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Effect of pumpkin powder as a fat replacer on rheological properties, specific volume and moisture content of cake

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Abstract. Reducing fat and calorie is an important priority in optimization of bakery products including high–fat cakes. The aim of this research was to evaluate the effects of shortening replacement with pumpkin powder at 0 %, 20 % and 40 % with or without water level increment on rheological properties of cake batter and two properties of produced cake. Pumpkin powder was obtained from pumpkin flesh through drying, grinding and sieving processes. The rheological attributes of the batter and the specific volume and moisture content of cakes were examined using a rheometer, rapeseed displacement method and air–oven method, respectively. Increasing shortening replacement, enhanced viscosity (87.00 Pa.s), while increasing water in shortening–replaced treatments reduced it (11.30 Pa.s). Samples showed shear thinning behavior. In linear viscoelastic range, samples indicated solid viscoelastic behavior. Loss tangent, storage and loss moduli obtained from frequency sweep test, were investigated in three frequencies. In each frequency, with increasing shortening replacement, their viscoelastic properties enhanced. Contrary, increasing water amount in shortening reduced–batter samples, weakened system structuring. With increasing frequency, both moduli of treatments increased and the loss tangent of 20 % reduced–shortening cake without water level increment showed a more similar trend to the control (0 % replacement without increasing water amount). The moisture content of cakes containing pumpkin was greater than control. The specific volume of cake with 20 % replacement without additional water (2.68 cm^3/g) was similar to the control and higher than other shortening–replaced treatments. Therefore, this treatment was chosen as the best reduced–fat cake.
Keyword: Cake batter, Pumpkin, Rheological properties, Shortening replacement, Specific volume.

Introduction

Approximately one–quarter of the top–selling new foods presented during 2010 to 2011, has been claimed enriched with great amount of nutrients, grain or fiber or they were low–fat/fat–free or reduced calorie foods [SLOAN, 2012].

Reducing fat and calorie is the most significant priority in optimization of bakery products [BATH *et al*., 1992]

Cake, is a confectionery product with a special texture with main ingredients constitute flour, oil, sugar and eggs.

Nowadays, Cake possess an important role in the nutrition of people in the world [MALEKI *et al*., 2017].

A fat replacer is an ingredient which can produce less energy than fat while providing some or all of fat functions in a fat–modified food [SCHWENK and GUTHRIE, 1997].

Fat replacer can be broadly classified into two groups: fat substitutes and fat mimetics.

Fat mimetics are ingredients with the clearly different chemical structure from the fat. They are usually based on carbohydrate or protein [OGNEAN *et al*., 2006].

Carbohydrate–based fat replacers are plant polysaccharides [CHUGH *et al*., 2015].

Fruit–based fat replacer is also a type of the carbohydrate–based fat replacers [KALINGA, 2010].

The origin of pumpkin (*Cucurbita mochata* L.) is North America.

Pumpkin is rich in fibers (such as pectin and cellulose), carbohydrates (including starch), beta carotene, vitamin A and minerals.

Starch, pectin and cellulose individually and some types of fruit powders have the ability for being a good fat replacer. These materials are among the carbohydrate–based fat replacers.

For instance, pectin as a gelling and thickening agent is used to improve textural and rheological properties of foods [KALINGA, 2010; MALEKI *et al*., 2017; MIN *et al*., 2010]. Carbohydrate–based fat replacers increased the moisture content of fat–reduced product [LEE and INGLETT, 2006].

Different researches have been worked on drying pumpkin fruit and use it in the food systems. In some recent researches, powder of pumpkin flesh was incorporated into cake formulations as an additive or wheat flour substitute.

These changes in formulations gave rise to the cake batter viscosity and made changes in some physical attributes of resultant cake, such as increasing in the volume of the cake [HOSSEINI GHABOOS, 2016; MIN *et al*., 2010; ONWUDE *et al*., 2016]. It has been several attempts, with a degree of success, about using processed fruit products, for instance, apple puree, prune puree and materials rich in pectin (obtained from apple), as shortening alternatives in some bakery products [MIN *et al*., 2010; SWANSON and MUNSAYAC, 1999].

To our knowledge, there is no research about addition of pumpkin powder as a potential fat replacer to cake formulation and studying the rheological properties of resultant cake batter. Since the qualitative characteristics of the baked cake such as volume and texture can be linked with rheological properties of cake batter, determination of its rheological properties is valuable. Rheological attributes of liquid foods are influenced by a lot of factors (for instance, composition, period of shearing and shear rate) and it can be applied for predicting the cake quality [SAKIYAN *et al*., 2004; KALINGA, 2010].

The necessity of increasing water level in the reduced–fat formulation of cake with additional fiber–rich powder is due to the insufficient amount of water in the formulation as a result of formation of bonds between fibers and molecules of water and eventually for providing similar mouth feel of fat [KALINGA, 2010].

Therefore, the aim of this research was to assess the effect of replacing shortening with pumpkin powder and water addition in the formulation of reduced–fat cake, on the rheological characteristics of cake batter, moisture content and specific volume of resultant cake.

Material and methods

Preparation of materials and cake: Fresh pumpkins (*Cucurbita moschata* L.) were purchased from the local market of Meshginshahr. After washing, their outer skin layer, fibrous matter and seeds were removed.

The flesh cut into small pieces (approximately 0.6 cm × 0.6 cm) by a slicer. Then it was dried at 65 °C for 8 h using a conventional oven (600, Memmert, Schwabach, Germany). The dried slices were ground using mill**.** The coarse powder was passed through a mesh sieve (pore size 0.5 mm), packed in the laminated plastic bag (Zarin Pakat, Iran) and stored at 5 °C for further use [BHAT and BHAT, 2013; MIRHOSSEINI *et al*., 2015].

Then, other ingredients, including wheat flour (Moshtary Flour, Iran), sugar (Golestan, Iran), egg white (Telavang, Iran), baking powder (Mahsa, Iran), potassium sorbate (Dalian Future, China), salt (Crystal, Iran), vanilla (Polar Bear vanilla, China), gel cake (Foleks, Turkey) and shortening (Behshar Industrial, Iran) for production of cakes were prepared.

Different levels of shortening, pumpkin and water in the formulations of cake was shown in Table 1.

Cake batter treatments were prepared according to the method of Felisberto and colleagues [FELISBERTO *et al*., 2015] with a bit of modification. Sugar, shortening and gel cake, were cream using a mixer (Model MUM4405, BOSCH, Slovenia) at high–speed (speed number three of the device) for 10 min. Then the white egg and vanilla was added and was mixed at high speed for five minutes.

Wheat flour, salt, baking powder, potassium sorbate and pumpkin powder (for cakes with a reduction in amount of shortening) was mixed together, screened and added to the mixture.

The mixture was mixed for five minutes at low speed (speed number 1). Finally, water was added. Then the batter was mixed for one minute at low speed, one minute at high speed and then was mixed a minute with low speed. Cakes were cooked in an oven (Model FC 87 IX, Ariston, Fabriano, Italy) at 180 °C for 28 min and then were cooled up to 25 °C and were packed.

Table 1.

Different levels of shortening, pumpkin and water based on the baker's weight (%) in the formulations of cake[a]

Components	Control %(Baker's weight)	20P	40P	20PW	40PW
Wheat flour	100	100	100	100	100
Shortening	35	28	21	28	21
Pumpkin powder	0	7	14	7	14
Water	60	60	60	90	90

[a] P=Pumpkin, W=Water

Rheological properties of cake batter: The rheological properties of cake batter were evaluated using a rheometer (Physica MCR 301, Anton Paar GmbH, Ostfildern, Germany), operating with Rheoplus/32 software, V 2.81, 2006 (Anton Paar GmbH). Measurements were conducted at 25 °C using 40 mm diameter serrated parallel plates. Prior testing, the gap between plates was calibrated to 1 mm. the viscosity of treatments was examined as a function of shear rate (10^{-2}–400 s^{-1}) under steady shear conditions. At each shear rate, the sample was sheared for 15 sec. to obtain steady state conditions. Data were fitted to Power Law (throughout middle–range shear rates) model ($\eta_a = K\gamma^{n-1}$) and flow behavior index (*n*) that is dimensionless were obtained. η_a is apparent viscosity (Pascal second), *K* is consistency coefficient ($Pa.s^n$) and $\dot{\gamma}$ is shear rate (1/s) [KALINGA AND MISHRA, 2009; LEE *et al*., 2004].

Strain sweep test was performed at 1 Hz in amplitude strain of 0.01–500 % to specify the limiting value of linear viscoelastic range (LVE), in order to ensure that the applied strain for frequency sweep test was within the LVE of each of the treatments. Also, loss tangent (tan δ or damping factor) was calculated at the limiting value of LVE.

Frequency sweep test was conducted to identify storage (or elastic) modulus (G′), loss (or viscous) modulus (G″) along with tan δ as a frequency function (0.1–50 Hz) at 0.1 % strain and 25 °C. G′ and G″ moduli and damping factor were reported in three frequencies of 0.1, 1.76 and 31 Hz as representatives of low, moderate and high frequencies, respectively [KALINGA and MISHRA, 2009; LEE *et al*., 2004; ZARGARAN *et al*., 2013].

Cake properties

Moisture content: Moisture content of cakes were determined using air–oven method according to the American Association of Cereal Chemists (AACC) method 44–15A [AACC, 2000].

Specific volume: Specific volume of cakes were evaluated using rapeseed displacement method via Seed volume apparatus (Simon Corrugating Machinery LTD, Runcorn, Cheshire, England) according to AACC method 10–05 [AACC, 2000].

Statistical analysis: To evaluate the effect of replacing shortening and water increment on the rheological properties of cake batter for five treatments (Control, 20P, 40P, 20PW and 40PW), analysis of variance (ANOVA) with a completely randomized design (CRD) and Duncan's Multiple Range Test (DMRT) at α=5 % was used to compare the means. All experiments were performed in triplicate.

Results and discussion

Rheological properties of cake batter

Viscosity: The flow behavior was described by power law model. Apparent viscosity of samples (at shear rate of 1.59 s^{-1}) were given in Table 2. The coefficients of determination (R^2) were

0.98 or higher for all samples, showing appropriateness of the power law model to characterize flow properties of different samples. Comparison of means indicated that there was significant difference ($p<0.05$) between the apparent viscosity of different treatments which became greater with enhancement of shortening replacement. In contrast, rising water in the shortening–replaced formulations led to decreasing in viscosity compared to the other samples.

Samples of 40 P and 20 PW showed the highest and the lowest viscosity, respectively. As it was shown in Figure 1, apparent viscosity of all samples decreased while shear rate increased, indicating non–newtonian flow behavior.

Table 2.

Apparent viscosity (at the shear rate of 1.59 s^{-1}) and flow behavior index of different treatments[a]

Samples	Control	20P	40P	20PW	40PW
Apparent viscosity (Pa·s)	44.40±1.8[c]	60.50±1.4[b]	87.00± 0.00[a]	23.30± 0.20[e]	33.80± 0.10[d]
Flow behavior index	0.342±0.003[c]	0.358±0.003[b]	0.357±0.001[b]	0.377±0.008[a]	0.355±0.001[b]

[a]Values are mean ± standard deviation (n = 3). Values with the same letter in the same row were not significantly different ($p>0.05$).

Similar trend of the viscosity of 20P and 40P was obtained by Khalil [KHALIL, 1998] and Lee and colleagues [LEE *et al.*, 2004], using carbohydrate compounds and oat bran derivative as a fat replacement in cake formulations, respectively.

Hydrocolloids, due to the linking with a substantial amount of water molecules, cause higher viscosity in the batter. Cake batter viscosity acts as one of controlling factor in the final volume of a cake, due to its effect on trapping the bubbles and avoiding their movement and displacement. If the batter does not have enough viscosity, air bubbles will link to each other. Large bubbles will come to the surface and finally will exit from the system.

It can be found out that the higher batter viscosity, the greater role in maintenance air bubbles [GOMEZ *et al.*, 2007]. Obviously, the addition of water could dilute dough [LIU, 2014]. Therefore, it could reduce the viscosity.

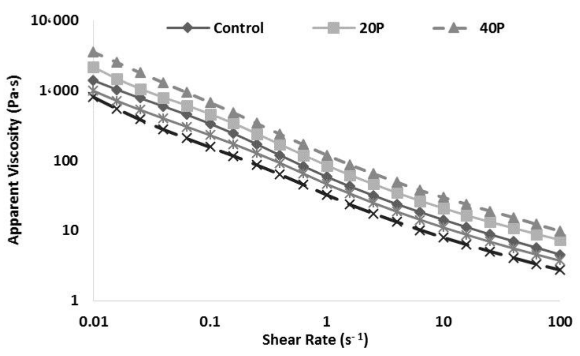

Figure 1. Plots of apparent viscosity vs. shear rate of treatments

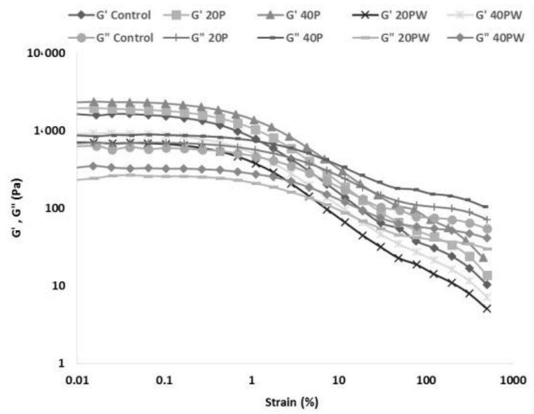

Figure 2. Strain sweep curves of treatments

Flow behavior index (n): Comparison of means (Table 2) indicated, the flow behavior index of all shortening–replaced treatments (SRT) was higher than control significantly ($p<0.05$). There was no significant difference among the *n* values of 20 P, 40 P and 40 PW ($p>0.05$). 20 PW showed the highest n.

Kalinga and Mishra who replaced shortening with beta glucan concentrates in the formulation of cake showed similar results [KALINGA and MISHRA, 2009].

Since the flow behavior index of all treatments was less than one, shear–thinning behavior of samples was concluded [KALINGA, 2010].

All SRT had weaker viscosity dependency to shear rate than control. Since 20P W and 40 PW contained greater water level in their formulations, their higher n value, compared to the control, was completely expected.

Strain sweep test

Limiting value of LVE: Cake batter is well–known to display a viscoelastic behavior that can affect the overall quality and handling characteristics of final cake [KALINGA and MISHRA, 2009]. Evaluation of LVE of a sample is a fundamental step in assessing its rheological properties.

When materials are tested in their viscoelastic linear range, their characteristics do not depend on magnitude of stress, strain or the utilized strain rate and only the functions of materials such as the ratio of stress to strain depend on time [GHANBARZADEH, 2009; MARIOTTI *et al*., 2009]. Strain sweep curves of batters were shown in Figure 2. Overall, strain sweep curves showed that both of G′ and G″ decreased after a certain limit.

As was shown in Table 3, there was no significant difference ($p>0.05$) between the limiting value of LVE among treatments. Patel and Dewettinck [PATEL and DEWETTINCK, 2015] determined that hydroxy propyl methyl cellulose oleogel was a good shortening alternative because of the larger LVE of reduced–shortening batter containing it, compared to the cake batters comprising other alternatives and more similarity with the length of LVE of full fat batter. Generally, LVE range is the range of stability of a sample before it experiences the structural changes.

A sample with a longer LVE region stating more stable and well–distributed system [LIEW *et al*, 2014; MARIOTTI *et al*., 2009].

Considering the similarity of LVE region, it can be deduced that presumably, the structural stability of samples was roughly similar. In general, a reduction in elastic modulus of all the batter samples started to occur higher than 0.11 % strain, proposing the gradual breakdown of the cake batter structure above this shear strain level.

Thus the strain level of 0.1 % for the following frequency sweep test was suggested.

Loss tangent at the limiting value of LVE: For determination whether the samples behaved as solids or liquids, damping factor was computed at the limiting value of LVE. It is calculated from ratio of loss modulus to elastic modulus.

Comparison of means indicated that the loss tangent (at the limiting value of LVE) of 20 PW and 40 PW treatments was similar to each other ($p>0.05$) and less than other treatments ($p<0.05$).

In a study, by reviewing G', G" and tan δ of gluten–free dough samples with different formulations, at the limiting value of LVE similar trend with this research was observed [MARIOTTI *et al*., 2009].

According to power law equation, there is a direct relationship between the apparent viscosity and consistency coefficient, so the magnitude of the consistency (concentration) among treatments was 40 P, 20 P, control, 40 PW and 20 PW from more to less, respectively. It has been proven that when the concentrated and diluted liquids are subjected to a strain wave with a constant amplitude and constant frequency, the concentrated liquid has a higher loss modulus than diluted one owing to greater output maximum stress of concentrated liquid [GHANBARZADEH, 2009].

Therefore, treatments with water increment (20P W and 40 PW) showed lower G", in addition to less G', compared to other samples. Also, at the limiting value of LVE the difference between G' of each of the two samples with other treatments was more than the difference of their viscous modulus, so according to tan δ formula (G"/ G'), the loss tangent of 20 PW and 40 PW was less than other treatments.

Overall, the difference between loss tangents of all treatments was very slight and tan δ of all was in the range of 0.373 to 0.398, indicating a solid viscoelastic behavior of treatments in the LVE range.

Frequency sweep test

G' and G" moduli: Figure 3 and Figure 4, displayed storage modulus and loss modulus as function of frequency, respectively. It was observed that the amount of G' in all treatments was consistently greater than G" over entire

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frequency ranges, deducing a solid elastic–like behavior of batters [MARIOTTI et al., 2009]. It was found that G' and G" of all samples illustrated a moderate frequency–dependent, which represented an example of soft gel rheological behavior [MARTÍNEZ–CERVERA et al., 2011].

Table 3.
Limiting value of LVE and loss tangent (tan δ) at the limiting value of LVE of different treatments obtained from strain sweep test[a]

Samples	Control	20P	40P	20PW	40PW
Limiting value of LVE (%)	0.1302±0.0074[a]	0.1268±0.0010[a]	0.1276±0.0109[a]	0.1170±0.0133[a]	0.1234±0.0083[a]
Tan δ at the Limiting value of LVE	0.389±0.002[a]	0.392±0.002[a]	0.397±0.004[a]	0.373±0.015[b]	0.376±0.000[b]

[a]Values are mean ± standard deviation (n = 3).
Values with the same letter in the same row were not significantly different (p>0.05).

The values of elastic and viscous moduli obtained from frequency sweep test in three different frequencies were shown in Table 4. The difference between G' and G" were higher in 40 P and then 20 P, compared with other treatments. Comparison of means indicated, in each frequencies of 0.1, 1.76 and 31 Hz, with the exception in 31 Hz for G', both G' and G" of different treatments showed significant difference ($p<0.05$). With increasing shortening replacement alone, G' and G" of batter increased, but more water in the SRT formulations decreased these moduli, compared with other samples ($p<0.05$). Lack of significant different between G' of 20 PW and 40 PW in the frequency of 31 Hz was the only changes in G' trend compared to two other frequencies. Comparison of means indicated that in different frequencies, both G' and G" moduli of each treatment showed significant difference and raised with increasing frequency ($p<0.05$).

The observation in case of moduli of treatments with no water level increment was in agreement with Kalinga and Mishra [KALINGA and MISHRA, 2009]. Also, Lee and colleagues showed, similar results when 20% of shortening was replaced with oat bran derivative in cake formulation [LEE et al., 2004, BUTNARIU, et al., 2015a, SAMFIRA, et al., 2015]. Rodríguez–García and colleagues reported, by replacing fat along with increasing fluid component in cake formulation, both moduli of its batter decreased, similar to the results of this research [RODRÍGUEZ–GARCÍA et al., 2014].

Generally, increasing in frequency and increasing in concentration are work with the same pattern in dynamic tests. Increasing each of them leads to increase tangling biopolymer chains in solution and ultimately weak gel will be formed [GHANBARZADEH, 2009, BUTNARIU, et al., 2016].

With this point, the reason of increasing the difference between G′ and G" moduli of 40 P and 20 P samples in comparison with other samples became clear. In general, high G' and low G" indicate a more rigid and stiff substance that tan δ is small [MARIOTTI et al., 2009]. The reason for solid elastic–like behavior (being more elastic than viscous) of all SRT could be owing to water binding ability and gel–forming capability of added fiber (present in pumpkin), since viscoelastic attributes depend on moisture content and surrounding air content in the batter during mixing of it and the stability of cake structure within baking [KALINGA and MISHRA, 2009, BUTNARIU, et al., 2015b].

With increasing replacement and without water level increment, the viscoelastic properties of the batter enhanced. The decline in the G' and G" values of 20 PW and 40 PW compared to other samples indicated a lower degree of system structuring, inferring that batter samples showed more fluid behavior and less solid elastic–like behavior [RODRÍGUEZ–GARCÍA et al., 2014].

There was an overall agreement on the inverse relationship between moduli (G′ and G") and the amount of available water present in the batter [LEE et al., 2004].

Possibly, in the batters of the 20 P and 40 P samples, water reacted with some components present in the pumpkin such as pectin, starch and proteins.

These interactions can lead to making water less available, making the deformation of the batter become harder and causing its storage modulus become more than full fat batter [LEE *et al.*, 2004].

Likely, more pumpkin powder in the formulations of 40 P and 40 PW compared to 20 P and 20 PW, respectively, was also the reason of greater solid elastic–like behavior of their batter. Also, with water level increment in low–fat formulations (20 PW and 40 PW) probably amount of available water in batter increased and as a result, viscous modulus became higher [LEE *et al.*, 2004].

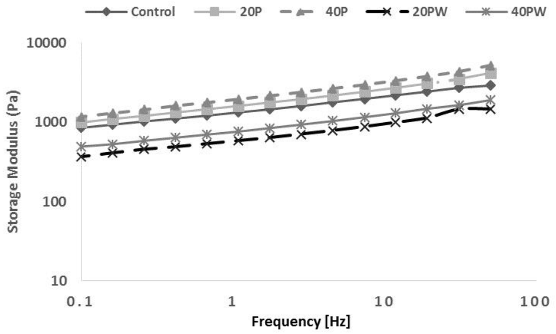


Figure 3. Effect of frequency on storage modulus of different treatments

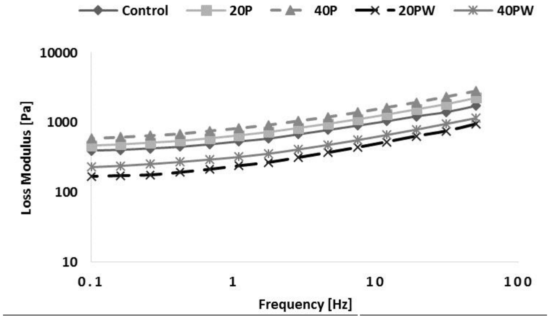


Figure 4. Effect of frequency on loss modulus of different treatments

Loss tangent: Values of tan δ obtained from frequency sweep test in three different frequencies were shown in Table 4. In all frequencies, there was not any significant difference between tan δ among treatments (p>0.05).

Comparison of means indicated that by enhancing frequency, the tan δ of each control, 20P and 40P treatments firstly dropped and then raised in frequency of 31 Hz significantly (p<0.05).

Table 4.

G', G'' and tan δ values of treatments, obtained from Frequency sweep test, in three frequencies, namely, low f= 0.1 (Hz), medium f= 1.76 (Hz) and high f= 31 (Hz) frequencies[a]

Samples		Control	20P	40P	20PW	40PW
G' (Pa)	f= 0.1	849.50±92.50^{cC}	991.00±49.00^{cB}	1180.00±40.00^{cA}	366.50±20.50^{cE}	493.67±10.97^{cD}
	f=1.76	1450.00±160.00^{bC}	1770.00±110.00^{bB}	2165.00±5.00^{bA}	638.00±13.00^{bE}	843.50±14.50^{bD}
	f= 31	2703.33±28.87^{aC}	3515.00±115.00^{aB}	4365.00±45.00^{aA}	1450.00±138.56^{aD}	1636.67±150.11^{aD}
G'' (Pa)	f= 0.1	397.00±47.00^{cC}	467.50±32.50^{cB}	592.00±8.00^{cA}	169.00±2.00^{cE}	229.33±9.82^{cD}
	f=1.76	590.00±53.00^{bC}	732.50±27.50^{bB}	921.50±15.50^{bA}	268.50±3.50^{bE}	358.00±6.00^{bD}
	f= 31	1411.67±37.53^{aC}	1840.00±40.00^{aB}	2340.00±0.00^{aA}	751.17±8.95^{aE}	958.00±0.00^{aD}
Tan δ	f= 0.1	0.467±0.004^{bA}	0.471±0.009^{bA}	0.502±0.024^{bA}	0.463±0.022^{abA}	0.465±0.009^{abA}
	f=1.76	0.408±0.009^{cA}	0.416±0.011^{cA}	0.425±0.008^{cA}	0.420±0.003^{bA}	0.425±0.001^{bA}
	f= 31	0.522±0.021^{aA}	0.524±0.006^{aA}	0.536±0.005^{aA}	0.522±0.059^{aA}	0.588±0.050^{aA}

[a]Values are mean ± standard deviation (n = 3). Means followed by the same lowercase letters in the same line, for the same parameter (treatment and property), were not significantly different (p> 0.05). Means followed by the same uppercase letters in the same column for the same parameter (frequency and property), were not significantly different (p> 0.05).

But with enhancing frequency, loss tangent of 20PW and 40PW showed just a significant increase at frequency of 31Hz compared to the 1.76 Hz.

Similar results were reported by Lee and colleagues when 20 % shortening was replaced with oat bran derivative in cake batter formulation [LEE *et al.*, 2004, BUTNARIU, 2014, BUTU, *et al.*, 2014b]. The tan δ values of all treatments (being less than one), represented their solid elastic–like behavior. Since treatments with higher concentration, showed greater both G'' and G' moduli, there was no significant difference between the yield ratio of these moduli (G''/ G') among treatments (p> 0.05). In general, the intensity of frequency–dependent of moduli in low frequencies was less than higher frequencies. In all samples, from frequency of 0.1 to 1.76 Hz, G′ had more dependency on frequency than G″.

Therefore, by increasing frequency up to 1.76 Hz, the intensity of G′ increment was greater than G″ and after that the intensity of G′ increment and its dependency on frequency became less than G″. This could be the reason for the reduction of tan δ of all treatments in frequency of 1.76 Hz in comparison with the loss tangent in 0.1 Hz and the enhancement of this parameter in 31 Hz compared to tan δ in lower mentioned frequencies. Whatever the solid–like behavior is greater than liquid–like behavior, tan δ is less [GHANBARZADEH, 2009].

So, with increasing frequency from 0.1 to 1.76 Hz and 1.76 to 31 Hz, solid–like behavior of batter rose and declined, respectively.

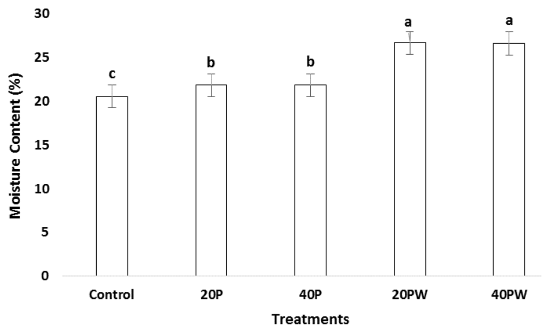
Cake properties

Moisture content: Comparison of means (Figure 5) showed the moisture content of 20P and 40P was higher than control significantly ($p<0.05$) and there was no significant difference ($P>0.5$) between the moisture content of 20P and 40P and between 20PW and 40PW.

With increasing water in SRT formulation moisture content became greater ($P<0.5$). Similar results were observed by Ptitchkina and colleagues [PTITCHKINA et al., 1998, BUTNARIU and GIUCHICI, 2011, PETRACHE, et al., 2014] when bread (containing weak flour) fortified with pumpkin powder (up to 10 %). Lee and Inglett also noticed moisture of less–fat cookies containing bran derivative of oat was greater than full fat cookie [LEE and INGLETT, 2006]. Fat reduction causes food moisture content to reduce [BITAGHSIR et al., 2014].

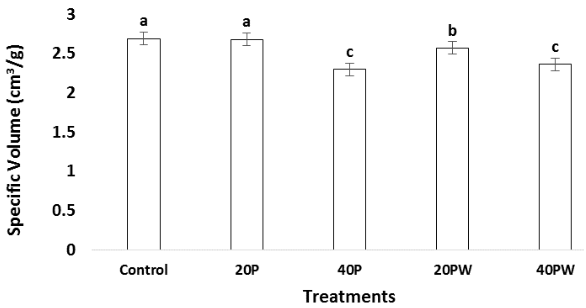
Since carbohydrates mimic the fat roles via binding water and, as a result, forming gel structure, increasing moisture content in reduced–fat products containing carbohydrate–based fat replacer is necessary [LEE and INGLETT, 2006].

Higher moisture content of 20P and 40P compared to the control showed the ability of pumpkin powder to work as a carbohydrate–based fat replacer. The highest content of moisture of 20PW and 40PW was quite reasonable for the reason of having more water in their formulations. Similarity between the moisture content of treatments with just different levels of shortening replacement might be the reduction in fat content.



[a]Values are mean ± standard error (n=3). Values with the same letter were not significantly different ($p>0.05$).

Figure 5. Comparison of moisture content of cakes[a].



[a]Values are mean ± standard error (n=3). Values with the same letter were not significantly different ($p>0.05$).

Figure 6. Comparison of specific volume of cakes[a].

Specific volume: Comparison of means (Figure 6) showed, there was no significant difference ($p>0.05$), only, between specific volume of control and 20 P and their amounts were the highest.

With increasing shortening replacement (at 40 %) and water level increment (in both treatments containing different percent of shortening), the specific volume of cake decreased significantly ($p<0.05$).

These results was in line with the results of previous research of author about reduced–fat cake containing oat bran derivative [HASHEMIRAVAN et al., 2013].

The similarity of specific volume between 20 P and control can be due to the resemblance of their volume.

Despite lower amount of fat in 20 P, because of its greater batter viscosity compared to control and the surface activity of pectin present in pumpkin, its specific volume was not decreased.

Pectin might have maintained the gas cells in the cake batter [LEE et al., 2004;

PTITCHKINA *et al*., 1998, BUTNARIU, *et al.*, 2012, BUTU, *et al.*, 2014a].

To achieve high–volume cake, the cake batter viscosity should be optimized.

Overall, if the viscosity of cake batter is too low, it cannot hold air during mixing or baking and this might be the reason for lower volume and, therefore, less specific volume of 20 PW and 40 PW compared to 20 P and control.

Very high viscosity can also limit the expansion of the batter during baking. This could be the cause of lower specific volume of 40 P compared to control and 20P.

In addition, the water binding ability of fiber (present in pumpkin) could make the weight of cakes containing greater level of pumpkin higher and weight of cake has an inverse relationship with its specific volume.

Also, it is obvious that the weight of cakes with higher remarkable moisture content (20 PW and 40 PW) was higher and this increment had negative impact on their specific volume.

Conclusions

Use of pumpkin powder in the reduced–shortening formulations caused the viscosity of the cake batters increase, and likely too high viscosity of 40P batter had a negative impact on the quality of its final cake. All batter samples showed shear–thinning behavior.

From the point of limiting value of LVE, the structural stability of batters was similar, but the results of both moduli (G' and G") obtained from frequency sweep test indicated that shortening–replaced batters without water level increment were more structured compared to the other samples.

All treatments showed a solid viscoelastic behavior in the LVE range, under the conditions of strain sweep and frequency sweep tests. Looking at the end, in terms of rheological attributes, using pumpkin powder, alone, was recognized a suitable choice for partial shortening replacement in the cake.

Shortening replacement with pumpkin powder made cake moisture contents higher, showing one of carbohydrate–based fat replacer roles. 20P was selected as the best reduced–shortening formulation owing to its high specific volume and totally more similar rheological properties to the control. Adding an appropriate emulsifier or less water addition in the fat replaced formula for producing a high-quality cake with less fat content is purposed for future work.

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