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Waxy Starch to Replace Vegetable Fat in Extruded Snack Aromatisation and Different Salt Delivery Way to Decrease Sodium Intake

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Food industries must adapt their formulations to consumer needs, for a healthy diet. Extruded snacks are products where 10 to 20 % of fat, and large amounts of salt, are sprinkled on to fix flavours. Considering the need for flavouring and simultaneously reducing fat and sodium on snacks, an alternative flavouring method based on polysaccharides and a different salt delivery method was studied. This work aimed to evaluate waxy starch solutions to replace the oil in snacks, and a different approach to deliver salt, decreasing sodium content while keeping the same salt perception. To change the salt level, agglomerates were made with 70 %, and 85 % salt amounts, 30 % and 15 % starch added, respectively, in three different treatments, T1 (70 % of salt), T2 (85 % of salt), and T3 (100 % of salt, without waxy starch) as a control sample. All samples were milled in the same granulometry as regular salt. The snacks were flavoured using coatings consisting of waxy-water solutions. The products were analysed by evaluating: i) physical-chemical parameters (lipids and sodium content, agglomeration index analysis (IA), and colour); ii) instrumental hardness; iii) sensorial parameters with 52 non-trained tasters. The main results showed no significant differences between T1, T2, and control samples in terms of lipids, sensorial perception, colour, and texture. As expected, in the sodium content, 30 % of reduction were found in T1 and 15 % of reduction in T2 compared with control. In this context, snacks produced in the present study would be healthier without a significant saltness perception difference from the controls.

1. Introduction

Consumers are constantly looking for a healthier diet and are more aware of the ingredients present in food. However, on the other hand, they also live a more tumultuous routine, with often less time to prepare their food, looking for more ready and easy to consume products, such as snacks, cookies, cereal bars, among others (Harada-Padermo et al., 2020). These foods are generally rich in sodium, sugars, and fats (Harada-Padermo et al., 2020).
Besides being a concern of most consumers, knowing the relationship of these ingredients with the development of chronic diseases (Buyukkestelli and El, 2019; World Health Organization, 2012). The challenge of reducing the consumption of sodium, sugars and fats is a mandatory issue of public health, and consequently a big challenge for the food industry (Aued-Pimentel and Kus-Yamashita, 2021; Cappuccio et al., 2019). One cannot find a single factor that influences the emergence of chronic diseases, it is a multifactor issue. However, there is a consensus among health professionals and governments that healthy habits, such as the practice of physical exercise and a balanced diet, act directly in their prevention (ABIA, 2013). For example, Salgado et al. (2017) described that the food industry has been under pressure from regulators and consumers to develop

healthier products, since high-fat content intake is one of the main factors that can cause obesity and contribute to the onset of several chronic diseases.

Snacks and snacking as been increasingly trendy for some time now. Consumption of extruded snacks grew 8% worldwide, according to Mintel (2017) Group (London, UK. The same market research company showed that in 2018, 96 % of consumers usually eat some snack and 69 % of those claims to consume snacks at least once a day (Grasso, 2020). In Brazil, for example, it was estimated in 2018 that sales of extruded snacks moved about 7.3 billion reais, with more than 1000 new products being launched in the country (Menis-Henrique, Janzantti and Conti-Silva, 2017). MindMiners (São Paulo, Brazil), a Brazilian market research company, has developed research that showed that 74 % of the evaluated consumers showed interest in healthier versions of salty snacks and stated that there is a market to be explored joining the interest for nutritional benefits and practicality (Mathias, 2018).

While extrusion-cooking is known for being an efficient application in the production of snacks (Rocky, 1995), in the flavouring stage, usually, 10 to 20 % lipids are added, and the amount of sodium chloride added to such snacks usually represents between 2 to 3 % of the total weight (Bombo, 2006; Monteiro et al., 2016). According to Korkerd et al. (2016), the significant components of extruded snack are carbohydrates and fat, so it is considered unhealthy food, especially for kids.

With these challenges, the food industries look for substitutes to vegetable oils, widely used to flavour snacks, that cause the minimum sensory impact on the final products and maintain these foods' market (Aued-Pimentel and Kus-Yamashita, 2021). The use of waxy starch has proven to be a viable alternative maintaining typical characteristics in final products (Nakagawa et al., 2019; ` árka and DvoYá• ek, 2017).

Consumers are also beginning to have some awareness about high sodium consumption and prefer products with a light salty taste (Harada-Padermo et al., 2020), most of the EU countries are regulating salt addition to largely consumed foods.

Faced with the two challenges of reducing salt and fat consumption, this work aimed to evaluate waxy starch solutions to replace the oil in extruded snacks and a different approach to deliver salt, decreasing sodium while keeping the same sensory salt perception.

2. Material and methods

2.1 Materials

To prepare the snacks, maise grits (milled and sieved from 80 to 150 mash Tyler), provided by Nutrimilho (Maringá, Brazil), were used.

Sodium chloride (Sal Cisne, Brazil) with 99 % purity was employed, and the waxy starch was provided from Puratos (Portugal).

2.2 Samples preparation

2.2.1 Salt agglomerates preparation

The salt agglomerates were produced as to obtain a product resistant enough not to be soluble during snacks coating. However, it must be entirely available for saltness perception during consumption. The salt agglomerates were produced in three concentrations to achieve this goal, were T3 was a control (table 1).

Table 1: Concentrations of salt and waxy starch in the three treatments

Treatment	NaCl (g)	Waxy starch (g)
T1	70	30
T2	85	15
T3	100	0

Waxy starch + salt mixtures were homogenised with 100 g of water and heated to 85 °C for complete starch gelatinisation. After that, it was dried for 24 hours at 80 °C in an oven with air circulation until it was completely dry and milled to the same granulometry as regular salt. The salt agglomerates were kept in sealed polypropylene bags until applying in the coating process.

2.2.2 Coating solution preparation

The coating solution, made by mixing 4 g of waxy starch and 96 g of water, was gelatinised at 85 °C for 5 minutes and cooled until room temperature. The solution was equilibrated in a glass bottle for at least 24 hours, at room temperature, before use.

2.2.3 Extrusion process

The extrusion was carried out according to Justen et al. (2017) in INBRA RX50 (INBRAMAQ, Ribeirão Preto, Brazil), with a single thread of 50 mm in diameter and 200 mm in length with 3 mm diameter holes die plate. The parameters were set with the motor amperage at 20 A and the system feed at 12 $g \cdot s^{-1}$. 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.

2.2.4 Coating process

The coating process was performed in a 20-litter coater with 200 g of extruded snacks, 30 g of coating solution and 2 g of each treatment of salt, at room temperature, for 15 minutes process. After each treatment coating, the snacks were kept in sealed polypropylene bags until the analysis.

2.3 Material characterisation

2.3.1 Lipids

Total lipid content was determined by Bligh & Dyer (1959) method. The analysis was carried out in triplicate.

2.3.2 Sodium content

The sodium content of the snacks was evaluated by AOAC method 972.29, 2005.

2.3.3 Texture characterisation of coated snacks

Instrumental hardness analyses were carried out using a Texture Analyzer TAXT2 Plus (Stable Micro Systems, England) in compression mode. The evaluation was performed according to previously defined (Berwig et al. (2017).) texture measurements.

An acrylic cylindrical probe with 25 mm of diameter (P/25L) was used. The tests were performed using this parameters values: (i) pre-test speed = 1.5 $mm.s^{-1}$; (ii) test speed = 2.0 $mm.s^{-1}$; (iii) post-test speed = 10.0 $mm.s^{-1}$; iv) distance = 20.0 mm; v) count cycle = 5 s; (vi) trigger force 15 g, with force measurement in compression.

2.3.4 Radial expansion index (IE)

Radial expansion index (IE) was determined, 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 (0.001 mm resolution, Mitutoyo, Japan).

2.3.5 Specific volume (SV), apparent density (AD) and retraction index (RI)

To calculate the specific volume (SV), a one-litre container was used. A mass of 100 g of snacks was added and the volume completed with millet seeds. Seed displaced was measured by checking its volume using a 500 mL graduated cylinder.

To measure the apparent density (AD), samples were placed into a one-litre container and weighted. The apparent density in $g \cdot mL^{-1}$ was calculated by dividing the mass obtained by 1000 mL.

The retraction index (IR) was calculated based on reduction of the initial specific volume after coating the product.

2.3.6 Agglomeration index analysis (AI)

Agglomeration index (AI) was performed according to Nakagawa et al. (2019) to measure how adhesion of each coating type can affect the snack quality during mixing in the flavouring step. Randomised 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 number of agglomerates indicates that the coating adhesion concerning the snacks is high and may affect the product presentation quality.

2.3.7 Colour

Colour was evaluated using a Minolta Chroma Meter CR-400 colourimeter (Konica Minolta Sensing Brazil) with D65 illumination as the reference, reading in three-point each sample for each treatment. Results were expressed by CIELAB system with values of L*, a* and b* whose L* values vary from black (0) to white (100), values of a* range from green (-60) to red (+60), and b* values, from blue (-60) to yellow (+60).

2.3.8 Sensory evaluation

The sensory evaluation was performed in the Sensory Analysis Laboratory of the Food Engineering Department, State University of Maringa. The analysis were carried out by 52 untrained panellists using 9 points hedonic scale (from 1 = completely without salt, 5 = ideal in salt to 9 = extremely salty). For this test, ten units of each sample were presented in disposable cups, duly identified with random three-digit numbers, accompanied by a glass of water. The Research Ethics Committee approved sensory tests of the State University of Maringa (CAAE 18718013.3.0000.0104).

2.4 Statistical analyses

All data were treated statistically, by analysis of variance (ANOVA) with subsequent determination of the Tukey tests' means at 5 % probability and correlation test. The statistical test was made using software Sisvar 5.6 (Ferreira, 2011).

3. Results and discussion

The snack physicochemical proprieties are presented in Table 2, as expected there were no differences among the three treatment in terms of lipids because there was no fat added in all of them. The values found for lipids are a bit higher than the results found in samples without oil by Nakagawa et al. (2019) (from 0.96 to 2.13) and Monteiro et al. (2016) (from 0.35 to 0.73). These differences could depend on the different agricultural maise varieties used in these works since there was no fat added to the extruded snacks formulation or to the coating solutions.

The results prove that waxy starch can reduce the content of lipids in snacks because compared to the content commonly found in products available in the market, which varies from 10 to 20 % (Monteiro et al., 2016), the reduction was significant.

The sodium content in T1 was slightly more than 30% lower than control (T3). This confirms that the proposed reduction (30 %) was made. Similarly, T2 has 14,8% less salt than control (T3), as was expected.

Table 2: Physicochemical properties of the snacks

Treatment	Lipids (g/100 g DW)	Sodium (mg/100 g DW)
T1	3.27[a]	272.84[c]
T1	3.01[a]	335.18[b]
T3	2.91[a]	393.24[a]

Means with different letters in the same column are significantly different (P d 0.05).

Table 3 shows the mechanical properties of the snacks; there were no significant differences between the three treatments in terms of hardness, specific volume (SV), apparent density (AD), and retraction index (RI). This is caused by the fact that all the samples come from the same extrusion process, and the coating process does not make physical changes in the snack. In the same way, there were no expressive differences between these results and the results earlier found in control snacks by Graça et al. (2020), Salgado et al. (2017), and Monteiro et al. (2016).

For the agglomeration index (AI), there was no statistical difference between the three treatments, showing that the changing of salt concentration does not impact agglomeration. The results for AI were lower than the results obtained by Nakagawa et al. (2019), showing that waxy starch is better in terms of final product quality since higher AI indicates that there will be more snack stuck to each other in the product pack.

Table 3: Mechanical properties of the snacks

Treatments	Hardness (kg)	SV ($mL.g^{-1}$)	AD ($g.L^{-1}$)	RI	AI
T1	2.18[a]	15.38[a]	50.57[a]	0.94[a]	14.20[a]
T2	2.21[a]	15.87[a]	51.40[a]	0.94[a]	12.13[a]
T3	2.31[a]	15.07[a]	50.03[a]	0.93[a]	11.75[ab]

Means with different letters in the same column are significantly different (P d 0.05).

Sensory saltness and instrumental colour values for the snacks are shown in Table 4. There were no significant differences in instrumental colour among all the treatments, as expected since the extrusion conditions of the snacks were the same. It was possible to confirm that the coating does not influence the snacks' visual characteristics. The same results were found by Graça et al. (2020) in the work with xanthan gum in snacks. Monteiro et al. (2016), Nakagawa et al. (2019) and Graça et al. (2020) have compared their coating with an oil coating, and in all these studies, there was no meaningful difference between them.

The saltness perception in this research was lower than in Vasques et al. (2020), but they used a significantly higher salt in their recipes, both in control and treatments. The most important results are the indistinguishability in terms of saltness perception for all treatments.

It shows that the different way to deliver the salt could preserve the saltness while reducing the salt amount added, and this is a major result for the food industry.

Table 4: Sensorial saltness and instrumental colour of the snacks

Treatment	Colour			Saltness perception
	L	a	b	
T1	71,62^{a}	-8.05^{a}	30,42^{a}	4.07^{a}
T2	72,88^{a}	-8.99^{a}	29,61^{a}	4.18^{a}
T3	76,56^{a}	-9.71^{a}	30,11^{a}	4.16^{a}

Means with different letters in the same column are significantly different (P d 0.05).

As presented by instrumental colour results, Figure 1 shows photographic comparison of the three treatments; it is possible to visually observe that it is hard to distinguish among the three treatments.

T1 T2 T3

Figure 1: The appearance of snacks obtained from the three treatments.

4. Conclusions

Based on the results obtained, noting that there were no significant differences between the samples in the sensory evaluation, it was possible to conclude that the salt clusters reduce the inclusion of salt in the recipe without reducing the product's perception of saltness.

Simultaneously, waxy starch as a coating medium for snacks proved to be efficient in eliminating the use of oil as few snacks were sticking together, thus maintaining the expected quality of the product. The other physicochemical and mechanical characteristics of the snacks were preserved.

Therefore, it is possible to conclude that snacks with a salt reduction of 30 % and the elimination of oil are achievable while maintaining the original product's characteristics, enabling the manufacture of a healthier product for consumers. These are important news for the food industry.

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