFM addition, were determined at room temperature (≅ 25°C) and frequencies range from 100 Hz to 100 kHz and illustrated in Fig. 2A and B. Both ε′ and ε" values were found to decrease dramatically by increasing the applied frequency up to 1 KHz after which a slight decrease was noticed. This may be attributed to the tendency of dipole moments to orient themselves in the direction of the applied field. At higher frequencies, the permittivity is slightly affected to become frequency independent. On the other hand, at a lower frequency, the high values of dielectric permittivity refer to the electrode effect and interfacial polarization [40]. Moisture and fat content are the main factors affecting the DPs of food [19, 41] particularly at a lower frequency [42]. Thus, the decreased ε′ and ε″ values of fortified wheat flour with SFM could be due to the higher fat and lower moisture contents of SFM compared to wheat flour (Fig. 1). The obtained results are comparable to those previously reported by [43, 44].

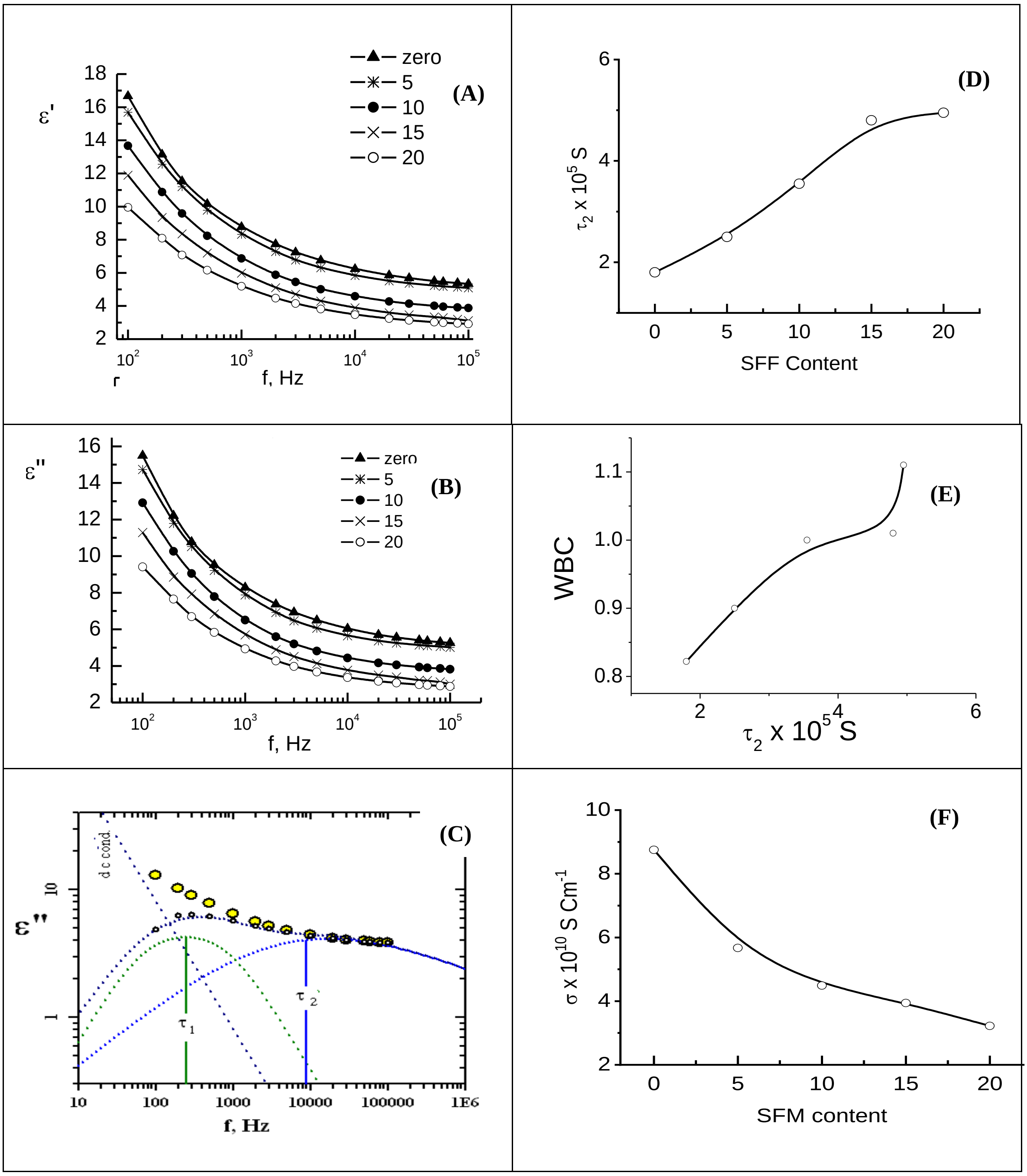

Fig (2): Dielectric properties of wheat flour as affected by sunflower meal addition: permittivity (A), dielectric loss (B), analyses for wheat flour containing 10% sunflower meal (C), second relaxation time (D), water binding capacity (E) and electrical conductivity (F)

The values of ε'' at low frequency range were so high and the obtained curves were found to be so broad indicating that more than one relaxation mechanism is present. To study such mechanisms, the curves relating ε'' values of wheat flour incorporated with 10% SFM, as an example, (Fig. 2C) were analyzed by a computer program based on the dielectric functions after subtraction of the losses due to DC conductivity. The high values of ε'' at lower frequency range are due to the Maxwell-Wagner-Sillars effect (MWS) [44], which is usually appear at such range of frequency. This region was fitted by Frohlich function with distribution parameter (P= 3). It was interesting to find that the relaxation time (τ1) associated with this region does not affect by the SFM concentration. This relaxation mechanism may be due to the mobile ions which can migrate within the sample material, hence giving rise to potential differences at the electrodes surfaces. This leads to a large increase in both ε′ and ε"values. These ions can then shift toward interfaces, because of the difference in conductivity and permittivity of the constituents composing the dielectric, producing an interfacial polarization [40].

The second process with relaxation time τ2, which is of our interest, ascribes the side chain of the composite flour. This region was shifted towards lower frequency by increasing SFM content. This finding reflects higher τ2 values which may be due to the enlargement of the rotating units as a result of the presence of the SFM with its bigger particle size [44]. The obtainded values of τ2 were illustrated graphically versus SFM content (Fig. 2D). It is seen that τ2 increased pronouncedly by increasing SFM content up to 15 % after which some sort of saturation obtaind. Furthermore, the relationship between water binding capacties and τ2 values were graphically illustrated in Figure (2E). From this figure it is seen that τ2 values increased by increasing water binding capacity. The higher water absorption of SFM than that of wheat flour was proved by Farinograph test given above (Table 1). Thus, the DPs values could be the outcome of chemical compsiton, conductivity, rheological effects and relaxation times interactions [21, 45].

The electrical conductivity (σ) versus SFM content was illustrated graphically in (Fig. 2F). It is seen that the values of σ for all samples under investigation are in the order of 10-10 S.Cm-1 which recommend such samples to behave as insulated materials [40]. From this figure, one can noticed that the values of σ decrease by increasing SFM content. This finding justifies the dielectric data given above as it is considered to be a logic result as the lower σ values of wheat flour containing SFM could be due to the low moisture of SFM and its high fat and fiber contents.

3.4. Physico-chemical properties of fino bread samples

The physico-chemical characteristics (chemical composition, baking quality, and color attributes) of the produced fino bread samples were determined and presented in Table 2. In this study, the fortification of fino bread with SFM to enhance its nutritional value. Thus, increasing the SFM level up to 20% led to an increase in the nutritional value of fino bread. Protein, fat, ash, fiber, and carbohydrate contents of fino bread ranged between 10.01-11.31, 2.47-2.87, 1.13- 1.37, .52- 1.89, and 85.87-82.56%, respectively. From these results, it is clear that SFM could be used to produce fino bread with lower content of carbohydrate and at the same time increasing its content of essential and non-essential amino acids, crude fiber, and protein. These findings showed some similarity with those previously reported by several authors [32, 46].

The results of baking quality revealed that loaf weight increased as the SFM level increased (Table 2). This effect is mainly due to the high fiber content in SFM as shown in Fig 1A, which characterized by its higher water holding capacity (Fig 2F). On the other hand, loaves volume decreased as the SFM level increased and the significant decrease was observed at 20% replacement compared to the other levels. Consequently, specific volume of SFM containing bread, which is a reliable quality indicator, had lower values compared to the control sample. The fact that inclusion of fibrous materials [47], or protein rich substances [48] in wheat flour reduces the specific volume of the produced bread was previously reported. The negative effects of SFM inclusion could be explained by the ruptured gluten network as shown in Fig. (3D-H). The deformation of gluten network led starch granules to aggregate resulting in faster Co2 loss and finally compact crumb structure [49].

Color is a quality indicator that influences the consumer decision for the selection of bakery products. The results of the color parameters are shown in Table (2). The crust of fino bread samples fortified with different levels of SFM had lower L* and b* values and the reduction increased as the fortification level increased. On contrary, a* values of bread crust showed a reversed trend to L* and b* values. The crumb of fortified bread samples showed lower a* and b* values compared to the control bread. In general, all fortified bread samples had darker crust and crumb compared to the control. These results could be due to the high protein and phenolic acid contents of SFM that accelerate the formation of Maillard reaction products during the baking process [8, 50]. These results agree with those reported by Grasso et al. [6] for biscuits fortified with defatted sunflower seeds.

Table 2 Physic-chemical properties of fino bread samples

Parameter	Control	Fino bread containing sunflower flour (%)			
		5	10	15	20
Proximate analysis of fino bread (% on dry weight basis)					
Moisture	24.03±0.23	24.57±0.18	25.80±0.35	26.97±0.15	27.75±0.19
Protein	9.37±0.19	10.55±0.11	11.82±0.17	12.70±0.13	13.67±0.15
Fat	2.07±0.06	2.47±0.07	2.98±0.06	3.42±0.11	3.87±0.10
Ash	0.98±0.05	1.13±0.03	1.49±0.03	1.85±0.05	2.22±0.07
Crude fiber	0.39±0.03	0.82±0.06	1.31±0.02	1.80±0.03	2.39±0.09
Carbohydrate	87.19±0.79	85.03±0.56	82.40±0.63	80.23±0.72	77.85±0.85
Baking quality of fino bread					
Weight (g)	70.1±1.2	72.2 ±1.5	75.1±1.9	77.1±1.2	79.0±1.8
Volume (cm^3)	232±3.15	207±2.19	185±3.1	165±3.91	150±4.25
Specific volume (Cm^3/g)	3.3 ±0.11	2.88±0.10	2.47±0.08	2.14±0.09	1.90±0.77
Color attributes of fino bread crust					
Lightness (L*)	42.65±1.13	36.22±1.53	34.05 ±1.7	33.25±1.62	31.17±1.1
Redness (a*)	10.57±0.61	11.31±0.83	12.05±0.77	13.13±0.69	14.69±0.87
Yellowness (b*)	25.23±1.76	18.34±1.66	19.82±1.95	18.75±1.87	17.88±1.69
Color attributes of fino bread crumb					
Lightness (L*)	71.62±2.20	64.76±1.92	51.90±1.99	47.39±1.69	38.55±1.52
Redness (a*)	3.45±0.08	1.09±0.05	0.94±0.03c	0.91±0.02b	1.02±0.04
Yellowness (b*)	22.23±1.00	15.41±0.97	15.58±0.96	14.38±0.90	14.05±0.82

3.5. Dielectric properties of bread samples

The permittivity and dielectric loss of bread samples were measured and presented in Fig 3. Both ε′ and ε″ values dramatically decrease by increasing the applied frequency and the SFM fortification level. The values of ε″ were so high especially in the low frequency range which reflects very high values of electrical conductivity. For this reason, it was not possible to analyze the curves relating ε″ and the applied frequency as we did before in the case of flour. The very high values of ε″ is due to the higher water content in case of bread compared to the flour (Table 2). In order to understand how both ε′ and ε″ values behave by increasing SFM content, both values were plotted graphically versus SFM content (Fig. 3B). From this figure, it is clear that both values decrease by increasing SFM content. This decrease is due to the fiber nature of the sunflower seed which is responsible for the decrease in the electrically accessible water content and consequently the decrease in both ε′ and ε″ values.

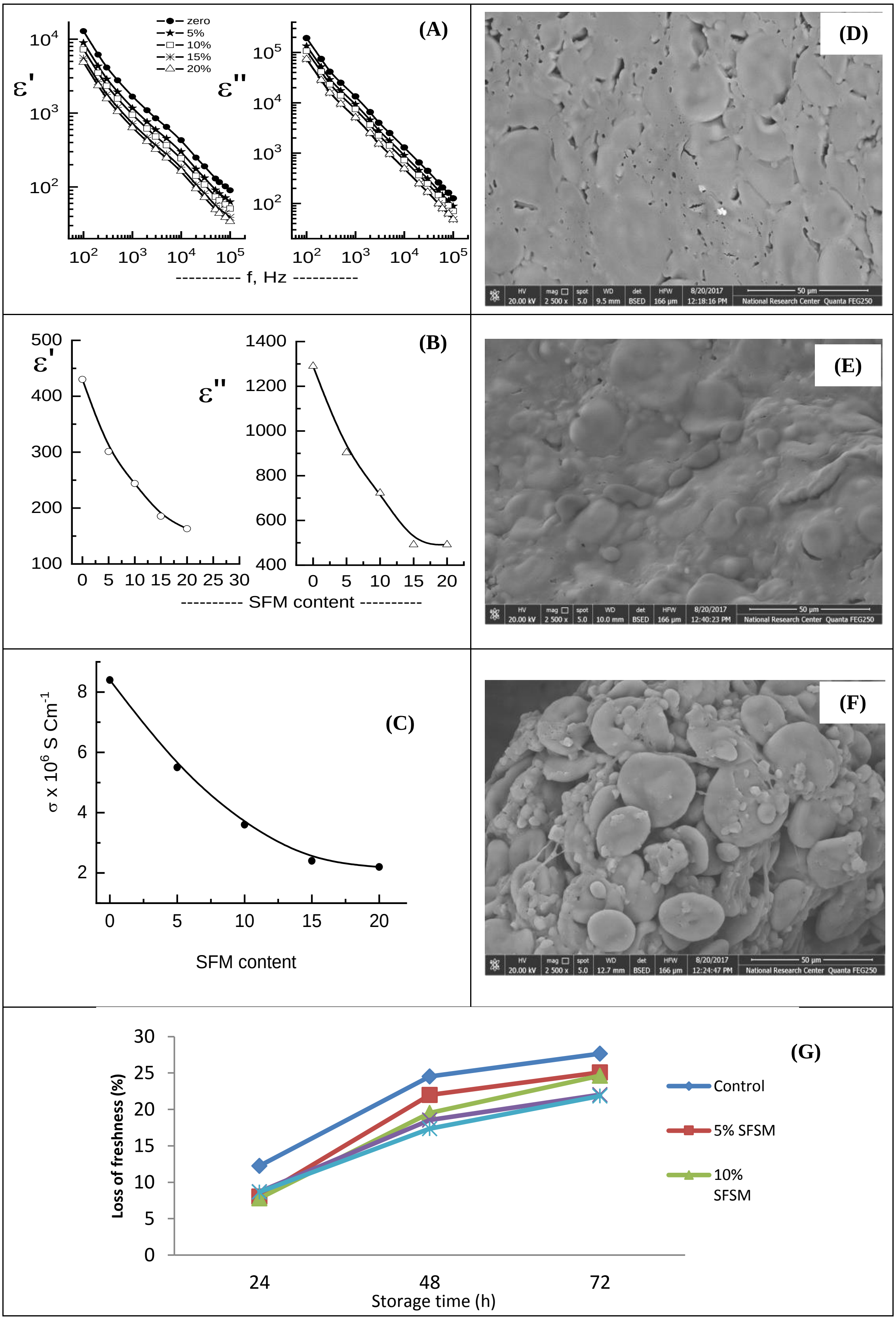

Fig (3): Dielectric properties (A-C), Photomicrographs (D = control, E = 10% SFM, F = 20% SFM) and staling properties (G) of fino bread samples as affected by sunflower meal addition (SFM)

The electrical conductivity (σ) was calculated and illustrated graphically versus SFM content (Fig. 3C). From this figure it is seen that σ values were in the order of 10-6 S.Cm-1 and decrease by increasing SFM content. These higher values of σ when compared with those obtained in case of flour were due to the higher water content in the bread when compared with the flour. This finding was a good justifiaction to the data of dielectric measurements and was also due to the fiber nature of SFM. Similar results were reported by Liu et al. [51] as they found that ε′ and ε″ of white bread decreased sharply with the increase in frequency up to 100 MHz, and then gradually decreased at frequency above 100 MHz.

Since starch represents about 70% of wheat flour, it is possible to consider starch gelatinization as the main factor that govern the DPs of bread samples. In this concern, Chaiwanichsiri et al. [52] found that the σ values of starch slurries increased upon gelatinization. They attributed this increase to the released ions from starch granules during gelatinization process. Furthermore, they difined two temperature degrees for the initiation and completion of ion release as the beginning and ending temperatures of gelatinisation, respectively. Also, Motwani et al. [53] confirmed the increase in ε″ value during gelatinization as the concentration of starch increased in the system. They attributed that increase to the relaxation effects in the starch molecules due to interaction between the bound water and the molecular chains, modifying the dielectric properties of free water in the system. Regarding these findings, the decreased DPs properties of SFM incorporated bread samples could be explained by the ability of SFM to hinder the gelatinization of starch during baking process.

On the other hand, the effects of SFM on the gluten network and its relation with the DPs of the produced bread cannot be neglected. The high correlation between ε″ and gluten quality (yield and the sedimentation factors) of wheat flour as affected by oat meal addition was previously stated by Luczycka et al. [21], being 0.96 and 0.95, respectively. On that basis, the DPs values measured in bread samples largely depend on the quantity and quality of gluten network. Photomicrographs of control bread and those containing 10 and 20% SFM showed different appearance (Fig. 3g-h). In control bread, relatively well-developed dough appeared to have smooth surface in which starch granules were embedded under continuous sheet believed to be the protein that forms the gluten network with numerous cavities. SFM containing bread appeared to have broken and rough surface with no distinguishable shape for the gluten network and the gas cells and less number of cavities. At 20% replacement level, the leached starch granules were completely fused with the gluten matrix. The rupture gluten structure, not capable of withstanding the expansion and pressure that occur during baking, is responsible for the waxy appearance of the bread crumb.

All of these observations clarify the changes occurred in bread samples after baking, known as staling rate, which are another considerable quality attribute that determined its shelf-life. Although this phenomenon has been studied in several previous studies, its fundamentals are still vague. Alkaline water retention capacity (AWRC) is one of the implemented investigations to follow up the staling rate in bakery products. The freshest baked products have higher alkaline water retention capacity [54]. Our results revealed a gradual increase in the staling rate of all processed fino bread samples with prolonged storage time for 72 hrs (Fig. 3G). Slight differences were observed among all processed fino bread up to 24 hrs, while there was an observed increase in the staling rate of all bread samples after 48 and 72 hrs of storage. From this figure, it is clear that fino bread containing SFM was fresher than control sample under the same experimental conditions.

Although, it is known that the reduction of bread specific volume can accelerate the staling rate [55]. Nevertheless, this was not happened in SFM containing bread. This might be due its higher water binding ability that can delay the amylopectin retrogradation which is responsible for bread staling [56]. Also, it is known that lipids hinder the amylopectin retrogradation [57]. Such assumptions could further be supported by the lower dielectric properties of SFM containing bread (Fig. 3A-C). The lower ε′ and ε″ values indicate that SFM reduced the polarizability of water molecules through its higher water binding ability. On the other hand, the oxidation of these lipids could represent a vital problem, especially in long life baked products [58]. However, the higher phenolic content of SFM could partially solve this problem through antioxidant activity [59].

3.6. Sensory evaluation of fino bread

Organoleptic properties of fino bread samples were evaluated in terms of taste, aroma, crumb texture, mouthfeel, crust color, crumb color, break & shred and symmetry of shape as presented in Table (3). The panelists rated SFM containing bread samples lower overall organoleptic properties than the control sample. Significant differences at <0.05 were noted within all SFM containing bread samples and between the control sample for all organoleptic characteristics, but all changes were in acceptable range. The lower color and aroma values of SFM containing bread, which are in agreement with the instrumental Hunter results (Table 3), may be due the higher protein and fiber contents in SFM compared to wheat flour that increase Millard reaction products [50].

On the other hand, the lower crumb texture, break & shred and symmetry of shape values for SFM containing bread samples were in accordance with the rheological and backing quality data. The obtained results indicate that these bread samples were characterized with dense, less aerated structure and consequently different mastication behavior. Furthermore, the phenolic compound of SFM (Fig 1) may conjugate with saliva glyco-proteins. Thus reduce the saliva being available for bread dissolving and fat spreading in the mouth, resulting in dry and bitter mouthfeel [60]. In general, the incorporation of SFM in bread could be acceptable up to 15%. Similarly, Grasso et al. [6] reported that replacing up to 18% of wheat flour with defatted sunflower seeds flour for biscuit enrichment was acceptable.

Table 3 Organoleptic characteristics of fino bread

Parameter	Control	*Fino bread containing sunflower seeds meal (%)*				LSD
		5	10	15	20	
Taste (20)	18.70[a]	17.30[b]	16.78[c]	16.55[c]	14.65[d]	0.725
Aroma (20)	19.22[a]	17.53[b]	16.11[c]	15.25[d]	13.75[e]	0.812
Crumb color (10)	9.20[a]	7.14[b]	7.11[b]	7.05[b]	5.31[c]	0.405
Crust color (10)	8.95[a]	6.97[b]	6.50[b]	6.35[c]	5.30[d]	0.511
Crumb texture (15)	14.36[a]	13.12[b]	13.04[b]	13.55[b]	11.66[c]	0.656
Break & shred (10)	9.50[a]	8.24[b]	7.45[c]	7.30[c]	7.11[d]	0.495
Mouth feel (10)	9.12[a]	8.62[b]	8.00[c]	7.52[d]	5.95[e]	0.455
Symmetry shape (5)	4.6[a]	4.01[b]	3.56[c]	3.15[d]	2.94[e]	0.343

4. Conclusion

The incorporation of SFM enhanced the nutritional value of fino bread in terms of protein, amino acids, fibers and bioactive compounds. However, this inclusion affected the rheological properties of the dough, the quality characteristics of the bread and consequently the consumer's acceptability. In general, it seems that inclusion of SFM in fino bread up to 15% can be acceptable. On the other hand, the DPs results of wheat flour blends and the processed bread samples showed that dielectric spectroscopy is a promising tool to follow the molecular interaction of food constituents and to control the production process.

5. Conflicts of interest

There are no conflicts to declare.

6. References

[1] D.M. Peterson, D.M. Wesenberg, D.E. Burrup, C.A. Erickson, Relationships among Agronomic Traits and Grain Composition in Oat Genotypes Grown in Different Environments, Crop Science 45(4) (2005) 1249-1255.

[2] M. Nadeem, F. Anjum, M. Arshad, S. Hussain, Chemical characteristics and antioxidant activity of different sunflower hybrids and their utilization in bread, African Journal of Food Science 4 (2010) 618-626.

[3] E.M. Salem, N.A. Hamed, O.F.A. Awlya, Implementation of the sunflower seeds in enhancing the nutritional values of cake, Journal of Applied Sciences Research 8(5) (2012) 2626-2631.

[4] B. Škrbić, B. Filipčev, Nutritional and sensory evaluation of wheat breads supplemented with oleic-rich sunflower seed, Food Chemistry 108(1) (2008) 119-129.

[5] S. Man, A. PĂUCEAN, S. MUSTE, A. Pop, A. Sturza, V. MUREȘAN, L.C. SALANȚĂ, Effect of incorporation of sunflower seed flour on the chemical and sensory characteristics of cracker biscuits, Bulletin UASVM Food Science and Technology 74(2) (2017) 1-7.

[6] S. Grasso, E. Omoarukhe, X. Wen, K. Papoutsis, L. Methven, The use of upcycled defatted sunflower seed flour as a functional ingredient in biscuits, Foods 8(8) (2019) 305.
[7] C. Burel, F. Médale, What about the utilization of plant-proteins in fish feed?, OCL-Oilseeds and Fats, Crops and Lipids 21(4) (2014).
[8] S.R. Wildermuth, E.E. Young, L.M. Were, Chlorogenic acid oxidation and its reaction with sunflower proteins to form green‐colored complexes, Comprehensive Reviews in Food Science and Food Safety 15(5) (2016) 829-843.
[9] S. Rama Rao, M. Raju, A. Panda, M. Reddy, Sunflower seed meal as a substitute for soybean meal in commercial broiler chicken diets, British Poultry Science 47(5) (2006) 592-598.
[10] M.M. Pedrosa, M. Muzquiz, C. García‐Vallejo, C. Burbano, C. Cuadrado, G. Ayet, L.M. Robredo, Determination of caffeic and chlorogenic acids and their derivatives in different sunflower seeds, Journal of the Science of Food and Agriculture 80(4) (2000) 459-464.
[11] N. Liang, D.D. Kitts, Role of chlorogenic acids in controlling oxidative and inflammatory stress conditions, Nutrients 8(1) (2016) 16.
[12] B. De Lamo, M. Gómez, Bread enrichment with oilseeds. A review, Foods 7(11) (2018) 191.
[13] P. Ramasamy, A dielectric relaxation study of starch–water and starch–glycerol films, Ionics 18(4) (2012) 413-423.
[14] J. Einfeldt, D. Meißner, A. Kwasniewski, Contributions to the molecular origin of the dielectric relaxation processes in polysaccharides–the high temperature range, Journal of Non-Crystalline Solids 320(1-3) (2003) 40-55.
[15] B. Lin, S. Wang, Dielectric properties, heating rate, and heating uniformity of wheat flour with added bran associated with radio frequency treatments, Innovative Food Science & Emerging Technologies 60 (2020) 102290.
[16] A.a. Metaxas, R.J. Meredith, Industrial microwave heating, IET1983.
[17] S. Nelson, L. Soderholm, F. Yung, Determining the dielectric properties of grain, Agricultural Engineering 34(9) (1953) 608-610.
[18] Y.Ö. Alifakı, Ö. Şakıyan, Dielectric properties, optimum formulation and microwave baking conditions of chickpea cakes, Journal of food science and technology 54(4) (2017) 944-953.
[19] S.O. Keskin, G. Sumnu, S. Sahin, A study on the effects of different gums on dielectric properties and quality of breads baked in infrared-microwave combination oven, European Food Research and Technology 224(3) (2007) 329-334.
[20] O. Sakiyan, G. Sumnu, S. Sahin, V. Meda, Investigation of dielectric properties of different cake formulations during microwave and infrared–microwave combination baking, Journal of food science 72(4) (2007) E205-E213.
[21] D. Łuczycka, A. Czubaszek, M. Fujarczuk, K. Pruski, Dielectric properties of wheat flour mixed with oat meal, International Agrophysics 27(2) (2013).
[22] G. Üstun, L. Kent, N. Cekin, H. Civelekoglu, Investigation of the technological properties ofNigella sativa (black cumin) seed oil, Journal of the American Oil Chemists' Society 67(12) (1990) 958-960.
[23] M. Murru, C.L. Calvo, Sunflower protein enrichment. Methods and potential applications, OCL 27 (2020) 17.
[24] C. AACC, Approved methods of the American association of cereal chemists, Methods 54 (2000) 21.
[25] M.A.-A. Kamel, M.H.H. Aly, A.R. El-Tawel, Production and Improvement of Fino and Pan Breads Made from Different Extractions of Wheat Flour, Asian Journal of Advances in Agricultural Research (2018) 1-13.
[26] AOAC, Official methods of analysis, 18th Ed. Association of Official Analytical Chemists AOAC International, Gaithersburg, MD, USA. (2005).
[27] S. Žilić, A. Serpen, G. Akıllıoğlu, M. Janković, V. Gökmen, Distributions of phenolic compounds, yellow pigments and oxidative enzymes in wheat grains and their relation to antioxidant capacity of bran and debranned flour, Journal of Cereal Science 56(3) (2012) 652-658.
[28] K.-H. Kim, R. Tsao, R. Yang, S.W. Cui, Phenolic acid profiles and antioxidant activities of wheat bran extracts and the effect of hydrolysis conditions, Food Chemistry 95(3) (2006) 466-473.
[29] P. Van Soest, J. Robertson, Systems of analysis for evaluating fibrous feeds, Standardization of analytical methodology for feeds: proceedings... IDRC, Ottawa, ON, CA1979.
[30] M.R. Luo, C. Li, CIE color appearance models and associated color spaces, Colorimetry: Understanding the CIE system (2007).
[31] J. Sidhu, J. Al-Saqer, S. Al-Zenki, Comparison of methods for the assessment of the extent of staling in bread, Food Chemistry 58(1-2) (1997) 161-167.
[32] P. Rosa, R. Antoniassi, S. Freitas, H. Bizzo, D. Zanotto, M. Oliveira, V. Castiglioni, Chemical composition of brazilian sunflower varieties/composición química de las variedades de girasol brasileñas/composition chimique de sortes de tournesol brésiliennes, Helia 32(50) (2009) 145-156.
[33] S. Aishwarya, V. Anisha, Nutritional composition of sunflower seeds flour and nutritive value of products prepared by incorporating sunflower seeds flour, (2014).
[34] K.J. Dabrowski, F.W. Sosulski, Quantitation of free and hydrolyzable phenolic acids in seeds by capillary gas-liquid chromatography, Journal of agricultural and food chemistry 32(1) (1984) 123-127.
[35] J. Stringhini, M. Café, C. Fernandes, M. Andrade, P. Rocha, N. Leandro, Scientific report: evaluation of the nutritional value of sunflower meal for poultry, Ciência Animal Brasileira 1(2) (2000) 123-126.
[36] N. Singh, R. Singh, K. Kaur, H. Singh, Studies of the physico-chemical properties and polyphenoloxidase activity in seeds from hybrid sunflower (Helianthus annuus) varieties grown in India, Food chemistry 66(2) (1999) 241-247.
[37] A. De Leonardis, V. Macciola, N. Di Domenico, A first pilot study to produce a food antioxidant from sunflower seed shells (Helianthus annuus), European journal of lipid science and technology 107(4) (2005) 220-227.
[38] T. Maier, A. Schieber, D.R. Kammerer, R. Carle, Residues of grape (Vitis vinifera L.) seed oil production as a valuable source of phenolic antioxidants, Food Chemistry 112(3) (2009) 551-559.
[39] T.D. Hadnađev, A. Torbica, M. Hadnađev, Rheological properties of wheat flour substitutes/alternative crops assessed by Mixolab, Procedia Food Science 1 (2011) 328-334.
[40] S. Ibrahim, A. Labeeb, A.F. Mabied, O. Soliman, A. Ward, S.L. Abd-El-Messieh, A.A. Abdelhakim, Synthesis of super-hydrophobic polymer nanocomposites as a smart self-cleaning coating films, Polymer Composites 38 (2017) E147-E156.
[41] H. Lizhi, K. Toyoda, I. Ihara, Dielectric properties of edible oils and fatty acids as a function of frequency, temperature, moisture and composition, Journal of food engineering 88(2) (2008) 151-158.
[42] S.O. Nelson, S. Trabelsi, Influence of water content on RF and microwave dielectric behavior of foods, Journal of Microwave Power and Electromagnetic Energy 43(2) (2008) 13-23.
[43] S.N. Jha, K. Narsaiah, A.L. Basediya, R. Sharma, P. Jaiswal, R. Kumar, R. Bhardwaj, Measurement techniques and application of electrical properties for nondestructive quality evaluation of foods—a review, Journal of food science and technology 48(4) (2011) 387-411.
[44] E. Sadek, S. Abd-El-Messieh, A. Khalil, N. Fatthallah, A. Eid, K. El-Ashry6and, A. Motawie, Some Studies on Poly (vinyl chloride)/Layered Silicate Nanocomposites: Electrical, Antibacterial and Oxygen Barrier Properties, IOSR Journal of Applied Chemistry (IOSR-JAC) e-ISSN (2014) 2278-5736.
[45] P. Piyasena, C. Dussault, T. Koutchma, H. Ramaswamy, G. Awuah, Radio frequency heating of foods: principles, applications and related properties—a review, Critical reviews in food science and nutrition 43(6) (2003) 587-606.
[46] M. Kweon, L. Slade, H. Levine, Solvent retention capacity (SRC) testing of wheat flour: Principles and value in

predicting flour functionality in different wheat-based food processes and in wheat breeding—A review, Cereal Chemistry 88(6) (2011) 537-552.

[47] M. Gómez, F. Ronda, C.A. Blanco, P.A. Caballero, A. Apesteguía, Effect of dietary fibre on dough rheology and bread quality, European Food research and technology 216(1) (2003) 51-56.

[48] J. Zhou, J. Liu, X. Tang, Effects of whey and soy protein addition on bread rheological property of wheat flour, Journal of texture studies 49(1) (2018) 38-46.

[49] Z. Kohajdová, J. Karovičová, M. Magala, V. Kuchtová, Effect of apple pomace powder addition on farinographic properties of wheat dough and biscuits quality, Chemical papers 68(8) (2014) 1059-1065.

[50] S.I. Martins, W.M. Jongen, M.A. Van Boekel, A review of Maillard reaction in food and implications to kinetic modelling, Trends in food science & technology 11(9-10) (2000) 364-373.

[51] Y. Liu, J. Tang, Z. Mao, Analysis of bread dielectric properties using mixture equations, Journal of Food Engineering 93(1) (2009) 72-79.

[52] S. Chaiwanichsiri, S. Ohnishi, T. Suzuki, R. Takai, O. Miyawaki, Measurement of electrical conductivity, differential scanning calorimetry and viscosity of starch and flour suspensions during gelatinisation process, Journal of the Science of Food and Agriculture 81(15) (2001) 1586-1591.

[53] T. Motwani, K. Seetharaman, R.C. Anantheswaran, Dielectric properties of starch slurries as influenced by starch concentration and gelatinization, Carbohydrate polymers 67(1) (2007) 73-79.

[54] J. Gray, J. Bemiller, Bread staling: molecular basis and control, Comprehensive Reviews in Food science and food safety 2(1) (2003) 1-21.

[55] M. Gómez, B. Oliete, V. Pando, F. Ronda, P.A. Caballero, Effect of fermentation conditions on bread staling kinetics, European Food Research and Technology 226(6) (2008) 1379-1387.

[56] E. Iglesias-Puig, M. Haros, Evaluation of performance of dough and bread incorporating chia (Salvia hispanica L.), European Food Research and Technology 237(6) (2013) 865-874.

[57] A.C. Eliasson, G. Ljunger, Interactions between amylopectin and lipid additives during retrogradation in a model system, Journal of the Science of Food and Agriculture 44(4) (1988) 353-361.

[58] F.D. Conforti, S.F. Davis, The effect of soya flour and flaxseed as a partial replacement for bread flour in yeast bread, International journal of food science & technology 41 (2006) 95-101.

[59] E. Villanueva, G. Rodríguez, E. Aguirre, V. Castro, Influence of antioxidants on oxidative stability of the oil chia (Salvia hispanica L.) by rancimat, Scientia Agropecuaria 8(1) (2017) 19-27.

[60] G. Davidov-Pardo, M. Moreno, I. Arozarena, M. Marín-Arroyo, R. Bleibaum, C. Bruhn, Sensory and consumer perception of the addition of grape seed extracts in cookies, Journal of Food Science 77(12) (2012) S430-S438.

استخدام التقنيات الطبيعية والكيميائية والعزل الكهربى لتقييم الخصائص التغذوية والجودة لخبر الفينو المدعم بكسبة بذور دوار الشمس

أحمد محمد سعيد حسين[1] ، أيمن عبد العزيز محمد [1]، سلوى لويس عبد المسيح [2]، شيماء فرج حميده [2]، فتحى محمد مهيا[1]

[1] قسم الصناعات الغذائية . المركز القومى للبحوث ، شارع البحوث ، الدقى ، القاهرة ، مصر

[2] قسم فيزياء الموجات الميكروئية والعازلات الكهربية ، المركز القومى للبحوث ، شارع البحوث ، الدقى ، القاهرة ، مصر

تهدف الدراسة الى تدعيم خبر الفينو بكبسة دوار الشمس كمصدر غنى بالبروتين والمركبات النشطة حيويا بمستويات 5، 10 ، 15، 20 % . تم تقدير التركيب الكيماوى والاحماض الامينية والمركبات الفينولية لكسبة دوار الشمس . وكذلك تم تحليل الخصائص الطبيعية والكيماوية والعزل الكهربى والخواص الريولوجية والحسية لخلطات الدقيق المدعم والخبز المصنع منها. أظهرت النتائج المتحصل عليها أن كسبة دوار الشمس غنية فى محتواها من الاحماض الامينية والالياف والمركبات الفينولية . أظهرت نتائج الاختبارات الريولوجية لدقيق القمح المدعم بكسبة دوار الشمس أدى الى ضعف العجينة وانخفاض المرونة والمطاطية . كذلك حدث انخفاض تدريجى فى خواص العزل الكهربى بزيادة مستوى التدعيم بكسبة دوار الشمس. كما أظهرت النتائج أن عينات الخبز المدعم كانت كثيفة القوام وداكنة اللون عند مقارنتها بالعينة الكنترول. كما أظهرت نتائج فحص الميكروسكوبى الالكترونى لقوام عينات الخبر المدعم تمزق الشبكة الجلوتينية مما أدى لظهور تجمعات منفصلة من حبيبات النشا. كانت الخواص الحسية لعينات الخبز المدعم بكسبة دوار الشمس مقبولة بشكل عام. أكدت النتائج أمكانية استخدام كسبة دوار الشمس كمصدر مستدام ، رخيص الثمن وغنى بالمغذيات لتحسين القيمة الغذائية لمنتجات المخابز. كما اكدت النتائج وجود علاقة وثيقة بين الخواص الطبيعية والكيميائية وخواص العزل الكهربى للمواد الخام وجودة المنتج النهائى.