CHEMICAL ENGINEERING TRANSACTIONS
VOL. 57, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Sauro Pierucci, Jiří Jaromír Klemeš, Laura Piazza, Serafim Bakalis

ISBN 978-88-95608- 48-8; **ISSN** 2283-9216

Shelf Life Evaluation of Extruded Snacks Coated with Maize Starch to Eliminate the Use of Fats in the Flavoring Process

Diego R. Marques*[a], Kimberli P. Berwig[b], Cláudia C. F. Monteiro[c], Dalany M. Oliveira[d], Antonio R. G. Monteiro[a]

[a] State University of Maringa, Postgraduate Program in Food Science, Av Colombo, 5790, 87030-900, Maringá, PR, Brazil
[b] State University of Maringa, Department of Food Engineering, Av Colombo, 5790, bl 13, 87030-900, Maringá, PR, Brazil
[c] State University of Maringa, Campus Cianorte, Department of Design, Rua Dom Pedro II, 598, Cianorte, PR, Brazil
[d] Instituto Federal de Educação, Ciência e Tecnologia da Paraíba, Rua Presidente Tancredo Neves, s/n, Sousa, PB, Brazil
diegomarques86@gmail.com

The consumption of extruded snacks has been suffering from severe restriction in several countries by its high content of fat and low nutritional value. An important manufacturing step that provides desirable characteristics for snack food is flavouring, where the product is pulverized with vegetable fat, at a rate of 10 to 20 %, for complete fixation of the flavours in the product. This study objective was to eliminate the use of fat in the snack flavouring process replacing it by an aqueous solution of maize starch and compare the, physical, chemical and sensory characteristics of the flavoured snacks with and without fat. Experimental design was conducted to identify the best concentration of the water diluted maize starch to be pulverized in the product. The snacks were produced by the single screw IBX50 extruder. Analyses of instrumental hardness, moisture content, water activity, expansion ratio, specific volume, acidity, total lipid repeated every 15 days for 45 days, adsorption isotherms and sensory evaluation after manufacture were performed. Since the low acidity contributes to the increase in shelf life, the acidity number of the aromatized snack without fat, 0.560 mgKOH / g, had a better result when compared to the aromatized snack with fat, 1.065 mgKOH / g. Another major result between samples with and without fat were the reduction of total lipids from 15.07 % to 1.56 % followed by the absence of significant difference ($p < 0.05$) in the sensorial and physical-chemical analysis. Hence, is possible to conclude that vegetable fat elimination replaced by a 4 % maize starch aqueous solution, gelatinized at 85 ºC, is a viable alternative to reduce the lipid content in flavoured snacks without loss of consumer attractiveness

1. Introduction

Extrusion process is capable of producing assorted products such as breakfast cereal, modified starch, pasta, animal feed and extruded snacks (Alam et al., 2016). For the snacks manufacturing, cereal flour is the most used raw material (Korkerd et al., 2016).

After snacks extrusion, it is necessary to use seasonings to improve sensorial characteristics, this step is done after the drying of the freshly extruded snacks by sprinkling oil or vegetal fat, then adding flavours and salt, being able to then sprinkle oil again (Bhandari et al., 2001). Monteiro et al. (2016) reported that 10 to 20 % (m / m) of lipids are pulverized on the snacks surface during the flavouring steps.

According to Bhandari et al. (2001) there are other ways of snacks flavouring such as incorporation of pre-extrusion seasonings, incorporation of pre and post extrusion seasonings and injection of seasonings in the last heating zone of the process. All mentioned processes does not achieve the same effect of the most industry used technique which is the pulverization of oil or vegetable fat. Extruded snacks are high in calories and fat, with low protein and fibre noticing as an unhealthy food for many consumers (Korkerd et al., 2016). Further studies are needed for the flavouring process in snacks, aiming manufacturing for a healthier product, as well as attend the consumer expectations. The objective of this work was to eliminate the use of fat in the flavouring of snacks being replaced by an aqueous solution of maize starch and to compare the physical, chemical and sensorial characteristics of the flavoured snacks with and without fat.

2. Material and Methods

2.1 Raw Material

The snacks were manufactured using corn grits provided by Caramurú Alimentos.
For the coating solution, maize starch (Pasquini, Brazil) fine herbs seasoning (All-Flavors, Brazil), sodium chloride (Vitão, Brazil) and soybean oil (Cocamar, Brazil) were used.

2.2 Snack Manufacturing

The corn grits used for snacks production were humidified by adding 2.5 % water (m / m) and preconditioning for 24 hours at 5 °C (the final moisture of grits was 12%). Then the extrusion cooking was performed in a single-screw equipment (INBRAMAQ, Brazil) with 50 mm in diameter and 200 mm in length. The die plate used has two 3.1 mm diameter holes and the consecutive parameters: motor amperage at 20 A, cutting speed 50 rpm and feed speed of 12 g / s.
After extrusion the snacks were oven dried with forced air circulation at 60 °C for 30 minutes to standardize the humidity (DS Treatment).

2.3 Flavouring procedures

Standard treatment (S) was manufactured by sprinkling 150 g of oil for every 1 kg of snacks then adding 20 g of seasonings and 20 g of sodium chloride followed by 2 minutes of homogenization in a 20-liter stainless steel coating pan at 40 rpm rotation. For the maize starch samples, a preliminary coating test was performed using 100 g of maize starch (in green dyed), leading to a lack of coverage for one kilo of snack. Gradually, the solution quantity was increased in order to complete the coating (Figure 1).

Figure 1 – Preliminary coating test result. On the left, 100 g of the maize starch solution for each kilogram of snacks and on the right, 320 g of the maize starch solution for each kilogram of snack.

To replace the fat in the aromatized snacks, 12 treatments were tested. The concentration of maize starch diluted in water was varied and the gelatinization temperature, performed under 1 minute of heating exposure (Table 1). The 320 g of solution in different concentrations were dissolved in 20 g of seasoning and 20 g of sodium chloride. The flavouring process was performed in batch using 1000 g of dried snacks, heated in the coating pan. The maize starch solutions were pulverized on the snack surface using a compressor with air flow of 2.66×10^{-3} m^3/s and 0.81 MPa pressure.
The samples were packed in polyethylene packages 200 x 200 x 0.04 mm weighing 150 g each and stored in BOD (biochemical oxygen demand) incubator at controlled temperature of 25 ± 1 ºC and 60 ± 5 % relative humidity.

2.4 Instrumental hardness

The instrumental hardness analysis was performed in the Texture Analyser TAXT2 Plus (Stable Micro Systems, England), according to Chinellato et al. (2016).

2.5 Moisture Content

Moisture content was determined by oven drying at 105 ºC (Association of Official Analytical Chemists, AOAC, 2005).

2.6 Water activity

Water activity 25ºC was performed using the AQUALAB (Aqualab Dew Point Water Activity Meter 4te) equipment.

2.7 Expansion ratio and specific volume

Expansion ratio (ER) and specific volume (EV) were calculated according to Mercier et al. (1998).

2.8 Acidity

Acid value (AV) was determined according to Instituto Adolfo Lutz, (2008).

2.9 Total lipids

The total lipid was determined by the Bligh & Dyer (1959).

2.10 Adsorption isotherms

Moisture adsorption isotherms was assessed through static gravimetric method, described by Wolf et al. (1985) using saturated solutions of salts (CH_3COOK, K_2CO_3, NaBr, $SnCl_2$, KCL, $BaCl_2$) at 25ºC ± 2ºC temperature.

For experimental data mathematical adjustment of the dye isotherms, the mathematical models of GAB, BET, Henderson and Oswin were used.

The fit quality of adjusting different models was evaluated through the best values obtained of the explained variation coefficient (R) and the relative mean deviation (E%), defined by Iglesias and Chirife (1976)

2.11 Sensory evaluation

Sensory evaluation was carried according to description by Monteiro and Cestari (2013) with 120 non-trained tasters of ages ranging from 18 to 45 years old. The test cabins had white illumination. The sensory tests received the approval of the Research Ethics Committee of the State University of Maringa (CAAE 18718013.3.0000.0104) and were carried out for all of the treatments only at initial time.

2.12 Statistical analysis

Analysis were performed in triplicate and the results are reported through mean and standard deviation. The data were evaluated by Statistical Analysis of Variance (ANOVA) and Tukey test in order to verify significant difference ($p < 0.05$) using the software ASSISTAT Version 7.7.

Table 1: Experimental design of the maize starch percentage dissolved in water, hardness, moisture content, water activity (A_w) and Specific Volume (SV) of each treatment.

Treatment	Coating	Temperature (ºC)	Hardness (N)	Moisture (%)	A_w	SV ($mL.g^{-1}$)
T1	1 %	65ºC	$12.62±3.68^{d}$	$5.58±019^{a}$	$0.320±0.011^{ab}$	$12.74±1.24^{a}$
T2	2 %	65ºC	$13.60±3.41^{cd}$	$4.66±0.03^{b}$	$0.266±0.004^{cd}$	$13.59±2.34^{a}$
T3	4 %	65ºC	$17.59±3.52^{a}$	$4.99±0.26^{ab}$	$0.267±0.003^{c}$	$14.31±0.70^{a}$
T4	1 %	75ºC	$17.08±2.14^{abc}$	$5.42±0.20^{a}$	$0.304±0.004^{b}$	$14.78±1.10^{a}$
T5	2 %	75ºC	$17.19±2.66^{ab}$	$4.98±0.55^{ab}$	$0.322±0.002^{ab}$	$14.89±0.55^{a}$
T6	4 %	75ºC	$17.80±2.77^{a}$	$4.53±0.05^{b}$	$0.331±0.002^{a}$	$14.62±0.36^{a}$
T7	1 %	85ºC	$13.82±2.29^{bcd}$	$3.98±0.28^{bc}$	$0.251±0.003^{cde}$	$15.08±0.61^{a}$
T8	2 %	85ºC	$14.86±2.96^{abcd}$	$3.87±0.26^{bc}$	$0.223±0.003^{e}$	$14.74±0.12^{a}$
T9	4 %	85ºC	$15.99±2.41^{abcd}$	$3.48±0.14^{c}$	$0.247±0.004^{cde}$	$14.82±0.85^{a}$
S	15 %	-	$15.60±2.90^{abcd}$	$3.72±0.05^{c}$	$0.244±0.002^{de}$	$13.95±0.98^{a}$
DS	-	-	$16.12±2.09^{abcd}$	$3.69±0.22^{c}$	$0.246±0.011^{cde}$	$12.91±0.66^{a}$

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

3. Results and Discussion

By comparing the table 1 results, treatments T9 and DS have no significant difference ($p < 0.05$) to the standard in all tests. In order to evaluate a shelf life investigation, DS, S and T9 treatments were chosen.

Table 2: Sensorial analysis results

Treatment	Hardness	Flavour
DS	$7.13 ± 1.03^{a}$	$1.29 ± 1.23^{b}$
S	$7.53 ± 1.14^{a}$	$7.51 ± 1.13^{a}$
T9	$7.26 ± 1.23^{a}$	$7.49 ± 1.19^{a}$

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

The sensorial analysis results showed no significant difference ($p < 0.05$) between treatments S and T9 (table 02). An attributed low flavour values to DS treatment was expected since the sample was not flavoured. This fact reinforces the flavouring process as an important step for consumer acceptance of snacks products. Monteiro et al. (2016) also observed low acceptance for the same attribute in unflavoured snacks corroborating this work data.

As for the instrumental hardness shown in table 3, there was no significant difference between the samples during the same period. Although, comparing the same treatment during 45 days, an upward trend for the hardness occurred, the product ceased its crunchiness and became compressible. This behaviour was observed either in the standard and starch coated samples. Studies have approached same results for snacks foods (Obadina et al., 2013; Wang et al., 2015) and the hardness is inferior compared to breakfast cereals, an expected characteristic (Oliveira et al., 2013).

Table 3: Snacks instrumental hardness (N)

Treatment	0 Days	15 Days	30 Days	45 Days
DS	6.59 ± 1.14^{aC}	8.19 ± 1.65^{aBC}	10.42 ± 3.37^{abB}	16.04 ± 1.95^{aA}
S	7.36 ± 1.69^{aC}	8.20 ± 2.01^{aC}	11.98 ± 1.71^{aB}	16.99 ± 3.66^{aA}
T9	6.65 ± 1.68^{aC}	9.67 ± 2.31^{aC}	9.48 ± 3.07^{bB}	15.53 ± 5.89^{aA}

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 content in table 4 exhibited the same behaviour of the instrumental hardness analysis, in other words, humidity raises during the shelf life justifying the ascending hardness observed. According to Gates et al. (2008) the increase of humidity in snacks results in a softer and more plastic snacks.

Table 4: Snacks moisture content (%) results

Treatment	0 Days	15 Days	30 Days	45 Days
DS	3.91 ± 0.05^{bC}	5.41 ± 0.24^{aB}	5.67 ± 0.10^{aB}	6.21 ± 0.08^{aA}
S	4.37 ± 0.15^{abD}	5.02 ± 0.10^{aC}	5.57 ± 0.09^{aB}	6.41 ± 0.14^{aA}
T9	4.57 ± 0.33^{aC}	5.27 ± 0.19^{aB}	5.63 ± 0.05^{aB}	6.27 ± 0.28^{aA}

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 ($p < 0.05$).

Specific volume (table 5) is an important attribute to be evaluated since it indicates the volume needed for the product storage (Alam et al., 2016). Meanwhile, the expansion ratio, was found between 4.27 to 4.44, is related to the water content present in raw material extrusions, high moisture obtains low expansion rates (Alam et al., 2016). The results were similar to those found by Mikalouski et al., (2014), where expansion ratio of snacks produced with corn grits ranged from 3.99 to 4.73.

Table 5: Snacks specific volume ($mL.g^{-1}$)

Treatment	0 Days	15 Days	30 Days	45 Days
DS	15.91 ± 0.47^{aA}	15.39 ± 0.03^{aA}	15.52 ± 0.44^{aA}	15.66 ± 0.86^{aA}
S	14.63 ± 0.46^{bA}	14.55 ± 0.32^{bA}	14.65 ± 0.50^{aA}	14.74 ± 1.58^{aA}
T9	14.55 ± 0.27^{bA}	14.16 ± 0.32^{bA}	14.79 ± 1.99^{aA}	14.61 ± 1.21^{aA}

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 ($p < 0.05$).

Acidity indicates that the oil or fat is suffering chain breakdowns, so its increment gives the product an unpleasant flavour characteristic of oil oxidation (Gutkoski and Pedó, 2000). Results from snacks acidity (Table 6) were significantly higher ($p > 0.05$) in the T9 sample compared to S indicating an oxidation of the oil flavoured snacks stored in polyethylene packages.

Table 6: Snacks acidity (mgKOH / g) results.

Treatment	0 Days	15 Days	30 Days	45 Days
DS	0.560 ± 0.06^{bA}	0.653 ± 0.038^{bA}	0.613 ± 0.039^{bA}	0.560 ± 0.060^{bA}
S	0.801 ± 0.025^{aB}	0.933 ± 0.038^{aB}	1.052 ± 0.082^{aA}	1.065 ± 0.081^{aA}
T9	0.560 ± 0.060^{bA}	0.627 ± 0.025^{bA}	0.574 ± 0.037^{bA}	0.587 ± 0.045^{bA}

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 ($p < 0.05$).

The results of lipids contents had a large difference between treatments (Table 7). DS and S showed close values and T9 had approximately 15 times more lipids than DS or S, it happens caused by oil coating on treatment S.

Table 7: Snacks lipids (%) results.

Treatment	0 Days	15 Days	30 Days	45 Days
DS	1.23 ± 0.29^{bA}	1.20 ± 0.16^{bA}	1.22 ± 0.29^{bA}	1.29 ± 0.29^{bA}
S	16.02 ± 0.28^{aA}	16.66 ± 0.47^{aA}	16.09 ± 0.36^{aA}	16.59 ± 0.42^{aA}
T9	1.19 ± 0.27^{bA}	1.21 ± 0.24^{bA}	1.24 ± 0.35^{bA}	1.34 ± 0.41^{bA}

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 ($p < 0.05$).

The applied model parameters to the experimental values of the adsorption isotherms for the treatments DS, P and T9, as well as the values of the explained variation (R) and the relative mean deviations (E%) used as evaluation criteria for the representation of the isotherms are shown in Table 8.9 and 10.
According to Aguerre et al. (1989), after applying the mathematical models and obtaining R above 95 and E% between 0 - 10%, the models indicate reasonable representativeness and according to Labuza et al. (1985), isotherm representation is considered to be extremely good for E% less than 5%.
The mathematical model that presented the best results for all the treatments was the GAB model with R above 99 and E% below 0.55.

*Table 8 *: Experimental data adjustment results of the adsorption isotherm at 25 °C for DS treatment.*

Model	Parameters				
	Xm	C	K	R	E%
GAB	0.048	28.27	0,946	99.74	0.42
	Xm	C	n	R	E%
BET	0.042	32.82	23.05	99.37	0.68
	A	b		R	E%
HENDERSON	0.943	6.80	-	98.09	1.13
	A	b		R	E%
OSWIN	0.090	0.58	-	99.62	0.47

Table 9: Experimental data adjustment results of the adsorption isotherm at 25°C for S treatment.*

Model	Parameters				
	Xm	C	K	R	E%
GAB	0.041	90.85	1.028	99,92	0.53
	Xm	C	n	R	E%
BET	0.062	1.88	391.59	98.56	2.20
	A	b		R	E%
HENDERSON	0.468	2.91	-	95.59	4.45
	A	b		R	E%
OSWIN	0.068	0.98	-	98.34	2.66

Table 10: Experimental data adjustment results of the adsorption isotherm at 25°C for T9 treatment.*

Model	Parameters				
	Xm	C	K	R	E%
GAB	0.058	3.79	0.990	99.94	0.43
	Xm	C	n	R	E%
BET	0.055	4.61	52.41	99.86	0.33
	A	b		R	E%
HENDERSON	0.615	3.40	-	98.56	2.21
	A	b		R	E%
OSWIN	0.088	0.81	-	99.86	0.58

*R: explained variation. E%: relative mean error. Xm: monolayer moisture content. C: constant related to the sorption heat of the molecular layer. K: GAB constant related to multilayers. n: BET constant related to multilayers. a and b: adjustment parameters of the Henderson and Oswin models.

4. Conclusion

Flavoured snack food using 4% maize starch aqueous solution gelatinized for 1 minute at 85 °C resulted in excellent results compared to flavoured snacks using vegetable oil. Based on the results, this study showed the possibility of oil substitution in flavouring snack process obtaining a healthier final product due to the reduced lipid content. The new product has the same sensorial and physical chemical characteristics compared to oil flavoured snack.

Acknowledgments

Financial support CAPES, Brazil for the doctorate scholarships, and the Fundação Araucária for the support in promoting the results.

References

Aguerre R.J., Suarez C., Viollaz P.E., 1989, New BET Type Multilayer Sorption Isotherms Part II: Modelling Water Sorption in Foods, LWT-Food Science and Technology, 22, 192-195.

Alam M.S., Kaur J., Khaira H., Gupta K., 2016, Extrusion and Extruded Products: Changes in Quality Attributes as Affected by Extrusion Process Parameters: A Review, Critical Reviews in Food Science and Nutrition, 56:3, 445-473, DOI: 10.1080/10408398.2013.779568

AOAC (Association of Official Analytical Chemists, 2005, Official methods of analysis of the AOAC International. 17th ed., Gaithersburg.

Bhandari B., D'arcy B., Young G., 2001, Flavour retention during high temperature short time extrusion cooking process: a review. International Journal of Food Science Technology, Oxford, 36, 453-461.

Bligh E.G., Dyer W.J., 1959, A rapid method of total lipid extraction and purification, Can. J. Biochem. Physiol., 37, 911-917, Chemists, 199 p.

Chinellato M.M., Conegero J., Marques D.R., Oliveira D.M., Clemente E., Monteiro A.R.G., 2016, Physical-chemical and sensory quality of cassava extrused snack added with Hibiscus sabdariffa L., Chemical Engineering Transactions, 49, 403-408, DOI: 10.3303/CET1649068

Gates F.K., Dobraszczyk B.J., Stoddard F.L., Sontag-Strohm T., Salovaara H., 2008, Interation of heat-moisture conditions and physical properties in oat processing: I. mechanical properties of steamed oat groats, Journal of Cereal Science, 47, 239-244.

Gutkoski L.C., Pedó I., 2000, Aveia, composição química, valor nutricional e processado, São Paulo, Varela.

Henderson S.M.A., 1952, basic concept of equilibrium moisture, Agric. Engng, 33: 29–32.

Iglesias H.A., Chirife J., 1976, A Model for Describing the Water Sorption Behaviour of Foods, J. Food Sci., 41, 984-992.

Instituto Adolfo Lutz, 2008, Normas analíticas do Instituto Adolfo Lutz: métodos químicos e físicos para análise de alimentos. 4.ed. São Paulo.

Korkerd S., Wanlapa S., Puttanlek C., Uttapap D., Rungsardthong V., 2016, J Food Sci Technol, 53:561. DOI:10.1007/s13197-015-2039-1

Labuza T.P., Kaanane A., Chen J.Y., 1985, Effects of Temperature on the Moisture Sorption Isotherms and Water Activity Shift of Two Dehydrated Foods, Journal of Food Science, 50, 385-392.

Mercier C., Linko P., Harper J. M., 1998, Extrusion Cooking, 2. ed., St. Paul, American Association of Cereal.

Mikalouski F.B.S., Monteiro A.R.G., Marques D.R., Monteiro C.C.F., Benossi L., 2014, Influência da granulometria da matéria-prima na expansão de extrusados de milho, Brazilian Journal of Food Technology, 17, 28-32.

Monteiro A.R.G., Cestari L.A., 2013, Análise sensorial de alimentos: testes afetivos, discriminativos e descritivos, Maringá, Brasil, EDUEM, 1-53.

Monteiro A. R. G., Marques D. R., Marchi L. B., Chinellato M. M., Berwig K. P., Wolf B., 2016, Eliminating the use of fat in the production of extruded snacks by applying starch coating, Chemical Engineering Transactions, 49, 625-630, DOI: 10.3303/CET1649105

Obadina A.O., Oyewole O.B., Williams, O.E., 2013, Improvement in the traditional processing method and nutritional quality of traditional extruded cassava-based snack (modified Ajogun), Food Sci Nutr, 1, 350–356, DOI:10.1002/fsn3.43

Oliveira D.M., Marques D.R., Kwiatkowski A., Monteiro A.R.G., Clemente E., 2013, Sensory analysis and chemical characterization of cereal enriched with grape peel and seed flour, Acta Scientiarum, Technology, Maringá, v. 35, n. 3, 427-431. DOI: 10.4025/actascitechnol.v35i3.13176

Oswin C.R., 1946, The kinetics of package life III, The Isotherm, J Chem. Indust., 65, 419–421.

Wang S., Opassathavorn A., Zhu F., 2015, Influence of Quinoa Flour on Quality Characteristics of Cookie, Bread and Chinese Steamed Bread, J Texture Stud, 46, 281–292, DOI:10.1111/jtxs.12128

Wolf W, Spiess WEL, Jung G. Standarization of isotherm measurements. In: Simatos D, Multon JL, editors, 1985, Properties of water in foods. The Netherlands: Martinus Nijhoff; 661–679.