



EFFECT OF ADDED GELATIN ON RHEOLOGICAL AND TEXTURAL PROPERTIES OF A POUND CAKE REDUCED IN MARGARINE

EFFECTO DE LA ADICIÓN DE GRENETINA EN LAS PROPIEDADES REOLÓGICAS Y DE TEXTURA DE UN PANQUÉ REDUCIDO EN MARGARINA

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Abstract

The use of different hydrocolloids in the partial substitution of margarine by vegetable oils, are evaluated to achieve products with characteristics similar to the traditional product. The objective of this study was to evaluate the effect of the addition of different concentrations of gelatin (0%, 0.75%, 1.25%, and 2.0%) in pound cake formulation reduced in margarine and partially replaced with canola oil. It was determined specific gravity (SG), apparent viscosity, modules of viscoelasticity (G' and G'') and number and size of air bubbles in the batter. In the pound cake was determined texture (TPA and sensory evaluation), crumb structure and moisture. By increasing the concentration of gelatin, it was observed a proportional increase of SG, apparent viscosity and elastic and viscous modules, predominating the viscous module with respect to elastic module, and a decrease in the number and size of air bubbles in the batter. In the pound cake, there was a proportional decrease in the volume and uniformity of the crumb, with respect to the size and number of cavities formed, however, sensorially, the most accepted formulation was the addition of 1.25% of gelatin because it perceives a more consistent and moist crumb, therefore, adding gelatin can be an alternative to improve the acceptability of a pound cake reduced in margarine, which it is also less expensive.

Keywords: gelatin, margarine reduction, pound cake, batter, rheology, bubble count, texture profile, crumb structure.

Resumen

El uso de diferentes hidrocoloides en el área de panificación, como coadyuvantes en la sustitución de margarina por aceites vegetales, son evaluados para lograr productos con características similares al producto tradicional. El objetivo de este trabajo fue evaluar el efecto de la adición de diferentes concentraciones de grenetina (0%, 0.75%, 1.25%, y 2.0%) en una formulación para panqué reducida en margarina y parcialmente reemplazada con aceite de canola. Se determinó gravedad específica (SG), viscosidad aparente, módulos de viscoelasticidad (G' y G'') y número y tamaño de burbujas de aire en el batido. Además se evaluaron la textura (TPA y evaluación sensorial), estructura de la miga y humedad del panqué. Al aumentar la concentración de grenetina, se observó un aumento proporcional de la SG, viscosidad aparente y módulos elástico y viscoso, predominando el módulo viscoso respecto al elástico, y una disminución en el número y tamaño de burbujas de aire en el batido. En el panqué, hubo una disminución proporcional del volumen y uniformidad de la miga, respecto al tamaño y número de cavidades formadas, sin embargo, sensorialmente, la formulación más aceptada fue la adicionada de 1.25% de grenetina debido a que se percibe una miga más consistente y húmeda, por tanto, la adición de grenetina puede ser una alternativa para mejorar la aceptabilidad de un panqué reducido en margarina, que además es de menor costo.

Palabras clave: grenetina, reducción margarina, reología, evaluación sensorial, batido panqué, perfil textura, estructura miga.

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1 Introduction

Traditional pound cake contains high portions of fat, sugar, egg, and flour; each ingredient exhibits an important role in defining the structural, rheological and textural properties of the final cake (Wilderjans *et al.*, 2013; Hesso *et al.*, 2015). In cake making, shortening performs basic functions such as entrapment of air, a coating of starch and protein molecules, and emulsification of large amount of liquid that contributes to greater crumb moisture and, concomitantly, to the softness of the cake product (Román *et al.*, 2015). Several fat substitutes in baking have been evaluated, such as vegetable oils, modified starches, hydrocolloids as gums in combination with emulsifiers, oleogels and others (Ronda *et al.*, 2011; Patel *et al.*, 2014; Hussien *et al.*, 2016; Doan *et al.*, 2018).

On 17 June 2015, the US Food and Drug Administration (FDA) determined that partially hydrogenated oils were no longer “GRAS” (generally recognized as safe) and needed to be removed from food products by June 2018. Moreover, it has also been suggested that the nutritional profile of our diet can be improved if saturated fat is replaced with unsaturated fat (Mensink *et al.*, 2016). In response to these new regulations and changing consumer preferences, finding a healthier alternative to technically reduce the saturated and/or trans-fat content has drawn the attention of food scientists and food producers in recent years. If the saturated lipid fraction is simply replaced with an unsaturated fat, for example a vegetable oil, which also provides essential fatty acids, the final structure of the products cannot match the quality characteristics expected by consumers (functional and sensorial properties) (Mensink *et al.*, 2016; Doan *et al.*, 2018).

Hydrocolloids are a heterogeneous group of long chain polymers (polysaccharides and proteins) characterised by their property of forming viscous dispersions and/or gels when dispersed in water. Presence of a large number of hydroxyl (-OH) groups markedly increases their affinity for binding water molecules rendering them hydrophilic compounds (Dipjyoti *et al.*, 2010). The addition of gums (hydrocolloids) and emulsifiers in baking, together with vegetable oil, considerably improve the properties of the final product. Carboxymethyl Cellulose (CMC) and Hidroxipropilmetil Cellulose (HPMC) are used to compensate for certain attributes

of solid fat such as moisture retention, volume, final texture, and are commonly used synergistically with other gums and emulsifiers for enhance these attributes (Kumari *et al.*, 2011, Sowmya *et al.*, 2009).

The mainly functional properties of hydrocolloids in foods are as thickening agents, and gelling agents (Li *et al.*, 2016). Hydrocolloids modify the rheology of the system, which includes two basic properties: flow behavior (viscosity) and mechanical properties as a solid (texture), which invariably changes the sensory properties of the final product. Gelatin can be considered one of the most versatile hydrocolloids in the food industry because its taste-free and odourless, it has no allergenic potential and it can be used as a gelling, thickening, water-binding, emulsifying, foaming and film-forming agent, being able to create a fat-like matrix in emulsions where exhibit shear-thinning properties and creaminess similar to fat but free of calories (Damodaran *et al.*, 2007). Besides its use is easier and its cost is lower respect to other hydrocolloids. Therefore, the purpose of this study was to evaluate the effect of different concentrations of gelatin as hydrocolloid, with attributes similar to the gums in a formulation for pound cake reduced in margarine with canola oil (rich in omega 6), determining rheological properties and microstructure in the batter, relating it with the properties of texture of the pound cake.

2 Materials and methods

2.1 Ingredients

Wheat flour (San Antonio, Tres Estrellas®, México) with protein content, reported by supplier of 10.88%; gelatin 260°B (Gelita®, Gelita México S. de R.L. de C.V., México), baking powder (Royal®, Kraft Foods de México, S. de R.L. de C.V., México), margarine (Iberia®, Unilever de México, S. de R. L. de C.V., México), oil canola (Canoil®, AGYDSA Aceites, Grasas y Derivados, S.A. de C.V., México), purified water (Bonafont®, Bonafont S. A. de C.V., México). The rest of the ingredients (whole eggs and sugar) were obtained from local suppliers.

2.2 Pound cake preparation

The formulation was based on the method of Kumari *et al.* (2011) with some modifications. Pound cake batter reduced 70% in margarine and partially replaced

with canola oil (50% of total fat), was prepared as follows: 45 g of margarine, 75 g of canola oil, and 150 g of sugar were mixed for 2 min at low speed (306 rpm) using a Hamilton Beach mixer (63232, Hamilton Beach Brands, USA), 2 min at medium speed (380 rpm) and a minute at high speed (450 rpm), then, 136 g of fresh whole egg was added and mixed 2 min at low speed and 2 min at medium speed, after thorough sifting, 250 g of wheat flour and 1.5 g of baking powder were added and mixed 1 min at low speed; finally, 1.88 g (0.75%), 3.13 g (1.25%) and 5 g (2.0%) of gelatin dissolved previously in 56 mL water was added and mixing 2 min at low speed. A formulation without gelatin was used as a control. Pound cake batter (600 g) was poured in cake pans (21.0 × 11.0 × 6.0 cm) and baked at 180 °C for 35 min in a preheated oven Rational Self-CookingCenter® whiteefficiency® baking Oven (Rational, Germany).

2.3 Cake batter characteristics

2.3.1 Specific gravity

The specific gravity (SG) is determined immediately after preparing the batter. Specific gravity was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water at 20 °C (Method 72-10-AACC, 2007).

2.3.2 Apparent viscosity

The apparent viscosity (η_a) of cake batter was determined using a rheometer (HAAKE MARS III, Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA) with a parallel plate-plate of 60 mm and a constant gap height of 1.0 mm at 20 °C. For each test, the sample was sheared at a programmed rate, which linearly increased from 0 to 100 s⁻¹ in 5 min; apparent viscosity (η_a) and shear rate ($\dot{\gamma}$) plots were obtained. Analysis was monitored with RheoWin 4 Job Manager software and the rheological parameters were calculated using the Rheowin 4 Data Manager software (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA) by performing a regression analysis to adjust the graphs to a power-law model (Eq 1)

$$\sigma = K(\dot{\gamma})^n \quad (1)$$

where σ is the shear stress (Pa) and $\dot{\gamma}$ is the shear rate (s⁻¹), K is consistency index (Pa·s) and n is the flow behavior index for Power law model (Barnes, 2000).

2.3.3 Viscoelasticity

Dynamic frequency sweeps (0.1–10 Hz) were performed under a constant strain ($\gamma = 1\%$), in order to determine the linear viscoelastic region (LVR) of the cake batter samples. From the LVR a constant frequency of 1 Hz was chosen to perform a strain amplitude sweep ($\gamma = 0.01 - 100\%$), to determine the storage modulus (G'), loss modulus (G'') and loss tangent ($\tan\delta$), (Eq 2)

$$\tan\delta = G''/G' \quad (2)$$

The coefficients G' , G'' and $\tan\delta$, represent the elastic and viscous moduli and the loss tangent at a frequency of 1 Hz, with the oscillation frequency.

2.3.4 Number and size of bubble

Cake batter microstructure was evaluated using a DM750 microscope (Leica Microsystems, Wetzlar, Germany) equipped with an EC3 video camera, and images were captured using LAS-EZ software (Leica Microsystems, Wetzlar, Germany) based on the methodology proposed by Allais *et al.* (2006). The sample was covered by another microscope slide and the two slides were pressed to obtain a layer of batter of a constant thickness, approximately 20 μm of thickness, due to the image analyzer does not consider the depth of field, it is particularly important to standardize the height of the sample. The batter samples were examined at 40 times magnification. The images obtained by microscopy were saved in bpi format and were processed optimizing contrast with Adobe Photoshop, then were analyzed using ImageJ 1.46r (Wayne Rasband, National Institutes of Health, USA). Distribution of the cell size and area were reported.

2.4 Physical characteristics of pound cake

2.4.1 Volume

The volume was determined by the seed displacement (method 10-05 AACC, 2010), the volume accuracy was between 9 and 14 cm³.

2.4.2 Texture Profile Analysis

The texture of the pound cake was measured using a texture analyzer (Stable Micro System TA-XT plus Texturolab, Godalming Surrey UK), according to the AACC (2000) (74-09.01) method. The samples (25 mm thick) were sliced using a wooden box with

grooves at 2.5 cm. The double compression test was performed with a 50 mm diameter aluminum plate (P/50) and a 5 s interval between the 2 compression cycles, under the following working conditions: speed of 1.0 mm/s for the pre-test; speed of 1.7 mm/s for the test; speed of 10.0 mm/s for the post-test; 40% compression and load cell 5 kg. The firmness was expressed as (N).

2.4.3 Cake crumb structure

Pound cakes were cut in slices (25 mm thickness) and were scanned (HP Scan-HPLJM1530 MFP Series Scan Idaho, USA) at 300 dpi of resolution. Images were taken from the 100% of the pound crumb eliminating the crust, were saved in JPEG format and were converted to grey scale (8 bit). Otsu algorithm tool was used for the segmentation using Image J software (Image Processing Analysis in Java. Wayne Rasband, National Institute of Mental Health, Bethesda, Maryland, USA) (Baixauli *et al.*, 2008; Rodríguez-García *et al.*, 2014). Distribution of the cell size and area were reported.

2.5 Sensorial analysis

A ranking discrimination test was carried out with 58 untrained judges, 23 men and 35 women between 15 and 65 years of age, to compare the attribute of firmness among the four formulations studied (Stone *et al.*, 2012). In addition, the global percentage of liking for each formulation was determined. The results were interpreted using an analysis of variance using the Statgraphics X64 program.

2.6 Statistical analysis

Data were analyzed using a one-way analysis of variance (ANOVA) and a Tukey's test for a statistical significance $P \leq 0.05$, using the Statgraphics X64. All experiments were done in triplicate.

3 Results and discussion

3.1 Specific gravity

Specific gravity (SG) is related to the number of air bubbles incorporated into a cake batter. Higher SG values indicate less incorporation of air bubbles, this is usually correlated to the texture and final volume

of the pound cake. The values of specific gravity are shown in Table 1, where the control cake batter has an SG of 0.92 g/cm^3 , whereas batters containing gelatin was of 0.95, 0.96 and 1.00 g/cm^3 at 0.75, 1.25 and 2% of gelatin, respectively. The addition of hydrocolloids increases the density of the batter, which can obstruct air incorporation during mixing (Gómez *et al.*, 2007). Possibly the proportional increase of specific gravity when increasing the concentration of gelatin, is due that the gelatin, like other proteins, is highly hydrophilic and binds water during the mechanical agitation, making the water less available in the emulsion, the batter then it becomes dense, decreasing in this way, the ability to form air bubbles (Matos *et al.*, 2014; Ronda *et al.*, 2011). The behavior of the SG in cake batter reported by others authors is variable, depending mainly on the type of gum, the formulation and its interaction with other components (Turabi *et al.*, 2008).

Low specific gravity is desired in cake batter since it indicates that more air is incorporated into the batter. Control batter has the lower SG. The capacity of air retention of this sample is due to the stability that gives the protein of the egg white and yolk for its functional properties like emulsifying activity or foam stability. Egg albumen increased the emulsifying activity (Marco & Rosell, 2008; Park *et al.*, 2012). Moreover, the mixture of margarine and canola oil in the proportion used in this formulation: 30% shortening-50% canola oil, (reduced 20% of total fat in the traditional formula), shows an effect similar to the addition of an emulsifier; in this case, reducing the density, that is to say, facilitated air entrapment during batter mixing (Kumari *et al.*, 2011).

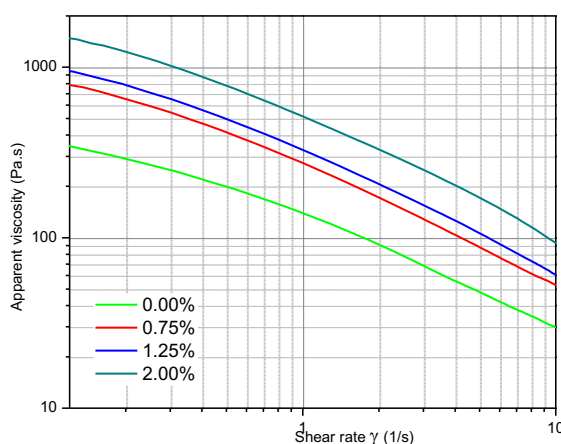


Fig. 1. Apparent viscosity of cake batters added with gelatin.

Table 1. Specific Gravity and rheology of the batter added with gelatin.

Gelatin concentration (g/100g)	Specific gravity	Power-law fluid model		
		K (Pa s ^{<i>n</i>})	n	r^2
0	0.919±0.02 ^a	110.13±10.97 ^a	0.511±0.016 ^a	0.965
0.75	0.945±0.01 ^a	248.31±30.17 ^b	0.448±0.014 ^a	0.982
1.25	0.962±0.02 ^a	312.82±32.29 ^b	0.405±0.061 ^a	0.984
2	1.007±0.02 ^b	320.99±40.72 ^b	0.419±0.103 ^a	0.998

Average values ± standard deviation of three replicates. ^avalues followed by different letter in the same column are significantly different ($P < 0.05$).

3.2 Apparent viscosity

All the formulations of the cake batters with or without gelatin showed shear thinning (pseudoplastic) behavior, which means that apparent viscosity decreases as the shear rate increases (Figure 1). Shear thinning behavior can be explained by the alignment of microstructure with the flow direction as shear rate increases, thus apparent viscosity decreases (Song, Kim, & Chang, 2006). The shear stress (σ) versus shear rate ($\dot{\gamma}$) data obtained from rheometer for cake batters at 20 °C were fitted well to Power Law model (Eq. (1)) with a coefficient of determination values ($r^2 > 0.965-0.998$) (Table 1), indicating the suitability of the Power law model to describe the flow properties of the cake batters.

Table 1 shows the flow behavior index (n) of batters ranged from 0.405 to 0.511, were less than 1, indicating the pseudoplastic (shear thinning) nature of the batters. No significant differences ($p < 0.05$) were observed in the flow behavior index at different concentrations of gelatin. The values for consistency coefficient (K) (Table 1) increasing significantly ($P < 0.05$) when the gelatin concentration on cake batters was increased, this reduced the ability of batter to flow. The higher viscosity observed at the concentration of 2% gelatin respect to the control is due to the high capacity of hydrocolloid to retain water, like other proteins, hindering the mobility of other components. Dogan *et al.* (2005) and Ronda *et al.* (2011), found that the addition of some proteins increases the water binding capacity and can reduce the amount of free water available to facilitate the movement of particles in batters and consequently gives higher apparent viscosity values respect to the control. Other authors have found an increase in apparent viscosity in batters added with other type of proteins as gluten (Wilderjans *et al.*, 2008) and

when soy protein is added (Dogan, *et al.*, 2005). In the substitution of fat by other no proteic hydrocolloids such as inulin (Rodriguez-Garcia *et al.*, 2012) and β -glucan and amyloextrin (Lee *et al.*, 2005), an opposite effect was observed.

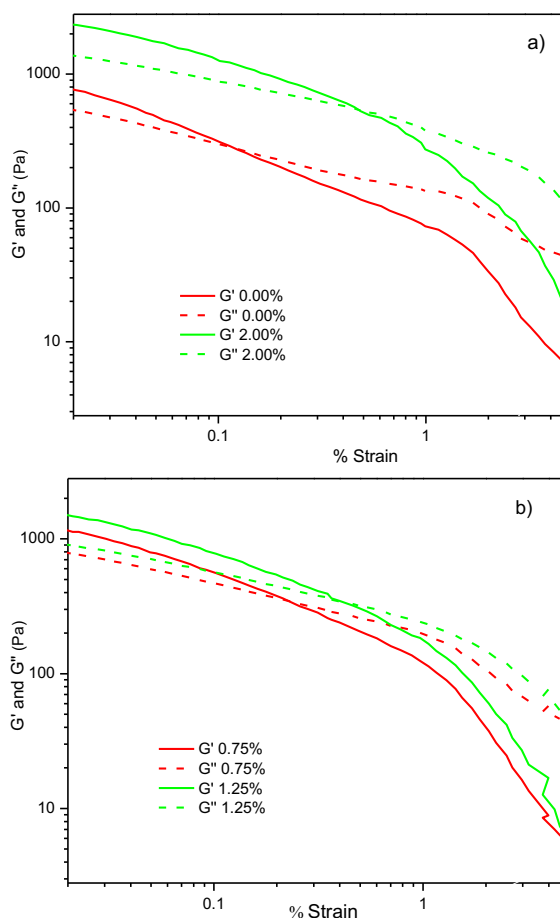


Fig. 2. Viscoelasticity of cake batters added with gelatin.

Table 2. Number and size of bubbles of air incorporated in cake batter.

Gelatin addition (g/100g)	0%	0.75%	1.25%	2%
Num bubbles	151±37 ^a	97±25 ^b	93±39 ^b	81±12 ^c
Average area (μm^2)	215±48 ^a	84±23 ^b	43±18 ^c	34±8 ^c
Max area (μm^2)	2230	460	302	221

3.3 Viscoelasticity

Viscoelastic behavior of the pound cake batters at constant frequency (1 Hz) also was evaluated (Fig. 2a and 2b). These results show that increasing the concentration of gelatin, increase the values of both G' as G'' in the strain amplitude sweep evaluated ($\gamma = 0.01 - 100\%$). Initially, the elastic modulus predominates with respect to the viscous in all the formulations, however, at values greater than 0.1% of strain, a crossing of the lines is observed, changing the behavior to viscous. The point of intersection of the elastic module to viscous module occurs at approximately 0.12% of strain when not added gelatin, while the sample added from 2% of gelatin crosses at approximately 0.5% of strain. This tendency indicate that the proteic hydrocolloid addition promotes a behavior more solid like than liquid like of these cake batters; that is, it improves certain stability of the emulsion (Hernández-Rodríguez *et al.*, 2017).

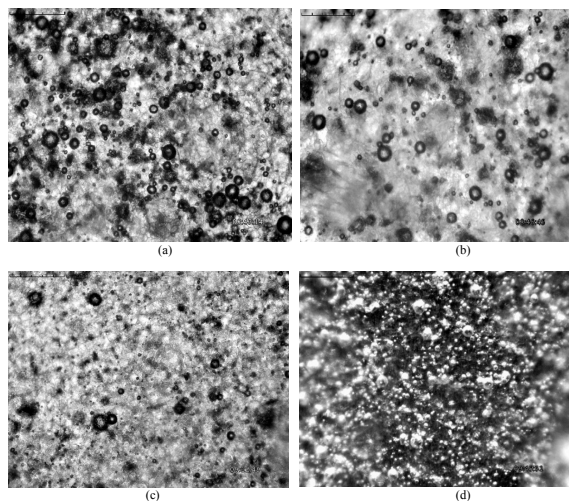


Fig. 3. Micrographs of the pound cake batter added with gelatin. (a) 0%, (b) 0.75%, (c) 1.25% and (d) 2.0% gelatin added at 40X of magnification.

However, according to the value obtained from the $\tan \delta > 1$, the behavior in all the samples is predominantly viscous (Steffe, 1996), that is to say, corresponds a weak gel, by increasing the deformation effort; this may be determined by a combination of weak inter-molecular forces like hydrogen bonds, electrostatic forces, Van der Waals forces, and hydrophobic interactions of gelatin gel (Banerjee & Bhattacharya, 2012), and by the emulsion of air in liquid, in a formulation reduced in solid fat (Kalinga & Mishra, 2009).

3.4 Number and size of bubble

A progressive decrease in the number and size of air bubbles were found as the gelatin concentration increased as shows in the micrographs in Figure 3. The number of bubbles is reduced almost 50% by adding of gelatin as shown in Table 2. The control has the largest number of bubbles (151) and more heterogeneous size ($0.5-2230 \mu\text{m}^2$) (Figure 4a), while the added 2% gelatin, shows the lowest number of bubbles (81) and of smaller size, in a range of area of 0.5 a $220 \mu\text{m}^2$) (Figure 4d). The number, size and distribution of the air bubbles in the cake batter, will determine the texture of the cake (Sahi & Alava, 2003), if the batter is sufficiently stable to the baking temperature. These values are in accordance to the specific gravity obtained in the different batters, where the lowest value corresponds to the sample which is not added from gelatin, this is, incorporates the largest amount of air bubbles. The histograms of the different concentrations (Figure 4) graphically show the distribution of areas of air bubbles from the cake batter and the range of size (area), this lower amount of bubbles incorporated is related to the viscosity of the batter. The increase in viscosity of the samples added of gelatin, limits the formation of bubbles. Some studies reported that higher viscosity would obstruct air incorporation (Gómez *et al.*, 2007).

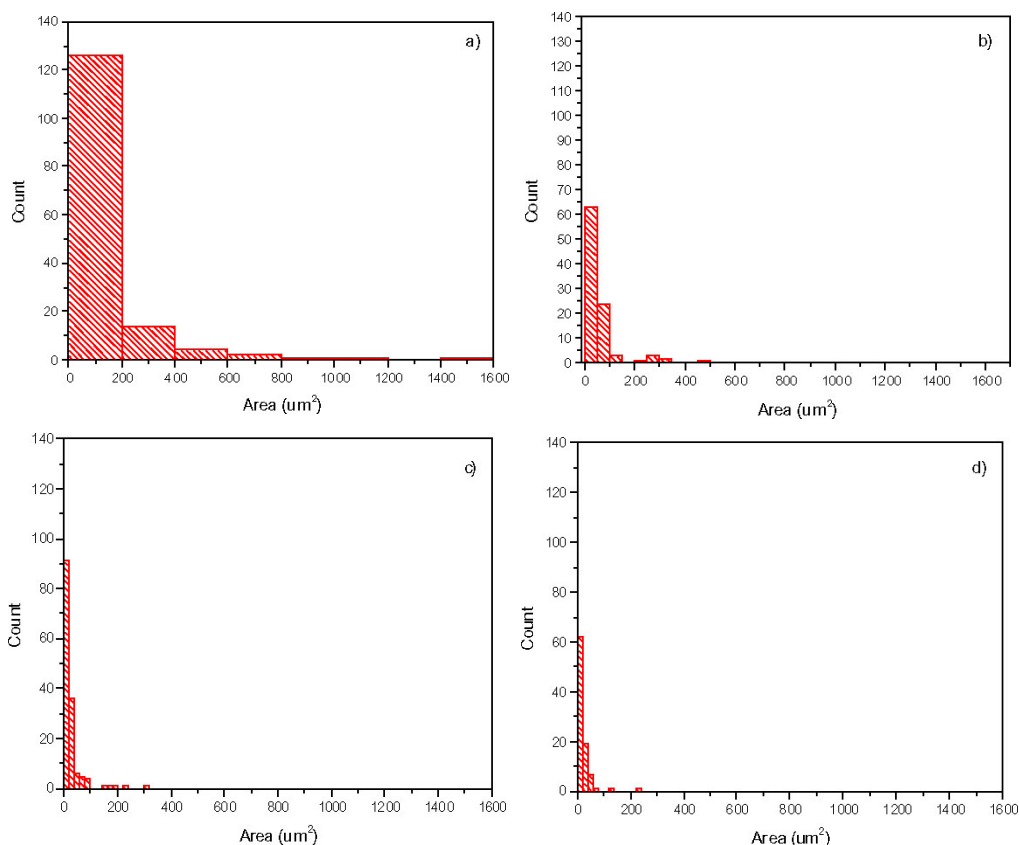


Fig. 4. Histograms of number of bubbles and cell area of cake batters: a) 0%, b) 0.75%, c) 1.25%, d) 2.0% of gelatin.

The affinity of the gelatin by the water and the formation of the gel that forms a three-dimensional network to retain water in the interstices (Dipjyoti *et al.*, 2010), contribute significantly to the increase of viscosity in the batter. Gelatin has the ability to decrease surface tension and stabilize emulsions, in addition to some foaming capacity, so you would expect an increase in the number of bubbles in the batter, however the higher viscosity observed interferes in this process. The size and number of bubbles in a batter for pound cake, is determined also

by the process of stirring and the type and amount of ingredients (Chesterton *et al.*, 2013, Nessrin *et al.*, 2015).

3.5 Volume of pound cake

The volume of different formulations are shown in Table 3, where the volume of the pound cakes added with gelatin (0.75%, 1.25%, and 2%) was significantly ($P < 0.05$) lower than the pound cake not added of gelatin (0%). To increase the concentration of gelatin, the volume was decreasing, as shown in Figure 5.



Fig. 5. Images of volume of pound cakes added with different concentrations of gelatin. From the left to right: 2%, 1.25%, 0.75% and control.

Table 3. Quality and texture of the pound cakes added with gelatin.

Gelatin addition (g/100g)	Volume (cm ³)	Moisture (g/100g) gravity	Texture			
			Firmness (N)	Adhesiveness (N/s)	Cohesiveness	Chewiness
0	1108.6±14.6 ^a	27.1±0.9 ^a	20.1±2.5 ^a	0.045±0.02 ^a	0.530±0.02 ^a	10.62±1.09 ^a
0.75	1070.7±11.3 ^b	26.9±0.6 ^a	22.9±2.9 ^{ab}	0.074±0.03 ^a	0.539±0.02 ^a	12.31±1.64 ^b
1.25	1061.4±11.8 ^b	25.5±1.6 ^a	23.3±4.6 ^{ab}	0.059±0.01 ^a	0.550±0.02 ^a	12.73±2.37 ^b
2	979.3±9.3 ^c	26.5±1.2 ^a	26.4±5.9 ^b	0.100±0.06 ^b	0.536±0.02 ^a	14.01±2.59 ^b

^aValues followed by different letter in the same column are significantly different ($P < 0.05$).

In this case there is a relationship between the increase in specific gravity and volume reduction, since it has incorporated a lower amount of air when the gelatin is added.

Usually the viscosity of the batter is a determining factor in the retention of air during the baking. Batters with very low viscosities cannot hold air bubbles in batter matrix and cakes collapse in the oven, whereas a highly viscous batter can restrict its expansion during baking (Ronda *et al.*, 2011). The viscosity provided by the gelatin does not favor the incorporation of air in the cake batter, and during baking, the gelatin gel melts, and a fraction of little-retained air is released before the structure of the cake is formed, producing a lower volume pound cake. In formulations reduced in margarine, and added with hydroxypropylmethyl cellulose (HPMC), the addition of the gum, supports the cake batter to achieve good air retention during baking, these gums form a complex with starch that confer thermal stability during baking, which is not the case of the gelatin, that by its structure, forms only weak bonds (links by hydrogen bonds) between themselves making her less stable to the temperature (Dipjyoti *et al.*, 2010). Some studies reported that the combination of different hydrocolloids, acts a synergistic effect, improving their properties (Psimouli, *et al.*, 2013; Gómez *et al.*, 2007; Dipjyoti *et al.*, 2010), but others authors have been reported both increase and decrease of volume using certain gums in yellow layer cake, attributing these differences principally to the concentration of used gum (Gómez *et al.*, 2007).

3.6 Moisture content of the pound cake

The moisture content of the pound cake is shown in Table 3, where there was not significant difference ($P < 0.05$) between the added samples of gelatin

and the not added. It is well known the ability of hydrocolloids of increasing moisture retention that, at the same time, depends on their chemical structure and their interactions with the rest of food ingredients. The gums interact with the starch to increase water retention, which does not occur with gelatin. The formation of the gelatin gel is given by initial heating followed by cooling (ionotropic gel) (Glicksman, 1982), therefore the high capacity of linking water of this hydrocolloid is limited since the gel is really formed during the cooling, where another type of interactions has already been carried out between other ingredients. In a study reported by Gómez *et al.* (2007), determined that the cakes containing hydrocolloids always showed lower moisture losses during baking than the control cakes, and shows similar dehydration rate during storage of 3 days.

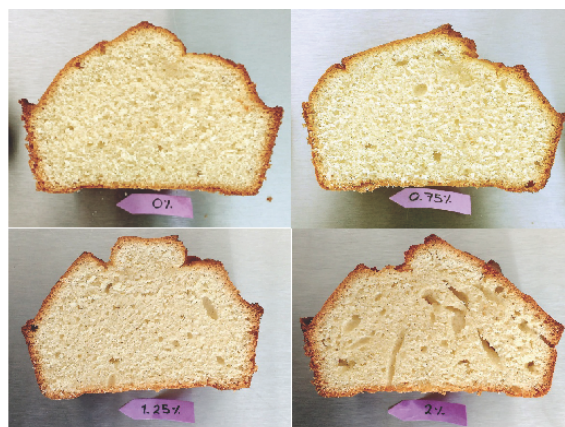


Fig. 6. Images of slides of pound cake shows cake structure at different concentration of gelatin.

Table 4. Image analysis of the crumb structure of the slice of pound cake.

Parameter	Gelatin addition (g/100g)			
	0	0.75	1.25	2
Number of cell	19.8±5 ^a	61.8±19.4 ^b	112.8±49.8 ^b	78.4±10.6 ^c
Average size cell (mm ²)	2.0±0.5 ^a	3.4±1.5 ^b	4.8±1.4 ^b	8.0±4.7 ^c
Crumb cell area (mm ²)	39.7±12.6 ^a	267.1±85.8 ^b	381.5±188.4 ^c	597.3±315.6 ^c

Average values ± standard deviation of three replicates. ^aValues followed by different letter in the same row are significantly different ($P < 0.05$).

3.7 Texture of the pound cake

The textural characteristics of the pound cakes were determined by texture profile analysis in terms of firmness, cohesiveness adhesiveness and chewiness, and are shown in Table 3. Firmness increased as the level of gelatin increased. Maximum firmness (26.4 N) was noted for pound cake added with 2% gelatin. Increase in firmness was due to less entrapment and loss of the bubble air during baking, that produced a crumb more compact and heavy and it is related also to the volume decrease. Cohesiveness generally indicate the development of internal bonding in a three-dimensional protein network in cakes. There were no significant differences ($P > 0.05$) in cohesiveness of any of the pound cakes (Table 3). This may be due to the predominant protein from the egg and gluten on the concentration of gelatin added (to low).

Chewiness, is a parameter dependant on firmness, observing a similar tendency. There is a significant difference between the samples added of gelatin and the control. Adhesiveness was significantly different ($P < 0.05$) at concentration of 2% this is due to increased competition for water, these tend to join together, giving effect of stickiness, which in pound cake is not desirable, usually this effect is based on the concentration of the hydrocolloid (Dipjyoti *et al.*, 2010; Marco, 2009).

3.8 Cake crumb structure

Structure of the baked cakes added with gelatin is shown in Figure 6. As you can see the structure of the crumb was modified by increasing the concentration of gelatin. A higher concentration of gelatin produce a larger pore size. The histograms of the crumb structure shows an increase in the number of pores larger than 0.5 mm² as the gelatin concentration increases (Figure 7). Exist a marked difference between the smallest and the largest pore size as the gelatin

concentration increases as seen in the crumb pore area (Table 4).

A larger crumb area of the pores observed at concentration of gelatin at 2%, it is related to the weak gelatin gel bonds, which are susceptible to rupture by increasing the temperature, prior to starch gelatinization and protein coagulation of the cake batter, producing coalescence of small air bubbles of air incorporated, forming large holes in the crumb.

A more uniform crumb is observed when the gelatin is not added. The behavior observed when adding gelatin, does not correspond to the behavior of the gums used in bakery. Gums as hydroxypropylmethylcellulose (HPMC) and carboxymethylcellulose (CMC), form a complex with starch that gives them greater stability to the baking temperature, therefore, are those that best results reported in the final aspect of cake (Dipjyoti *et al.*, 2010).

3.9 Sensorial evaluation

The evaluation was carried out with 58 judges untrained between 15 and 65 years of age, 39.7% men and 60.3% women. The discriminating test of the ranking type to identify the degree of softness of each formulation, is consistent with the result obtained from the texture profile analysis, as shown in Table 5, where the control sample is significantly smoother compared with gelatin added ones. The samples of intermediate concentration “0.75% and 1.25%” showed no significant difference in softness, while the less smooth was 2% of gelatin. It was also carried out a test of preference resulting in the most pleasant formulation being 1.25% of gelatin (34.5%), due to a more humid and less crumbling crumb, followed by the control (24%) which is the softest, concluding that not necessarily a pound cake softer is better or more acceptable.

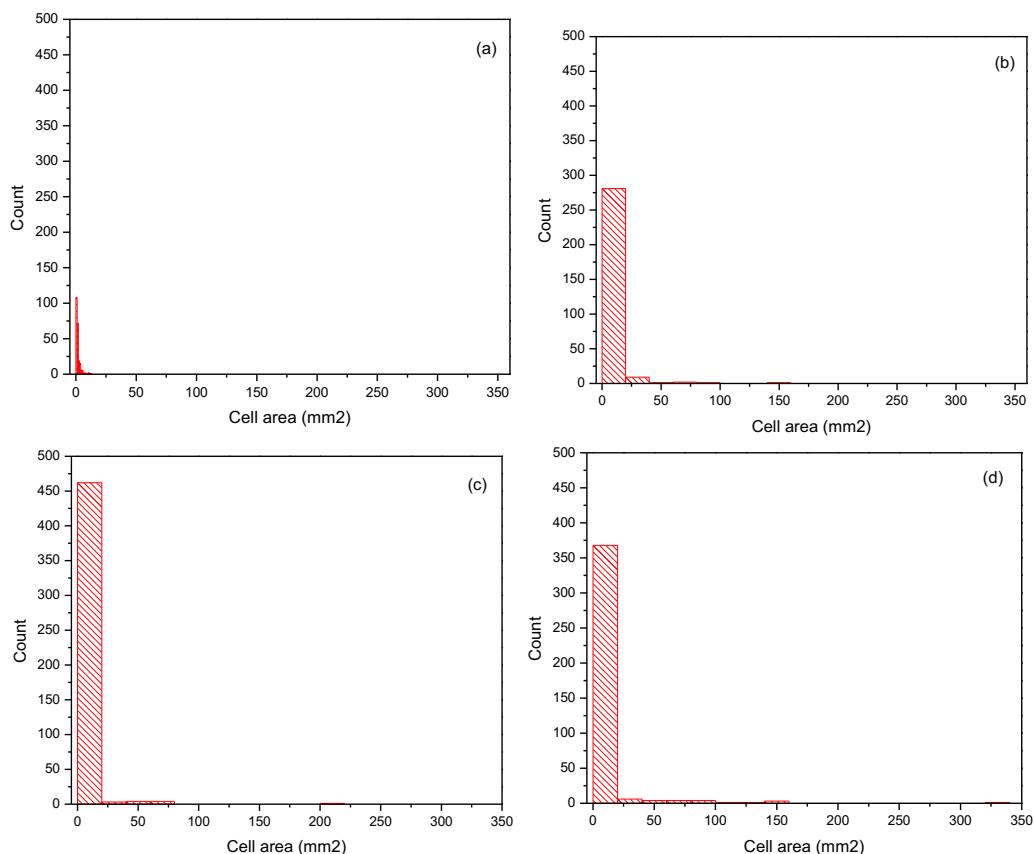


Fig. 7. Histograms of number and size of crumb pores area of pound cake: a) 0%, b) 0.75%, c) 1.25%, d) 2.0% of gelatin

Gelatin is a highly hydrophilic proteic hydrocolloid, which traps water in its three-dimensional structure formed by weak links primarily hydrogen-type bridges, which while the gel does not heat up works as a stabilizer emulsions by having some affinity for both the hydrophilic and hydrophobic ingredients. However, the thermoreversibility of gelatin to melt at temperature of 35 °C in the first minutes of baking, produces the release of air before the formation of the solid structure end of pound cake (gelatinisation

of starch and protein coagulation), affecting the final structure of the crumb and the volume, although retaining some moisture that is only perceptible to the sense of taste.

The physical characteristics of crumb uniformity and volume of the pound cake at a concentration of 1.25% have an intermediate value between the control and the added of 2% of gelatin, and although statistically they are different, the preference for the type of crumb is important.

Table 5. Sensorial analysis using a Ranking test.

Parameter	Gelatin addition (g/100g)			
	0	0.75	1.25	2
Score texture*	3.40±0.94 ^a	2.76±0.80 ^b	2.47±0.86 ^b	1.38±0.81 ^c
Preference (%)**	24	19	34.5	22.4

*Softness degree (1 less soft, 4 softer). ^aValues followed by different letter in the same row are significantly different ($P < 0.05$). **The preference considers the consistency of crumb.

Conclusions

To increase the concentration of gelatin in a formulation for pound cake reduced in margarine and partially replaced by canola oil, there is a proportional increase in specific gravity, apparent viscosity and viscoelastic modules, decreasing the size and number of bubbles formed in the batter. In pound cake, there is a proportional decrease in volume and uniformity of the crumb and increase in the firmness, however, the addition of 1.25% of gelatin was the most accepted sensory formulation due to perceived a crumb more consistent and wet, so, the functionality of the gelatin as hydrocolloid, is limited to the final texture of the pound cake, concluding that it may be an alternative to improve the acceptability of a pound cake reduced in margarine, which is also of lower cost.

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References

- AACC. (2010). *Approved Methods of American Association of Cereal Chemists*. St Paul, USA: American Association of Cereal Chemists.
- Allais, I., Edoura-Gaena, R., Gros, J., Trystram G. (2006). Influence of egg type, pressure and mode of incorporation on density and bubble distribution of a lady finger batter. *Journal of Food Engineering* 74, 198-210. doi:10.1016/j.jfoodeng.2005.03.014
- Baixauli, R., Sanz, T., Salvador, A., Fishman, S. (2008). Muffins with resistant starch: Baking performance in relation to the rheological properties of the batter. *Journal of Cereal Science* 47, 502-509. doi:10.1016/j.jcs.2007.06.015
- Banerjee, S. & Bhattacharya, S. (2012). Food gels: Gelling process and new applications critical reviews. *Food Science and Nutrition* 52, 334-346. doi: 10.1080/10408398.2010.500234
- Barnes, H.A. (2000). *A Handbook of Elementary Rheology*. Pp 59, Cambrian Printers, Aberystwyth, Wales.
- Chesterton, A., Pereira de Abreu, D., Moggridge, G., Sadd, G., Wilson, D. (2013). Evolution of cake batter bubble structure and rheology during planetary mixing. *Food and Bioprocess Processing* 3, 192-206.
- Damodaran, S., Parkin, K., & Fennema, O. (2007). *Fennema's Food Chemistry*, Fourth Edition. Taylor & Francis Group, pp 849. Boca Raton, Florida, USA.
- Dipjyoti, S. & Suvendu, B. (2010). Hydrocolloids as thickening and gelling agents in food: A critical review. *Journal of Food Science and Technology* 47, 587-597. doi: 10.1007/s13197-010-0162-6
- Doan, C.D., Taverniera I., Kiyomi, O.P., Dewettinck, K. (2018). Internal and external factors affecting the crystallization, gelation, and applicability of wax-based oleogels in food industry. *Innovative Food Science & Emerging Technologies* 45, 42-52. <https://doi.org/10.1016/j.ifset.2017.09.023>
- Dogan, S., Sahin, S., & Sumnu, G. (2005). Effects of soy and rice flour addition on batter rheology and quality of deep-fat fried chicken nuggets. *Journal of Food Engineering* 71, 127-132.
- Glicksman, M. (1982). *Food Hydrocolloids*, CRC Publ. Boca Raton, FL, USA.
- Gómez, M., Ronda, F., Caballero, A., Blanco, C., Rosell, C. (2007). Functionality of different hydrocolloids on the quality and the shelf life of yellow layer cakes. *Food Hydrocolloids* 21, 167-173. doi:10.1016/j.foodhyd.2006.03.012
- Hernández-Rodríguez, L., Lobato-Calleros, C., Ramírez-Santiago, C., Rodríguez-Huezo, M., Meraz, M., (2017). Microstructure and rheology of yogurt added with protein-L. *Plantarum-polysaccharide coacervate and stevia in substitution of milk-fat and sucrose*. *Revista Mexicana de Ingeniería Química* 16, 77-89. <http://www.rmiq.org/iqfvp/Pdfs/Vol.%2016,%20No.%201/Alim2/eAlim2.html>
- Hesso, N., Garnier, C., Loisel, C., Chevallier, S., Bouchet, B., Le-Bail, A. (2015). Formulation effect study on batter and cake microstructure: Correlation with rheology

- and texture. *Food Structure* 5, 31-41. <http://dx.doi.org/10.1016/j.foostr/2015.03.002>
- Hussien, H. (2016). Using vegetable puree as a fat substitute in cakes. *International Journal of Nutrition and Food Sciences* 5, 284-292. doi: 10.11648/j.ijnfs.20160504.18
- Kalinga, D., & Mishra, V. (2009). Rheological and physical properties of low fat cakes produced by addition of cereal β -glucan concentrates. *Journal of Food Processing and Preservation* 33, 384-400.
- Kumari, R., Jeyarani, T., Sowmya, C., Indrani, D. (2011). Use of vegetable oils, emulsifiers and hydrocolloids on rheological, fatty acid profile and quality characteristics of pound cake. *Journal of Texture Studies* 42, 377-386. doi:10.1111/j.1745-4603.2011.00297.x
- Lee, S., Kim, S., Inglett, G. E. (2005). Effect of shortening replacement with oatrim on the physical and rheological properties of cakes. *Cereal Chemistry* 82, 120-124.
- Li, J., & Nie, S., (2016). The functional and nutritional aspects of hydrocolloids in foods. *Food Hydrocolloids* 53, 46-61.
- Marco, C., & Rosell, C. (2008). Functional and rheological properties of protein enriched gluten-free composite flours. *Journal of Food Engineering* 88, 94-103.
- Matos, M.E., Sanz, T., & Rosell, C.M. (2014). Establishing the function of proteins on the rheological and quality properties of rice based gluten-free muffins. *Food Hydrocolloids* 35, 150-158. <https://doi.org/10.1016/j.foodhyd.2013.05.007>
- Mensink, R.P., Sanders, T.A., Baer, D.J., Hayes, K., Howles, P.N., Marangoni, A.G. (2016). The increasing use of interesterified lipids in the food supply and their effects on health parameters. *Advances in Nutrition* 7, 719-729. doi: 10.3945/an.115.009662
- Park, S. J., Ha, Ki-Y., & Shin, M. (2012). Properties and qualities of rice flours and gluten-free cupcakes made with higher-yield rice varieties in Korea. *Food Science Biotechnology* 21, 365-372.
- Patel, A. R., Cludts, N., Sintang, M., Lesaffer, A. Dewettinck, K. (2014). Edible oleogels based on water-soluble food polymers: preparation, characterization and potential application. *Food Function* 5, 2673-3028. doi: 10.1039/c4fo00624k
- Psimouli, V., & Oreopoulou, V. (2013). The Effect of Fat Replacers on Batter and Cake Properties. *Journal of Food Science* 78, C1495-C1502. doi: 10.1111/1750-3841.12235
- Razavi, S., & Karazhiyan, H. (2012). Rheological and textural characteristics of date paste. *International Journal of Food Properties* 15, 281-291. doi: 10.1080/10942912.2010.483615
- Rodríguez-García, J., Sahi, S., Hernando, I. (2014). Functionality of lipase and emulsifiers in low-fat cakes with inulin. *LWT - Food Science and Technology* 58, 173-182. doi:10.1016/j.lwt.2014.02.012
- Román, L., Santos, I., Martínez, M., Gómez, M. (2015). Effect of extruded wheat flour as a fat replacer on batter characteristics and cake quality. *Journal of Food Science and Technology* 52, 8188-8195. doi: 10.1007/s13197-015-1909-x
- Ronda, F., Oliete, B., Gómez, M., Caballero, P., Valentín, P. (2011). Rheological study of layer cake batters made with soybean protein isolate. *Journal of Food Engineering* 102, 272-277. doi:10.1016/j.jfoodeng.2010.09.001
- Sahi, S.S., & Alava, J.M. (2003). Functionality of emulsifiers in sponge cake production. *Journal of the Science of Food and Agriculture* 83, 1419-1429. doi: 10.1002/jfsa.1557
- Song, K.W., Kim, Y.S., & Chang, G.S. (2006). Rheology of concentrated xanthan gum solutions: Steady shear flow behavior. *Fibers and Polymers* 7, 129-138.
- Sowmya, M., Jeyarani, T., Jyotsna, R., Indrani, D. (2009). Effect of replacement of fat with sesame oil and additives on rheological, microstructural quality characteristics and fatty acid profile of cakes. *Food Hydrocolloids* 23, 1827-1836. URL: <http://www.sciencedirect.com/science/article/B6VP9...>

- Steffe, J. (1996). *Rheological Methods in Food Process Engineering*. Second edition. Freeman Press. Pp 294-298. Michigan, USA.
- Stone, H., Bleibaum, N., Thomas, A. (2012). *Sesory Evaluation Practices*. Fourth edition. Academic Press. Pp 168-225. Oxford U.K.
- Turabi, E., Sumnu, G., Sahin, S. (2008). Rheological properties and quality of rice cakes formulated with different gums and an emulsifier blend. *Food Hydrocolloids* 22, 305-312. doi:10.1016/j.foodhyd.2006.11.016
- Wilderjans, E., Pareyt, B., Goesart, H., Brijs, K., Delcour, J. (2008). The role of gluten in a pound cake system: A model approach based on gluten-starch blends. *Food Chemistry* 110, 909-915. doi:10.1016/j.foodchem.2008.02.079
- Wilderjans, E., Luyts, A., Brijs, K., Delcour, J. (2013). Ingredient functionality in batter type cake making. *Trends in Food Science and Technology* 30, 6-15. <https://doi.org/10.1016/j.tifs.2013.01.001>