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Effect of liquid type on the quality of gluten-free muffins

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Celiac disease is an immune-mediated disease triggered in genetically susceptible individuals by ingested gluten from wheat, rye, barley and other closely related cereal grains. The only effective treatment is a strict gluten-free diet for life. Gluten-free bakery products are often considered of low eating quality because of their unappealing texture due to the lack of gluten network. Nowadays, the amount of people intolerable for grain albumen increase in Latvia, but Latvian producers almost do not offer gluten-free products. Therefore, the main task of food producers is to make new tasty gluten-free products of an elevated nutritive value to enrich the menu of celiac patients. One of such products could be sweets, such as muffins. The aim of the present research was to study the influence of various liquids used in the recipes on the quality of gluten-free muffins. In this research, three types of muffins, made using milk, milk and water mix, and water were studied. The main quality parameters of gluten-free muffins were determined using the following methods: hardness with a *TA.XT. plus texture analyser*, moisture content with *Precisa XM 120* at a temperature of 110 °C, their colour was measured in CIE L*a*b* colour system using a *ColorTec-PCM/PSM*. The type of the added liquid (milk, milk and water mix, or water) influenced the volume and crust colour of gluten-free muffins but did not affect their moisture content, hardness, and crumb colour.

Introduction

Celiac disease is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals. Celiac disease is a syndrome characterized by a damage of the small intestinal mucosa, caused by the gliadin fraction of wheat gluten and similar alcohol-soluble proteins (prolamines) of barley (hordein) and rye (secalin), which are collectively called "gluten", in genetically susceptible subjects [1, 2, 3]. The only effective treatment is a strict gluten-free diet throughout life [4]. Celiac disease is one of the most common genetically based diseases, its worldwide prevalence being 1 in 266 [5]. In the last decade, the number of people with celiac disease increased because of the improved diagnostic methods [2].

The gluten proteins in wheat have unique properties, such as a good water absorption capacity, cohesiveness, viscosity, and elasticity. In a dough system, gliadin contributes to the viscous properties, while glutelin contribute to elastic properties. A proper mixture of both fractions is essential to impart the viscoelastic properties to dough. The adequate mixture of these fractions is only found in wheat, making this cereal most valuable of all the food grains [6]. Maize, rice, tapioca, sorghum, amaranth, buckwheat and potato flour, which are allowed in a gluten-free diet, are not able to supply the same technological characteristics as gluten [7]. Replacement of gluten is one of the major challenges for gluten-free product development.

Many researchers have tried the improve gluten-free product quality by different methods – making flour mixtures [8, 9], using additives such as hydrocolloids, gums, enzymes, emulsifiers [10, 11]. Researchers from Brazil produced gluten-free bread using extruded rice flour as a gluten replacement. The results showed that the gelatinization of starch by extrusion could make the gluten-free bread production process viable and improve the colour of the crust and texture characteristics, which were similar to those of wheat bread, despite presenting a low specific volume [12].

Experiments of Ozola et al. show that addition of extruded maize flour to gluten-free bread recipe improves bread quality: samples with extruded maize flour are softer, have a higher moisture content, crumb porosity is more homogeneous, the equivalent diameter of pores decreases as compared with samples without extruded maize flour [13, 14].

Latvian producers do not offer gluten-free products; usually, they are imported to Latvia from foreign countries and are very expensive. The 2011 consumer questionnaire concerning gluten-free product quality available in the Latvian market showed that 37 % of respondents evaluated the gluten-free bread quality as average and 26 % as poor. The results of the questionnaire show that the consumers are satisfied with the quality of gluten-free flour, flour blends and pasta available in the Latvian markets and mainly characterize it as good, but they are not satisfied with the quality of bread and confectionery and characterize it as average [15].

Breads are classified as quick breads or yeast breads, based on whether or not they are leavened by yeast. Quick bread is leavened with carbon dioxide produced by a chemical reaction, mostly by baking powder or soda [16]. Muffins are described as a quick bread in which chemical leavening agents are used. During the last decade, muffins have become increasingly popular as hot bread served with meals or eaten as a snack [17, 18].

The type and the amount of liquid used in making muffins can vary. Liquids perform several functions in

baked products. These include dissolving dry ingredients, gelatinization of starch, and providing moisture in the final baked products [17, 18]. Ordinarily, milk is used, but occasionally orange juice, water, or other liquid may be chosen. Celiac patients need to be careful with dairy products as well, because lactose intolerance is often associated with celiac disease. Lactose intolerance results from a decreased lactase production by the damaged villi [3, 19]. The liquid used for dough preparation influences flavour, texture, and browning [16].

The aim of this research was to study the influence of various liquids used in recipes on the quality of gluten-free muffins.

Materials and methods

Yellow maize (moisture 10.51 ± 0.08 %) and extruded maize (moisture 12.38 ± 0.03 %) flour from the Joint Stock Company "Ustukiu Malunas" (Lithuania), sugar, butter, eggs, gluten-free baking powder, vanilla sugar, milk, dry milk from the local market were the materials used in the study.

Three sets of samples were prepared, and the following abbreviations of the samples in the article are used:

- MM – muffins with milk;
- MMW – muffins with milk and water mix;
- MW – muffins with water (Table 1).

All samples were prepared using the same quantity of all ingredients, except the added type of liquid. Table 1 shows gluten-free muffin formulation. The dry milk and water ratio is 1 : 11 in muffins with milk and water mix formulation.

Muffins from each formulation were prepared in triplicate.

Table 1. Formulation of gluten-free muffins

Ingredients, g	MM	MMW	MW
Maize flour	186	186	186
Extruded maize flour	21	21	21
Sugar	120	120	120
Butter	90	90	90
Eggs	120	120	120
Baking powder	3	3	3
Vanilla sugar	2	2	2
Milk	150	-	-
Dry milk	-	13.6	-
Water	-	150	150
Total	692	705.6	692

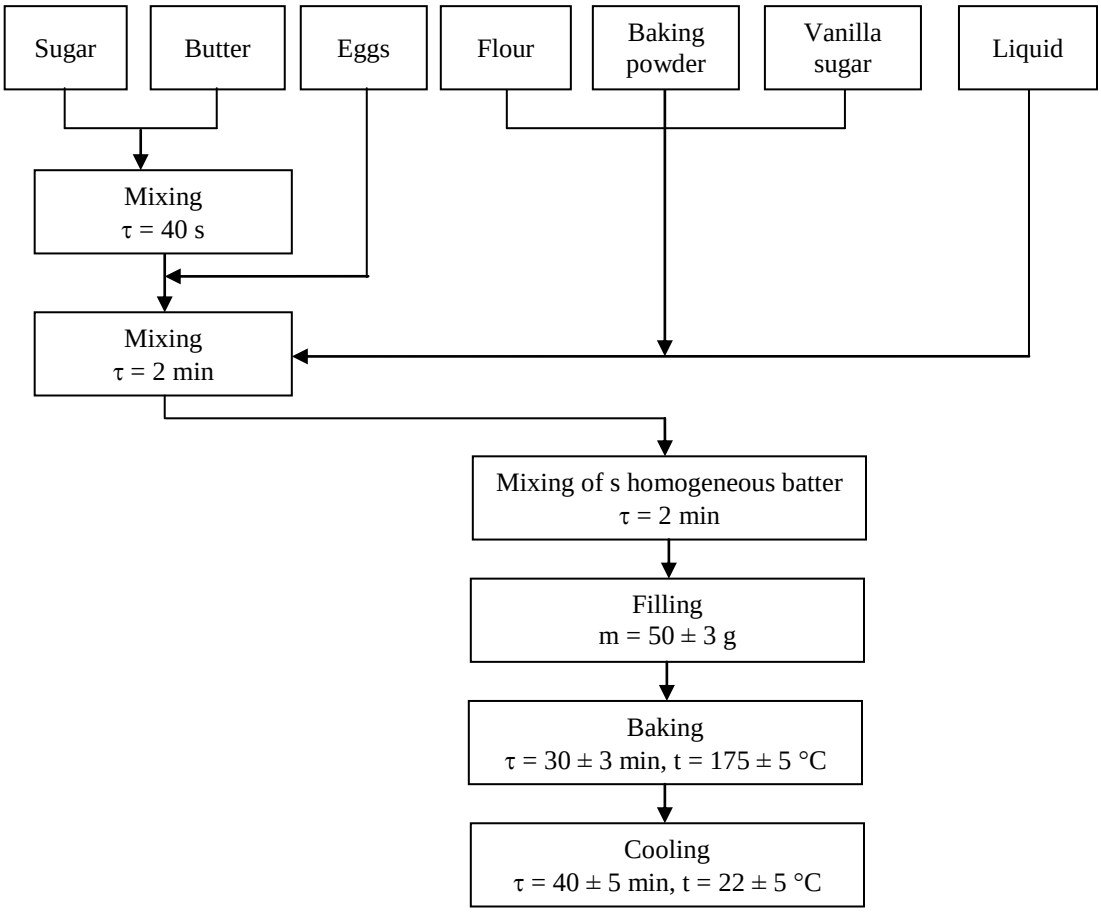

Fig. 1. The general technological scheme of gluten-free muffins

All dry ingredients were mixed together, then a liquid was added (milk, milk and water mix, or water) in muffins with milk and water mix case; before liquid addition, dry milk and water were mixed. All ingredients were mixed together for 5 min using a mixer until a homogeneous batter was obtained. A special muffin pan (12 muffin cups, 50 mm in diameter) was filled with batter. The muffins were baked at 175 ± 5 °C for 30 ± 3 min and then cooled. The general technological scheme used to make the gluten-free muffins is presented in Fig. 1.

Muffin height was measured from the highest point of the muffin to its bottom after 12 h of cooling at room temperature [20].

The hardness of muffins was objectively measured using a *TA.XT. plus* texture analyser (*Stable Micro Systems*) equipped with the following compression test parameters: flat-ended cylindrical probe 100 mm in diameter, test speed 1 mm/s, distance 15 mm.

Moisture content was analyzed with *Precisa XM 120* moisture balance at a temperature 110 ± 1 °C in five reiterations.

The instrumental measurements of crust and crumb colour of muffins was performed in CIE L*a*b* colour system using a *ColorTec-PCM/PSM*. Crust colour measurements were made by placing the samples directly under the colorimeter; to measure the crumb colour, each muffin was cut in to two halves. The colour was measured at four different points within the crust and crumb region, and the mean values were reported for each type of products. ΔE (colour difference) was defined using the following equation (1) [21]:

$$\begin{aligned} \Delta L &= (L - L_0), \\ \Delta a &= (a - a_0), \\ \Delta b &= (b - b_0), \\ \Delta E &= \sqrt{\Delta L^2} + \sqrt{\Delta a^2} + \sqrt{\Delta b^2}. \end{aligned} \quad (1)$$

The reference values for the calculation of ΔE were colour difference among each type of muffins. The values used to determine whether the total colour difference was appreciable by the human eye were the following:

- ΔE < 1 – colour difference is not obvious for the human eye;
- 1 < ΔE < 3 – colour difference is not appreciable by the human eye;
- ΔE > 3 – colour difference is obvious for the human eye [21].

All measurements were carried out on the next day, at least 12 h after muffin preparation. The means and the standard deviation of the means were calculated using Microsoft Office Excel.

Results and discussion

Replacing milk with dry milk (milk and water mix) or water without affecting the quality of gluten-free muffins is an important task. This will facilitate the production process, as milk powder use and storage are easier than those of milk.

In general, a good quality muffin has a symmetrical shape, slightly rounded or oval, a rounded top of a golden brown colour depending on the type, the cells that are uniform and moderate in size, a sweet flavour and a pleasant aroma. It should be tender and moist, be easily broken apart, and be easy to chew with a pleasant aftertaste [17, 18, 22].

Table 2. Gluten-free muffin height and hardness

Sample	Height (mm)	Hardness (N)
MM	31.83 ± 0.34	92.69 ± 4.29
MMW	30.12 ± 0.72	94.44 ± 2.76
MW	28.70 ± 0.64	97.49 ± 3.29

All muffin samples had a symmetrical shape, a rounded top (Fig. 2 *a–c*). The height and hardness of gluten-free muffins are presented in Table 2. The highest muffins were the ones prepared with milk (MM) – 31.83 mm, and the shortest with water (MW) – 28.70 mm. The results show that the type of liquid impacts the height of gluten-free muffins.

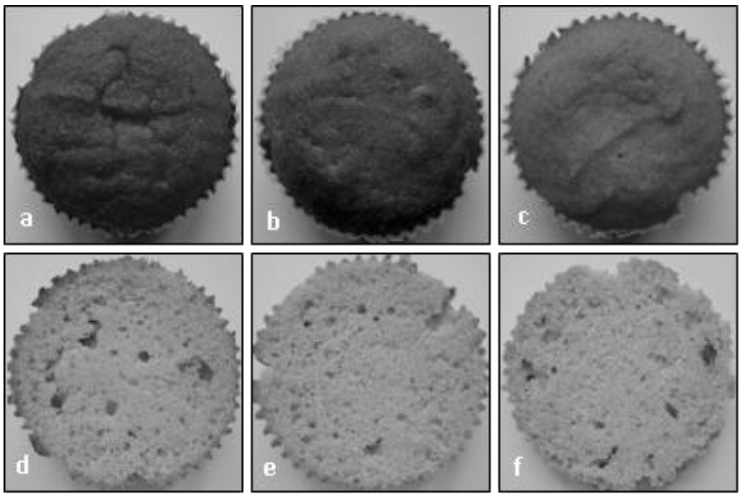

Fig. 2. Digital images of gluten-free muffins:
a, d – muffin with milk, *b, e* – muffin with a milk and water mix, *c, f* – muffin with water

The volume of muffins baked in the same pan is determined by the height; therefore, it can be concluded that the type of liquid influences the volume of muffins. The obtained results show that muffins with milk are by 1.88 % softer than MMW and by 5.17 % than MW. Hardness is closely related to the pore structure. A crumb of muffins with milk contained big pores (Fig. 2 *d*), but muffins with a milk and water mix and with water had a homogeneous pore structure (Fig. 2 *e–f*). Fig. 3 presents the moisture content of gluten-free muffins. All gluten-free muffins had a similar moisture content; differences among the samples are insignificant – from 0.45 % (between MMW and MW) to 1.32 % (between MMW and MM). The highest moisture content was found in muffins with a milk and water mix – 41.87 % as compared with other muffins, MM – 40.55 %, MW – 28.70 %.

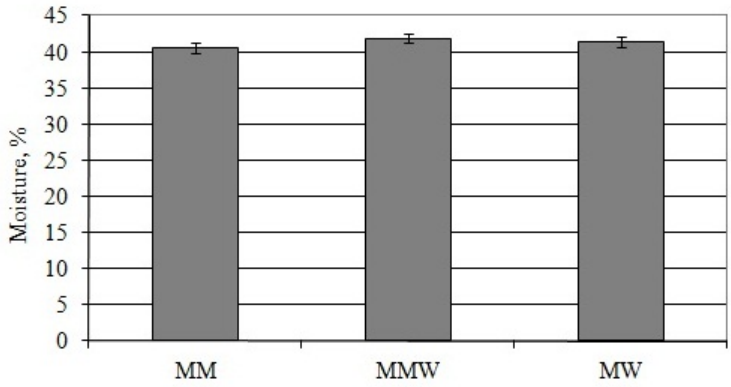

Fig. 3. Moisture content of gluten-free muffins:
MM – muffin with milk, MMW – muffin with a milk and water mix, MW – muffin with water

The study of Martinez-Cervera et al. [23] presents the moisture content range of chocolate muffins between 16.6–20.6 %, while its content in the studied gluten-free muffins was twice as high. The significant difference can be explained by the fact that using gluten-free flour it is necessary to adjust the amount of liquid in the formulation, because gluten-free flour has a better water absorbability.

Colour values of gluten-free muffins are shown in Table 3. The lightest colour of crust (L* = 50.88 ± 1.48) was determined for the samples with water (MW), also MW had the highest values of b* (yellow component 34.35 ± 1.34). In order to study whether the colour differences among the types of muffins could be detectable by human eye, the parameter ΔE was calculated (Table 4). As to the colour of crust, ΔE revealed the colour difference among the types of muffins to be obvious for human eye (ΔE > 3). The crust of muffins with milk (MM) had a dark, brown colour, but muffins with a milk and water mix (MMW) had a pale yellow colour. The Maillard reaction and with sugar caramelization are responsible for the brown crust of muffins [17].

Table 3. Colour values of gluten-free muffins

Samples	Colour		
	L*	a*	b*
Muffin crust			
MM	40.74 ± 1.18	8.84 ± 0.94	24.04 ± 1.24
MMW	45.09 ± 1.48	8.20 ± 0.95	29.04 ± 1.19
MW	50.88 ± 1.48	6.57 ± 0.99	34.35 ± 1.34
Muffin crumb			
MM	70.85 ± 1.22	-4.28 ± 0.66	39.55 ± 1.19
MMW	71.04 ± 1.15	-4.40 ± 0.66	40.50 ± 1.28
MW	70.46 ± 1.45	-4.05 ± 0.72	41.16 ± 1.33

When using milk in muffin formulation, extra sugar – lactose – it is added. It is involved in the Maillard reaction and caramelization. The type of added liquid affects the colour of muffin crust.

No significant differences ($p > 0.05$) were found in L*, a* and b* values of crumb (Table 2) among the types of muffins.

Table 4. Colour difference (ΔE) of muffin crust and crumb

Sample	Crust			Crumb		
	MM	MMW	MW	MM	MMW	MW
MM	0	6.66	14.64	0	0.98	1.67
MMW	6.66	0	8.02	0.98	0	0.95
MW	14.64	8.02	0	1.67	0.95	0

In muffins with milk (MM) and a milk and water mix (MMW), muffins with water (MW) and MMW, the colour difference was not obvious to the human eye (ΔE < 1), but between MM and MW was not appreciable by human eye (1 < ΔE < 3) (Table 3). The crumb colour of all muffins was similar, and the added type of liquid did not affect the crumb colour of muffins.

In the Sanz et al. study, the influence of the addition of four types of resistant starch (RS) containing ingredients on the colour of muffins was studied. No significant differences were found in the L* parameter between the control (without resistant starch) and the RS type 3 containing muffins. On the contrary, RS type 2 containing muffins showed a lighter colour (L* significantly higher) in comparison to the control and the RS type 3 containing muffins, which was obvious to the human eye (ΔE > 3) [20].

Conclusions

1. Muffins with milk were by 5.37 % higher than muffins with a milk and water mix and by 9.83 % higher than those with water.
2. The type of liquid did not significantly ($p > 0.05$) influence the hardness of gluten-free muffins.
3. All gluten-free muffins had a similar moisture content; differences among the samples were insignificant – from 0.45 % (between muffins with a milk and water mix and with water) to 1.32 % (between muffins with a milk-water mix and with milk).
4. The type of the liquid added to the formulation affected ($p < 0.05$) the crust colour of muffins, but did not affect ($p > 0.05$) their crumb colour.

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ĮVAIRIŲ SKYSČIŲ ĮTAKA AKYTŲ BANDELIŲ BE GLITIMO KOKYBEI

S a n t r a u k a

Pastaruoju metu daugėja žmonių, kurie netoleruoja grūdų baltymų. Todėl gana svarbi maisto gamintojų užduotis – gaminti naujus, skanius ir maistingus produktus be glitimo. Vienas iš tokių produktų – akytos bandelės. Šiame darbe tirta įvairių skysčių (pieno, pieno ir vandens mišinio bei vandens) įtaka akytų bandelių be glitimo kokybei: kietumui, drėgmės kiekiui ir spalvai. Nustatyta, kad tirtų skysčių priedas turi įtakos bandelių tūriui ir plutos spalvai, tačiau neturi įtakos drėgmei, kietumui ir minkštimo spalvai.