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THE IMPACT OF DIFFERENT MATCHA GREEN TEA POWDER ADDITIONS ON SELECTED QUALITY FEATURES OF CORN PUFFS

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Abstract

The aim of this research was to assess the possibility of using matcha green tea powder in the production of corn puffs, as well as to determine its impact on the quality features of the extrudates.

The research material consisted of corn puffs (without and with 1%, 3% and 5% addition of matcha green tea powder) obtained by the extrusion process under laboratory conditions. The aim of the research was realized by examining the mass, geometrical characteristics, hardness parameters using the Universal Testing Machine (Instron) and color using Digital Image Analysis of the extrudates. In addition, moisture and water absorption capacity of finished products and raw materials were determined.

It was shown that matcha green tea powder causes a significant extension of the products (with simultaneous effect on reducing the width), the lower share of the additive also affects the increase of their weight and volume. Matcha green tea powder changes the strength characteristics of corn puffs, primarily increases their hardness, which consequently leads to deterioration or even disappearance (5% addition) of elasticity and flexibility. On the basis of the obtained results, it can be concluded that 1–3% addition of matcha green tea powder to corn puffs not influence significantly on the quality features, and may be use in extrusion process to obtain a product with an attractive green color and probably a higher nutritional value.

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Introduction

A snack is a small portion of food that is often eaten between meals. Nowadays, consumers want snacks to be tailored to their needs and requirements (PĘKSA et al. 2007). The use of extrusion in the food industry enables the creation of a new range of products, definitely other than potato chips and pretzels that dominate the food snacks market (CISNEROS and KOKINI 2002). Corn puffs are very popular among consumers both adults and kids, the intake is about 21% of the total snacks consumption (MRUK and TELEŻYŃSKA 2009). They are most often made from corn or rice grits and are liked by consumers due to their characteristic sensory and physical characteristics (PASTOR-CAVADA et al. 2011). Corn puffs are characterized by small size, various shapes and also have a crisp texture. In addition, extrudates are completely microbiologically safe and can also be stored for a relatively long period of time due to their low moisture content (FILLI and NKAMA 2007).

The production process of extruded snacks consists of several stages, including mixing of ingredients (according to the recipe), material dispensing, extrusion with appropriate parameters adapted to the type of snacks (also shaping the final product using molding dies) and possibly drying the products to the appropriate moisture content for safe storage. The production of corn puffs is carried out at moisture content of the raw materials of 14–17% and at temperatures above 100°C, which allows to obtain a crunchy consistency of product as a result of rapid evaporation of water (MITRUS and WÓJTOWICZ 2011). Unfortunately, the nutritional value of extruded products, including corn puffs, is relatively low, this causes attempts to be made to enrich the products with nutrients using various additives (PĘKSA et al. 2007). Currently, cereals and vegetable additives such as amaranth, pumpkin, flax, and dry legume seeds are very popular (CHÁVEZ-JÁUREGUI at al. 2003). In addition, the production of corn puffs also uses protein preparations obtained from whey, soy, yeast, or potato (MIKOŁAJCZAK 2016, PĘKSA 2006), vitamin preparations and fiber (BISHARAT et al. 2013).

Matcha or matcha green tea is becoming increasingly popular product among consumers (TOWNSEND et al. 2011). It is obtained from the plant *Camellia sinensis*, which is grown in areas with mild climatic conditions and in shady places. Three to four weeks before harvest, the plants are almost completely shaded, which improves the quality of tea as a result of prolonged puberty (COOPER et al. 2005). Matcha tea is a valuable source of phenolic compounds (WEISS and ANDERTON 2003), among which the catechins dominate (they constitute 80% of all polyphenols). In addition, 59% of all catechins consist of epigallocatechin gallate (EGCG), which is the most widespread and bioactive polyphenol in green tea (COOPER et al. 2005, KOO and NOH 2007). WIGHTMAN et al. (2012) found that EGCG can reduce heart rate and the level of oxygenated hemoglobin, SCHOLEY et al. (2012) showed that it increases calmness and reduces stress, and the last studies of other authors clearly indicate its antiproliferative effect in cancer cells (DU et al. 2012).

Besides polyphenols, matcha tea contains significant amounts of free amino acids (mainly *L*-theanine, accounts about 50% of the total amino acids), and caffeine (WEISS and ANDERTON 2003). Studies with a dose of *L*-theanine in an amount of 200–250 mg showed that it affects mood, alertness, mental fatigue, relaxation and anxiety level (GOMEZ-RAMIREZ et al. 2009, ROGERS et al. 2008). While caffeine, which is a stimulant all over the world, increases blood pressure (BARRY et al. 2005), affects cognitive functions (EINÖTHER et al. 2010), and also provides better performance, motivation and concentration in a short time (PAULUS et al. 2015).

Research on the use of matcha green tea powder in food products are taken to a small extent (DIETZ et al. 2017). The technology of extruded products production allows the use of various raw materials that have a positive effect not only on nutritional and sensory elements of products, but also can cause significant and not always beneficial changes in their physicochemical properties (PASTOR-CAVADA et al. 2011). The aim of this research was to assessment of the possibility of using matcha green tea powder as an additive in the extrusion process, as well as its impact on selected quality features of corn puffs such as water absorption capacity, mass, color, geometrical and strength characteristics.

Materials and Methods

Corn grits (Krupiec, Krzymów, Poland) and matcha green tea powder (Taheebo, Michałowice, Poland) were purchased in one of the supermarkets in Olsztyn. Both products were characterized by the current date of shelf life, appropriate organoleptic characteristics, and until the extrusion process they were stored in a dry, cool and darkened place.

Corn puffs (without any addition, and with 1%, 3%, 5% share of matcha green tea powder) were obtained by extrusion process using an extruder type S45A-12-10U (Metalchem, Gliwice, Poland) with a power of 10 kW and efficiency of 10 kg h^{-1}, whose basic working element was a cylinder (length 12.0 mm, nominal diameter 15.0 mm) connected to the discharge nozzle (diameter 4.5 mm). The extrusion process was carried out at constant operating parameters: the cylinder temperature distribution profile was 105°C/130°C/110°C, the screw rotation was 80 rpm (revolutions per minute). Fresh extrudates were cooled (4 h at 19±2°C and relative humidity of 54±2%), packed in plastic bags and stored in cool and dry place until analyzes.

In raw materials (corn grits, matcha green tea powder) and corn puffs, the moisture content using the thermal research chamber KBC-100 W type (Wamed, Warsaw, Poland) according to the Polish Standard (*Chrupki – metody…* PN-A-88034:1998P) and water absorption capacity in accordance with the method given by EKIELSKI et al. (2013) were determined.

The mass of individual corn puffs was determined by weight using the laboratory weighing machine type PS600.3Y (Radwag, Radom, Poland), the volume by placing corn puffs in the cylinder, which was filled with a constant volume of amaranth seeds and read from the scale of the difference in volume, and geometrical features such as length and diameter were measured using a caliper. The specific density of corn puffs was determined by the weight-to-volume ratio of individual extrudates (MORSY et al. 2014). Based on the results of geometrical characteristics, the shape factor – elongation as the quotient of the length to the diameter of the product, as well as the expansion index as the quotient of the corn puff diameter to the diameter of the extruder nozzle were calculated (MORSY et al. 2014). The mechanical properties (displacement, hardness, energy compression) were determined by a Universal Testing Machine 4301 type (Instron, Massachusetts, USA), and the uniaxial compression test of individual product was used. The breaking stress was evaluated as the force divided by the cross-section area of corn puffs (LEE at al. 1999), while elasticity index as the product of strength (hardness) and displacement. The color of corn puffs (Figure 1) was measured with a Digital Image Analysis set and expressed in CIE L*a*b* color system (TAŃSKA et al. 2011). Images were acquired with a Nikon DXM-1200 (Nikon Instruments, Melville, USA) charge coupled device (CCD) color camera. Based on average values of CIE L*a*b* parameters for samples with green tea powder additive and control sample, estimated such color attributes as a total color difference

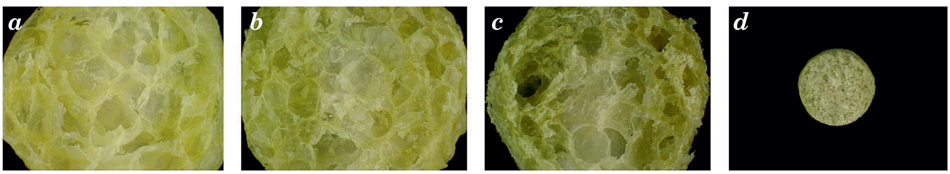

Fig. 1. Cross-section of obtained corn puffs: *a* – control; *b* – with 1% matcha green tea powder addition; *c* – with 3% matcha green tea powder addition; *d* – with 5% matcha green tea powder addition

(according to the equation given by TAŃSKA et al. (2017), a color saturation parameter (ΔC) and a saturation index (SI) (according to the equations given by GALUS and LENART 2012).

The results of all analyses (were made in five repetitions) were analyzed using Statistica 13.1 PL software (StatSoft, Kraków, Poland). The differences between the means were determined using analysis of variance (ANOVA) at a significance level $\alpha = 0.05$ with Tukey's test.

Results and Discussion

Table 1 shows the values of basic parameters such as moisture and water absorption capacity for raw materials (corn grits, matcha green tea powder) and obtained corn puffs.

The highest moisture was characterized by corn grits (12.76%). The use of the extrusion process and matcha green tea powder additives (moisture was 7.04%) significantly affected ($p < 0.05$) the moisture of the obtained products, reducing the moisture by an average of 5% in relation to the basic raw material (corn grits). The moisture content of corn puffs with matcha green tea powder additions were lower (7.02–7.80%) than the moisture of control corn puffs (7.98%) and were characterized by a positive correlation according to the share of the additive used.

Table 1

Basic characteristics of raw materials and obtained corn puffs

Parameter	Corn grits	Matcha green tea powder	Corn puffs			
			control	1% MP	3% MP	5% MP
Moisture [%]	$12.76^{a}\pm0.33$	$7.04^{d}\pm0.00$	$7.98^{b}\pm0.01$	$7.02^{d}\pm0.28$	$7.17^{c}\pm0.13$	$7.80^{b}\pm0.33$
Water absorption capacity [%]	$239.52^{f}\pm0.59$	$282.93^{d}\pm0.88$	$365.19^{c}\pm0.73$	$391.47^{b}\pm0.78$	$405.29^{a}\pm0.84$	$276.36^{e}\pm0.20$

MP – matcha green tea powder addition; *a*, *b*, *c*... – average values in lines with the same letter are not significantly different at $p > 0.05$

Corn grits was characterized by the lowest water absorption capacity of the analyzed products and amounted to 239.52%. The water absorption capacity of control corn puffs was 365.19%, while the use of 1% and 3% matcha green tea powder additives resulted in almost 30 and 40% increase in water absorption capacity of the obtained products, respectively (significant differences, $p < 0.05$). The addition of 5% matcha green tea powder had similar water absorption capacity as raw materials, in particular matcha green tea powder (282.93%).

Matcha green tea powder is characterized by low moisture content, which can affect the low values of this parameters in obtained corn puffs. Moisture content in obtained corn puffs is typical for brittle and crunchy extruded products obtained from cereals. Similar values were found for crispbread (GONDEK et al. 2013, JAKUBCZYK et al. 2015), breakfast extrudates with a varied composition (CHANVIER et al. 2014) and many other products. According to literature data, this moisture content is optimal from the point of view of storage stability (GONDEK et al. 2017).

The water absorption capacity index is a measure of the ability to absorb and maintain water by samples. It depends to a large extent on the applied temperature of thermal processing during the production of snacks and the water content in raw materials (GAMBUŚ et al. 2000). The research only partially confirms the accepted statement that corn puffs produced with a large share of starchy raw materials in the recipe show the greatest ability to absorb and retain water (WÓJTOWICZ and BALTYN 2006). A confirmation of this thesis is only a variant with 5% matcha green tea powder additive, where the share of corn grits (as a source of starch) account for 95% in whole product and ensures lower value of the water absorption capacity index than corn puffs (100% of corn grits in whole products).

Geometric characteristics of corn puffs were highly varied (Table 2). The largest mass (1.28 g) was obtained for corn puffs with 3% and 5% matcha green tea powder additions. This mass was more than 2-fold higher than for the control corn puffs and puffs with 1% matcha green tea powder additive. Different results were observed in the volume analysis, the largest volume was characterized by the control corn puffs and puffs with 1% and 3% matcha green tea powder additions (5.16–5.40 cm^3). Puffs with 5% addition had the smallest volume, which was only 1.68 cm^3 and was 3-fold lower than the control corn puffs (significant difference, $p < 0.05$). Densities of products, which were estimated as the quotient of mass and volume, showed a rising tendency (higher share of additive means higher density of products). According to this statement, the highest specific density was characterized by corn puffs with 5% matcha green tea powder additive (0.77 g cm^{-3}).

The use of 5% matcha green tea powder resulted in a significant increase in length (4.64 cm) and a simultaneous reduction in the width (0.60 cm) of products. Similar observations were noted for 3% matcha green tea powder addition, where the length was 4.29 cm and the width was 1.42 cm. The dimensions for the control corn puffs and puffs with 1% additive of matcha green tea powder slightly differed from each other ($p > 0.05$).

Analysis of parameters such as elongation and expansion ratio, which estimated on the basis of length and width, showed that the additives used in the research also influenced their values. In the case of elongation, matcha green tea powder addition of 3% and 5% significantly increased its value ($p < 0.05$), which was 2.4-(3% additive) and 6.2-fold (5% additive) higher than for the control corn puffs (1.25). However, the same additions resulted in a reduction of expansion ratio by almost 30 (3% additive) and 70% (5% additive), while expansion ratio was the highest for the control corn puffs and amounted to 4.07.

Table 2

Mass and geometrical characteristics of obtained corn puffs

Geometrical characteristics	Corn puffs			
	Control	1% MP	3% MP	5% MP
Weight [g]	$0.53^{b}\pm0.01$	$0.57^{b}\pm0.01$	$1.28^{a}\pm0.12$	$1.28^{a}\pm0.06$
Volume [cm^3]	$5.40^{a}\pm0.34$	$5.16^{a}\pm0.30$	$5.38^{a}\pm1.70$	$1.68^{b}\pm0.25$
Specific density [g cm^{-3}]	$0.10^{c}\pm0.01$	$0.11^{c}\pm0.00$	$0.26^{b}\pm0.10$	$0.77^{a}\pm0.10$
Length [cm]	$2.27^{d}\pm0.08$	$2.52^{c}\pm0.07$	$4.29^{b}\pm0.11$	$4.64^{a}\pm0.13$
Width [cm]	$1.83^{a}\pm0.02$	$1.64^{b}\pm0.04$	$1.42^{c}\pm0.08$	$0.60^{d}\pm0.00$
Elongation [-]	$1.25^{d}\pm0.04$	$1.54^{c}\pm0.06$	$3.00^{b}\pm0.12$	$7.77^{a}\pm0.16$
Expansion ratio [-]	$4.07^{a}\pm0.00$	$3.64^{b}\pm0.03$	$3.14^{c}\pm0.02$	$1.33^{d}\pm0.00$

MP – matcha green tea powder addition; a,b,c... – average values in lines with the same letter are not significantly different at $p > 0.05$

To sum up, the addition of matcha green tea powder increases the mass and density of corn puffs, and at the same time reduces their volume. The obtained corn puffs are also longer and thinner than the control corn puffs.

The expansion index indicates the degree of starch degradation in the product. The value of the expansion index depends on the type and amount of gelatinized starch, on the type and amount of additional raw materials, as well as on the extrusion conditions. The use of additives may contribute to a change in the temperature of starch gelatinization, which directly affects its expansion. The higher starch gelatinization index causes a higher value of the expansion index and contributes to a product with higher porosity and thinner pore walls (BISHARAT et al. 2013).

The addition of the largest amount (5%) of matcha green tea powder causes a reduction in the value of the expansion index. Literature data show that this effect may be caused by a higher share of protein and fiber fractions in the obtained product (STOJESKA et al. 2008).

The use of matcha green tea powder additions influenced the hardness parameters of corn puffs (Table 3). Analysis of the results showed a relation between the share of matcha green tea powder addition and the individual elements of hardness (a higher addition of matcha green tea powder resulted in higher values of individual parameters, $p < 0.05$).

Table 3

Strength characteristics of obtained corn puffs

Strength characteristics	Corn puffs			
	control	1% MP	3% MP	5% MP
Displacement [mm]	3.48^{b}±0.54	2.83^{c}±0.61	2.21^{d}±0.36	4.16^{a}±0.06
Hardness [N]	41.10^{d}±1.66	62.00^{c}±1.85	126.30^{b}±2.39	1005.10^{a}±2.96
Energy compression [mJ]	108.50^{c}±3.24	150.40^{c}±1.21	245.60^{b}±1.34	1105.22^{a}±6.45
Breaking stress [MPa]	9.74^{d}±0.34	13.93^{c}±0.96	20.13^{b}±1.42	354.82^{a}±1.88
Elasticity index [N mm]	153.45^{c}±3.44	181.63^{b}±1.07	162.96^{c}±2.45	4111.46^{a}±3.06

MP – matcha green tea powder addition; *a*, *b*, *c*… – average values in lines with the same letter are not significantly different at $p > 0.05$

Parameters such as hardness (41.10 N), energy compression (108.50 mJ), breaking stress (9.74 MPa) and elasticity index (153.45 N mm) were the lowest for the control corn puffs. The use of matcha green tea powder in an amount of 1% and 3% resulted in an increase in the value of individual parameters ($p < 0.05$), from 43% (1% addition for breaking stress) to even 126% (3% addition for energy compression). The most visible changes were observed for the highest matcha green tea powder addition in the amount of 5%. In this case, energy compression increased 10-fold, hardness and elasticity index 25–27-fold, and breaking stress up to 36-fold compared to control corn puffs (significant differences, $p < 0.05$). Slightly different results were obtained with regard to displacement. The addition of matcha green tea powder in the amount of 1% and 3% reduced the value of displacement by almost 20% for 1% additive and almost 38% for 3% additive in comparison to the control sample (3.48 mm). The significant increase ($p < 0.05$) was found only for corn puffs with 5% share of matcha green tea powder (4.16 mm).

Hardness is a parameter very often determined during the examination of food products. In the evaluation of extruded products, this is one of the most important decisive factors in their consumption suitability. The value of this parameter in extruded products should be as small as possible, which affects the high brittleness of products (SURÓWKA 2000).

The use of matcha green tea powder additive in the extrusion process results in an increase the hardness of the products, the significant differences at level of $p < 0.05$ are only present at the highest addition (5%). The literature data show the impact of production parameters and the composition of raw materials on the hardness of products. For example, FORNAL (1998) reports the hardness of extrudates with 10% of casein addition from 47 N to 86 N. Whereas RZEDZICKI (1999) states that extrusion with oat components up to 20% allows obtaining a high quality product with increased hardness of extrudates. A similar effect was observed by other authors who used various types of fiber (KITA et al. 2002) and protein preparations (PĘKSA et al. 2007).

Corn puffs without matcha green tea powder were the most flexible, which indicates their high ability to return to their original shape after stopping the deforming force. Matcha green tea powder contributed to the lower elasticity and flexibility of obtained corn puffs. The products with the highest addition (in amount of 5%) were characterized by very high values of these parameters, which results in the destruction of their structure during the compression test (no ability to return to the origin form), additionally they have a solid and hard structure (high values for hardness, breaking stress, energy compression).

One of the most important distinguishing features of the product, which are decisive for acceptance by the consumer, is color. Different systems and color models are used to define it, but the CIE L*a*b* model is the most popular. Parameter L* denotes brightness [%], parameter a* defines green (negative values) or red (positive values) color and b* defines blue (negative values) or yellow (positive values) color. The constituent values of the CIE L*a*b* model for the obtained corn puffs are presented in Table 4.

Negative values obtained for the a* parameter indicated the green color of the tested puffs. The highest share of greenness was observed for corn puffs with 5% matcha green tea powder addition (-6.46). The values for other variants were similar ($p > 0.05$) to each other ((-8.74) (-8.28)). The b* parameter was characterized by positive values, which was directly related to the occurrence of yellow color in the corn puffs. The most yellow color was observed for the control corn puffs (29.38) and puffs with 1% matcha green tea powder addition (29.46). The lowest value of this parameter was found for corn puffs with matcha green tea powder in the amount of 5% (almost 33% compared to the control sample). Analysis of the brightness parameter (L*) did not show significant differences between the control corn puffs and puffs with 1% matcha green tea powder additive. The least light were puffs with 3% matcha green tea powder (78.29%) and with 5% matcha green tea powder (78.38%) additions ($p > 0.05\%$).

Based on the constituent values of the CIE L*a*b* model, the difference in colors (ΔE) was determined by comparing the color of the control corn puffs with particular puffs variants with the addition of matcha green tea powder. In the discussion of results, the criteria given in RÓJ and PRZYBYŁOWSKI (2012) were used. Estimated values were in the ranges 2.44–11.78, which indicated the difference in color between the obtained corn puffs and control corn puffs. The determined difference in color between the control corn puffs and corn puffs with 1% matcha green tea powder was 2.44, which indicates a noticeable difference in color even for an inexperienced observer ($2 < \Delta E < 3.5$, according to RÓJ and PRZYBYŁOWSKI 2012). However, the significant differences ($p < 0.05$) was recorded for the control corn puffs and corn puffs with 3% and 5% matcha green tea powder additive (7.50 and 11.78, respectively), these values show a large deviation of color ($\Delta E > 5$, according to RÓJ and PRZYBYŁOWSKI 2012). Changes of color were also noticeable in the visual assessment of the obtained products (Figure 1).

Color saturation (ΔC) is characterized by the distance from the center of the system, the most saturated colors are on the outside, and the least saturated ones are in the middle of the system (CZAPSKI 1997). The estimated values of the color saturation parameter showed that the addition of matcha green tea powder causes a gradual increase in the color saturation of the tested extrudates (Table 4). The highest parameter value was observed for corn puffs with 5% matcha green tea powder addition (10.08), which indicates that the color of these corn puffs was more saturated (and thus more vivid) compared to the color of the control sample (the distance from the center of the system is large, the color directed towards the outside of the system). Whereas, 1% matcha green tea powder addition showed a small impact on the value of color saturation parameter, the estimated value for this variant was only 0.47 compared to the control sample. In addition, the color of these corn puffs was close to the center of the system (white color), which clearly indicated a light color (close to gray) and low saturated (shades of gray characterized by lack of saturation).

Table 4

Color attribute of obtained corn puffs

Color attribute	Corn puffs			
	control	1% MP	3% MP	5% MP
L* [%]	84.46^{a}±0.23	82.07^{b}±0.28	78.29^{c}±0.16	78.38^{c}±1.02
a* [-]	-8.28^{b}±0.26	-8.74^{c}±0.82	-8.39^{b,c}±0.57	-6.46^{a}±0.57
b* [-]	29.38^{a}±1.10	29.46^{a}±1.98	25.10^{b}±1.17	19.46^{c}±0.88
ΔE [-]	–	2.44	7.50	11.78
ΔC [-]	–	0.47	4.28	10.08
SI [-]	30.53	30.73	26.47	20.50

MP – matcha green tea powder addition; ΔE – total color difference between color attributes of sample with matcha green tea powder and control sample; ΔC – color saturation parameter between color attributes of sample with matcha green tea powder and control sample; SI – saturation index between color attributes of sample with matcha green tea powder and control sample; *a*, *b*, *c*… – average values in lines with the same letter are not significantly different at $p > 0.05$

The value of the saturation index (SI) for the control sample was 30.52 (Table 4). The use of matcha green tea powder addition during the production of corn puffs resulted in a decrease in the value of saturation index, excluding corn puffs with 1% matcha green tea powder additive (values comparable to the control sample). In the other two variants, the decrease in the saturation index value was noted by 13.30% (3% matcha green tea powder additive) and 32.85% (5% matcha green tea powder additive).

Color is an important physical feature of the product, which has a significant impact on the choice of the product by consumers. It can be a source of information about the chemical composition of the product, its suitability for consumption and the storage process (ŁUKASIEWICZ and ZAPOTOCZNY 2012). It was shown that the color parameters (in extrudates) change significantly even with small changes in the formula of mixtures and may be an indicator of their composition (ZIELIŃSKI 2013).

The addition of matcha green tea powder influences the color of the obtained products, which is mainly related to the dark and green color of additive. These changes were visible primarily with the addition of 3% and 5%, these results in a darker and greener color, as well as a lowering the share of yellow color. PĘKSA et al. (2015) studied the color of corn puffs with various additives. They found that brightness of the corn puffs after adding a mixture of flours containing powdered pumpkin resulted also in a decrease in the brightness of the color from level $L^* = 78.77\%$ to $L^* = 67.95\%$ compared to the control sample. Research conducted by LUCAS et al. (2018) showed that the addition of *Spirulina* sp. LEB 18 (in amount of 2.6%) had a significant effect ($p < 0.05$) on the color of the extrudates. The additive used by the authors resulted in a decrease in the values of the L^* and b^* parameters, which determined the darker color of the snacks. Similar tendencies were also found by TAŃSKA et al. (2017) during the analysis of corn extrudates properties (including color) enriched with spirulina.

The structure of corn puffs was porous, but its appearance depended on the amount of the additive (Figure 1). The control corn puffs were characterized by a small number of pores with thin walls (*a*). The use of matcha green tea powder additive resulted in an increase in the number of pores (*b*, *c*), and was also observed the presence of empty spaces filled with air (*c*). A change in the thickness of pore walls was also visible (*c*, *d*). The 5% addition of matcha green tea powder caused a compact structure with small pores (*d*).

Conclusions

The results obtained in this research indicate the possibility of using matcha green tea powder as the additive in the extrusion process. However, the use of a larger amount of the additive (in this case 5%) resulted in a dense and hard structure of corn puffs, which may mean the necessity of using additional treatments, e.g. grinding, which will allow the product to be used in direct consumption. Matcha green tea powder also changes the taste of corn puffs causing a noticeable bitterness during the consumption of the product which may result in a negative approach by consumers with a rather sweet taste preference.

Matcha green tea powder addition affects the quality features of obtained corn puffs:

1. The use of a small amount of additive (1% and 3%) affects the lower water content, while ensuring greater water absorption capacity of the final product.
2. Matcha green tea powder additions increase the mass and specific density of corn puffs (a larger share of matcha results in a higher value of these parameters), at the same time reduces the product volume (which the most visible changes are at 5% additive).
3. The addition affects the geometric characteristics of corn puffs. The obtained products are characterized by a gradual reduction in width, with simultaneous effect on product elongation.
4. The obtained products have other strength characteristics than control corn puffs. The addition of 5% matcha green tea powder significantly increases the hardness of the product, as well as reduces its elasticity and flexibility.
5. Matcha green tea powder additive affects the color of the final product, with increasing the share of matcha green tea powder, the color of the product becomes mimic and greener.

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