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Eliminating the Use of Fat in the Production of Extruded Snacks by Applying Starch Coating

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High content of fat and low nutritional value have led the consumption of extruded snacks to be strongly restricted in several countries. After extrusion, in conventional procedures of snacks production, the product is subjected to a fat spray to facilitate salt adherence. For this purpose, eight to ten percent (based on product mass) of vegetable fat is applied to the product. The objective of the research reported in this paper was to fully replace the use of fat in the production of snacks with a cassava starch coating focusing on reduced fat consumption. Based on experimental design the most satisfactory concentration of starch in aqueous suspension, sprayed on the snacks at 10% w/w based on final product following heating to 80°C, was identified. We used a single screw extruder Imbramaq IBX50 to produce the snacks. The extrudates were analysed for specific volume (m/v), texture (texturometer Stable Micro Systems Texture Analyser TAXT2), retraction index (vf/vs), moisture, total lipids, peroxide value and sensory properties using 64 tasters comparing the new and standard products. The analyses were carried out shortly after snack manufacture and every seven days during the whole shelf life of the product. The main results indicate that the treatments that used starch coating did not present significant differences among each other. However, these treatments had a positive impact on maintaining texture and protection against oxidation was significantly higher than for fat coated snacks. Thus, the use of cassava starch as a snack coating presents a viable alternative to oil coating. It not only enables the reduction of the lipid content in these products but it also imparts enhanced shelf life properties.

1. Introduction

Thermoplastic extrusion is known for being an efficient, versatile industrial technology applied in the production of breakfast cereals and snacks (ROCKY, 1995).
In contrast, according to Trevisan and Areas (2013); De Aguiar *et al* (2011), extruded snacks are popular foods but with little nutritional value contributing to a range of diet related health problems. Evidence has been found on the relationship between dietary factors and primary and secondary prevention of chronic diseases such as heart diseases and some types of cancer, as well as better muscle functioning or immune responses (WELCH et al., 2011). In this context improving the nutritional value of extruded snacks may contribute to improved public health. According to MIKALOUSKI *et al* (2014), extruded snacks not only have high starch content but also present between 10 and 20 percent of lipid, added at the coating phase in order to set the product flavor.
According to De Marco *et al* (2013), the biocoating of seed and cereals may contribute to an increase in stability in relation to oxidation and alterations in the moisture of the products.
The objective of the research reported in this paper was to substitute the oil-based coating used in the production of snacks with a cassava starch biofilm in order to reduce the lipid content in the final product as

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well as to promote increased shelf life considering that the starch coating will hamper moisture migration to the product.

2. Material and Methods

2.1 Raw materials

The snacks were prepared using maize grits provided by Caramurú Alimentos (batch: 04/15) with the granulometrical classification presented in Table 1. The granulometrical analysis was conducted in duplicate following methodology described by Abimilho (2003) as follows. A fraction of 100 grams of each sample was applied to a system of overlapping sieves (14, 16, 24, 28, 60, and 100 Mesh) and subjected to shaking until reaching a constant mass of the material retained in each sieve.

Table 1: Granulometric characterization of the grits employed in the extrusion.

Mesh	% retained
14	20.4%
16	29.1%
24	42.5%
28	3.7%
60	3.3%
100	0.7%
bottom	0.3%

For the coating of the extruded snacks was used soybean oil (Cocamar, batch 03/2015, Brazil) or cassava starch (Pasquini, Brazil) flavored with a mixture containing 2.0% of a seasoning prepared with fine herbs (All-Flavors, Brazil), and 2.0% of monosodium glutamate plus salt (1:1) (Ajinomoto, Brazil). The mass of the added ingredients was calculated in relation to the extruded mass.

2.2 Snacks processing

The extrusion was carried out using IMBRA RX50 single screw equipment (INBRAMAQ, Ribeirão Preto SP, Brazil) – 50 mm diameter and 200 mm length. The die had two holes of 3 mm diameter and extrusion parameters were 20 A of motor amperage, feed rate of 12 g/s and screw speed of 90 rpm. There was a rotating knife at 45 rpm to cut the extrudate. 4.5 kg of product were processed.
The extrudates were subjected to forced circulation kiln-drying at 5.5% humidity and 55 °C for 30 minutes and subsequently divided into nine samples of 500 g, each of which was submitted to coating at the conditions presented in Table 2. All starches used for coating were dispersed in water (see Table 2 for concentrations) and heated to 80 °C for 5 minutes while stirring gently, followed by cooling to 40 °C and then used as coating. All of the coating processes were carried out using a 20-liter tablet coater with heating and rotation of 40 rpm where coating solution was sprayed. Treatments T3, T5, and T7 had salt and spice added along with the snacks coating; treatments T2, T4, and T6 had spice and salt added after the application of starch coating. T8 and T9 with standard oil and no coating, respectively, served as reference treatments. All of the coatings were applied at 10% w/w based on final product.

Table 2: Conditions of snacks coating

Treatment	1st step	2nd step
T1	Coating with water, salt and flavour solution	
T2	Coating with 4% starch solution	Add salt and flavour
T3	Coating with 4% starch, salt and flavour solution	
T4	Coating with 2% starch solution	Add salt and flavour
T5	Coating with 2% starch, salt and flavour solution	
T6	Coating with 1% starch solution	Add salt and flavour
T7	Coating with 1% starch, salt and flavour solution	
T8	Coating with soybean oil	Add salt and flavour
T9	Without coating	

After coating the snacks were once again placed into the forced circulation kiln at 55 °C for 30 minutes until reaching final moisture content of 5.5% w/w. Figure 1 presents the flowchart of the snacks production and evaluation.

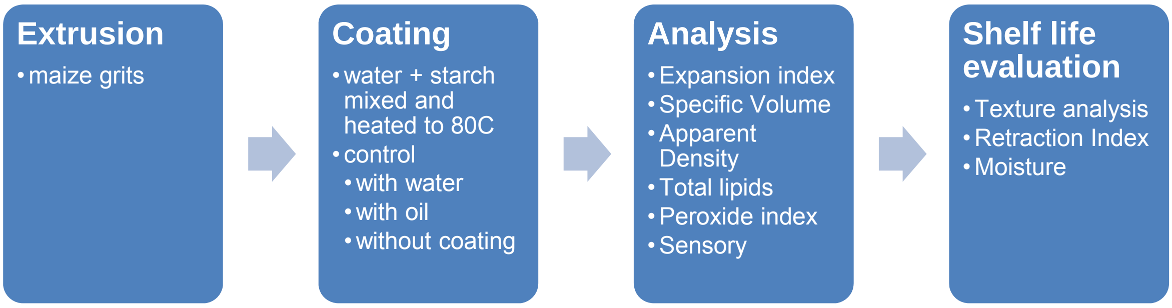

Figure 1: Flowchart of sample production and evaluation

2.3 Physical and chemical analyses of the produced samples
All of the physical and chemical analyses were conducted in triplicate.

Texture analysis
The analysis of texture was carried out using a TAXT2 Plus Texture Analyzer (Stable Micro Systems, England) fitted with the 5 kg load cell and the 12 x 7 cm (HDP/BS) Warner Bratzler guillotine block, following published protocol (Dischsen *et al*., 2013). The samples were positioned horizontally on the platform and the test parameters were the following: (i) pre-test velocity = 1.5 m/s; (ii) test velocity = 2.0 m/s; (iii) post-test velocity = 10.0 m/s; (iv) strength = 0.20 N; (v) counting cycle = five seconds; (vi) equipment sensitivity = 15 g, with compression force measurement. The results are expressed in kilograms and s the arithmetic average of ten determinations of tensile strength for samples from a single test.
The texture analysis was conducted for all of treatments from time zero to 28 days and analyzed every seven days.

Expansion index
The radial expansion index (EI) was calculated according to Mercier *et al*. (1998) using the ratio between the average diameter of the extrudate and the die diameter of the extruder in ten different expanded products for each treatment. The diameter was measured using a digital caliper (Marberg, Mb-300, São Paulo). Equation 1 represents the calculation of the (EI).

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

We established the expansion index in the snacks after the extrusion and before the treatments only at time zero.

Specific Volume, Apparent Density, and Retraction Index
In order to establish the specific volume (SV) was used a vessel of one liter added with a mass of 100 g of snacks and filled with millet seeds with subsequent measurement of the seeds volume using a 200 mL test tube and division of the volume displaced by the employed mass, according to Equation 2.

$$SV = \frac{Seed\ volume}{Snack\ mass\ (100\ g)} \quad (2)$$

In order to establish the apparent density (AD) the snacks were added to a vessel of one liter and subsequently weighted. The apparent density (in g/mL) was given by the division of the mass obtained by 1000mL, according to Equation 3.

$$AD = \frac{Snack\ mass}{Vessel\ volume\ (1\ L)} \quad (3)$$

The retraction index (RI) was calculated based on the decrease of the specific volume as function of time with measures of all of the treatments at time zero and 28 days, according to Equation 4.

$$RI = \frac{Final\ SV}{Initial\ SV} \quad (4)$$

We established the specific volume for all of the treatments only at time zero as well as the apparent density plus 28 days enabling the calculation of the retraction index.

Total lipids

In order to establish total lipids we employed the Bligh-Dyer method using the moisture content of the product as standardization parameter to the volume of water added in the extraction process. Proportion of chloroform solvents:methanol:water was 1:2:0.8. Total lipids were established only at time zero.

Peroxide index

The peroxide index was established through the dissolution of five grams of oils in 30 mL of acetic acid solution/chloroform (3:2) followed by the addition of 0.5 mL of saturated potassium iodide, leaving the solution to rest away from light for exactly one minute. After this period we added 30 mL of deionized water and one mL of starch indicator solution (thyodene) at one percent, and subsequently added the homogenized solution with 0.01N sodium thiosulfate until the bluish color had disappeared. Only treatments T2, T8, and T9 were subjected to an analysis of the peroxide index.

Moisture

The moisture was established of the samples according to the AOAC (934.01). The moisture analysis was carried out for all of the treatments every seven days for 28 days.

2.4 Sensory

The sensory tests was carried out at the Laboratory of Sensory Analysis of the Food Engineering Department of the State University of Maringa, according to description by Monteiro and Cestari (2013) with 64 non-trained tasters of ages ranging from 17 to 31 years old. The evaluation consisted of a 10 cm-scale test with the tasters identifying the intensity for the criteria of texture and taste. The test was conducted in blocks of 5 samples with repetition of treatment T8 for all of the tasters. We presented all of the samples using disposable plates labelled with random three-digit numbers followed by a glass of water. The test cabins had white illumination. The sensory tests received the approval of the Research Ethics Committee of the State University of Maringá (CAAE 18718013.3.0000.0104) and were carried out for all of the treatments only at initial time.

2.5 Statistical analysis

Experimental data were statistically assessed through the analysis of variance (ANOVA) with subsequent analysis of the averages using Tukey test at five percent probability with Statistica software 7.0, (2004).

3. Results and discussion

After the extrusion, the snacks had an expansion index of 4.26, which is similar than the value found by Mikalouski et al (2014) when working in similar granulometry of extruded feed material.
The samples subjected to the nine different treatments appeared homogenous and presented no visual differences among each other, see Figure 2.

Figure 2: Photographs of the produced samples.

The results of the sensory analysis revealed no statistical differences between the nine treatments with regard to texture. In the case of flavor treatments T1 and T9 (with coating containing only water, salt, and spice and without coating, respectively) had lower scores compared with the remaining treatments. Table 3 presents the results of the sensory analysis of the products.

Table 3: Result of the sensory analysis of the nine treatments at time zero

treatment	*flavour*	*Texture*
T1	1.09^{A}	7.05^{A}
T2	5.95^{B}	8.89^{A}
T3	4.30^{B}	8.58^{A}
T4	5.25^{B}	8.76^{A}
T5	5.39^{B}	8.31^{A}
T6	5.86^{B}	8.77^{A}
T7	5.77^{B}	8.34^{A}
T8	6.15^{B}	8.94^{A}
T9	0.99^{A}	8.35^{A}

Samples with same uppercase letters in the column do not differ based on Tukey's test ($p < 0.05$).

The analyses of specific volume (SV), apparent density (AD), retraction index (RI), and total lipids in the newly produced snacks revealed that all of the different treatments had little impact on these values, except for treatment T8 which led to a significantly higher lipid content since it was the only treatment to use oil as coating. Table 4 presents the results of the analyses obtained right after the manufacture of the snacks coatings.

Table 4: Physical, chemical analyses of the products after manufacture

Treatment	SV (mL/g)	AD (g/l)	RI	total lipids (% w/w)
T1	13.20	46.01	0.97	0.47
T2	12.78	45.83	0.98	0.53
T3	12.01	45.93	0.99	0.65
T4	11.46	45.14	0.97	0.53
T5	13.12	46.62	0.97	0.69
T6	12.96	45.67	0.98	0.35
T7	13.81	46.16	0.98	0.40
T8	12.02	45.37	0.95	10.45
T9	14.40	46.56	0.95	0.73

Regarding the peroxide index (PI) we observed that both the sample with starch coating and the sample without coating showed a significant reduction in PI every seven days, see Table 5. In contrast, the sample with oil coating presented an increase in this index. This result is due to the low lipid content in the snacks of treatments T2 and T9; in addition, the better results following T2 were expected due to the protection the starch layer provides to the snacks. In a study by Aguiar et al (2011), higher lipid oxidation also occurred in snacks with higher lipid incidence; the authors indicated that a protection was required to prevent the mentioned oxidation.

Table 5: Peroxide index in treatments T2, T8, and T9

	14 days	21 days	28 days
T2	12.5	8.3	4.0
T8	9.6	10.3	13.3
T9	15.0	10.0	6.7

Table 6: Texture and moisture of the samples throughout shelf life

Treatment	texture (force (N))					Moisture (% w/w wwb)				
	0 days	7 days	14 days	21 days	28 days	0 days	7 days	14 days	21 days	28 days
T1	8.34^{Aa}	8.36^{Aa}	8.44^{Aa}	9.99^{Ba}	10.32^{Bb}	5.51	6.07	7.34	6.61	6.94
T2	7.47^{Aa}	7.86^{Aa}	7.15^{Aa}	8.45^{ABa}	8.66^{Ba}	5.50	6.09	6.68	6.40	7.01
T3	7.84^{Aa}	7.91^{Aa}	8.73^{Aa}	8.81^{Aa}	8.70^{Aa}	5.50	5.60	6.44	5.87	6.26
T4	7.77^{Aa}	7.71^{Aa}	8.19^{Aa}	7.81^{Aa}	8.41^{Aa}	5.48	5.41	6.85	6.35	6.12
T5	8.06^{Aa}	7.89^{Aa}	7.82^{Aa}	8.08^{ABa}	8.89^{Ba}	5.51	5.21	6.24	5.93	6.37
T6	7.84^{Aa}	7.34^{Aa}	7.21^{Aa}	8.09^{Aa}	8.87^{Ba}	5.50	4.94	6.42	5.34	6.49
T7	7.92^{Aa}	7.93^{Aa}	7.66^{Aa}	7.34^{Aa}	8.59^{Ba}	5.51	4.69	6.21	5.24	6.22
T8	7.31^{Aa}	7.65^{Aa}	7.09^{Aa}	9.17^{Ba}	9.40^{Bab}	5.49	4.87	5.86	5.27	5.69
T9	7.92^{Aa}	7.07^{Aa}	7.91^{Aa}	8.76^{Ba}	9.88^{Cab}	5.48	4.66	6.09	6.01	6.64

Same lower case letters signify samples in a column that do not differ based on Tukey's test ($p < 0.05$).
Same upper case letters signify samples in a row that do not differ based on Tukey's test ($p < 0.05$).

Moisture and texture of the snacks was analyzed for up to 28 days every 7 days, see Table 6 for the results. We observed that the control samples T8 had a significant increase in compression strength indicating a gradual loss of crispness. Similarly, the samples T1 coated with water, salt and flavor solution and the samples T9 without coating showed a significant increase in compression strength. On the other hand all of the starch coated samples, while showing an increase in compression strength over 28 days of storage, the increase was less pronounced. With regard to the moisture content we were not able to identify significant differences among the treatments throughout shelf life indicating that there is no correlation between crispiness and moisture for these snacks. This somewhat unexpected behavior has previously been reported by Mikalouski *et al* (2013).

4. Conclusions

Based on our results we are able to conclude that the use of cassava starch coating on extruded snacks to substitute oil not only leads to healthier snack products, due to the reduced lipid content, but also to products with enhanced shelf life properties relating to texture and lipid oxidation. Suggestions for future studies include evaluating the impact of the selected method of coating application on final product quality; in particular barrier to moisture ingress and impact on shelf life.

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