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Research Article

Physicochemical and sensory characteristics of extrudates from rice enriched with pumpkin

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Abstract

The purpose of this work was to study the effect of pumpkin flour (10% and 20%), moisture content of initial mixture (14% and 20%) and working screw speed (180 min⁻¹ and 220 min⁻¹) on the physicochemical (expansion, density, hardness, colour) and sensory characteristics of rice extrudates enriched with pumpkin produced on a single screw extruder. The chemical composition before and after extrusion was also determined. The ash, lipids, reducing sugars, total sugars and total protein remained unchanged before and after extrusion while the carotenoids decreased after extrusion. The increase in the pumpkin flour led to a decrease in the expansion and lightness, and an increase in the density, hardness and redness of extrudates. The effect of the moisture content was inversely proportional on the expansion and redness, while it was directly proportional on the density, hardness and lightness. The screw speed increased the expansion, hardness and lightness of the extrudates, decreased the redness and had no significant effect on the density. The highest sensory score was achieved at a moisture content 14%, pumpkin flour 10% and screw speed 220 min⁻¹. The moisture content had the most significant effect on the characteristics of the extrudates.

Keywords: extrusion, rice, pumpkin

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Introduction

As the food industry continues to experience changes due to the constantly altering interests and habits of customers, producers tend to be innovative and productivity-driven. Consumers anticipate interesting appearance, attractive, flavourful and appetizing food that is as most as possible abundant in dietary fibre, protein, biologically active compounds with high antioxidant activity, such as polyphenols (Alvarez-Jubete et al. 2010; Černiauskiene et al. 2014; Peressini et al. 2015).

Extrusion technology allows the combination of different raw materials. During the process, they pass through many chemical and structural transformations, such as starch gelatinization, protein denaturation, complex formation between amylose and lipids, degradation reactions of vitamins, pigments, etc. (Ilo and Berghofer 1999). Total starch gelatinization provides production of extrudates with a typical porous structure, whilst proper expansion provides low density and soft, crunchy texture. The addition of raw materials containing significant amounts of dietary fibre, sugar or fat can delay or block this process of starch gelatinization, thus resulting in reducing of the sensory as well as the physicochemical properties of the extruded products (Peressini et al. 2015; Capriles et al. 2009; Bisharat et al. 2013; Ding et al. 2005; Mezreb et al. 2006). Despite the fact that extrusion processing is used a lot, it is a complicated process that can still be a challenge. Small variations in conditions of processing affect variables as well as product quality (Desrumaux et al. 1999).

Rice flour is one of the main raw materials that provides preferable properties of food in the extrusion industry due to its unique attributes such as bland taste, hypoallergenicity, and ease of digestion (Kadan et al. 2003). It is rich in group B vitamins, magnesium (Kayahara et al. 2000), essential amino acids, fibers (Frias et al. 2005), and many bioactive substances such as γ -oryzanol, tocopherols, tocotrienols and phenolic compounds that have health properties due to their antioxidant activity (Fernandez-Orozco et al. 2008).

Pumpkin flesh is rich in antioxidants, vitamins and other biologically active ingredients such as β -carotene, a vitamin A precursor (Hui 2004; Hien and Minh 2021). It also contains appreciable levels

of pectin, a soluble fibre that delivers many good health benefits (Nor et al. 2013).

Pumpkin fruit is widely used for production of pumpkin flour, suitable for different kind of foods. A potential use of pumpkin flour is for expanded products market where pumpkin can be used to enhance naturally the flavour and colour of these products (Nor et al. 2013).

Considering the fact that enrichment of foods with antioxidant compounds is useful to human health and nutrition, it seems worthy of optimizing the extruding conditions of newly designed extruded products enriched with pumpkin flour as a natural source of bioactive compounds.

The purpose of this research was to investigate the physicochemical and sensory characteristics of rice extrudates enriched with pumpkin.

Materials and Methods

Materials

Rice flour. The study was conducted with rice from the enterprise Familex Ltd. (Bulgaria), purchased from the market. The rice was ground to flour in a laboratory stone mill (BG Agro Ltd., Bulgaria).

Pumpkin flour. The pumpkin flour was obtained from pumpkin from the species *Cucurbita maxima*. The pumpkin was washed, peeled and cut into pieces with 6 mm thickness using a slicer (Berkel 250 TG, Van Berkel, USA).

The pumpkin pieces were dried in a convection oven (Lainox Aroma PE/005D, Lainox, Italy) with hot air at 70°C for 480 min until moisture content of 8.1 %, then milled with a blender (Moulinex Type A 505, Moulinex, France). The flour with a particle size below 450 μ m was sealed in polymeric bags and stored.

Methods

Preparation of the initial mixtures for extrusion.

The rice and pumpkin flour were mixed at 90:10 and 80:20 ratio. The samples were then moistened to achieve a specific moisture content, homogenized and placed in polyethylene bags for refrigeration storage at 5°C for 12 h. The samples were tempered for 2 h at a room temperature before extrusion.

Drinking water, complying with Ordinance № 9 of the Ministry of Health from 16.03.2001 on drinking

water quality, was used for moistening of the samples.

Extrusion. The extrusion was carried out on a Brabender 20DN single screw extruder (Brabender GmbH & Co KG, Germany) (Genev et al. 2019); with: nozzle diameter 3 mm; screw compression ratio 4:1; feeding screw speed 40 min⁻¹; temperatures in the first, second and third zones 140°C, 160°C and 180°C, respectively.

Statistical processing. A full factorial experiment (N=2³) was used to show the interaction between the pumpkin flour (X₁), the moisture of initial mixture (X₂), and the working screw speed (X₃) on the physicochemical (hardness, expansion ratio, bulk density, colour) and sensory (overall acceptability, colour, smell, product's texture, taste) characteristics of rice extrudates enriched with pumpkin. The design of the experiment is presented in Table 1. A three-fold repetition was used at each experimental point in the design.

Table 1. Design of the experiment with natural and coded values of the factors

№	Natural values			Coded values		
	Pumpkin flour, %	Moisture, %	Working screw speed, min ⁻¹	X ₁	X ₂	X ₃
1	10	14	180	-1	-1	-1
2	20	14	180	+1	-1	-1
3	10	20	180	-1	+1	-1
4	20	20	180	+1	+1	-1
5	10	14	220	-1	-1	+1
6	20	14	220	+1	-1	+1
7	10	20	220	-1	+1	+1
8	20	20	220	+1	+1	+1

A linear regression equation with interactions of the factors at a confidence level of 95 % was used to describe the dependencies with coded values:

$$y = b_0 + \sum_{i=1}^n b_i X_i + \sum_{i=1}^n \sum_{j=1}^n b_{ij} X_i X_j \quad (1)$$

where: b_0 , b_i , b_{ij} were a free coefficient, coefficient of linear effect and coefficient of interaction, respectively.

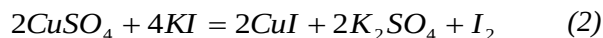
The critical value of Fishers-criterion F_c was used to evaluate the adequacy of the models.

All analyses were performed in triplicates. The values of chemical composition analysis were submitted to variance analysis, and the comparisons between the means were performed by the Fisher's least significant difference test at 5% significance level.

Determination of chemical composition of initial mixtures and extrudates:

- Determination of moisture content - ISO 712:2009;
- Determination of ash yield by incineration - ISO 2171:2007;
- Determination of the nitrogen content and calculation of the crude protein content - Kjeldahl method, ISO 20483;
- Total lipids - AOAC 945.16, 2000;
- Reducing sugars, %

Reducing sugar content was determined indirectly by titration of excess copper sulphate remaining after reduction of the Fehling solution. In excess of potassium iodite, the divalent copper from the Fehling solution releases an equivalent amount of free iodine by the equation:



The separated iodine was titrated with sodium thiosulphate solution in the presence of a starch indicator.

- Total sugars, %

Total sugar content was determined following the reducing sugar procedure after its inversion with the help of concentrated HCl.

- Total carotenoids, mg.kg⁻¹

The total carotenoid content of the initial mixtures and extrudates were analysed according to the method described by Higby (1962) with modification. A representative portion of the sample (2 g) was accurately weighed into a glass tube. Twenty-five ml of chilled acetone was added and the tube was kept in dim light for 10 min with shaking periodically. Then it was transferred to a Buchner funnel and filtered under vacuum. The procedure was repeated three times or until the sample was completely discoloured. The resulting extract was transferred to a 500 ml separatory funnel and 40 ml of petroleum ether were added. The acetone was removed by slow addition of ultrapure water to prevent the formation of an emulsion. The aqueous phase was discarded. This procedure was repeated four times until no residual solvent remained. The extract was then transferred through a funnel into a 50 ml volumetric flask containing 15 g of anhydrous sodium sulphate and made up to the mark with petroleum ether. Absorption at 440 nm was recorded by a UV-vis spectrophotometer Camspec M107 (Spectronic CamSpec Ltd., UK). The results were expressed in mg/kg and were calculated by the equation (3), where A was absorption at 440 nm, V - total volume in cm³, m - sample mass in g, $A_{1\%}^{1\text{cm}}$ - molar absorption coefficient for petroleum ether:

$$C_{\text{carotenoids}} = \frac{A \cdot V \cdot 10^4}{m \cdot A_{1\%}^{1\text{cm}}} \quad (3)$$

Physicochemical characteristics:

- Expansion ratio

Expansion ratio was measured as the ratio of the diameter of the extruded product to die diameter multiplied by 100. The diameter of 10 samples was

taken at random using a digital calliper (Model 823-160, Mannesmann, Germany) with accuracy of 0.01 mm.

- Bulk density

The bulk density of the dry extrudate (*D*) was defined as the ratio of the mass to the volume of the cylindrical sample.

$$D \text{ (density)} = \frac{4 \times m}{\pi \times D^2 \times L} \quad (4)$$

where *m* was the mass of a cooled extrudate (g) with a length *L* (cm) and a diameter *D* (cm). Ten replicates of extrudate were randomly selected and an average was taken.

- Hardness

The hardness of the extrudates was measured on a minimum of 15 samples with a TA.XT Plus Texture Analyzer (Stable Micro Systems Ltd., England) using a 50 kg load cell and a 2-bladed Kramer shear cell (Pre-test speed 1 mm.s⁻¹; Test speed 2 mm.s⁻¹; Post-test speed 10 mm.s⁻¹; Strain 90 %). The strength-time curve obtained in the test was analysed by determining the value of the maximum peak of the curve (*F*, *N*) representing the resistance exerted by the extrudate upon penetration of the probe and characterizing the hardness of the sample.

- Colour characteristics

The extrudates were ground in a laboratory mill to a particle size of 200 μm, after that their colour was instrumentally determined by a CIE Lab colour system Colorgard 2000 (Pacific Scientific, Maryland, USA), where: *L* - brightness (*L* = 0 - black, *L* = 100 - white), +*a* - red, -*a* - green, +*b* - yellow, -*b* - blue.

The difference in colour change Δ*E* was determined by the following formula:

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (5)$$

where:

L, *a* and *b* were the values of the extruded samples and *L*₀, *a*₀ and *b*₀ were the values of the non-extruded mixtures (Table 2).

Ten measurements were taken of each sample. The colour coordinates of each sample represented the arithmetic mean of the measured 10 coordinates.

Table 2. Colour coordinates of non-extruded mixtures of rice and carrot flour

Pumpkin flour, %	L_0	a_0	b_0
10	88.62	4.45	46.38
20	82.38	7.71	47.97

- Sensory evaluation

Thirty panellists comprising 15 males and 15 females were randomly chosen among staff and students of the University of Food Technologies - Plovdiv, Bulgaria to evaluate the extruded product without any knowledge of the formulation of the product. The panellists were asked to evaluate the

overall acceptability, colour, smell, product's texture and taste of this product using a structured nine-point hedonic scale (Stone and Sidel 2004). The sensory evaluation was conducted in a lab. Drinking water was provided to clean and rinse the mouth between samples. The samples were placed in shallow white cup and were coded using a random three-digit number. They were served under normal lighting conditions at a room temperature (24°C).

During the sensory analysis, the panellists determined how each extrudate was compared with the other by considering a number of different attributes related to appearance, taste, flavour, texture and overall acceptability.

Table 3. Composition of initial mixtures and extrudates from rice and pumpkin flours referred to an absolute dry weight basis

No	Ash, %	Lipids, %	Reducing sugars, %	Total sugars, %	Total proteins, %	Carotenoids, mg.kg ⁻¹
Mixture with 10 % pumpkin flour	1.57±0.04 ^a	0.43±0.03 ^a	2.54±0.08 ^a	9.38±0.09 ^a	7.90±0.09 ^a	62.40±0.90 ^a
Extrudate with 10 % pumpkin flour	1.51±0.05 ^a	0.36±0.03 ^a	2.94±0.04 ^a	9.51±0.20 ^a	8.05±0.11 ^a	13.59±0.55 ^b
Mixture with 20 % pumpkin flour	2.79±0.06 ^a	0.52±0.04 ^a	6.62±0.06 ^a	12.65±0.11 ^a	8.70±0.07 ^a	115.90±1.30 ^a
Extrudate with 20 % pumpkin flour	2.53±0.04 ^a	0.46±0.04 ^a	6.81±0.03 ^a	12.94±0.21 ^a	8.91±0.12 ^a	25.25±0.70 ^b

Note: Different small letters (a, b) showed a significant difference between the composition of mixture and extrudate with the same pumpkin flour ($p < 0.05$)

Results and Discussion

Chemical composition. Table 3 shows the chemical composition of initial mixtures and extrudates from rice and pumpkin flour. There was no statistically significant difference in the ash, lipids, reducing sugars, total sugars and total protein content between initial mixtures and extrudates ($p > 0.05$). The amount of total carotenoids decreased in the extrudates compared to the initial mixtures ($p < 0.05$). The reason for this is included in the high speed and temperatures during extrusion which leads to higher amounts of mechanical and thermal stress in the extruded material. The combination of these two factors leads to a significant loss of β -carotene due to its unsaturated structure. In addition, the high temperature accelerates the oxidation and isomerization reactions associated with the

degradation of carotenoids (Carbonell-Capella et al. 2014). The effects of the high temperature and mechanical forces during extrusion on the β -carotene content were also studied by Kaisangsri et al. (2016).

Physicochemical characteristics

Expansion ratio. Table 4 presents the averages and standard deviations of the expansion ratio of extrudates. It varied between 1.97 and 3.40. The results were similar to those of Ding et al. (2005), who obtained expansion index values from 2.02 to 3.87 for rice-expanded products.

Table 4. Expansion ratio of the extrudates

No	Expansion ratio
1	2.93±0.03
2	2.21±0.07
3	2.52±0.10
4	1.97±0.03
5	3.40±0.07
6	2.26±0.03
7	2.48±0.07
8	2.07±0.12

The obtained regression model is presented in equation (6). The variables X_1 and X_2 both influenced inversely proportional on the examined parameter, while X_3 – directly proportional. The factor with most significant effect was X_1 , the less significant effect had X_3 .

$$\text{Expansion} = 2.480 - 0.353X_1 - 0.221X_2 + 0.075X_3 + 0.114X_2 - 0.059X_2X_3 \quad (6)$$

$$R^2 = 95.9 \% \quad F = 2.5 < F_C = 3.6$$

The effect of the pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3) on the expansion ratio is represented on Fig. 1. When the moisture content of the initial mixture increased, the expansion ratio decreased, which is in accordance to the data of [Ding et al. \(2005\)](#) and [Toshkov et al. \(2021\)](#). Increasing the moisture content of the initial mixture leads to a change in the molecular structure of amylopectin, which reduces the elasticity and thus decreases the expansion. Increasing the extruder screw speed results in a higher pressure of the product which increases the expansion while the density decreases ([Gat and Ananthanarayan 2015](#)). Increasing the pumpkin flour from 10 % to 20 % decreased the expansion which proved the result of [Nor et al. \(2013\)](#). This could be explained by the reduction in the amount of starch in the initial mixtures with a higher pumpkin flour.

Density. Table 5 shows the averages and standard deviations for the density of the extrudates. It varied between 0.12 and 0.37 g.cm⁻³. The results showed that the density of the extruded products changed inversely to the expansion index because denser products tend to be less expanded. The same tendency was observed by [Gat and Ananthanarayan \(2015\)](#) for other types of extrudates.

Table 5. Density of the extrudates

No	Density (D), g.cm ⁻³
1	0.11±0.003
2	0.18±0.004
3	0.26±0.021
4	0.37±0.009
5	0.12±0.004
6	0.18±0.006
7	0.26±0.019
8	0.37±0.035

The variables X_1 and X_2 had directly proportional effect on the examined parameter, and the X_2 had the most significant effect (equation 7). Among the three factors examined, X_3 had no significant effect.

$$\text{Density} = 0.231 + 0.042X_1 + 0.083X_2 + 0.011X_1X_2 \quad (7)$$

$$R^2 = 97.2 \% \quad F = 1.3 < F_C = 3.0$$

The lowest density values were obtained at a low moisture content and low working screw speed, while the highest values - at high levels of these two factors (Fig. 2). The strong dependence of the density on moisture content is due to its influence on the elastic properties of starch. Increasing the moisture content of the extrudates alters the molecular structure of amylopectin in the material, reducing the elasticity and thus increasing the density of the extrudates ([Ding et al. 2005](#)). Increasing the working screw speed leads to a decrease in the processing time of the product in the extruder and an increase in the mass of the

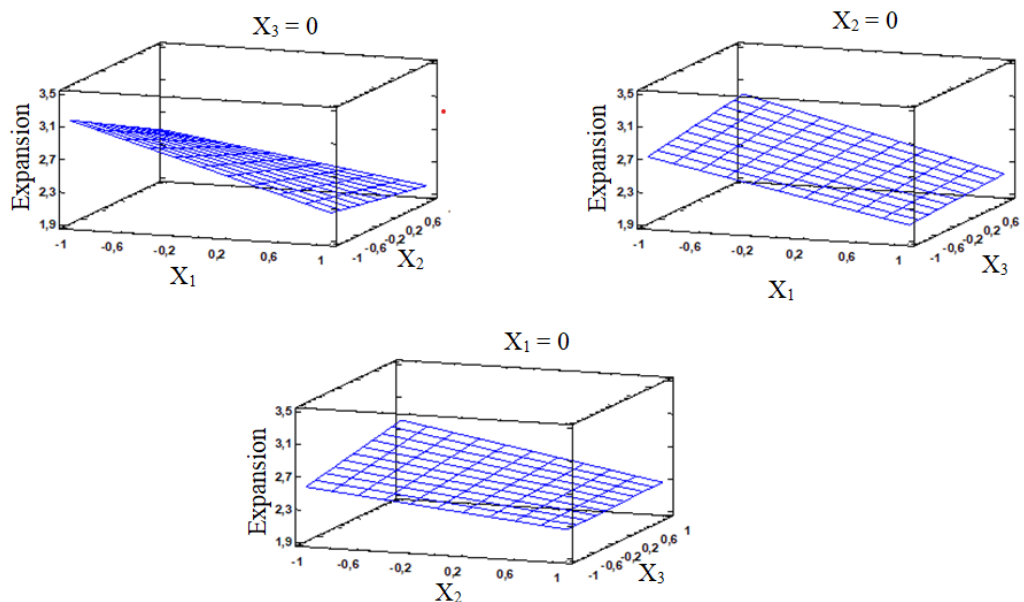


Figure 1. The effect of the content of pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3) on the expansion ratio

extrudates, as well as their density (Wang et al. 2012). As the level of pumpkin flour was increased from 10% to 20%, the density of the extruded product was approximately 1.3 times higher. This could be explained by the reduced expansion of the

extrudates due to the higher fibre content and the reduced starch content. According to Promsakha na Sakon Nakhon et al. (2018), the higher pumpkin flour level led to a production of extrudates with lower puffing and greater density.

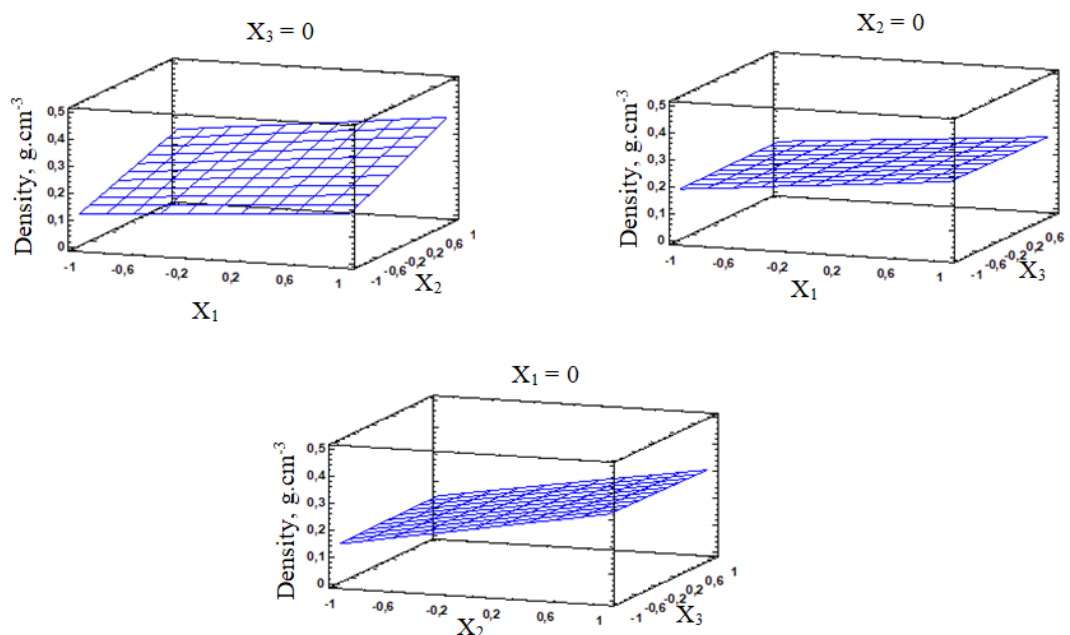


Figure 2. Response surfaces for the density depending on the pumpkin flour of (X_1), moisture content (X_2) and working screw speed (X_3)

Hardness. The averages and standard deviations of the hardness of the extrudates are given in Table 6. It varied between 13.96 and 49.84 N.

Table 6. Hardness of extrudates

No	Max Force, N
1	13.96±0.40
2	23.37±0.56
3	29.71±0.71
4	49.84±0.70
5	25.60±0.56
6	23.84±0.66
7	28.74±0.62
8	45.44±0.57

Regression model was obtained and presented in equation (8). It could be seen that the factor X_2 had the highest effect and X_3 - the lowest.

$$\text{Hardness} = 30.062 + 5.561X_1 + 8.371X_2 + 0.843X_3 + 3.648X_1X_2 - 1.825X_1X_3 - 2.185X_2X_3 \quad (8)$$

$$R^2 = 98.8 \%$$

$$F = 3.5 < F_C = 4.5$$

The response surfaces of the hardness depending on the pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3) are presented on Fig. 3.

The effect of the moisture was more pronounced at high level of pumpkin flour than at low level. The moisture content of the material was found to have a significant effect on the texture/hardness of the resulting product (Ding et al. 2005; Chakraborty et al. 2011; Meng et al. 2010; Altan et al. 2008)

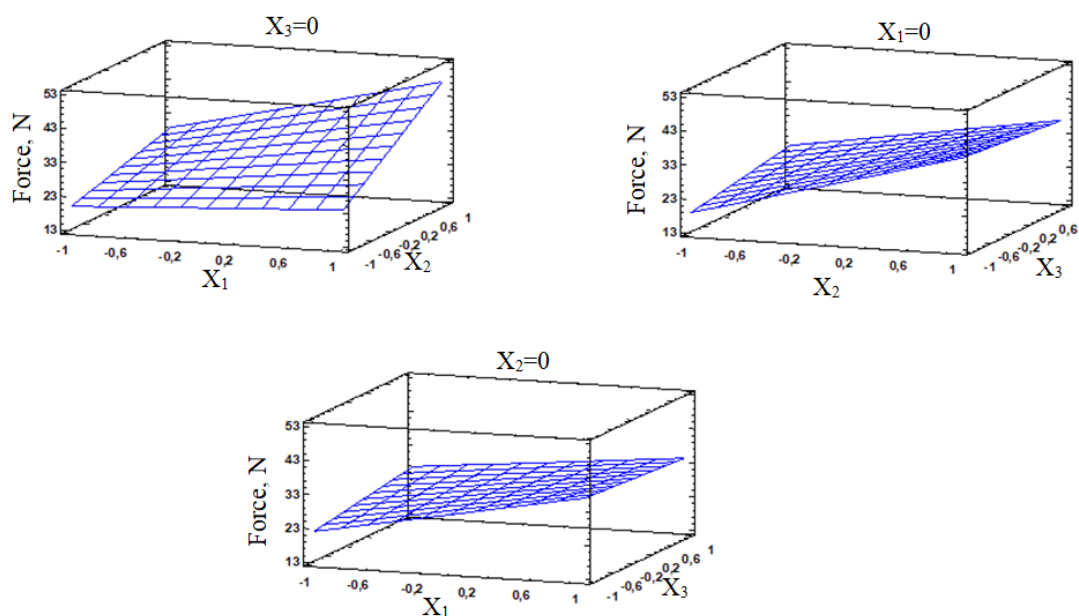


Figure 3. Response surfaces for the hardness depending on the pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3)

Moisture is the factor that influenced both the expansion and the density of the extrudates, and it can be expected that a product with a high density and a low expansion would be firmer (Ding et al. 2006). The moisture input of the material plays a key role in the generation of vapour bubbles in the molten mass when it exits the nozzle. In general, the nozzle pressure decreases with the increase in the moisture content, resulting in a denser and firmer product (Ding et al. 2005; Meng et al. 2010; Altan

et al. 2008). Increasing the pumpkin flour in the mixtures increased their hardness. This is probably due to the dietary fibres that cause premature bursting of the air bubbles, which reduces the overall expansion leading to a product with a less porous structure (Altan et al. 2008; Dehghan-Shoar et al. 2010).

Colour characteristics of the extrudates. The colour of the samples was denoted by three

parameters – lightness (L), redness (a) and yellowness (b). The measured values of the colour parameters of extruded mixtures, given in Table 7, varied in the range from 68.18-75.49 for L , 9.10-11.97 for a , and 39.29-49.05 for b .

Table 7. Changes in colour characteristics of extrudates

No	L	a	b	ΔE
1	68.23±0.41	9.75±0.29	39.29±0.35	22.29±0.14
2	68.18±0.48	11.97±0.41	42.77±0.34	15.75±0.27
3	75.49±0.40	9.10±0.34	48.90±0.36	14.07±0.20
4	69.18±0.48	11.03±0.33	47.24±0.38	13.63±0.20
5	71.00±0.43	9.65±0.39	44.60±0.38	18.50±0.26
6	68.36±0.46	11.74±0.40	42.82±0.37	15.49±0.25
7	74.69±0.43	9.24±0.28	49.05±0.38	14.95±0.17
8	69.24±0.36	10.85±0.56	47.19±0.34	13.53±0.31

Extrudates had a darker colour than non-extruded mixtures due to non-enzymatic darkening reactions occurring during extrusion (Milan-Carrilo et al. 2000). The L values for the extruded samples (Table 7) were lower than the L_0 values of the non-extruded mixtures (Table 2). The lowest value for L was obtained at a pumpkin flour of 20% and at lower levels of moisture content and working screw speed. The highest value was obtained at a moisture content of 20% and low levels of the remaining variables.

The linear model created for L is presented in equation (9). Among the three factors studied, X_1 had the biggest effect.

$$L = 70.545 - 1.80583X_1 + 1.605X_2 + 0.278333X_3 - 1.13417X_1X_2 - 0.46X_2X_3 \quad (9)$$

$$R^2 = 97.5 \%$$

$$F = 1.1 < F_C = 3.6$$

It can be seen that increasing the pumpkin flour decreased the value of lightness (L) (Fig. 4), a result similar to these obtained by Poliszko et al. (2019). Promsakha na Sakon Nakhon et al. (2018) established that the higher pumpkin flour level (30%) led to extrudates with lower puffing and greater density resulting in a deep brown colour and less lightness.

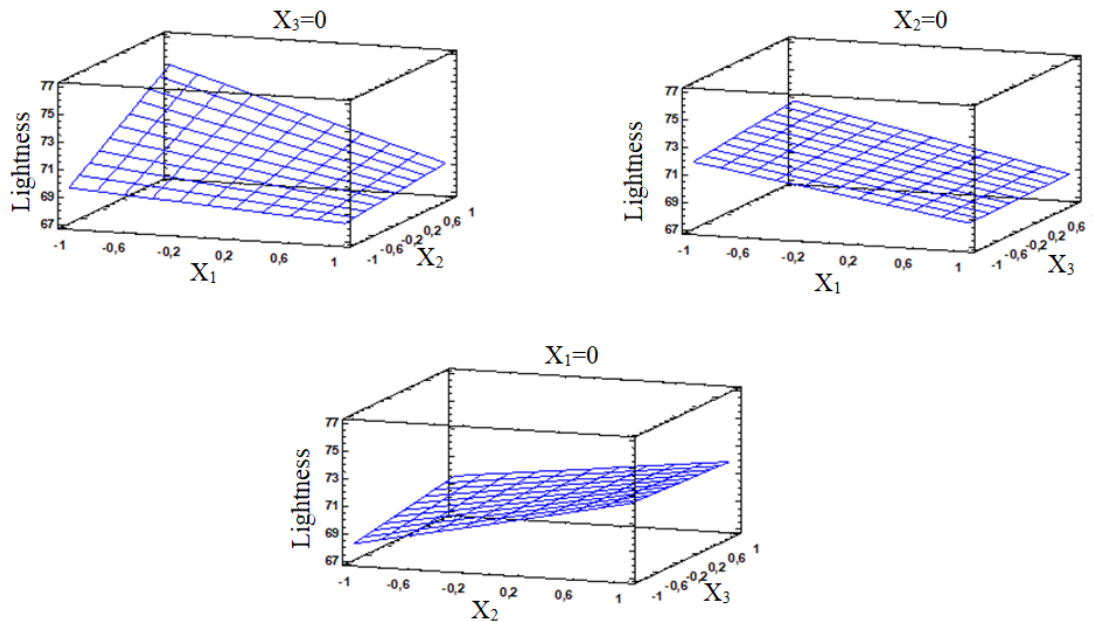


Figure 4. Response surfaces for the lightness (L) depending on the pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3)

Increasing the feed moisture content from 13 to 19% changed the product colour from yellow to brown. Some authors found a correlation between the expansion and the lightness of extrudates (Altan et al. 2008; Stojceska et al. 2009).

The linear model created for redness (a) (equation (10)) shows that the relationship between the

variable X_1 and the redness was directly proportional, between the variables X_2 and X_3 , and the redness – inversely proportional.

$$a = 10.417 + 0.982X_1 - 0.360X_2 - 0.046X_3 - 0.097X_1X_2 - 0.056X_1X_3 \quad (10)$$

$$R^2 = 99.5 \%$$

$$F = 2.2 < F_C = 3.6$$

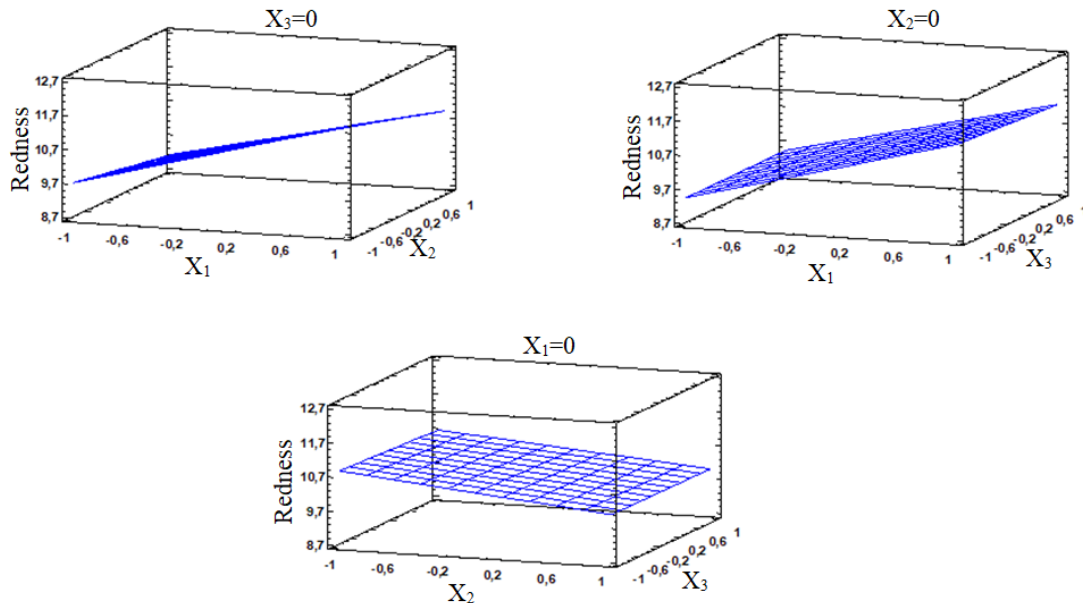


Figure 5. Effect of pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3) on the redness (a)

Fig. 5 shows that increasing the pumpkin flour increases the redness a . This is probably due to the high carotenoid pigment from the pumpkin flour and Maillard browning reaction of ingredients during extrusion process. Increasing the moisture content from 10 to 20% changed the product colour from yellow to brown. These results corresponded to those established from Promsakha na Sakon Nakhon et al. (2018).

The model obtained for the total colour difference ΔE is given in equation (11). It showed a strong inversely proportional relationship between the variables X_1 , X_2 , X_3 and ΔE .

$$\Delta E = 16.020 - 1.422X_1 - 1.977X_2 - 0.413X_3 + 0.956X_1X_2 + 0.322X_1X_3 + 0.609X_2X_3 \quad (11)$$

$$R^2 = 95.9 \% \quad F = 2.8 < F_C = 4.5$$

The results from studies by a number of authors indicate that the moisture content of the materials subjected to extrusion has a significant effect on the

colour characteristics of the final products. The higher moisture content leads to a brighter colour of the extrudates, characterized by high L value (Badrie and Mellowes 1991; Hagenimana et al. 2006; Leonel et al. 2009; Lin et al. 2002; Phillips et al. 1984; Sgaramella and Ames 1993) and low colour change value, which is also consistent with our results (Fig. 6). According to some authors (Ilo and Berghofer 1999), the screw speed does not significantly influence on the colour parameters (L , a , b) and its change (ΔE), which is also shown by our results.

The change in colour values (ΔE) of the extrudates ranged from 13.53 to 22.28. The lowest value was obtained at high levels of the independent variables, and the highest value was obtained at their low levels. The results for the parameter a showed that products with higher a values were darker and had lower L values, which is consistent with other studies (Ilo and Berghofer 1999; Altan et al. 2008).

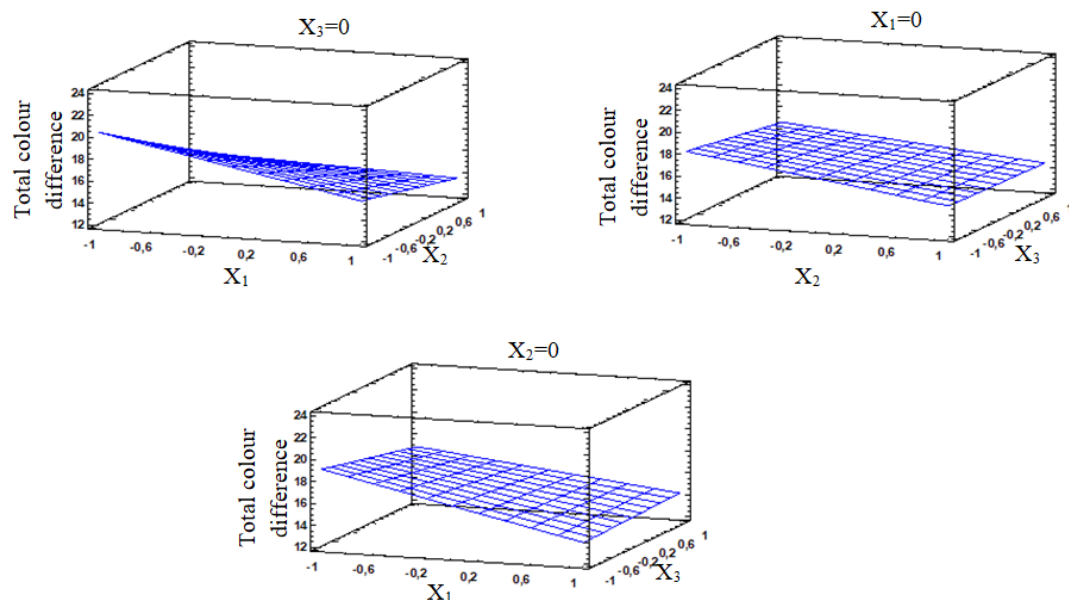


Figure 6. Effect of pumpkin flour (X_1), moisture content (X_2) and working screw speed (X_3) on the total colour difference (ΔE) of the extrudates

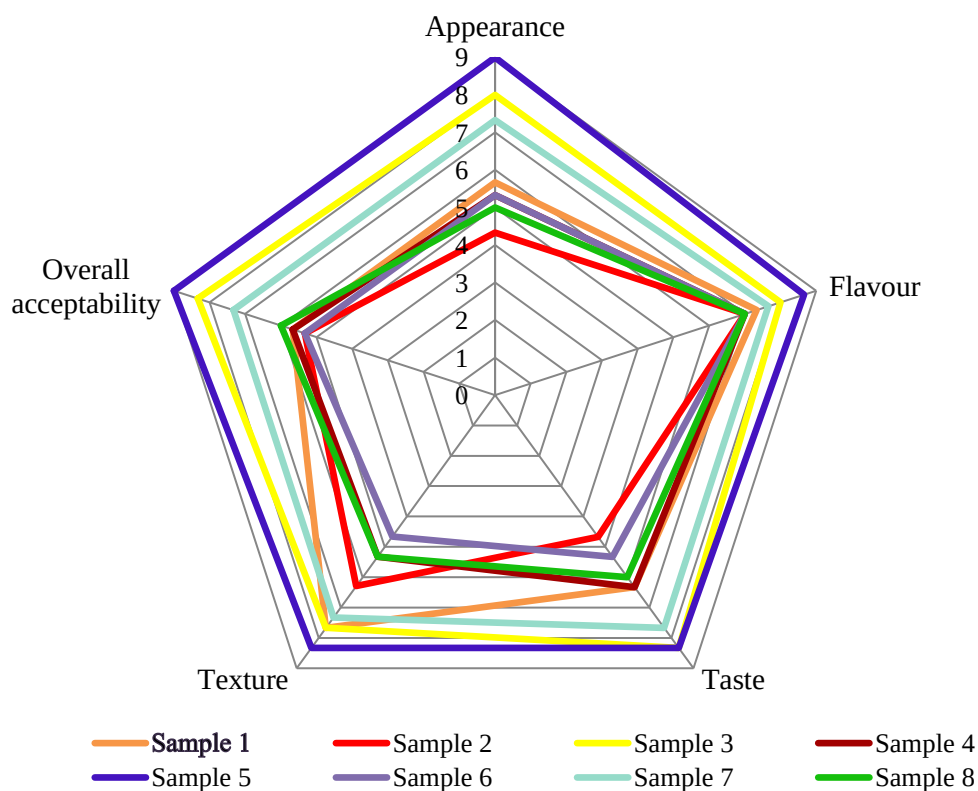


Figure 7. Sensory evaluation of the extrudates

Sensory characteristics. The results of the sensory analysis are shown on Fig. 7. The higher scores represent better acceptance of the product. The increase in the pumpkin flour in the extrudates led to a lower score of all characteristics.

Higher levels of pumpkin flour (20%) tended to make products less acceptable overall. These results indicated that extrusion of rice flour in combination with pumpkin flour in concentration more than 10% cannot produce acceptable extrudate. However, the highest score was obtained for the extrudate made from pumpkin flour of 10%, moisture content of 14% and working screw speed of 220 min⁻¹ and the lowest score – for the extrudate made from pumpkin flour of 20%, moisture content of 14% and working screw speed of 180 min⁻¹.

Conclusions

Changing process conditions affected the physicochemical characteristics of extrudates. The factor having the most significant effect on the characteristics of the extrudates was the moisture content, followed by the pumpkin flour. The increase in the pumpkin flour led to a decrease in the expansion and lightness, and an increase in the density, hardness and redness. The effect of the moisture content was inversely proportional on the expansion and redness, while it was directly proportional on the density, hardness and lightness. The screw speed increased the expansion, hardness and lightness of the extrudates, decreased the redness and had no significant effect on the density. The highest sensory evaluation of the extrudates was achieved at a moisture content of 14%, pumpkin flour of 10% and screw speed of 220 min⁻¹.

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