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Obradović, Valentina; Babić, Jurislav; Jozinović, Antun; Ačkar, Đurđica; Panak Balentić, Jelena; Grec, Marijana; Šubarić, Drago

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Teksturalna i senzorska svojstva kukuruznih ekstrudata s dodatkom mrkve u prahu i askorbinske kiseline

Obradović, V., Babić, J., Jozinović, A., Ačkar, Đ., Panak Balentić, J., Grec, M., Šubarić, D.

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TEXTURAL AND SENSORY CHARACTERISTICS OF EXTRUDED SNACKS PREPARED FROM CORN AND CARROT POWDER WITH ASCORBIC ACID ADDITION

Obradović, V.[1], Babić, J.[2], Jozinović, A.[2], Ačkar, Đ.[2], Panak Balentić, J.[2], Grec, M.[2], Šubarić, D.[2]

Original scientific paper
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SUMMARY

The primary object of this paper was to investigate the influence of carrot powder (CP) addition to corn grits at levels 4, 6 or 8% and ascorbic acid (AA) addition at levels 0.5 and 1%, on hardness, fracturability, expansion and density of the extrudates. Sensory attributes of the selected extrudates were scored by the panel of ten professional tasters. Extrusion was done at two temperature regimes: 135/170/170°C and 100/150/150°C. Lower temperature regime led to increased hardness and density of extrudates, but at the same time to better expansion. The addition of CP and AA led to decreased hardness and the expansion, but increased density at both temperature regimes. Sensory assessment gave satisfactory results, especially for E1 temperature regime and 4% of carrot powder addition.

Key-words: extrusion, snacks, corn, carrot, texture, sensory attributes

INTRODUCTION

Extrusion is high-temperature-short-time (HTST) physical treatment during which flours or starches are subjected to high temperatures and mechanical shearing at relatively low levels of moisture content (Martinez et al., 2014). Extrusion is rather attractive process because of its versatility (wide range of food products applications), high productivity, relative low cost, energy efficiency and lack of effluents (Selani et al., 2014). Extruded foods are composed mainly of cereals, starches and/or vegetable proteins. The major role of these ingredients is to give structure, texture and mouth feel (Anton et al., 2009). Unfortunately, these products tend to be nutritionally poor since they are energy dense, and low in health promoting ingredients. Furthermore, extrusion promotes starch depolymerisation leading to the amount of easily digestible carbohydrates increase resulting in high glycemic index product (Selani et al., 2014). Extrusion cooking has been investigated as a means of producing snacks meeting the dietary requirements of particular population groups. In order to achieve better acceptability of these products aromatization in which the flavor is sprayed onto final product (Menis et al., 2013) is commonly used after extrusion. The main objective of the first attempts to incorporate fruits or vegetables in extruded snacks was to introduce flavor inside the extrudates, rather than as a coating (Karkle et al., 2012). Unfortunately, the addition of alternate ingredients to starch significantly affects the texture, expansion and overall acceptability (Anton et al., 2009). These changes vary according to the nature

(1) Valentina Obradović, Ph.D. - Polytechnic of Požega, Vukovarska 17, Požega, Croatia, (2) Prof. Dr. Jurislav Babić (jbabic@ptfos.hr), Assist. Prof. Antun Jozinović, Assoc. Prof. Đurđica Ačkar, Jelena Panak Balentić, M. Eng., Marijana Grec, M. Eng., Prof. Dr. Drago Šubarić - Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, Osijek, Croatia

of added material. Texture is a critical sensory attribute that can dominate the quality of a product, as in snacks obtained through thermoplastic extrusion. Physical properties and sensory attributes of an extruded product are generally influenced by a large number of process and ingredient variables (Liu et al., 2000). In this research carrot powder is added to corn grits in order to improve nutritional and functional value of the snacks. Ascorbic acid is also added as a strong antioxidant which should protect nutritionally valuable ingredients originating from carrots.

The objective of this research was to investigate the influence of carrot powder and ascorbic acid addition to corn grits on textural and sensory attributes, being critical for actual acceptance of final product.

MATERIAL AND METHODS

Corn grits (particle size >500 μm) was obtained from "Žito" company Ltd, Osijek. Dried carrots (stripes) were purchased from Xinghua lianfu food Co. Ltd. China. They were ground to a powder by IKA MF 10 grinder (Ika-Werke GmbH & Co., Germany) through 2.0 mm sieve, vacuum sealed and stored in dark at room temperature. Ascorbic acid was purchased from T.T.T. Ltd, Sv. Nedjelja, Croatia.

Sample preparation

Levels of carrots addition and moisture content were selected according to the preliminary studies, in order to achieve extrusion process continuity and products with satisfying organoleptic properties. Corn grits and carrot powder were mixed in 96:4, 94:6 and 92:8 ratios (dry to dry weight), and ascorbic acid was also added to mixtures at 0%, 0.5% and 1% levels (dry basis). Total moisture of the mixtures was set to 15%, the mixtures were put in plastic bags, sealed and left in dark for 24 hours before the extrusion.

Extrusion experiments were performed using a laboratory single-screw extruder (model Do-Coder, Brabender 19/20 DN, Duisburg, Germany). Extrusion parameters were as follows: Temperature profiles: 135/170/170°C and 100/150/150°C; compression ratio screw 4:1; screw speed 100 rpm; feed rate 15 rpm. The obtained extrudates were air-dried at ambient temperature overnight, put in plastic bags, vacuum sealed and stored in darkness until the analysis.

Hardness and fracturability determination

Texture analysis was conducted on the texturometer TA.XT2 Plus, Stable Microsystem using the method "Measurement of the hardness and fracturability of pretzel sticks" with following settings: Pre-Test speed: 1.0 mm/s; Test speed: 1,0 mm/s; Post-Test speed: 10.0 mm/s; Distance 3 mm; Trigger Type: Auto - 5 kg (Altan, 2008). Results were expressed as a mean of 10 replications. Hardness is the peak force required for a probe of parallel blades to penetrate the extrudate. The higher the value of maximum peak force required, the higher the hardness of the sample (Meng, 2010).

Expansion ratio and bulk density

Expansion ratio: expansion ratio was measured according to Brnčić et al (2008) where expansion ratio (ER) was calculated as follows (Eq.1):

$$ER = \text{extrudate diameter (mm)/die diameter (mm)} \quad (1)$$

Bulk density (BD) of extrudates was measured according to Pan et al. (1998) and calculated according to Eq. 2:

$$BD = \text{extrudate mass (g)/extrudate volume (cm}^3\text{)} \quad (2)$$

Sensory analysis

Sensory analysis was conducted at Sensory Analysis laboratory in Karolina d.o.o. factory (manufacturer of snack products), Croatia, by the panel of ten professional judges. The analysis was done according to the quantitative response scale method. Following attributes were rated: Uniformity-color, structure-crispness, consistency-chewing, odor, flavor and overall quality. 15 samples (all 12 samples obtained at E1 extrusion temperatures, and only 3 samples obtained at E2 extrusion temperatures) out of 24 were selected for tasting. The selection of extrudates was based on preliminary tasting and instrumental determination of texture, which determined E2 samples as "to hard". The results are presented as the mean scores of sensory attributes.

Experimental design and data analysis

Textural analysis data were analysed using *Design expert 6.0.8*. software (Stat-Ease Inc., USA). Statistical significance of the regression coefficients was determined by analysis of variance (ANOVA), at 95% level. Sensory attributes results were analysed by *Statistica 8* software (StatSoft Inc., USA), using *post hoc LSD* at 95% level.

RESULTS

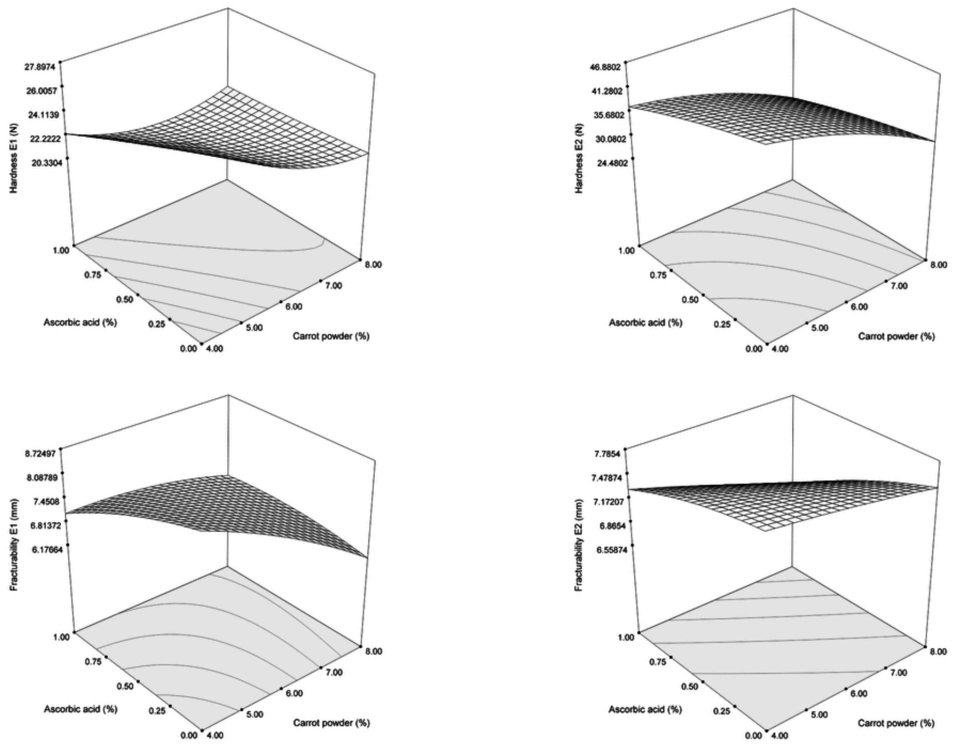

Figure 1. Textural properties of the extrudates
Slika 1. Tekstruralna svojstva ekstrudata

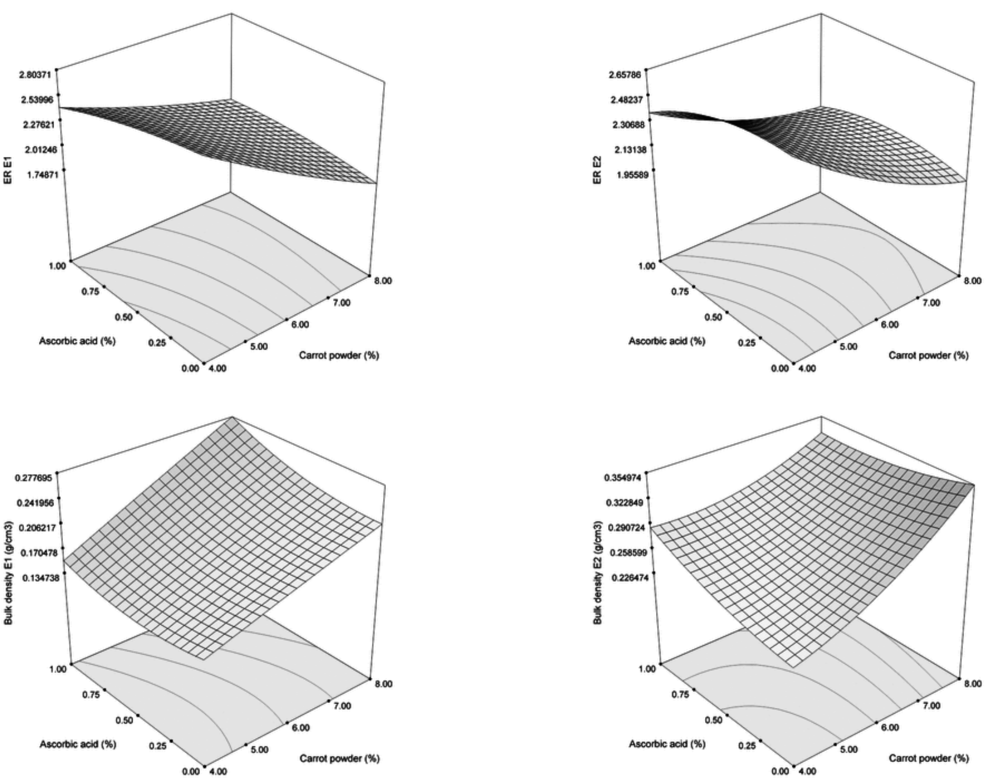

Figure 2. Expansion ratio and bulk density of extrudates
Slika 2. Ekspanzijski omjer i nasipna masa ekstrudata

Table 1. Sensory evaluation of the selected extruded samples

Tablica 1. Senzorska ocjena odabranih ekstrudiranih uzoraka

CP (%)	AA (%)	Extrusion temperature *Temperatura ekstruzije*	Uniformity, color *Ujednačenost, boja*	Structure, crispness *Struktura, hrskavost*	Consistency, chewing *Konzistencija, žvakljivost*	Odor *Miris*	Flavor *Ukus*	Overall quality *Cjelokupna kvaliteta*
0	0	E1	2.51^{a}	3.14^{a}	2.74^{ab}	2.57^{ab}	2.97^{a}	3.49^{a}
0	0.5	E1	3.31^{cde}	3.86^{abcde}	2.97^{abcd}	2.57^{ab}	3.20^{a}	3.98^{abc}
0	1	E1	3.43^{cde}	4.29^{e}	3.31^{bcd}	2.49^{ab}	3.31^{a}	4.21^{bc}
0	0.5	E2	3.66^{e}	3.14^{a}	2.60^{a}	2.80^{b}	3.43^{a}	3.77^{abc}
4	0	E1	2.70^{ab}	4.13^{de}	3.40^{cd}	2.63^{ab}	3.40^{a}	4.06^{abc}
4	0.5	E1	3.30^{cde}	4.25^{e}	3.50^{d}	2.70^{ab}	3.30^{a}	4.26^{c}
4	1	E1	3.20^{bcde}	4.38^{e}	3.40^{cd}	2.55^{ab}	3.00^{a}	4.13^{bc}
6	0	E1	3.00^{bcd}	4.13^{de}	3.20^{abcd}	2.55^{ab}	3.20^{a}	4.02^{abc}
6	0.5	E1	3.00^{bcd}	4.00^{cde}	3.20^{abcd}	2.48^{ab}	3.00^{a}	3.92^{abc}
6	1	E1	2.90^{abc}	3.88^{bcde}	3.00^{abcd}	2.40^{ab}	3.00^{a}	3.79^{abc}
8	0	E1	2.60^{a}	3.50^{abcd}	3.10^{abcd}	2.48^{ab}	2.90^{a}	3.64^{ab}
8	0.5	E1	2.60^{a}	3.88^{bcde}	3.30^{bcd}	2.48^{ab}	3.00^{a}	3.81^{abc}
8	1	E1	3.20^{cde}	3.88^{bcde}	3.00^{abcd}	2.55^{ab}	2.80^{a}	3.86^{abc}
4	0	E2	3.30^{cde}	3.25^{ab}	3.00^{abcd}	2.55^{ab}	3.30^{a}	3.85^{abc}
6	0.5	E2	3.50^{de}	3.38^{abc}	2.90^{abc}	2.33^{a}	2.90^{a}	3.75^{abc}

[A] Results were expressed as the mean of ten repetitions

[B] Means followed by the same letter in the rows are not statistically different at 5% probability.

CP-carrots powder level, AA-ascorbic acid level, E1- 135/170/170°C extrusion temperatures, E2-100/150/150°C extrusion temperatures

DISCUSSION

Instrumental measurement imitates bites and measures the peak force required for a probe of parallel blades to penetrate the extrudate. The higher the value of maximum peak force required, the higher the hardness of the sample (Meng et al., 2010). Hardness of the extrudates at different levels of carrot powder and ascorbic acid obtained at E1 and E2 extrusion temperatures is presented by surface plots (Figure 1). Comparing values for snacks with the same chemical composition, extrudates obtained at higher extrusion temperatures (E1) have lower hardness than extrudates obtained at E2 extrusion temperatures. Similarity was observed by Altan et al. (2008) and Obradović et al. (2015). Increasing temperature decreases melt viscosity, but it also increases the vapour pressure of water. This favours the bubble growth, being the driving force for expansion that produces low density products thus decreasing hardness of extrudates. Increasing level of carrot powder caused decrease of the hardness at both extrusion temperatures. Similarity was observed by Stojceska et al. (2010) during extrusion of corn, rice and potato starch with the addition of carrots, soy flour and milk powder and Obradović et al. (2015) during extrusion of corn grits with the addition of tomato powder, contrary to the findings of Huang et al. (2006) and Potter et al. (2013). Although it was expected that the addition of vegetables or other non-starch ingredients increase the hardness of the extrudates, it cannot be generalized. Several factors impact hardness: (1) fibre addition usually increases the hardness due to its effect on air bubble formation and cell wall thickness being confirmed by Huang et al. (2006) and Potter et al. (2013). On the other hand, Stojceska et al. (2008) showed that the addition of cauliflower to extruded products did not influence the hardness. (2) The level of sugar contributes to the increase in density and reduction in cell size of the extrudates which resulting in increased hardness (Potter et al., 2013). Increasing level of AA decreases the the extrudates hardness. Similarity was observed in the previous research (Obradović et al., 2015) during extrusion of corn grits with the addition of tomato powder and ascorbic acid. Decrease of the extrudates hardness with sulphurous acid level increase was observed by Chang and El-Dash (2003).

Fracturability can be described as the ability to break food into pieces when it is bitten using the incisors. As already mentioned, instrumental measurement simulates biting, hardness is maximum force required to break the snack stick, and distance in the moment of breaking is actually resistance of the sample towards bending. The sample which breaks at small distance, has big fracturability. Experimental results for fracturability of the extrudates, obtained at E1 and E2 extrusion temperatures are presented by surface plots (Figure 1). Application of lower extrusion temperatures E2 led to the increased values for fracturability as well as it was for hardness. Similarity was presented by Liu et al. (2000).

When the dough of extrusion mixture is leaving the die, the sudden drop in pressure causes rapid evaporation of superheated water present in the material. This leads to the bubbles formation, which grow in mass due to the pressure difference between the mass and the atmospheric pressure, i.e. expansion (Menis et al., 2013). It is considered that the dough viscosity is crucial for the degree of expansion (Ding et al., 2006). It is affected by several factors: temperature, water content, presence of other compounds like sugars or fiber. High temperatures reduce dough viscosity, allowing the matrix cells to collapse under the high vapour pressure (Bisharat et al., 2013). Besides, higher temperatures increase the temperature of superheated water present in the dough, thus increasing the pressure differential at the exit from the extruder promoting formation of bubbles and expansion (Menis et al., 2013). Water acts as a plasticizer which enables starch to undergo a glass transition during extrusion, facilitating the deformation of the mixture and reducing the expansion (Bisharat et al., 2013).

Figure 2 shows expansion ratio of the extrudates obtained at two different temperatures. Expansion ranged from 1.77 to 2.82 at E1 temperature regime, and from 1.95 to 2.61 at E2 extrusion temperatures. Comparing expansion of the extrudates with the same chemical composition but extruded at different temperatures, it can be seen that lower temperatures increased expansion (except in samples containing 4% of CP, with and without AA) which is in consistency with the results shown by Stojceska et al. (2010). There is a temperature range in which radial expansion of starch reaches maximum: this optimal temperature range depends on the type of starch and moisture content. Expansion decreases with temperature, most likely, due to excessive softening and potential structural degradation of the starch melt, which becomes unable to withstand the high pressure and, therefore, collapses (Lobato et al., 2011). In this case, maximum expansion is obviously between applied temperatures, and after that it decreases again because of the starch structural degradation. As shown on the surface plot (Figure 2), carrot powder level increase caused decrease of expansion ratio. Stojceska et al. (2010) also showed that incorporation of raw materials rich in fibre leads to decrease of air bubbles in microstructure of extrudates and reduced expansion. This can be explained by the interaction between fibres and proteins originated from vegetables and starch, and to the reduced elasticity due to the presence of proteins and fibres (Karkle et al., 2012). Besides, fibres may bind water more strongly than starch, inhibiting water loss at the die and reducing its ability for expansion. Fibres can also cause rupture of cell walls and prevent air bubbles to expand to maximum level (Bisharat et al., 2013).

Surface plots for bulk density of extrudates obtained at E1 and E2 extrusion temperatures are presented at Figure 2. Bulk density ranged 0.139-0.273 g/cm^3 for E1 extrusion parameters, and 0.221-0.372 g/cm^3 for E2 extrusion parameters. Low values for density are desirable and obtained values are considered good. Similar to ER, density is a parameter that can also be used to assess the degree of expansion of the extrudates. However, expansion ratio considers only cross-section of the material and density considers expansion in all directions (Menis et al., 2013). Lower extrusion temperature regime increased bulk density, being in accordance with the results shown by Anton et al. (2009). Higher temperatures increase degree of starch gelatinization (Hagenimana et al., 2006; Yu et al., 2013), resulting in decreased density. Samples with higher density (E2 temperature regime) have higher hardness, which is expected, but at the same time better expansion. Sealew et al. (2012) explained that ER and density can be related but it is not always the case. Addition of carrot powder caused increase of bulk density (Figure 2) at both extrusion temperatures, At the same time carrot powder addition increased hardness and decreased expansion. AA addition had significant positive influence only at E1 extrusion temperatures, while at E2 extrusion temperatures it did not affect density significantly.

Mean values of scores for sensory attributes are shown in Table 1. The worst scored samples for uniformity and color are: corn grits extrudate without any additives (2.51) and extrudates containing 8% of carrot powder (2.60). The highest scores for color were assigned for all extrudates obtained at lower extrusion temperature (E2). This temperature positively affected compounds (primarily carotenoids) responsible for color and reduced their degradation. Unfortunately, the same samples obtained the lowest scores for structure and consistency which is expected, considering instrumental measurement of hardness that showed the highest hardness for these samples. The best scored structure (above 4 out of 5) and consistency (approximately 3.50 out of 4) obtained samples with 4% of carrot powder, extruded at E1 temperatures, with or without AA. The best scores for odor obtained the pure corn grits extrudate with the addition of 0.5% AA, extruded at E2 extrusion temperatures. The worst scored was the sample containing 6% carrot powder and 0.5% ascorbic acid. Scores for other samples did not show any statistical difference. Flavor scores are similarly distributed as odor scores, but the worst scored (below 3 out of 4) were samples with the addition of 8% of carrot powder, without AA and with 1% of AA. The best scored overall quality (above 4 out of 5) obtained samples containing 4% of carrot powder, with and without AA, extruded at E1 extrusion temperatures. The worst scores obtained all samples extruded at E2 extrusion temperatures and sample without any additives extruded at E1 extrusion temperatures. Based on the above it can be concluded that the addition of carrots to corn grits is desirable since pure corn extrudates are usually flavored, but higher levels are not very attractive. AA is also more desirable at 0.5% level than 1% level since some tasters commented 1% as "too sour" although it cannot be seen directly from the mean values for scores.

CONCLUSION

The results of this research demonstrated possibility of producing fortified snacks with CP and AA addition with satisfactory textural and sensory properties. The product responses were affected by the proportions of CP and AA, but all levels of additives used in this research resulted in acceptable results. However, E1 temperature regime is favoured for hardness and density although it resulted in higher starch degradation and consequently lower expansion. The best sensory results had samples extruded at higher temperatures, 4% of CP and no more than 0.5% of AA.

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ETHICAL STATEMENTS

The authors declare that they do not have any conflict of interest.

This study does not involve any human or animal testing.

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TEKSTURALNA I SENZORSKA SVOJSTVA KUKURUZNIH EKSTRUDATA S DODATKOM MRKVE U PRAHU I ASKORBINSKE KISELINE

SAŽETAK

Cilj je ovoga rada bio odrediti utjecaj dodatka mrkve u prahu (eng. carrot powder/CP) u udjelima 4, 6 ili 8% i askorbinske kiseline (eng. ascorbic acid/AA) u udjelima 0,5 i 1% u kukuruznu krupicu na tvrdoću, lomljivost, ekspanziju i nasipnu masu ekstrudata. Senzorska svojstva odabranih ekstrudata odredio je panel od 10 senzorskih ocjenjivača. Ekstruzija je provedena pri dva temperaturna režima: 135/170/170°C i 100/150/150°C. Niži temperaturni režim doveo je do povećanja tvrdoće i nasipne mase ekstrudata te, istovremeno, do bolje ekspanzije. Dodatkom CP i AA, smanjila se tvrdoća i ekspanzija, ali se povećala nasipna masa kod oba temperaturna režima. Senzorska je analiza dala zadovoljavajuće rezultate, osobito za E1 temperaturni režim te 4%-tni dodatak mrkve u prahu.

Ključne riječi: ekstruzija, snack proizvodi, kukuruz, mrkva, tekstura, senzorska svojstva

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