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The Use of Waxy Starch and Guar Gum in Total Substitution of Vegetable Oil in Extruded Snack Aromatization

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Vegetable oil is used by the extruded snacks industries to fixate aromas and salt in proportions between 10 and 20%. Consumers have restricted the consumption of these products due to the high content of lipids and low nutritional value. In order to obtain a low-fat option, this work aimed to reduce the lipids content of extruded snacks by replacing vegetable oil with waxy maize starch and guar gum. The snacks were manufactured in an INBRA RX50 mono screw extruder using corn grits as a base ingredient. The snacks were flavoured with five coatings formulations varying the concentration of waxy maize starch (1-4%) and guar gum (0.25-1.0%). A total of 15% solution by weight of snacks was applied, and the control treatment consisted in vegetable oil only. The products were evaluated for moisture content, total lipids, radial expansion index, specific volume, apparent density, retraction index, instrumental hardness (Texture Analyzer TA-XT Plus - Stable Micro Systems) and sensory evaluation with 100 non-trained panellists. Moisture and lipid contents were determined in 0 and 30 days of storage. Temperatures of 65 °C were required for waxy starch solution preparation, lowering the temperature to 50°C for the formulations with the addition of guar gum. The results indicated that it was possible to replace the vegetable oil by waxy maize starch and guar gum in the aromatisation of the snacks, as the products presented similar moisture content, specific volume, apparent density, retraction index, sensory acceptance and instrumental hardness ($p > 0.05$). Furthermore, the products presented a reduction of 11-13% in the lipid content. The addition of waxy maize as the only substitute would be recommended, because of the quality characteristics of the products and the absence of significant influence with the addition of guar gum. The snacks produced in the present study would be a healthier option to the consumer.

1. Introduction

Extrusion is a versatile and very efficient technology highly recommended for processing human, and pet food and its application includes breakfast cereals, snack food and several cereal-based products (Bailey et al., 1991; LLO et al., 2000). Extrusion cooking is preferable among other continuous food process techniques since its highly productive and nutritious resistant due to the high temperature and short process (GUY, 2001).
Much of the success of extruded snack foods is due to the coating that is applied. Coatings are added to a variety of foods because they bring novelty, freshness, attract in appearance, shape the product, improve flavour, enhance quality, protect ingredients, prevent migration of core constituents, and create texture or maintain structural integrity (FISZMAN and SALVADOR, 2003).
The consumption of extruded snacks has suffered several adverse effects due to the high-fat content and low nutritional value. Snacks pulverisation with vegetable oil in a rate of 10 to 20%, contributes to seasoning fixation and, therefore, provides desirable sensory characteristics especially flavour (MARQUES et al., 2017).
Waxy corn starch is a promising raw material, which contains many variants. Has the low temperature of paste, high viscosity peak and low final viscosity, indicating the ability to expanding easily and retrograde with

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less frequency. These attributes are mainly due to the amount of amylose (almost 0%) in its composition. Also, this starch has better digestion than the others. Therefore, it is a very suitable raw material for food production (WANG et al., 2009). Hydrocolloids or gums are mostly naturally occurring, soluble in water and have thickening and/or gelatinising properties under specific conditions and are widely used as additives in food technology. Their function is to improve texture, delay starch retrogradation, increase moisture retention and, consequently, improves the quality of bakery products in general. The incorporation of hydrocolloids into starch solutions modifies rheological properties and increases viscosity levels. For this reason, gums are used to confer stability to products such as puddings and desserts (ROJAS et al., 1998; STAUFFER, 1985).
This work aimed to use waxy maize starch and guar gum as substitutes of vegetable oil in the expanded corn snacks flavouring process, obtaining a health product.

2. Material and methods

Raw material
Corn expanded snacks were produced using corn grits provided by Zaeli Alimentos (Brazil). The coating solution contains waxy maize starch (Black Belt, Brazil), guar gum (Daxia, Brazil), roasted onion (Nutrimental, Brazil), sodium chloride (Norsal, Brazil) and soybean oil (Coamo, Brazil).

Snacks processing
The extrusion was carried out in INBRA RX50 (INBRAMAQ, Ribeirão Preto, SP, Brazil), with a single thread of 50 mm in diameter and 200 mm in length. The matrix used had two 3 mm diameter holes, and the parameters were set with the motor amperage at 20 A and the system feed at 12 g/s. The cut was performed at 50 rpm. After extrusion, the snacks were placed in a drying oven at 60°C for 30 minutes to standardise the moisture.

Flavouring process
This experiment was conducted with six treatments detailed in table 1. The flavouring process for the control treatment (TC1) was carried out by aspersion spraying 150 g of vegetable oil for each 1 kg of snacks. Then, 20g of roasted onion powder and 20g of sodium chloride were added followed by 2 minutes of homogenization in the 20-litre stainless steel mixing drum at 40 rpm rotation (MARQUES et al., 2017). To replace the vegetable oil in the flavouring of the snacks, five treatments were tested (T1 to T5). The coating consisted of hydrating the waxy maize starch and guar gum in water at room temperature for 1 minute under stirring. Keeping the solution under stirring, the temperature was then raised to its gelatinisation point varying according to the type of solution. The flavouring process of T1 to T5 was carried out under the same conditions of the control, that is, spraying 150 g of the solution into 1 kg of snacks, followed by the addition of the seasonings and the sodium chloride using 304 stainless steel 20L mixing drum at 40 rpm. After the coating and flavouring, the snacks were placed in a drying oven at 60°C for 30 minutes in order to the standard the treatments moisture content.
The samples were packed in polypropylene (250 x 400 x 0.08 mm), weighing 200g in each package and stored at 25ºC for 30 days

Table 1. Corn snacks treatments

Treatments	Coating	Flavouring
TC0	No coating	No addition of salt and flavour
TC1	15% of vegetal oil	Addition of salt and flavour
T1	Water and 4% waxy starch	Addition of salt and flavour
T2	Water, 3% waxy starch and 0.25% guar gum	Addition of salt and flavour
T3	Water, 2% waxy starch and 0.50% guar gum	Addition of salt and flavour
T4	Water, 1% waxy starch and 0.75% guar gum	Addition of salt and flavour
T5	Water and 1% guar gum	Addition of salt and flavour

Control treatment TC0 had no coating and flavour addition, having only moisture standardisation in the oven at 60°C for 30 minutes

Physical and Chemical analyses of the treatments
Moisture
Moisture content was determined in a drying oven at 105°C for 24 hours (Association of Official Analytical Chemists, AOAC, 2005) and all samples were checked in triplicate. The analysis was performed on the first day after production (P0) and after 30 days (P30) of storage.

Lipids
Total lipid content was determined by the method of Bligh & Dyer (1959). The analysis was performed at the initial time (P0) on the first day after production and after 30 days (P30) of storage. Samples were checked in triplicate.

Radial expansion index
Radial expansion index (IE) was calculated according to MERCIER et al. (1998), by calculating the ratio between the mean of extrudate diameter to the diameter of the extruder die. The diameter of 10 extruded products for each treatment was measured using a digital micrometre (Marberg, Mb-300, São Paulo). The calculation of (IE) is represented in Equation 1:

$$IE = \frac{Sample\ diameter}{Die\ diameter} \quad (1)$$

Specific volume, Apparent density and Retraction index
To calculate the Specific Volume (V.E.) a one-litre container was used. A mass of 100 g of snacks was added and the volume completed with corn seeds. Seed displaced was measured by checking its volume using a 500 mL beaker, according to Equation (2).

$$VE = \frac{Seeds\ volume}{Snack\ mass\ (100g)} \quad (2)$$

To stabilise the Apparent Density (DA) samples were placed into a 1-litre container and weighed. The Apparent Density in g/mL was given by dividing the mass obtained by 1000 mL, according to Equation (3).

$$DA = \frac{Snack\ mass}{Recipient\ volume\ (1L)} \quad (3)$$

Retraction index (IR) was calculated based on the reduction of the initial specific volume after the coating and flavouring of the product, according to Equation (4):

$$IR = \frac{Final\ Specific\ Volume}{Initial\ Specific\ Volume} \quad (4)$$

Agglomeration Index Analysis (IA)
This test was performed to measure how adhesion of each coating type can affect the snacks quality during mixing in the flavouring step. Randomized samples of 100 g snack were weighted after flavouring and drying, and the formation of agglomerates (lumps) was counted for each type of cover used. A higher counting of agglomerates indicates that the coating adhesion in relation to the snacks is high and may affect the product presentation quality.

Hardness analysis
Instrumental hardness analyses were performed in the Texture Analyzer TAXT2 Plus (Stable Micro Systems, England) with DISCHSEN et al. (2013) and ZANQUI et al. (2014) parameters. Samples were placed horizontally on the platform, and the Warner Bratzler probe of 12 × 7 cm (HDP / BS) was used, with a maximum load of 5kg, breaking the sample like a guillotine. Results were expressed in kilograms and represent the arithmetic mean of 13 determinations of burst strength for samples from the same treatment. Parameters used in the tests were: (i) pre-test speed = 1.5 mm/s; (ii) test speed = 2.0 mm / s; (iii) post-test speed = 10.0 mm / s; (iv) force = 0.20 N; (v) count cycle = 5 s; (vi) apparatus sensitivity a= 15 g, with force measurement in compression.

Sensory evaluation
Sensorial evaluation, described by MONTEIRO AND CESTARI (2013), was performed in the Sensory Analysis Laboratory of the Food Engineering Department / State University of Maringá. The analysis was carried out by 100 untrained panellists using 9 points hedonic scale (1 point - Highly disliked to 9 points – Highly liked) and the product general acceptance characteristics were evaluated. For this test, five units of each sample were presented in disposable cups, duly identified with random three-digit numbers, accompanied by a glass of water. In the test booths, a white light was used. Sensory tests were approved by the Research Ethics Committee of the State University of Maringá (CAAE 18718013.3.0000.0104).

Statistical analysis
Collected data were statistically evaluated by the analysis of variance (ANOVA), with further Tukey test at 5% of probability using the Statistica 7.0 program (STATSOFT, 2004).

3. Results and discussion

Results of moisture and lipids content are presented in Table 2. The addition of a coating to the snacks surface increased the product moisture content ($p \leq 0.05$). Vegetable oil (TC1) or waxy starch (T1) presented higher moisture content than products containing starch and guar gum mixtures (T2 and T3) or only guar gum (T5) ($p \leq 0.05$). Water was used as a mean for coating preparation containing starch and guar gum (Table 1). Also, the increase in starch concentration increases the extent of gelatinisation during extrusion and, consequently, more water is absorbed (NISSAR et al., 2017).
An increase in moisture content ($p \leq 0.05$) (Table 2) was observed during the snack's storage. This fact is related to the hygroscopic nature of the extrudates and the water vapour permeability of the polypropylene package (KAUR et al., 2018). MONTEIRO et al. (2016) also obtained moisture increase during the 28 days of extruded corn snacks storage studying treatments without coating, 15% vegetable oil coating and 4% concentrated corn starch coating.
Vegetable oil (TC1) coating increased lipid content of 13.5% when compared to the uncoated product (TC0) ($p \leq 0.05$). Products containing waxy starch and guar gum (T1-T5) presented 11 to 13% fewer lipids than the vegetable oil (TC1) product. The use of waxy starch and guar gum as a substitute for vegetable oil (T1-T5) resulted in a lipid content reduction when compared to the uncoated product (TC0, $p \leq 0.05$). The decrease in lipid content would be associated with the increase in moisture content (PRIMO-MARTIN et al., 2010).

Table 2. Moisture and lipid contents of corn snacks during storage at room temperature

Treatments	Moisture t0	Moisture t30	Lipids t0	Lipids t30
TC0	1.924^{aA} ± 0.090	3.724^{aB} ± 0.056	2.138^{aX} ± 0.011	0.710^{aY} ± 0.314
TC1	2.970 ^{bA} ± 0.017	5.139^{bB} ± 0.016	16.284^{bX} ±0.350	14.182^{dY} ± 0.462
T1	2.796^{bA} ± 0.078	4.708^{cB} ± 0.066	0.990^{cY} ± 0.048	1.741^{cX} ± 0.050
T2	2.671^{cA} ± 0.026	4.112^{dB} ± 0.071	0.962^{cX} ± 0.095	0.975^{bX} ± 0.029
T3	2.719^{cA} ± 0.102	4.623^{cB} ± 0.189	1.124^{cX} ± 0.186	0.842^{abX} ± 0.107
T4	2.813^{bcdA} ± 0.013	4.629^{cB} ± 0.045	1.026^{cX} ± 0.174	2.372d ± 0.265
T5	2.573^{cdeA} ± 0.043	4.570^{cB} ± 0.084	0.973^{cX} ± 0.144	1.514^{cX} ± 0.333

Mean ± standard deviation followed by the same lowercase letter do not differ statistically from each other in the same column ($p > 0.05$). Mean ± standard deviation followed by the same capital letter do not differ statistically from each other on the same row ($p > 0.05$) for each parameter (moisture or lipids) — moisture and lipids in g/100g. P0 represents day 0, and P30 represents 30 days storage, for treatments see Table 1.

Radial expansion index varied between 4.33 and 4.66, corroborating the results obtained by MONTEIRO et al. (2016) (4.27 to 4.44) and PINTO et al. (2015) (4.33 to 4.43), therefore suitable for this type of product. Specific volume (V.E.) results, bulk density (D.A.) and retraction index (I.R.) are shown in Table 3. There was no effect of the coating addition in the V.E. and I.R. of corn snacks ($p > 0.05$), regardless of the coating type. Hence, the use of the waxy starch and/or guar gum coating results in products with V.E. and similar I.R ($p > 0.05$) to the vegetable oil-based product. According to SOARES JÚNIOR et al. (2011) and MESQUITA et al. (2013), the specific volume is directly related to the product expansion, being the primary performance index in the extrusion of expanded foods, thus, the degree of expansion is an essential factor to be monitored in the production of extruded snacks, mainly due to its influence on the weight and volume of the packages.
D.A. increased with the addition of the coating ($p \leq 0.05$), regardless of the material used (vegetable oil, starch and/or guar gum). Apparent density is one of the most important parameters in extruded snacks and represents the expansion of the products in all directions, being directly proportional to the product moisture (HAN E TRAN., 2018). In fact, the coated treatments (TC1 and T1-T5) presented higher moisture (Table 2) and, consequently, higher bulk density. The use of the waxy starch and/or guar gum coating resulted in products with similar D.A. ($p > 0.05$) to the vegetable oil-based product. The maintenance of V.E., I.R and D.A. with starch and/or guar gum similar to that of the product with oil in the coating is crucial while indicates that important quality parameters of this type of product are maintained.
The addition of vegetable oil cover (TC1) did not influence the agglomeration index (IA) of the snacks. Waxy starch addition caused an increase in this parameter. Furthermore, as the amount of guar gum in the

formulation of the coating increased, the lumps count formed in the snacks gradually increased, showing irregularities to the final product's visual presentation. Agglomeration is a defect in extruded snacks.

Table 3. Specific Volume (V.E), Apparent Density (D.A.), Retraction Index (I.R.) and Agglomeration Index (I.A) results.

Treatment	V. E. (mL/g)	D.A. (g/L)	I.R.	IA(unit.)
TC0	16.83 ± 0.83^a	42.31 ± 1.29^a	1 ± 0.00^a	0.000
TC1	16 ± 2.00^a	47.82 ± 0.86^b	0.95 ± 0.07^a	0.000
T1	15.16 ± 0.16^a	47.82 ± 0.86^b	0.9 ± 0.05^a	15.667
T2	16 ± 0.00^a	49.27 ± 1.63^b	0.95 ± 0.04^a	20.333
T3	15.66 ± 0.33^a	49.85 ± 1.29^b	0.93 ± 0.02^a	22.667
T4	16.66 ± 0.33^a	50.43 ± 1.00^b	0.99 ± 0.02^a	27.333
T5	16.33 ± 0.33^a	49.27 ± 0.81^b	0.97 ± 0.06^a	27.667

Mean ± standard deviation followed by the same lowercase letter do not differ statistically from each other in the same column (p> 0.05), for treatments see Table 1.

Results of sensorial acceptance and hardness are presented in Table 4. There was no interference of the coating addition on the instrumental hardness (p> 0.05), corroborating the observed results for V.E. and I.R (Table 3). Hence, the coated products containing waxy starch and/or guar gum presented similar hardness (p> 0.05) to the vegetal oil-based product. The present study snacks presented hardness higher than that reported by MARQUES et al. (2017) (0.67 a 1.73 kg). Snacks hardness data were not correlated with the moisture content fact also reported by MONTEIRO et al. (2016) and MIKALOUSKI (2014). Hardness maintenance of products with waxy starch and/or guar gum similar to oil-based is essential from a sensorial point of view since the consumers desire that reformulated products have the same characteristics of traditional ones. In the sensorial evaluation, it was possible to prove that it is possible to substitute the vegetable oil for starch and/or guar gum in the snacks flavouring, since the treatments T1 to T5 presented similar sensorial acceptance to the vegetal oil product (p> 0.05, TC1). All products had scores close to or greater than six on a 9-point scale, indicating that consumers liked the products slightly. The waxy starch-only snack (T2) presented a score close to 7, suggesting that consumers liked this formulation moderately. MARQUES et al. (2017) and MONTEIRO et al. (2016) found a similar conclusion for traditional snacks (oil flavouring) and snacks with 4% corn starch coating and grades between 5.95 and 7.51.

Table 4. Sensory acceptance and hardness of corn snacks.

Treatment	Sensorial	Hardness (kg)
TC0	--	2.08 ± 0.37a
TC1	5.96 ± 1.99ab	2.15 ± 0.39a
T1	6.76 ± 1.84a	2.31 ± 0.48a
T2	6.47 ± 1.75a	2.25 ± 0.41a
T3	5.55 ± 2.42b	2.25 ± 0.44a
T4	6.33 ± 1.77ab	2.00 ± 0.38a
T5	6.00 ± 2.04ab	2.17 ± 0.46a

Means ± standard deviation followed by the same lowercase letter do not differ statistically from each other in the same column (p> 0.05), for treatments see Table 1.

4. Conclusion

It is concluded that the substitution of vegetable oil in the process of flavouring extruded snacks with waxy maize starch and/or guar gum is possible, resulting in products with similar characteristics (humidity, specific volume, apparent density, retraction index, sensorial acceptance and hardness). The recommended formulation would be the waxy starch-only compound (4%), as no significant improvement was observed with the use of guar gum.

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