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ORIGINAL PAPER

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GREEN PEA WASTE FLOUR AS A WHEAT FLOUR PARTIAL REPLACER IN POUND CAKE: BATTER RHEOLOGY BEHAVIOR AND CAKE QUALITY PROPERTIES

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ABSTRACT

Background. The total annual amounts of food loss and waste represent approximately 30% of all food supplied for human consumption. Reducing this loss and waste is a challenge and valorizing this reduction requires more effort. The present study aimed to investigate the feasibility of replacing wheat flour (WF) with different levels of green pea waste flour (GPWF) to produce pound cake.
Materials and methods. To prepare GPWF, green pea waste was dried at 65°C; the dried samples were pulverized and sieved through 50 mesh sieves. Six cake samples were prepared, wherein wheat flour was replaced with GPWF at the following levels: 0 (control), 10, 20, 30, 40 and 50%. Sensory evaluation was performed to determine the acceptability of various cake samples. Based on the results of the sensory evaluation, the acceptable replacement levels were determined and the effects of the GPWF-WF replacement level (10–30%) on the rheological behavior of cake batters and the quality characteristics of baked cakes were evaluated.
Results. Cake samples incorporating GPWF at levels higher than 30% significantly ($p < 0.05$) exhibited the lowest scores for all organoleptic characteristics compared to other samples. The storage modulus (G') and loss modulus (G'') of all cake batters involving GPWF were higher than those of the control cake batter and they were found to be less dependent on frequency. Increasing the GPWF-WF replacement level significantly ($p < 0.05$) decreased cake volume, springiness, and cohesiveness; however, cake density and hardness significantly ($p < 0.05$) increased. The lightness (L^*) and yellowness (b^*) of the cake crust and crumb significantly decreased with an increase in the replacement ratio, while the highest impacts on the crumb color in terms of greenness (a^*) were noted when GPWF were used at all the studied replacement levels.
Conclusion. High quality cakes could be obtained at GPWF-WF replacement ratios up to 20%, as they had sensorial, textural and appearance characteristics close to that of the control cake samples.

Keywords: green pea waste flour, pound cake, sensory evaluation, rheological properties, quality properties

INTRODUCTION

Dried pea (*Pisum sativum* L.) belongs to the pulse seeds, which are considered to be an important part of the human diet because of their valuable nutrient components such as starch, protein, fibers, and minerals (Dahl et al., 2012). Peas are cultivated worldwide and extensively consumed in several forms: fresh,

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canned, dried, and frozen (Fahmi et al., 2019). The annual world production of green peas in 2018 reached 21,225,579 tons. Meanwhile, Egypt was ranked as the fifth country in the production of peas with a total production of 202,760 tons (FAOSTAT, 2018). The health benefits of consuming peas have been reviewed by Dahl et al. (2012), wherein the association between improvements in metabolic, gastrointestinal, and cardiovascular health and pea consumption has been demonstrated.

Leguminous flours are added to bakery products as supplementary components due to their high protein content as well as their amino acids, which improve the nutritional quality of cereal proteins (Dhen et al., 2016). Previous studies have established that partial replacement of wheat flour with leguminous flours is feasible during the preparation of bakery products (Fahmi et al., 2019). Pea flour has been utilized to replace wheat flour partially or completely in various bakery products such as bread (Millar et al., 2019) and cakes (Gómez et al., 2008).

As a response to the problem of increasing demands of food in addition to the limited available sources for food production, several studies have been performed to assess the food losses that occur in food chains and to overcome this problem. Through these studies, the amount of food loss was calculated, and its causes were identified and categorized. According to Gustavsson et al. (2011), the total annual amount of food loss and waste is 1300 million tons, which represents approximately 30% of all food supplied for human consumption. They also reported that more than 40% of these food losses occur in developed countries at postharvest and processing levels. Among the various forms of food waste, massive amounts of fruit and vegetable waste which is produced during the processing of fruit and vegetables is abundant all over the world (Wadhwa and Bakshi, 2013). Thus, several world agencies and organizations have directed their members towards the necessity of reducing food loss and waste. For example, the African union has committed their members to halving their postharvest losses by 2025 (Xue and Liu, 2019).

In the light of previously published information, the present work set out to find a new method for finding a use for pea loss and waste that occurs during frozen pea packing and production. Hence, the possibilities of using green pea waste flour (GPWF) to replace wheat flour (WF) at various replacement ratios during cake making was investigated. The influence of the GPWF-WF replacement level on the rheological behavior of cake batter and the quality of the obtained cake was studied in terms of color, volume, density, and texture profile. In addition, the correlation between flour characteristics and the quality parameters of the cake was studied using Mixolab.

MATERIALS AND METHODS

Materials

Pea waste was collected from a packing area of the international company for agriculture and processing in Egypt. The pea waste consisted of whole peas, blond whole peas, whole pea fragments, spilt peas and pea waste from the packing machine which is separated during the packing phase. Wheat flour (72% extraction), butter, salt, baking powder, fresh egg and vanilla were purchased from a local market.

Methods

Green pea waste flour (GPWF) preparation. Green pea waste was dried in a tray dryer (Heraeus electronics, Germany) at 65°C to a constant weight. Then, the dried samples were ground in a laboratory mill (Cole-Parmer, USA), sieved through 50 mesh sieves, and stored in glass bottles at room temperature.

Proximate composition analysis of pea flour and wheat flour. The moisture, crude fat, crude fiber, protein and ash content of GPWF and wheat flour (WF) were determined in triplicate according to AOAC (2005), while the carbohydrate content was determined by difference (AOAC, 2005).

Cake preparation. The basic recipe of pound cake involves 85.2 g wheat flour, 64.5 g sugar, 42.6 g egg, 63.6 g butter, 0.3 g vanilla, 0.3 g salt and 1.2 g baking powder. In addition to the control sample (basic recipe), five cake samples were prepared, wherein wheat flour was replaced with GPWF at the following levels: 10, 20, 30, 40 and 50%. For cake batter preparation, the eggs and sugar were firstly mixed on the highest speed to form a cream using a kitchen mixer (Moulinex, France). Then, all the remaining ingredients were added and mixed for five minutes. The cakes were baked in aluminum foil cups that were coated with vegetable oil. Each cup contained 50 g of batter, which was evenly spread throughout the cup. The cakes were baked at 190°C for 20 minutes.

Sensory analysis. The acceptability of different cake samples was evaluated by 20 untrained panelists using a 9-hedonic scale, where 1 means extremely dislike and 9 extremely like (Belghith-Fendri et al., 2016). The sensory evaluation was conducted by a panel made up of students (12 male and 8 female) from the Food Science Department, Faculty of Agriculture, Cairo University. Various cake samples were coded and evaluated according to their taste, odor, color, texture, and overall acceptability. The obtained data were statistically analyzed using a completely randomized design ($p \leq 0.05$) followed by Duncan's multiple range tests to compare the mean of various organoleptic attributes. The acceptance indices (AI) of various cake samples were computed using the following equation (1) (Lucas et al., 2018):

$$\mathrm{AI} = \frac{\mathrm{OA}}{9} \times 100 \qquad (1)$$

where: OA – the average scores of overall acceptability for various cake samples.

Hierarchical cluster analysis (HCA). The score values of the organoleptic attributes of the different evaluated cake samples were subjected to a hierarchical cluster analysis (HCA) using Ward's method, in which Euclidean distances were implemented to calculate the distances between various samples. Based on the results of the sensory evaluation and HCA, the most accepted cake samples were chosen for further examination.

Oscillatory rheology of cake batter. The dynamic viscoelastic properties of different cake batter samples were determined using a parallel plate rheometer (MCR 301, Anton Paar GmbH, Graz, Austria). The batter was placed onto the base plate (50 mm diameter and 1 mm gap) and allowed to rest for 5 min. Measurements were taken at 25°C. The examinations were conducted in two steps. Firstly, deformation sweeps were performed at a constant frequency to determine the strain range (0.01 – 100%) for linear viscoelastic behavior. Secondly, frequency sweeps (0.1 to 100 1/s) were performed within a linear viscoelastic range at a constant strain of 0.1%. Storage modulus (G'), loss modulus (G'') and complex viscosity (η^*) were plotted against the frequency values. The obtained data were fitted using the Power law model (Razavi et al., 2016):

$$G' = k' \times \omega^{n'} \qquad (2)$$

$$G'' = k'' \times \omega^{n''} \qquad (3)$$

where:

k', k'' – intercepts, Pa s^n,

n', n'' – slopes of frequency dependence of G' and G'', respectively,

ω – the angular frequency, rad s^{-1}.

Cake volume and density. The volume of each cake sample was determined in triplicate according to AACC (2001) using the rapeseed displacement method (no. 10-05.01). The weight of various cake samples was measured, and the density of individual samples was calculated as the ratio of sample weight to its volume.

Cake color. The crust and crumb color of various cake samples were evaluated in triplicate using a Chroma meter CR-410 (Konica Minolta, Japan) according to Ayadi et al. (2009), where color was expressed in terms of L^*, a^* and b^*, which indicate lightness, redness/greenness and yellowness/blueness, respectively.

Cake texture. The obtained cake samples were subjected to a texture profile analysis (TPA) to assess their textural properties using a texture analyzer (CT3, Brookfield, USA) equipped with a load cell of 10 kg and a cylindrical probe diameter of 36 mm, respectively. Pre-test, test, and post-test speed were set to 2, 1, and 1 mm/s, respectively. The compression percentage was set to 25%. TPA was performed after 24 h of baking in a cube cut from the center of each cupcake. The cube had dimensions of 2.5 × 2.5 × 2 cm (length, width and height, respectively). The examinations were conducted in duplicate.

Rheological tests of wheat flour and wheat flour incorporated with different percentages of GPWF using Mixolab®. A Mixolab® device (Chopin Technologies Villeneuve La Garenne, France) was implemented to determine the mixing and pasting behavior of wheat flour and wheat-green pea waste composite flour according to AACC (2010) 54–60.01. The standard "Chopin+" protocol was followed throughout the examinations, in which the temperature was kept at 30°C for first 8 min, then increased to 90°C at a heating rate of 4°C/min (over 15 min) and held at this temperature for 7 min. Then the temperature was decreased to 50°C at a cooling rate of 4°C/min (over 10 min) and held for 5 min. The mixing blades were rotated at a constant speed of 80 rpm.

Statistical analysis. All measurements were reported as mean values ±standard deviations. One-way ANOVA with post-hoc Duncan's multiple range test ($p < 0.05$) and Pearson's correlation were implemented to analyze the obtained data. XLSTAT software version 2014.5.03 (Addinsoft, USA) was used to perform all statistical analyses.

RESULTS AND DISCUSSION

Proximate composition analysis of pea flour

The data listed in Table 1 show that the protein, ash, crude fiber, and fat content of GPWF were 21.9% ±0.100, 3.34% ±0.043, 14.6% ±1.696 and 2.38% ±0.260, respectively. The obtained results are consistent with data previously found in the literature for dried pea flour, where their content of protein, ash, crude fiber and fat varied between 22.83–28.04%, 2.9–3.66%, 8.78–15.28% and 1–1.89%, respectively (Červenski et al., 2017; Krumina-Zemture et al., 2016). Also, the data in Table 1 show the chemical composition of wheat flour which is consistent with data previously found in the literature (Kohajdová et al., 2012).

Table 1. Proximate composition of green pea waste flour and wheat flour

Component g/100 g flour	Green pea waste flour	Wheat flour
Protein	21.90 ±0.10	9.85 ±0.52
Moisture content	3.09 ±0.05	11.50 ±0.45
Lipids	2.38 ±0.26	1.99 ±0.01
Ash	3.34 ±0.04	0.48 ±0.02
Fiber	14.63 ±1.70	0.58 ±0.03
Carbohydrates	54.65 ±1.93	75 ±0.90

Data are means ±standard deviation values of 3 replicates.

Organoleptic characteristics of cake

The consumer acceptance of any food product depends on its organoleptic characteristics. Thus, sensory evaluation of various cake samples was carried out, and the obtained results are illustrated in Figure 1. The data in Figure 1 (a–e) reveal that the partial substitution of wheat flour (WF) with different proportions of GPWF had significant ($p < 0.05$) effects on all the organoleptic characteristics of the obtained cakes. It could be noted that the cakes prepared using replacement ratios of 10 and 20% (Fig. 1 a, b, c and e) were not significantly ($p > 0.05$) different to the control for all organoleptic characteristic ratings except color ratings. On the other hand, increasing the GPWF-WF replacement ratio to more than 30% had a significant ($p < 0.05$) adverse effect on the organoleptic characteristics of the produced cake. This finding is consistent with that of Belghith-Fendri et al. (2016), who found that increasing the replacement levels of wheat flour with pea flour and broad bean flour decreased the organoleptic characteristic scores of the examined cake samples. Also, Sudha et al. (2007) and Ayadi et al. (2009) found that increasing the apple pomace flour and spiny and spineless cladode flour in cake formulations decreased the organoleptic characteristic scores. Lucas et al. (2018) reported that for any food product to be sensorially accepted, it must have an acceptance index (AI) higher than 70%. The AI of all the samples (Table 2) was higher than 70%, which indicates their sensorial acceptance. Moreover, the AI of the cakes prepared using replacement ratios of 10 and 20% was 81.11%, which reduced dramatically to the nearest of 71% as the replacement ratios further increased.

Hierarchical cluster analysis (HCA) is a multivariate technique that has been successfully used to classify foods into various clusters or groups based on their chemical composition or their phytochemical constituents and associated bioactivity (Hossain et al., 2011). HCA was implemented to classify the obtained cakes into different clusters based on their organoleptic attribute scores and the obtained results are illustrated as

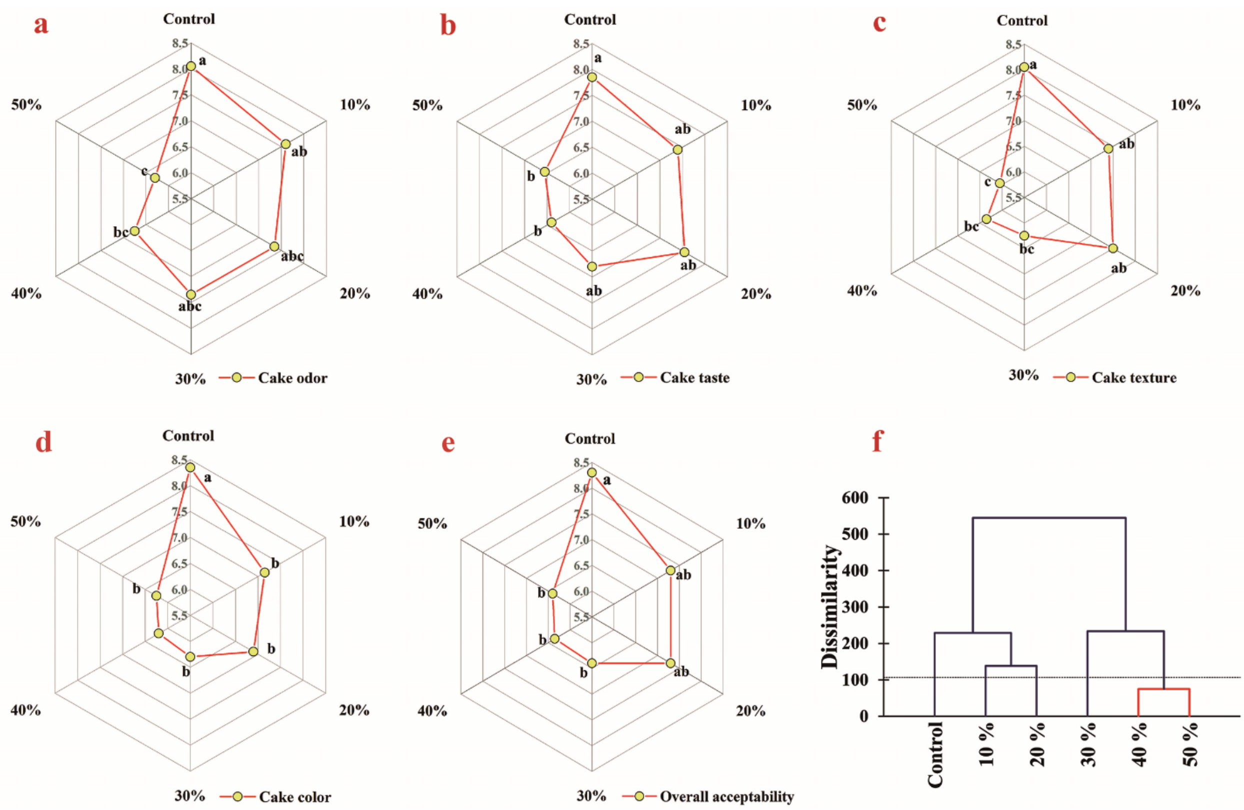

Fig. 1. Effects of GPWF-WF replacement ratios on the organoleptic characteristics of cake (a–e) and dendrogram of HCA for various cake incorporating different GPWF ratios using Ward's method (f)

Table 2. The acceptance index of various cake samples prepared using different GPWF-WF replacement ratios

Treatment	Acceptance index
Control	92.22^{a} ±11.46
10%	81.11^{ab} ±13.54
20%	81.11^{ab} ±14.01
30%	71.11^{b} ±19.54
40%	70.55^{b} ±22.30
50%	71.11^{b} ±21.75

Data are means ±standard deviation values of 20 replicates.

a dendrogram (Fig. 1f), in which five clusters/groups were identified. The first group involves the control cake which had the highest scores for all organoleptic characteristics. The second, third and fourth clusters comprise cakes with replacement ratios of 10, 20 and 30%, respectively, which were preferred in the same order and followed the control cake. The fifth group consists of cakes with replacement ratios of 40 and 50%, which had the lowest scores for all organoleptic characteristics. Based on the previous results, cakes prepared with replacement ratios of 10, 20 and 30% in addition to the control were chosen for further evaluation.

Rheological properties of cake batter

An oscillatory (frequency sweep) test was used to analyze the viscoelastic properties of various cake batters and the obtained results are illustrated in Figure 2 (a–c). All the tested samples exhibited mechanical spectra identical to the behavior of soft gels, as the storage modulus (G') values were higher than that of the loss modulus (G'') and both showed a minor reliance on the frequency. These results are in agreement with those obtained by Aydogdu et al. (2018). In addition,

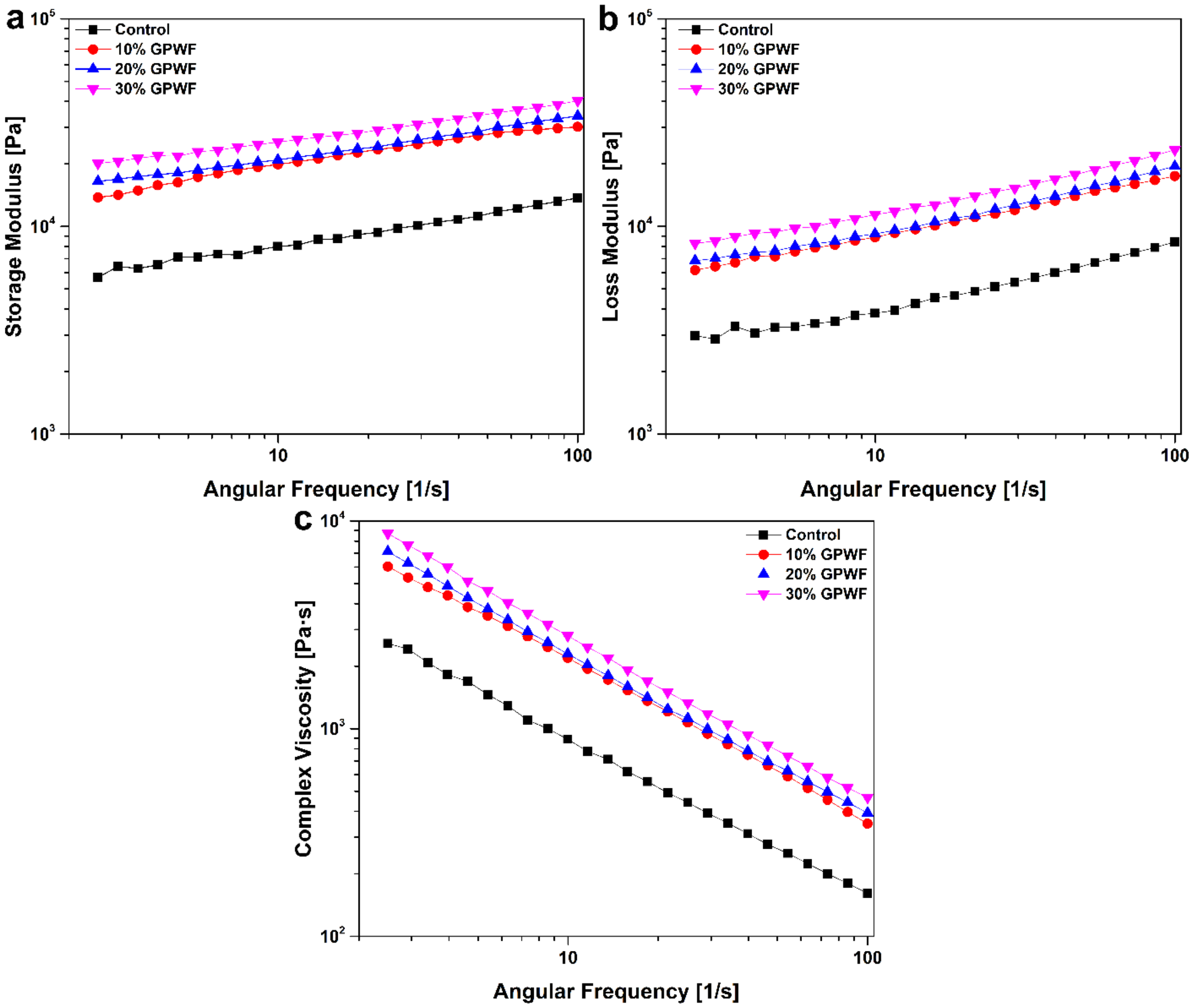

Fig. 2. Storage modulus G' (a), loss modulus G'' (b) and complex viscosity (c) of various cake batters at different GPWF-WF replacement ratios

the data in Figure 2 (a–c) indicate that the storage modulus (G'), loss modulus (G'') and complex viscosity (η^*) of all cake batters involving GPWF were higher than that of the control cake batter. These increases in storage (G') and loss (G'') moduli could be attributed to the high protein content of GPWF. Heldman et al. (2007) correlated the increase of these moduli in the protein-starch-water system with the higher protein content. On the other hand, Aydogdu et al. (2018) related these increases in storage (G') and loss (G'') moduli to the reduction in the moisture content as a result of the addition of GPWF (fibers) to the cake batters.

The G' and G'' data for various cake batters using the power law model are listed in Table 3. High values of the determination coefficient (R^2) and adjusted determination coefficient (adj.-R^2) indicate the adequacy of the power law model for the obtained data. The intercepts (k' and k'') of G' and G'' increased from 4764.45 to 16 488.20 and from 1935.86 to 5857.28 as the GPWF replacement ratio increased from 0% (control) to 30%, respectively. Contrarily, the slopes

Table 3. Modeling of rheological properties of cake batters using power law model and Mixolab characteristics of composite flours under different GPWF-WF replacement ratios

Treatment	Fitting of rheological properties of cake batters using power law model								Mixolab characteristics of composite flours						WA %
	G'				G''										
	k'	n'	R^2	adj.-R^2	k''	n''	R^2	adj.-R^2	C_1 Nm	C_2 Nm	C_3 Nm	C_4 Nm	C_5 Nm	ST min	
Control	4 764.45	0.23	0.995	0.995	1 935.86	0.31	0.988	0.988	1.10	0.53	1.86	1.78	3.12	8.88	59.8
10%	12 191.55	0.21	0.988	0.988	4 622.33	0.29	0.999	0.989	1.06	0.41	1.53	1.68	2.65	8.30	58.7
20%	13 225.93	0.20	0.997	0.997	4 688.23	0.30	0.992	0.991	1.10	0.61	1.94	1.75	3.33	9.60	58.0
30%	16 488.2	0.19	0.997	0.967	5 857.27	0.29	0.993	0.993	1.10	0.56	1.92	1.85	3.08	9.25	57.1
Standard deviation									0.02	0.09	0.19	0.07	0.29	0.56	1.14

G' – storage modulus, G'' – loss modulus, k' – intercept of G', k'' – intercept of G'', n' – slope of G', n'' – slope of G'', R^2 – determination coefficient, adj.-R^2 – adjusted determination coefficient, Mixolab parameters [C_1, C_3, C_5 – maximum consistency at stage 1, 3, 5; C_2, C_4 – minimum consistency at stage 2, 4; ST – dough stability], WA – water absorption.

(n' and n'') of G' and G'' decreased as the GPWF replacement ratio increased, which indicates a low frequency dependence and an increased elasticity behavior of these cake batters (Razavi et al., 2016). These results are in agreement with the findings of Kırbaş et al. (2019), which showed the adequacy of the power law model in representing the rheological data of cake batter. In addition, their results indicated that increasing the proportions of apple, carrot and orange pomace powder in cake formulations increases the intercepts and decreases the slopes of G' and G''.

Volume and density of cake

The data illustrated in Table 4 reveal that the GPWF-WF replacement level significantly ($p < 0.05$) affected the volume and density of the baked cake. Increasing the GPWF-WF replacement level from 0 to 30% significantly ($p < 0.05$) decreased the cake volume from 118 ±2.0 to 95 ±1.0 cm^3 and increased the cake density from 0.3888 ±0.010 to 0.4958 ±0.005 g/cm^3, respectively. Data in the literature state that incorporating pea flour, broad bean flour (Belghith-Fendri et al., 2016) and apple pomace flour (Sudha et al., 2007) during cake preparation significantly increases baked cake density. This increase in cake density could be related to the high elasticity behavior of cake batters incorporating GPWF, as previously outlined. Furthermore, Erben and Osella (2017) ascribed the increase in cake density containing pea flour to the strong water holding capacity of pea flour.

Table 4. Cake density, volume, and texture profile under different GPWF-WF replacement ratios

Treatment	Density* g/cm^3	Volume* cm^3	Hardness** N	Cohesiveness** mJ	Springiness** mm	Gumminess** N	Chewiness** mJ
Control	0.389^c ±0.010	118.00^a ±2.00	17.61^c ±1.12	0.49^b ±0.01	8.29^a ±0.08	8.56^a ±0.42	70.90^a ±4.24
10%	0.402^c ±0.007	114.00^a ±2.00	18.60^{bc} ±1.95	0.51^a ±0.00	7.96^{ab} ±0.02	9.51^a ±1.00	75.55^a ±7.71
20%	0.449^b ±0.021	103.33^b ±6.11	23.67^a ±1.16	0.44^c ±0.01	7.87^b ±0.05	10.42^a ±0.88	82.00^a ±7.35
30%	0.496^a ±0.005	95.00^c ±1.00	22.00^{ab} ±1.72	0.42^d ±0.01	7.61^b ±0.25	9.55^a ±0.07	74.10^a ±0.85

*Data are means ±standard deviation values of 3 replicates.
**Data are means ±standard deviation values of 2 replicates.

Textural properties of cakes

Soft texture is an important quality parameter of cake which is highly reliant on pore size distribution and the mechanical properties of the cake. Texture profile analysis (TPA) is used to explain assessor textural perception through simulating the biting and chewing process in the mouth in terms of chewiness, gumminess, cohesiveness, springiness, and hardness (Christaki et al., 2017).

The data listed in Table 4 show that the GPWF--WF replacement level significantly ($p < 0.05$) affected the texture profile of the obtained cake. The hardness of cake formulated with GPWF at 10% was not significantly ($p > 0.05$) different than that of the control sample. The hardness of various cake samples significantly ($p < 0.05$) increased as the GPWF-WF replacement level increased. The lowest and highest hardness values were observed at replacement ratios of 0 and 20%, respectively. The correlation test indicated that the relationship between cake hardness and volume was significant and negative ($r = -0.75$, $p < 0.05$) which was consistent with the results reported in several studies (Aydogdu et al., 2018; Dhen et al., 2016). In these studies, opposite correlations between cake hardness and volume were found. This increase in hardness could be ascribed to the low amount of incorporated air in the cake batter, which consequently led to the production of a more compact/harder cake (Gómez et al., 2010). As previously outlined, increasing the GPWF-WF replacement level increases the storage and loss moduli and alters the rheological behavior of various cake batters to be more elastic, which decreases the amount of incorporated air in the cake batter. In addition, Belghith-Fendri et al. (2016) ascribed the increase in cake hardness in cake incorporated with legume flour to legume protein.

The data in Table 4 show that the control sample exhibited the highest springiness (8.28 ±0.078 mm) and significantly ($p < 0.05$) differed from the other cake samples, except the sample with a 10% GPWF-WF replacement level. In addition, increasing the GPWF-WF replacement level from 10 to 30% insignificantly ($p > 0.05$) decreased cake springiness from 7.96 ±0.02 to 7.61 ±0.25 mm. De la Hera et al. (2012) found that increasing the replacement ratio of wheat flour with lentil flour significantly decreased the layer cake springiness. They also found that the partial replacing of wheat flour with lentil flour did not have a significant effect on sponge cake springiness. Cake cohesiveness significantly decreased with an increase in the GPWF-WF replacement levels to more than 10%. Cakes with low cohesiveness values tend to crumble easily, and consequently they are difficult to handle and slice (Ávila et al., 2017). Springiness and cohesiveness were significantly and positively correlated to cake volume ($r = 0.87$, $p < 0.05$ and $r = 0.88$, $p < 0.05$, respectively). Previous studies have shown positive relationships between cake volume and its springiness and cohesiveness (Gómez et al., 2010). The effect of the GPWF-WF replacement level at all studied levels on cake gumminess and chewiness was insignificant ($p > 0.05$). In contrast to our results, García-Segovia et al. (2017) found that the partial replacement of wheat flour with composite flour (52% quinoa, 22% dry pea, 25% dry carrot, and 1% tocte) decreased the hardness, chewiness, and gumminess of the produced cake, while its effects on cake springiness and cohesiveness were insignificant.

Cake color

The influences of the GPWF-WF replacement level on cake color are illustrated in Figure 3. Significant impacts on the color of the crust and crumb were noted. The color parameters of the control cake were significantly ($p < 0.05$) different than those of the other samples. In the crust, L^* (lightness) and b^* (yellowness) values significantly decreased from 71.77 ±0.07 to 55.51 ±0.15 and from 35.23 ±0.16 to 24.02 ±0.30 as the replacement ratio increased from 0% to 30%, respectively. Similarly, the L^* (lightness) and b^* (yellowness) values for the crumb significantly decreased from 76.84 ±0.20 to 67.11 ±0.24 and from 36.10 ±0.23 to 32.71 ±0.20 as the replacement ratio increased from 0% to 30%, respectively. Ayadi et al. (2009) found that increasing the replacement ratio of wheat flour with either spiny or spineless cladode flour decreased the L^* values of the cake crust and crumb. They related the decrement in L^* values of the cake crust to Maillard and caramelization reactions that increased at high replacement levels. Also, the relationship between Maillard and caramelization reactions and the added ratio of GPWF could explain the changes in a^* values of the cake crust from negative values (green) at 10 and 20% to positive values (red) at 30%. However, the a^*

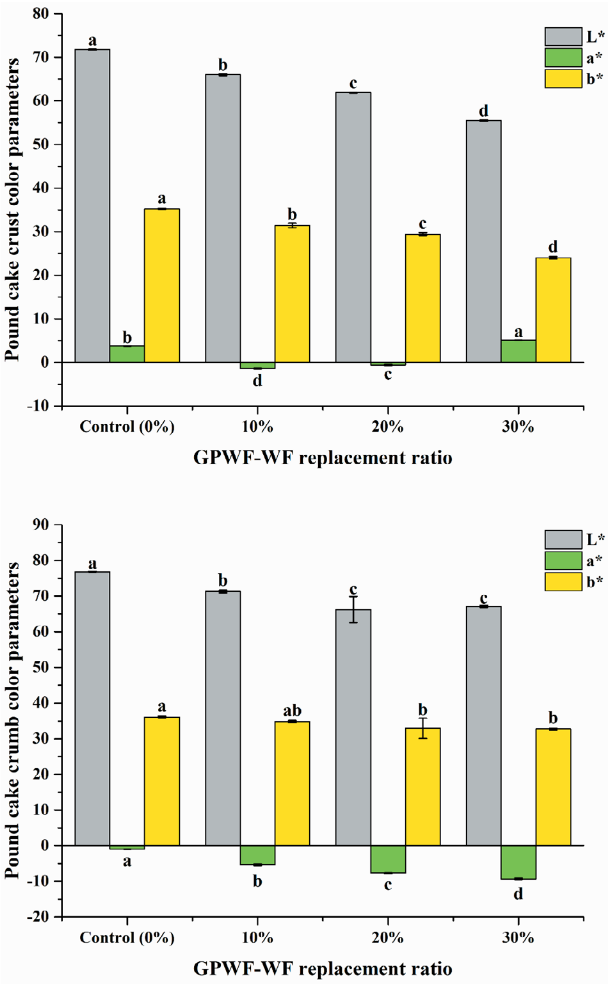

Fig. 3. Effects of GPWF-WF replacement ratios on cake crust and crumb color

values of the crumb decreased significantly ($p < 0.05$) as the used GPWF level increased, which can clearly be attributed to the added proportion of GPWF and its associated chlorophyll content. Belghith-Fendri et al. (2016) found that the L^* and a^* values of the cake crumb decreased with an increase in the ratio of pea pod flour used.

Rheological properties of wheat flour and wheat flour incorporating different percentages of GPWF using Mixolab®

Several studies have been performed to correlate the quality characteristics of bakery products, including cakes, to their flour properties using a Mixolab device (Kahraman et al., 2008). Thus, the rheological properties of wheat flour and the composite flours (GPWF-WF) at different replacement levels were analyzed using a Mixolab and the obtained results are outlined in Figure 4 and Table 2. The data in Table 2 indicate that the Mixolab parameters do not take a particular pattern for various GPWF-WF replacement levels. Surprisingly, the association between all cake quality characteristics and Mixolab parameters was found to be insignificant ($p > 0.05$). Also, it could be noted that the composite flour with replacement levels of 20 and 30%, which resulted in lower cake volumes, almost had the highest C_2, C_3, C_4 and C_5 values. These results are in agreement with those of Kahraman et al. (2008), who found a negative correlation between Mixolab parameters for C_2, C_3, C_4 and C_5 values and cake volumes.

It can be noted from the data in Table 3 that the water absorption values decreased as the GPWF-WF replacement level increased. These results are in accordance with those obtained by Millar et al. (2019) and Mironeasa and Codină (2019) who found that the partial replacement of wheat flour by raw yellow pea flour and tomato seed flour decreased the water absorption. Mironeasa and Codină (2019) ascribed this decrease in water absorption values to the decrement in gluten content in the composite flour. In contrast, dough stability values increased as the GPWF-WF replacement level increased to levels higher than 10%. Mironeasa and Codină (2019) found that the dough stability values of wheat-tomato seed composite flour were higher than those of wheat four alone. Meanwhile, the data in Table 3 show that the Mixolab C_2 parameter increased to its maximum value at a GPWF-WF replacement level of 20% and slightly decreased as the replacement level increased to 30%. These results indicate that increasing the incorporated level of GPWF to 20% resulted in a stronger dough than the control sample; however, increasing the GPWF level to 30% slightly decreased the strength of the dough which could be attributed to gluten dilution. Similarly, the Mixolab C_3 parameter had an identical trend to the C_2 parameter, which indicates that dough incorporating GPWF at a replacement level of 20% exhibited the maximum gelatinization capacity, which slightly decreased as the GPWF increased to 30%. These results are consistent with those of Dabija et al. (2017) who

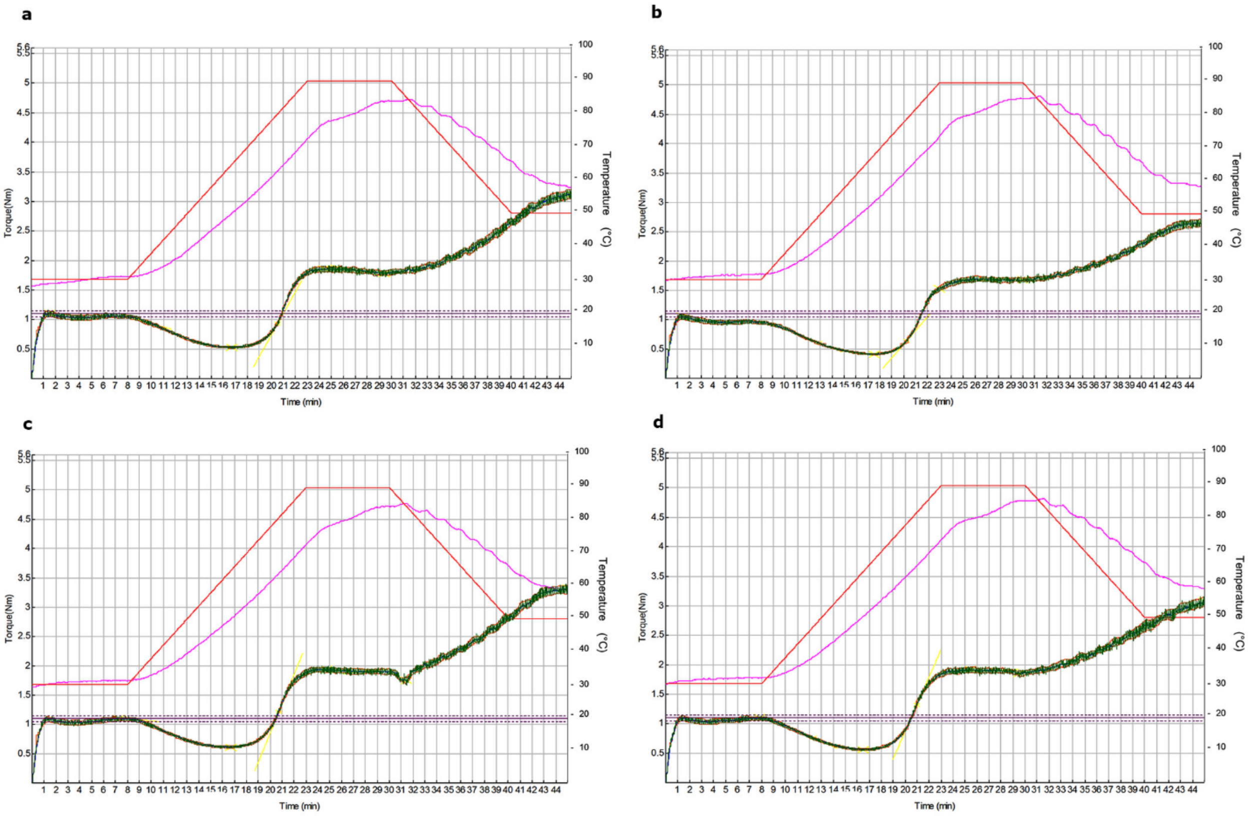

Fig. 4. Mixolab graphs for various flours at GPWF-WF replacement ratios of: a – 0% (control), b – 10%, c – 20%, d – 30%

found that the maximum gelatinization capacity for yellow pea-wheat blended flour was observed at a replacement level of 15% and further increase in the replacement level decreased the gelatinization capacity.

CONCLUSION

The current work shows that the partial replacement of wheat flour with GPWF at various levels to develop pound cake is possible; however, higher GPWF-WF replacement levels adversely affected the acceptability of the obtained cakes. There were no significant differences between the control samples and the other cake samples formulated with GPWF at replacement levels of 10–20% for all organoleptic properties, except for cake color. Adding GPWF to the cake batters altered their rheological properties, which became more elastic and consequently decreased in volume and springiness, and increased in hardness and density when they were baked. The crumb color of the baked cakes was the most affected quality parameter due to the addition of GPWF, especially at higher replacement levels, as their color turned to green.

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