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SENSORY CHARACTERISTICS OF MUFFINS ENRICHED WITH CARROT AND BEETROOT BY-PRODUCTS

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Abstract

Sensory characteristics significantly impact the quality of food products, and conducting sensory analysis is crucial in evaluating consumer acceptability. Therefore, this study aimed to investigate the sensory characteristics of muffins enriched with by-product flours (specifically carrot and beetroot pomace flour).

Five types of muffins were produced: control muffins (100% wheat flour), and muffins in which 10% and 20% of the wheat flour was substituted with carrot pomace flour, and 10% and 20% with beetroot pomace flour. The raw materials used in muffin production included white wheat flour, carrot and beetroot pomace flour, sugar, margarine, sunflower oil, milk, eggs, and baking powder. The muffin production process included measuring the raw materials according to specified recipes, homogenizing the ingredients, pouring the mixture into paper molds, baking (180 ^{0}C; 20 minutes), cooling to room temperature, and packaging. Sensory analysis was conducted using a hedonic scale ranging from 1 to 9 to evaluate individual criteria (color, shape, texture, smell, taste), and the overall acceptability of the muffins. The results were analyzed and statistically processed using Microsoft Office Excel and the statistical package XLSTAT 2017. The analysis of variance (ANOVA) with Fisher's least significant difference test was applied to indicate a significant difference at a 95% confidence level between the obtained results for the overall acceptability of the samples.

Of all the muffins produced, the muffins with 10% beetroot pomace flour were rated with the highest average color rating (8.20 points). In terms of shape and texture, muffins with 20% beetroot pomace flour were rated with the highest average score (8.53 and 8.20 points, respectively). Control muffins scored the best in terms of smell and taste (8.23 and 8.37, respectively). In terms of overall acceptability, the muffins with 10% beetroot pomace flour were rated the best (8.30 points). The muffins produced were not statistically different in terms of overall acceptability ($p > 0.05$).

From the conducted sensory analysis, it was established that the replacement of wheat flour with carrot and beetroot pomace flour in the amounts of 10% and 20% does not significantly affect the sensory characteristics of the muffins.

***Key words**: Sensory analysis, Muffins, Carrot pomace, Beetroot pomace.*

1. Introduction

Muffins are ideal products through which functional ingredients can reach consumers, because they are often consumed as breakfast or snacks by all age groups, primarily due to their specific characteristics such as strong sweet taste, specific shape and size, soft and delicate structure, and low cost [1]. Standard muffin batter is prepared from wheat flour that should contain 8% to 10% protein [2], vegetable fat or oil, eggs, milk, and baking powder [3, 4]. Each of these primary raw materials significantly affects the structure, appearance, and quality of the muffins [5, 6]. The muffin preparation technology described by Samokhvalova *et al.*, [7] and Yadav *et al.*, [8], involves separate mixing of liquid and dry ingredients.

During the past years, a large number of researches have been conducted to enhance the nutritional quality of muffins, as this type of product is known for its high energy content and low nutritional value [7] i.e. it is high sugar and fat content while lacking in protein, dietary fiber, antioxidants, and minerals [9, 10]. The preparation of muffins with high nutritional and biological value includes the incorporation of functional raw materials such as soy milk and flaxseed [11], almond flour and soybean flour [12], black rice flour [13], ground flaxseed [1], defatted sunflower seed flour [9], leaves and stems of spinach [14], processed sunflower flour [15], black rice flour, coconut flour and cocoa powder in different concentrations [4], barley flour [16], fruit and vegetable by-products [17 - 22], and others.

Vegetable by-products are the residues (peels, seeds, subcutaneous tissues, pulp, and pomace) that are created during the industrial processing of vegetables [23, 24] and end up as waste, which largely harms the environment, causing serious environmental problems mainly due to microbial degradation [25, 26]. They contain many beneficial components such as bioactive compounds, dietary fiber, fatty acids, proteins, and others [27] which are known to have anticancer, antiviral, antitumor, antimicrobial, and antioxidant properties [28].

Large quantities of by-products in the form of pomace are created during juice production [29]. The pomace is the remaining solid matter after the juice has been extracted and is usually the combination of the remaining seeds, husks, or peel and pulp [30]. Carrot pomace and beetroot pomace do not contain peel and seeds and consist of moist pieces of carrots and beetroot obtained by extracting carrot and beetroot juice [31]. In the production of carrot juice, 30 - 50% pomace is created [32, 33], and in the production of beetroot juice, 15 - 30% pomace is created [34].

Carrot pomace is rich in carotenes, particularly β-carotene (a pro-vitamin A), as well as dietary fiber, proteins, carbohydrates, vitamins, and minerals [35 - 38]. On the other hand, beetroot pomace is abundant in bioactive pigments called betalains, responsible for red coloration, as well as higher levels of phenolic compounds and dietary fiber [29, 34].
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Traditionally, vegetable by-products have been used as animal feed or processed into biogas, or compost for biofertilizer. However, current research indicates that these by-products can also be incorporated into various food products to enhance their nutritional value [39]. This approach not only helps to reduce the waste of by-products but also contributes to the improvement of the nutritional content of the final products [40].

Fresh carrot and beetroot pomace is easily susceptible to microbial spoilage due to its high moisture content, so to increase its shelf life and its further use, it is dried [29, 36, 38, and 41], and ground into flour/powder that can be further used as a functional ingredient in the production of various bakery-confectionery products [33, 36, 38, and 42].

There is currently a shortage of scientific data on incorporating by-products from carrot and beetroot juice production into muffins. However, scientific literature has reported the successful incorporation of carrot and beetroot pomace into various products such as wheat bread [41], low-fat doughnuts [43], extruded cereals [44], pasta [40, 45], biscuits [46], candies [47], and fermented drinks [48]. Nevertheless, the substitution of carrot and beetroot pomace flour alters the conventional composition of the products and may affect consumer acceptance [6].

The analysis of the sensory characteristics determines whether the product is acceptable to the consumer or not. Sensory characteristics are the first and often the only parameters based on which the majority of consumers evaluate the quality of food [49]. Sensory analysis is a subjective technique that relies on human senses to assess these characteristics [50]. Before being introduced to the market, new or improved products are typically subjected to sensory analysis to determine if they possess desirable and acceptable properties [51].

Based on the aforementioned findings, we deemed it crucial to examine how replacing wheat flour with varying amounts of carrot and beetroot pomace flour would impact the sensory characteristics of the resulting muffins. Sensory evaluation is crucial to the success of a new product in the market. To this end, we modified the basic muffin recipe and incorporated carrot and beetroot pomace flour to produce muffins that were subsequently subjected to sensory analysis.

2. Materials and Methods

The following raw materials were used as materials for the production of the muffins: white wheat flour T-500 (Žito Luks AD Skopje), sugar (Frukt Import, Skopje), margarine (Crystal, Blagoj Gjorev, Veles), eggs (Veni Kom, Čelopek), cooking oil (Crystal, Blagoj Gjorev, Veles), baking powder (Vitaminka, Prilep), and carrot and beetroot pomace flour. All raw materials are purchased from a local store in the city of Veles, Macedonia, except for carrot and beetroot pomace flour, which were laboratory-produced and procured from Bulgaria.

Carrot pomace flour and beetroot pomace flour are by-products derived from wet waste, or pomace,

generated during the production of carrot and beetroot juice. The pomace was dried at 45 ^{0}C for 48 hours using a dryer (UFE 500, Germany), ground into a fine powder using a grinder (IKA MF10, IKA®-Werke, Germany), and subsequently stored in air-tight containers until ready to be utilized.

The production of the muffins was carried out in a laboratory-controlled environment at the Faculty of Technology in the city of Veles, Macedonia according to the formulations presented in Table 1.

Table 1. Formulation adapted to different proportions of wheat flour, carrot pomace flour, and beetroot pomace flour

Raw materials; %*	Muffins				
	1M	2MC	3MC	1MB	2MB
Wheat flour	100	90	80	90	80
Carrot pomace flour	-	10	20	-	-
Beetroot pomace flour	-	-	-	10	20
Sugar	80	80	80	80	80
Margarine	28	28	28	28	28
Eggs	20	20	20	20	20
Milk	45	45	45	45	45
Cooking oil	23	23	23	23	23
Baking powder	2.4	2.4	2.4	2.4	2.4

Legend: *The quantity of all raw materials is expressed as a percentage of wheat flour; 1M - muffins with 100% wheat flour (control), 2MC - muffins with 10% replacement of wheat flour with carrot pomace flour; 3MC - muffins with 20% replacement of wheat flour with carrot pomace flour; 1MB - muffins with 10% replacement of wheat flour with beetroot pomace flour; 2MB - muffins with 20% replacement of wheat flour with beetroot pomace flour.

All raw materials were measured and brought to room temperature by the formulation presented in Table 1. First, sugar and margarine were homogenized (mixed) using a mixer for 3 minutes. Eggs, milk, and cooking oil were added to the mixture and the mixture was again homogenized for 3 minutes. Then the previously prepared homogenized mixture of baking powder, wheat flour/carrot pomace flour/beetroot pomace flour was added, and homogenization was continued for another 3 minutes. The resulting mixture (dough) was poured into paper molds (2/3 of their height). The filled paper molds were baked at a temperature of 180 ^{0}C for 20 minutes. After baking, the finished muffins were left to cool at room temperature. After cooling, the muffins were packed in PET packaging until they were used for the sensory analysis.

The sensory analysis of the produced muffins was carried out on the premises of the Faculty of Technology in the city of Veles, Macedonia, by 30 untrained panelists (staff and students from the faculty) aged 23 to 50 years. Using a hedonic scale, from 1 (extremely dislike) to 9 (extremely like) the odor, taste, color, shape, texture, and overall acceptability of the produced muffins were rated [20]. Before the start of the sensory evaluation, the evaluation procedure and the way of tasting each of the samples were explained to each of the panelists. Water was provided to rinse the mouth before tasting each sample.

The results obtained were analyzed and statistically processed using Microsoft Office Excel and the statistical package XLSTAT 2017. The statistical analysis of the results for the overall acceptability of the samples involved conducting an analysis of variance (ANOVA) and Fisher's Least Significant Difference - LSD test for the least significant differences with a significance level of 95% ($p < 0.05$).

3. Results and Discussion

Under laboratory conditions, we produced five types of muffins, namely: control muffins (100% wheat flour; 1M), muffins with 10% carrot pomace flour (2MC), muffins with 20% carrot pomace flour (3MC), muffins with 10% beetroot pomace flour (1MB), and muffins with 20% beetroot pomace flour (2MB). To provide a visual reference, Figure 1 presents digital images of the muffins we produced.

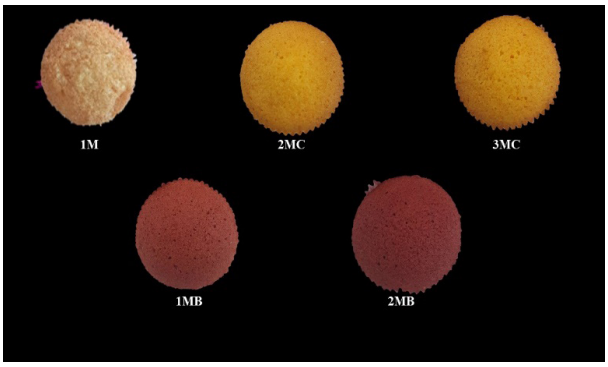

Figure 1. Digital images of the muffins produced with different percentages of carrot pomace flour and beetroot pomace flour
***1M - muffins with 100% wheat flour (control), 2MC - muffins with 10% carrot pomace flour; 3MC - muffins with 20% carrot pomace flour; 1MB - muffins with 10% beetroot pomace flour; 2MB - muffins with 20% beetroot pomace flour**

From Figure 1, it can be observed that the carrot and beetroot pomace flour muffins are characterized by a more intense yellow (2MC and 3MC) and red color (1MB and 2MB), respectively, compared to the control muffins. Sahni and Shere [52, 53] observed similar effects for fortifying cookies made with beetroot pomace flour and carrot pomace powder, respectively. The color of the muffins comes from the basic raw material (flour), but it is also created during the baking of the muffins when the products of the Maillard reaction are created. These compounds are

responsible for the color and also contribute to the flavor and texture of the muffins [54].

Carrot pomace flour's yellow-orange color is attributed to the presence of β-carotene [35] carotene, and its incorporation into the recipe intensified these hues (2MC and 3MC) [55]. The results were consistent with the analysis of bread made with the addition of 5, 10, and 15% carrot pomace powder, where an increase in color intense of products with pomace was reported as the amount of carrot pomace powder increased, which is due to carotenoids contained in carrots and the intensified reaction of melanoidin formation during baking [56]. As confirmed by Gull *et al.*, [57], who investigated the effect of carrot pomace flour on pasta, including its color and other parameters. β-carotene is a bioactive component with potent antioxidant activity that provides various health benefits, such as lowering the risk of heart disease and some types of cancer, strengthening the immune system, and more, in addition to the color it imparts to food products [57].

The intense red color of the muffins in which wheat flour is replaced with beetroot flour (1MB and 2MB) comes from the red-violet betacyanins present in the beetroot flour. These betacyanins are one of the two primary structural units of the bioactive natural pigments known as betalains [58], which are abundantly present in beetroot pomace [34]. Betalains possess antioxidant, anticancer, hepatoprotective, antibacterial, and anti-inflammatory properties, as well as intestinal and immune regulatory effects [58]. Due to the presence of betacyanins, beetroot pomace can be utilized as a natural colorant in the food industry [29].

The results obtained from the sensory analysis of the produced muffins with different proportions of carrot pomace flour and beetroot pomace flour are shown in Figure 2 and Figure 3. The values shown are calculated as the mean values of the evaluators' results.

Color is one of the major attributes which affects the consumer perception of quality and consumers have a preferred color for a specific food [59]. The results shown in Figure 2(A) indicate that replacing wheat flour with carrot pomace flour improves the color of the muffins. Muffins with 10% carrot pomace flour (2MC) and 20% carrot pomace flour (3MC) scored a higher number of points (8.03 and 8.00, respectively) compared to the control muffins (7.93). And for the muffins produced with beetroot pomace (Figure 2(B)), it can be stated that the muffins with 10% beetroot pomace flour (1MB), and 20% beetroot pomace flour (2MB) are rated with a higher number of points (8.20 and 8.17, respectively) compared to the control muffins (7.93). Muffins with 10% beetroot pomace flour were rated with the highest average color rating (8.20 points out of a possible 9.00).

The shape of the muffins is mostly correlated with their volume, and the volume of the muffins comes from the gluten present in the wheat flour used. Very often, the increased volume and attractive appearance of muffins after baking are lost during their cooling [60]. In our case, the replacement of wheat with carrot and beetroot pomace flour (which do not contain gluten) in the amount of 10% and 20% had a positive effect on the shape of the muffins (Figure 2). Namely, in terms of shape, muffins 2MC, 3MC, 1MB и 2MB are rated with a higher number of points (8.13, 8.07, 8.20, and 8.53, respectively) compared to the control muffins (7.87). Muffins with 20% beetroot pomace flour (2MB) were rated with the highest average rating for shape (8.53 points out of a possible 9.00).

The texture of muffins can be determined through an analytical method (using a texture analysis instrument) and can also be counted as a characteristic assessed through sensory analysis. From the results shown in Figure 2(A), it can be concluded that the control muffins in which the wheat flour was not replaced with

Figure 2. Sensory characteristics of the produced muffins
(A) Sensory characteristics of the produced muffins without carrot pomace flour (control muffins, 1M), with 10% (2 MC) and with 20% (3 MC) carrot pomace flour
(B) Sensory characteristics of the produced muffins without beetroot pomace flour (control muffins, 1M), with 10% (1MB) and with 20% (2MB) beetroot pomace flour

carrot pomace flour (1M) were evaluated with a higher number of points (8.00 points out of a possible 9.00) compared to the muffins in which the replacement was made. Muffins with 10% carrot pomace flour (2MC) and 20% carrot pomace flour (3MC) are rated with a lower number of points (7.80). In terms of texture (Figure 2(B)), muffins with 20% beetroot pomace flour (2MB) were rated as better (8.20 points out of a possible 9.00) compared to muffins with 10% beetroot pomace flour (1MB) and control muffins (1M) (7.97 and 8.00 points, respectively). Of all the muffins produced, muffins with 20% beetroot pomace flour scored the highest average score in terms of texture (2MB).

From the results shown in Figure 2, it can be noted that the control muffins (1M) in terms of odor and taste are rated with a higher number of points (8.23 and 8.37, respectively) compared to the muffins in which the replacement of wheat flour with 10% and 20% carrot pomace flour and with 10% and 20% beetroot pomace flour. The reason for the lower number of points scored for the muffins made with carrot pomace and beetroot pomace flour may be the new taste and odor, which deviates from the standard taste and odor of muffins made only from wheat flour, and consumers usually hesitate to accept modifications of the usually consumed products [61]. The incorporation of carrot pomace powder significantly influences the taste and odor of wheat rolls. It has been primarily attributed to terpenoids and sugars which are mainly responsible for the carrot flavor of carrot pomace powder [55]. Sani and Shere [52] observed that the values for the taste parameter varied with the addition of beetroot pomace flour in the cookies Increase in taste score was observed at a 10% level of supplementation due to the presence of peculiar beetroot taste in the cookies. Further, an increase in the level of incorporation resulted in a decrease in the sensory score for taste. According to researchers, this might be due to the development of bitter taste which could be attributed to the high tannin content of beetroot pomace flour.

Figure 3 presents the results obtained for the overall acceptability of the produced muffins.

Based on the results presented in Figure 3(A), it can be concluded that the control muffins (1M) are better accepted by the panelists. The control muffins in terms of overall acceptability were rated with 8.27 points, while the 2MC and 3MC muffins substituted with 10% and 20% carrot pomace flour were rated with 7.90 points. Similar results were reported by Turksoy and Özkaya [62] for cookies incorporated with carrot pomace powder (10%, 15%, 20%, and 25%). Sahni and Shere [53], also proposed developing cookies with carrot pomace powder (5%, 10%, 15%, 20%, and 25%). Cookies with 10 % carrot pomace powder were found to be the most acceptable.

From the results presented in Figure 3(B), it can be noted that in terms of overall acceptability, the muffins with 10% beetroot flour (1MB) were rated the best (8.30 points out of a possible 9,00). The control muffins were rated with 8.27 points, while the muffins in which the substitution was made with 20% beetroot flour (2MB) were rated with 8.10 points. The results were consistent with the analysis of cookies made with the addition of beetroot pomace flour. Overall acceptability scores of the cookies increased by up to 10 % of beetroot pomace flour [52]. Of all the muffins produced, in terms of overall acceptability, the muffins with 10% beetroot flour were rated the best (8.30 points). The statistical processing of the results showed that there is no statistical difference between 1M, 2MC, and 3MC and between 1M, 1MB, and 2MB in terms of overall acceptability ($p > 0.05$).

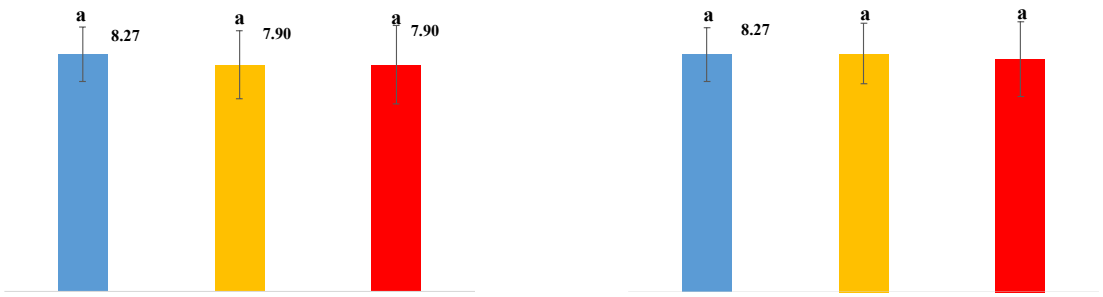

Figure 3. Overall acceptability of the produced muffins
(A) Overall acceptability of the produced muffins without carrot pomace flour (control muffins, 1M), with 10% (2 MC) and with 20% (3 MC) carrot pomace flour
(B) Overall acceptability of the produced muffins without beetroot pomace flour (control muffins, 1M), with 10% (1MB) and with 20% (2MB) beetroot pomace flour

Similar tests have been carried out on muffins enriched with different fruit and vegetable by-products, and a different level of acceptance of the enriched muffins has been determined. Different levels of apple pomace (5%, 10%, and 15%) from two apple cultivars were used to develop functional muffins [63]. Muffins with 10% apple pomace were rated with higher sensory scores compared to other muffins. Jung *et al.*, [64], prepared muffins replacing wheat flour with 10% and 20% apple pomace. The partial substitution of up to 20% of apple pomace had a positive effect on the sensory characteristics of the muffins. This was also confirmed by Sudha *et al.*, [65]. Górnas *et al.*, [17], found that the addition of sour cherry, raspberry, strawberry, and blackcurrant pomace (50 g/kg) to muffins did not affect the overall sensory acceptability of the enriched muffins. No significant changes in the sensory profile of muffins enriched with 20% grape pomace were determined by Mildner-Szkudlarz *et al.*,[66], and also insignificant differences between control muffins and muffins enriched with 7.5% and 15% flour from grape seeds were ascertained by Yalcin *et al.*, [67]. Bende *et al.*, [68], conducted a study incorporating Riesling and Tannat grape skin flour in the production of muffins (5%, 7.5%, and 10%) showing that this by-product can be used as an alternative for enrichment in muffins without harming the sensory characteristics of the products. A high level of acceptability of muffins containing white and red grapes pomace in concentrations of 10% was ascertained by OrtegaHeras *et al.*, [21].

4. Conclusions

- To respond to the increasing demand for healthy and functional products, innovations in the production of muffins are increasing. In this research, by modifying the basic formulation for making this baked product, muffins enriched with carrot pomace flour and beetroot pomace flour were trial produced, which resulted in obtaining an attractive product in terms of texture, color, shape, odor, taste, and overall acceptability, which is extremely important for the success of new products in the market. From the conducted sensory analysis, it was established that the replacement of wheat flour with carrot and beetroot pomace flour in the amounts of 10% and 20% does not significantly affect the sensory characteristics of the muffins.
- Future studies would be aimed at expanding the modified base formulation, finding an appropriate replacement ratio, and determining the physicochemical characteristics of the enriched muffins. The obtained results would fully define their nutritional profile and would represent a good basis for the development of acceptable functional muffins.
- Using these types of by-products (carrot pomace and beetroot pomace) on one hand tends to reduce waste from the food industry and achieve a sustainable economy, and on the other hand, underlines their use in the bakery-confectionery industry which can generate new functional products.

5. References

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