Sensory Characteristics and Textural Changes during Storage of Sponge Cake with Functional Ingredients

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Abstract. Sensory and textural characteristics of sponge cake prepared with different functional ingredients (einkorn wholemeal flour, Jerusalem artichoke powder, cocoa husk powder) in replacement of the part of the wheat flour were investigated during 6 days storage (on the 1st, the 3rd and the 6th day). Descriptive sensory analysis was used to compare the new and the control sponge cakes. The functional ingredients did not produce significant changes in the sensory characteristics of the sponge cakes, except of crumb's texture. The texture changes are characterised by elastic modulus, hardness and cutting force. These parameters of sponge cakes changed differently during the storage period. During the 6 days storage period the samples with functional ingredients preserved in better way the elastic modulus in comparison with the control sample, because they are more reach in fibre. The sponge cake, containing 20% Jerusalem artichoke powder, keeps their freshness longer time.

INTRODUCTION

The texture is one of the main characteristics of the sponge cakes that can be affected by the addition of functional ingredients. It can be determined by instrumental or sensory methods. Instrumental methods offer some advantages over sensory analysis because they are rapid and objective. Sahi & Alava (2003) studied the crumb structure of sponge cakes to evaluate the effect of different emulsifiers. Texture profile analysis of cake crumb was performed by Singh, Rosell, Sharma, & Singh, (2003) to study the effect of sodium lauryl sulphate. Kamel & Rasper (1988) investigated the effect on cake crumb firmness of preparing reduced-calorie cakes with sorbitol or polydextrose to replace sugar.

The storage stability or the shelf life of the baked products could be defined as maintenance the sensory and physical characteristics associated with the freshness such as crumb tenderness, compressibility and moistness by preventing alteration associated with staling during the storage (Baixauli, R., Salvador, A., & Fiszman, S. M., 2008). However, sensory methods are the only ones that make it possible to assess consumer acceptance. Consumers expect a product with a soft, spongy, tender crumb, but also a certain degree of resistance, not crumbling easily; these characteristics worsen during the storage and, in general, consumer rejection of the product occurs before any microbiological spoilage makes it unsuitable for human consumption

(Hough, G., Langohr, K., Gomez, G., & Curia, A., 2003). Different methods maybe used to determine the sensory characteristics of a food product using consumer data.

Different flour types have been investigated for developing cakes of lower cost and better quality in terms of consumer acceptance (Karaoglu, M.M. & Kotancilar, H.G., 2009). The baking time and temperature have an impact on the morphology and the texture of bread and on its quality (specific volume, crust colour, crust/crumb ratio, crumb firmness and moisture content). This morphology affects the kinetics of moisture transfer during the aging and, consequently, the mechanical properties. Among the different physical properties, which can be considered as characterizing the cakes, the porosity is important not only for the mechanical properties of the crumb but also for moisture transfer within the product. B1aszczak, Sadowska, Fornal, and Rosell (2004) found that during the staling, the porosity decreased and the crumb pores became smaller and rounder. A static compression mode, such as texture profile analysis (Carson & Sun, 2001) (determined using a texture analyzer), firmness (based on force-deformation), stress relaxation, penetration, and compression tests have provided data about bread crumb mechanical changes associated with the staling process (Angioloni & Collar, 2009). Other aspects related to staling may also be considered such as the loss of resilience. Goasaert, Slade, Levine, and Delcour (2009) measured the firmness and resilience of bakery products after 6 days of storage using a texturometer and concluded that an increase in crumb firmness led to a decrease in crumb resilience due to a less flexible gluten network. Instrumental and sensory evaluations on sponge cake textures have been widely performed, but it is important to establish which tests and probes are more appropriate for describing the sensory attributes of texture, thereby ascertaining which objective test correlates in best way with the sensory perception of the texture.

The objectives of this study are to compare the influence of replacing 20%, 35% and 50% of wheat flour with different functional ingredients on the textural characteristics of the sponge cake, freshly baked and stored for 6 days, and to assess the sensory characteristics of the fresh sponge cakes.

MATERIAL AND METHODS

Cake batters preparation

Standard raw materials such as wheat flour of type 500 – ash 0.5% (GoodMills, Bulgaria EAD), granulated sugar (Zaharni zavodi AD), eggs (local market) used in the current study are authorized by the Ministry of Health as manufactured in Bulgaria. The control cake was prepared, following a traditional technology and formulation (Angelov et al., 1974).

The batter formulation of the control cake was as follows (based on flour weight): egg yolk 43.23%, egg white 96.77%, refined granulated sugar 83.87%, and wheat flour 100%. In particular, a double mixing procedure was applied by partitioning whipping of whites and egg yolks. Jerusalem artichoke powder (JAP), cocoa husk powder (CHP) and einkorn wholemeal flour (EWF) were added into sponge cake flour at different levels 20, 35 and 50%, by replacing wheat flour, respectively (Table 1, Figure 1).

Each sponge cakes batter of 95 g was poured out into metallic forms and baked in an electric oven (Rahovetz - 02, Bulgaria) at 180°C for 30 min. The sponge cakes were stored at standard conditions (at temperature of 18°C and 75 % relative humidity) up to the sixth day from production date according to standard requirements (BSS, 1982). The humidity and the temperature were kept constant by means of a desiccator supplied with psychrometer, and put in a thermostat with accuracy of ± 0.5°C.

Table 1: Sponge cake batters formulations

Ingredients	Amount based on:			
	flour weight, [%]	flour mix /wheat flour and functional ingredient / weight, [%]		
	control sample	with 20 % Jerusalem artichoke powder	with 35 % cocoa husks powder	with 50 % einkorn wholemea l flour
Yolk of egg	43.23	43.23	43.23	43.23
White of egg	96.77	96.77	96.77	96.77
Refined granulated sugar	83.87	83.87	83.87	83.87
Wheat flour type 500	100.00	80.00	65.00	50.00
Functional ingredient	-	20.00	35.00	50.00

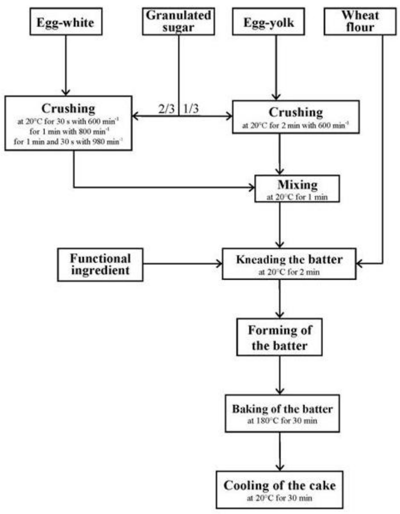

Figure 1
Technology flowsheet of the sponge cake preparing with functional ingredient

Sensory characteristics

The descriptive test for a quantitative sensory profiling was used to establish the sensory characteristics (shape, colour, cell size and uniformity, odour, sweetness, aftertaste, crumb tenderness) of the sponge cakes, 6 h after baking, following the ISO 8586:2014 and ISO 13299:2011 methods. The sponge cakes samples were ready 1 h before the evaluation. Samples of different cakes were kept in coded plates covered with aluminium foil. Twelve trained panelists were selected to guarantee the evaluation accuracy. The intensity of each sensory characteristic was recorded on a ten-point linear scale after 1 h orientation sessions of the panelists, where they specified terminology and anchor points on the scale. The coded samples were shown simultaneously and evaluated in random order among the panelists. The sensory characteristics are shown in Table 2.

Table 2: Sensory characteristics and their definitions

Sensory characteristics	**Definition**	**Evaluation method**	**Scale**
Shape	Visual assessment of surface and preserved form of sponge cake.	Presence of large cracks on the surface	0-3
		Numerous smaller cracks	3-6
		Without cracks, smooth upper surface	6-9
Colour	Visual assessment of the colour of the crust and crumb of sponge cake (to control crust the colour of the crust is golden brown and the crumb has a light yellow colour)	A significant discolouration	0-3
		Unevenly colour of surface and in the crumb of the cakes	3-6
		Characteristic colouring of crumb and crust	6-9
Cell size and uniformity	Visual assessment of the size and even distribution of pores in crumb crust sponge cake	Visible differences in the size and distribution of pores	0-3
		A small difference in the size and distribution of pores in the crumb	3-6
		Evenly distributed small and uniform in size pores	6-9
Odour	Rating odour during consumption of sponge cake	Presence of strong, unusual odour – pushy	0-3
		Slight uncharacteristic odour	3-6
		Characteristic pleasant odour	6-9
Sweetness	Evaluation of the sweet taste of sponge cake	Insufficient pronounced sweet taste	0-3
		Moderate sweetness	3-6
		Strong sweet taste	6-9
Aftertaste	Evaluation of the aftertaste after consumption of sponge cake	Missing aftertaste or unpleasant taste sensation (palatability)	0-3
		Presence of slightly discernible side aftertaste	3-6
		Strong, unpleasant after taste	6-9
Crumb tenderness	Evaluation of the applied compressive force required for deformation of the crumb	The need to apply more force to deformation	0-3
		Applying moderate compression force to deformation	3-6
		Use less force to deformation	6-9

Textural characteristics

The textural parameters of the sponge cakes were investigated by texture analyzer Stable Micro Systems XT2Ai equipped with loading cell 50 kg and specialized software „Texture Exponent". The software allows force calibration and sample height calibration before the measurements. The instrument works in the deformation range 0 - 500 mm (with resolution 0.001 mm) and the force range 0 - 500 N (resolution: 0.001 N, minimal measured force: 1 N).

The sample preparation includes measurement of the sample sizes (length, width and height) by digital calliper, measurement of the sample weight by laboratory scales.

1. Investigation of the sponge cake elasticity: The test was done at low deformation rate 1mm/s till 20% strain was achieved using a cylinder probe with diameter 50 mm. The elastic modulus (ε, kPa), defined as the slope of the linear part in the stress/strain curve was determined from this measurement.
2. Determination of the sponge cake hardness by rupture test (imitation of the biting process). The test was done at high deformation rate 5 mm/s using a thin cylinder probe with diameter 5 mm till 40 mm deformation. The stress (σ, kPa) of the rupture point was determined from this test.
3. Cutting of the sponge cakes. The test was done with a "knife" probe, which is wider and higher than the sizes of the cake. The cutting was done till 100% of the sponge cake height with cutting rate 2 mm/s. The maximum cutting force (F, N) was determined.

Physico-chemical characteristics

For the determination of the sponge cake structure, optical photographs were taken of the top surface and of the cross sections of the half-cut cake**.**

Determination of dietary fibre

The total, soluble and insoluble dietary fibre content was determined by the enzymatic-gravimetric method AOAC 985.29, using the total dietary fibre assay kit TDF 100A (Sigma-Aldrich) and the instructions provided by the manufacturer.

Determination of total fat

The total fat content was determined by the Randall extraction method (ISO 11085:2008).

Data analysis

Depending on the type of the studied characteristic from 3 to 12 repetitions of each measurement were done. For the assessment of the measured results accuracy a statistical method with level of significance $p \leq 0.05$ was used. The data were analyzed and presented as average values ± standard deviation.

RESULTS AND DISCUSSION

Sensory analysis

The results of the sensory analysis suggested that the addition of functional ingredients in the cake formula interfere positively on the product acceptability, in fact the samples with the 50% einkorn wholemeal flour showed the highest value of "overall acceptability". It was observed that the higher crumb tenderness scores for control resulted an increase in the overall liking values. The cakes had similar shape with an exception for the cake with 35% cocoa husks powder (Figure 2). This cake had the smallest height, and its surface had visible cracks (Figure 3).

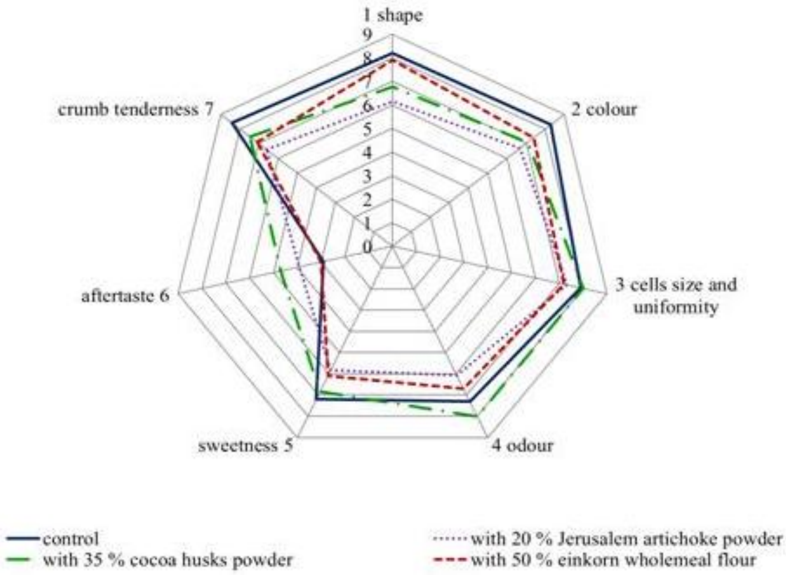

Figure 2
Sensory profiles of sucrose-sweetened sponge cakes*
*A scale from 0 to 9 was used to evaluate sensory characteristics. Nine is ideal for the third sensory characteristic when the cells are small and equal in size.

a) Without an additive control cake-sample	**b)** With an additive of 20 % Jerusalem artichoke powder;	**c)** With an additive of 35 % of cacao husks powder;	**d)** With an additive of 50 % einkorn wholemeal flour.

Figure 3
Photographs of top surface and of cross sections of the fresh

sucrose-sweetened sponge cakes

The crumb pore cells of the cakes with 35% cocoa husks powder had thicker walls, and they were larger and equal in size (Figure 2 and Figure 3). The cells of the sponge cake-sample were smaller and almost uniformly distributed in the crumb, with thinner walls. The cake-samples had a crust and crumb with more pronounced light-yellow colour due to the presence of the color components in the yolks of the egg (carotenoids). The colour of the crust and crumb of the cakes with 35% cocoa husks powder was brown, of cakes with 50% einkorn wholemeal flour is light-yellow - light-brown, cakes with 20% Jerusalem artichoke powder – gray brown (Figure 3). The odour of the cakes with 20% Jerusalem artichoke powder was more strongly expressed and more specific towards the control sample odour, and was not perceived by the sensory panelists as unpleasant. The intensity of the sweetness for all investigated sponge cakes is close, but when the adding of the functional ingredients is greater and aftertaste was read.

Instrumental texture

The elastic modulus (Figure 4) for all the investigated cakes was very similar on the first day and increased during the storage. The increasing was the smallest for the control cake and the highest for the sample with 50% einkorn wholemeal flour.

The hardness (puncture stress) of the cakes is shown on Figure 5. The hardness of the control cake had a very small decreasing. For sponge cakes containing functional ingredients, the hardness increased during the sixth day storage. The increasing was the highest for the sponge cakes with 20% Jerusalem artichoke powder and 50% einkorn wholemeal flour and the smallest for cake with 35% cocoa husks powder.

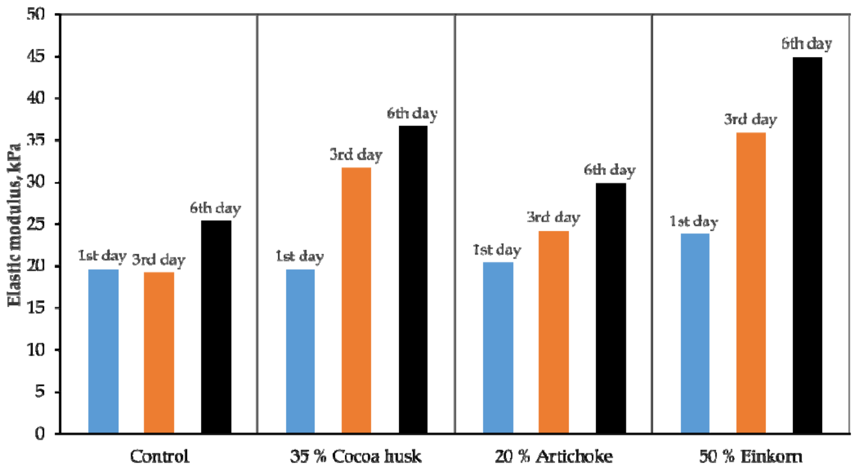

Figure 4
Elastic modulus of sponge cakes during the storage

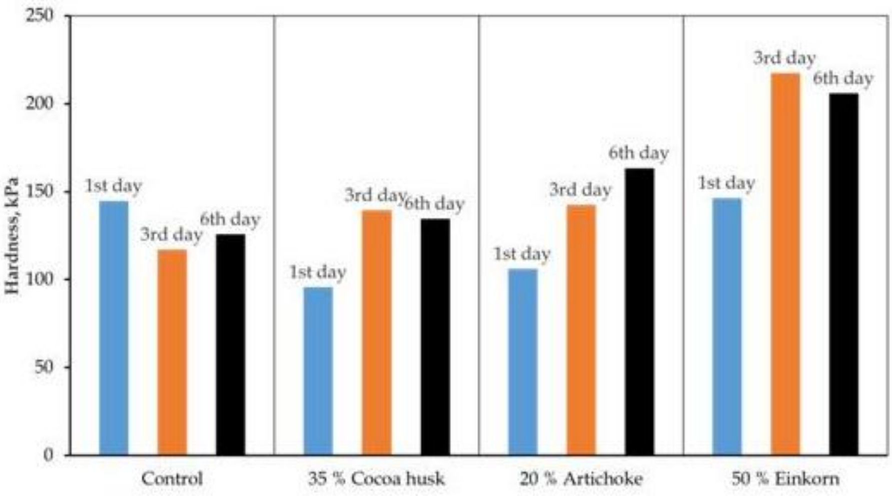

Figure 5
Puncture test (hardness) of sponge cakes during the storage

The changes of the cutting force is shown on Figure 6. The cutting force of the control sample showed an increasing during the storage. The samples with 35% cocoa husk powder and 20% Jerusalem artichoke powder showed the highest cutting force on the 3rd day, and after that smaller like on the first day, because they became to crackly texture.

The observed differences in the textural properties of sponge cakes with functional ingredients are due to their different composition.

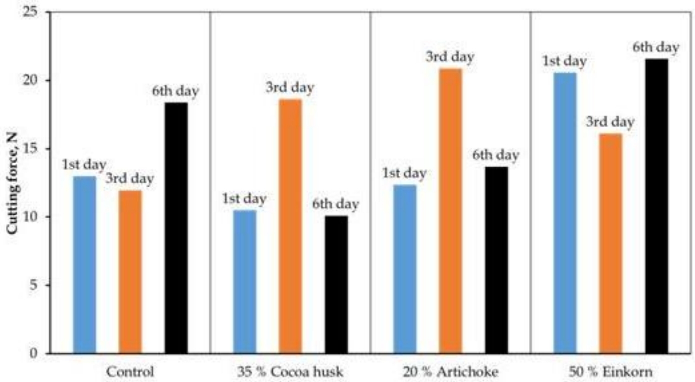

Figure 6
Cutting force pf sponge cakes during the storage

The sponge cake with 50% einkorn wholemeal flour contains large amounts of fiber, most of which are insoluble (Table 3). As a result, the cake is characterized by the highest elasticity and hardness. During the storage the elasticity and the hardness grow fastest.

The sponge cake with 35% cocoa husk powder contains the greatest amount of insoluble fiber and fat (Table 3). Perhaps the larger amounts of fat in the cake with 35% cocoa husk powder causes less elasticity and hardness of the cake crumb in comparison to the sponge cake with 50% einkorn wholemeal flour.

The sponge cake with 20% Jerusalem artichoke powder contains large amounts of soluble fibre (Table 3). As a result, the elasticity of the cake is retained to the greatest extent during the storage (i.e., the changes are minimal).

Table 3: Average values of the dietary fiber and of the total fat of the sponge sucrose-sweetened cake samples without and with functional ingredient (per 100 g product)

Type of sponge sucrose-sweetened cake	Dietary fiber, [%]			Total fat, [%]
	insoluble	soluble	total	
Control	1.56±0.07	0.45±0.51	2.01±0.58	6.32±0.03
With 20 % Jerusalem artichoke powder	2.24±0.05	1.43±0.58	3.67±0.63	4.06±0.27
With 35 % cacao husks powder	3.97±0.03	0.34±0.39	4.31±0.42	7.03±0.12
With 50 % einkorn wholemeal flour	2.73±0.06	0.48±0.27	3.21±0.33	6.79±0.11

CONCLUSIONS

The texture is the most important parameter in the product design because the texture and food matrix are linked to the micro- and macrostructural composition of foods, which determines the sensory perception. Any change in the formulation or processing directly influence the structural composition of the foods. The biggest challenge in the food manufacturing is to produce food products with a consistent high quality. The influence of the ingredients on slowing down starch retrogradation was initially tested by instrumental methods and later correlated to the results of a sensory panel. On the first day of storage the greatest cutting force is applied to the sponge cake with 50% einkorn wholemeal flour, i.e. it has the strongest internal resistance, and the less power is used for cutting the cake with 35% cocoa husks powder. During the storage, the smallest change was recorded in the cakes containing more dietary fiber – with 35% cocoa husks powder and with 50% einkorn wholemeal flour.

The addition of 50% einkorn wholemeal flour in sponge cake produced a harder texture: the samples were harder than the others and showed higher elastic modulus. During the 6 days storage period the samples with functional ingredients remained stable elastic modulus not like the control sample.

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