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Research Article

Effect of Chickpea in the Physicochemical And Sensorial Properties of Third Generation Extruded Snacks

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Abstract

This research evaluated the physicochemical properties of third generation snacks of wheat and chickpea flour (60 or 80 % moisture). They were processed in a simple screw extruder at 100, 110 or 120 ºC. After extrusion, they were cut in square pieces (1.5 cm), dehydrated during 12 h and expanded in hot air. Expansion index (EI), density (D), hardness (H), crunchiness (C), water absorption index (WAI) and water solubility index (WSI) and sensory acceptance were evaluated. The snacks extruded at 110 -120 ºC and 80 % moisture showed the highest acceptability, as well as high EI, low D and H. We concluded that incorporation of proteins to snacks modify their expansion index and texture which affect consumer acceptability.

Keywords: Third Generation Snacks; Extrusion; Chickpea

Introduction

There is a wide variety of snacks in the market including the third-generation snacks. They are known as semi-finished products and are distinguished because they preserve their quality characteristics for a long time and require a reduced storage space [1].

Actually, the market is demanding a better nutrimental value of snacks and the industry is responding with the addition of functional and nutraceutical products, such as legumes [2]. Chickpea is one of the most important legumes in Mexico [3] ; it is a good source of minerals, essential fatty acids, protein and fiber, as well as essential amino acids [4].

However, the incorporation of high protein ingredients to snacks may affect their texture, expansion index and acceptability

[5]. This was experienced [6] obtaining pellets from potato starch, high-protein maize and soya flour; they processed it in a single screw extruder at 123 – 140 ºC and 27 – 31 % moisture; [7] obtained snacks from extruded rice starch and maize proteins flour; and [8] from extruded rice starch and chickpea flour.

The extrusion technology allows to change the texture and structural characteristics of the products. Extrusion involves high temperature and short time [5], transforming the cereal and legume dough into a very high viscosity fluid [9]. This technology has been used to produce second and third generation snacks, but processing is different between them, especially in the extruder's die zone. Second generation snacks require a die with a chamber between the screw and the die nozzle, which during extrusion is a high-pressure area. The nozzle must have a reduced orifice to enhance the pressure, so when the material comes out, the change in pressure and temperature provokes the snack expansion. Third generation snacks do not need to expand when come out from the extruder, so there is no need to generate pressure in the die zone, and the die configuration obeys the desired shape in the snack. Besides, the low velocity of the screw allows to obtain a cooked product without a high-pressure zone, which is convenient for third generation snacks. An additional advantage of the extrusion process is that fiber, minerals and some other functional compounds are preserved, as well as the reduction on microbial load [1,10].

This work will study the effect of two extrusion factors, moisture and temperature, on the quality characteristics of third generation snacks from wheat and chickpea flour.

Materials and Methods

Raw material

Commercial wheat flour which chemical composition was moisture 5%, protein 10%, lipids 1 %, fiber 4 %, ashes 3 % and carbohydrates 77 %, and chickpea flour (Nuevo León, México) containing moisture 13 %, protein 20 %, lipids 7 %, fiber 15%, ashes 4 % and carbohydrates 41 %.

Extrusion

The wheat and chickpea flour were processed in a single screw extruder [11] with two heating zones, a L/D ratio of 21, 18 mm diameter and 3 mm depth. It was used a stainless-steel die with a rectangular orifice of 10 mm X 2 mm. The barrel temperatures during processing were 100 ºC in the first zone and 100, 110 or 120 ºC in the second, and the screw speed was 10 or 20 rpm. Once extruded, the material was cut in 1.5 cm square sheets and dehydrated at 52 ºC during 12 h in an Excalibur dryer model 2900EB (Califormia, U.S.A.), and stored in plastic bags (with zipper) at room temperature (25ºC). It was used as control wheat flour snack.

Expansion

It was used a Sunbeam domestic equipment, model FPSBPP7052, which generates hot air at 280 ºC and a speed of 2 m /s, exposed during 30 – 50 s.

Physicochemical analysis

Expansion index

It was determined using the method reported [12], which is based in the volume of millet displaced by the material, in this case, the snacks. The volume of millet displaced by the unexpanded snack was subtracted to the volume of millet displaced by the expanded snack and dividing it by the volume of unexpanded snack. This determination was carried out by triplicate.

Density

It was calculated dividing the weight of the snacks between their volume. Weight was determined in an analytical balance and volume was calculated as described previously.

Hardness and crunchiness

Hardness and crunchiness were determined using a TA. XT Plus (Germany), with a conical (30º) probe (TA-17). Hardness was recorded as the maximum force required to break the snack and crunchiness was recorded as the number of fractures during its compression. This determination was repeated six times.

Water absorption and water solubility indexes

They were determined using the method described by Anderson et al. (1969), with some modifications. Water (10 mL) was added to snacks (1 g), milled and sieved (mesh 60 US) and placed in conical tubes (15 mL). They were shaken in a Vortex during 1 min and placed in a water bath at 30 ºC, agitated at 70 rpm, during 30 min, and centrifuged at 6,000 rpm and 25 ºC during 10 min. They were performed by triplicate. WAI and WSI were calculated using (Equation 1 and 2), respectively.

$$\text{WAI}=\frac{\text{Weight of the centrifugation residue}}{\text{Weight of the sample}-\text{Weight of the evaporation residue}} \quad (1)$$

$$\text{WSI}=\frac{\textit{Weight of the evaporation residue}}{\textit{Weight of the sample}} \quad (2)$$

Sensory evaluation

It was performed a randomized preference paired test with 50 untrained panelists. They evaluated hardness, crunchiness and general acceptability. Two samples were tested, one of them processed at 110 ºC and the other one at 120 ºC, both of them contained 80% moisture before extrusion.

Experimental design and statistical analysis

Experimental design was factorial 3x2, independent variables were X1 temperature at the second heating zone of extruder, levels 100, 110 and 120 ºC and X2 moisture of wheat and chickpea flour before extrusion, levels 60 and 80%. Statistical analysis (Table 1) consisted in the application of an F test and subsequently a Student T test (Minitab 17.1.0) and there were performed response surface graphics.

Table (1): Experimental design used to produce third generation extruded snacks.

Tratamiento	X_1	X_2
1	-1	-1
2	-1	+1
3	0	-1
4	0	+1
5	+1	-1
6	+1	+1

X_1 = Temperature at the second heating zone of extruder:
X_2= moisture

To optimize the production of extruded snacks it was applied the methodology of response surface, as a technique to know the effect of the independent variables of the extrusion process (temperature and moisture) on the dependent variables. Once obtained the model, were included the intercepts, the lineal coefficients and the interactions between dependent variables obtained from the regression analysis. The non-significant terms ($p < 0.05$) were eliminated and a new polynomial (prediction model) was re-calculated for each one of the dependent variables. Contour graphics of each one of the dependent variables were used (surface over-position methodology) to observe and select the best combination of moisture (of the fed material) and temperature (of the extruder). Result was considered as the optimized model to obtain the extruded sheets of the third-generation snacks. They were calculated using the Minitab program 17.1.0.

Results and Discussion

Expansion index (EI)

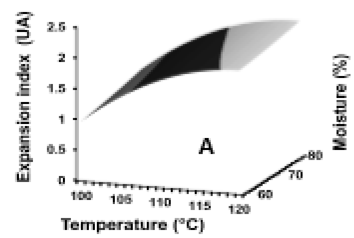
The EI of wheat and chickpea snacks were 0.97 – 2.19, lower than the wheat snack, as expected (Figure 1A). Both independent variables influenced the EI (Table 2), and the prediction model explained 95 % of the total variation ($p < 0.000$). The highest EI of wheat and chickpea snacks were from those processed at 110 and 120ºC and 80 % moisture (Figure 1 A).

Table (2): Regression coefficients and analysis of variance of first order equations (prediction models)

Coeficients	EI	D	C
Intercept	1.68	387.8	3.29
Lineal			
X_{11}	-0.599	71.4	-0.875
X_{12}	0.171	-31	0.5
X_{13}	0.429	-40.3	0.375
X_{21}	-0.099	15.1	-0.236
X_{22}	0.099	-15.1	0.236
Interactions			
$X_{11}X_{21}$	-0.004	9.4	0.236
$X_{11}X_{22}$	0.004	-9.4	-0.236
$X_{12}X_{21}$	-0.013	2.4	-0.139
$X_{12}X_{22}$	0.013	-2.4	0.139
$X_{13}X_{21}$	0.017	-11.8	-0.097
$X_{13}X_{21}$	-0.017	11.8	0.097
R^2	0.95	0.79	0.83
P	0.000***	0.043**	0.023**

EI = Expansion index; D = Density; C = Crunchiness (*P > 0.05). *P ≤ 0.1; **P ≤ 0.05; ***P ≤ 0.01

Figure (1A): Surface response of the combined effect of processing temperature and moisture on expansion index.



The influence of temperature on the EI was also reported by [13] for second generation snacks of barley and chickpea, who found that increasing temperature (120 - 150ºC) may obtain higher EI, as well as [14] for second generation snacks of pea protein isolates (130 – 170ºC). [15] expressed that temperature has an important influence on the EI of starch snacks, because over the glass transition temperature (Tg) of starch, this compound acquires an elastic behavior and favors its expansion.

Moisture is another factor to consider on the EI of extruded snacks. It was reported that low moisture is required for a high EI when extrusion temperatures are 130 – 170 ºC [13]. However, when extrusion temperatures are 100 – 120ºC, high moisture (60 – 80%) is required to obtain a good EI, as it occurs in this research. It also must be considered that some ingredients, such as protein and fiber interact with water, competing with starch, and EI must be affected. The effect of fiber on expansion index seems to be related with fiber concentration; above a critical concentration, fiber may disrupt the structure of the extrudate preventing its elastic deformation during expansion.

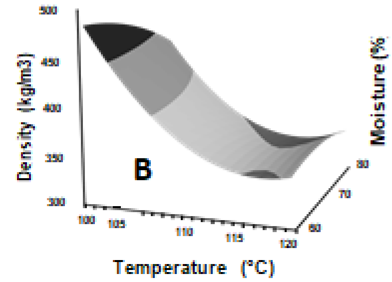
Starch is an important ingredient of expanded snacks, and its relationship with EI of snacks was reported by [16] in second generation snacks of rice and beer industry waste, who observed that EI is lower when the amount of starch decreases. Some other researches showed that starch is an important compound in extruded snacks [17-21]reported that starch is the main ingredient that contributes to obtain a high EI, which is related with the texture characteristics of this product [15]. Conversely, the addition of ingredients rich in proteins decreases the EI of extruded snacks, as were reported by several researches, such as [7] for high protein nutritious snacks of glutinous rice flour, vital wheat gluten and toasted soy grits, [16] for rice and beer industry waste (snacks with 30 % of beer industry waste contains 22 % protein and 52 % non-digestible fiber). However, [18] reported that proteins affect EI positively or negatively, depending on their chemical structure, concentration and their influence on water interaction with the matrix of the extruded snack; they indicated that soy protein (globulin) increases expansion, as well as egg white protein (albumin and globulin), attributing this effect to increase in viscosity caused be protein crosslinking; whereas wheat proteins (gliadin and glutelin) reduced it.

There must be considered that third generation snacks and second-generation snacks are processed by different way. The first are extruded at low pressure to obtain sheets, that are expanded later by hot air or frying, whereas the latter are extruded at high pressure and are obtained expanded when leaving the die. Whereby, the effect of processing variables in the product may be observed.

Density (D)

Feeding temperature during extrusion (X1) had a significant inversely effect on snack D, whereas feeding moisture (X2) did not (Figure 1B). The prediction model explained 79 % of total variance ($p < 0.043$), as can be seen in (Table 2).

Figure (1B): Surface response of the combined effect of processing temperature and density



D and EI of snacks are inversely correlated, as expected, because the expansion causes the formation of pores [13, 22] obtained low D (103 – 204 g /L) on second generation barley snacks and chickpea snacks when they were processed at high temperature, low moisture and medium-high screw speed (processing temperature, moisture and screw speed were 120 - 150 ºC, 20 – 24 % and 260 – 340 rpm, respectively. [22] reported D (168 – 260 kg /m3) on rice and beer industry waste second generation snacks. [23] reported D (approximately 150 – 260 kg /m3) on third generation snacks from potato starch, corn starch, milled oranges and monoglycerides. Process was performed at 100 – 150 ºC, moisture 20 -34 % and screw speed 25 rpm.

Expansion of third generation snacks is related with the starch gelatinization degree, which must be of approximately 50 %. This is why the extrusion temperature is so important; starch gelatinization occurs at high temperatures (> 135 ºC) causing low D and high EI [1, 17, 22-24].

Hardness and crunchiness

Hardness is defined as the needed mechanical force to deform or break a piece of food between the molars, in the first bite [25-28], and crunchiness as cumulative intensity, perceived, of the force required by repeated fractures of the five times chewed food, between the molars [29], and it is related with the auditory sensation, low tone and loud sound, which accompanies the mastication [30]. It has been reported that, when hardness increases, crunchiness decreases. However, in this research did not happen that way (Figures 1C and 1D). Even more, in the control snack (formulation without chickpea), the hardness is lower than those of snacks with chickpea, but its crunchiness is similar. Several researches [31-34] have indicated that air bubbles formed, inside the product, during expansion are related to crunchiness. They also indicated that an increase of the processing temperature promotes the formation of bubbles and crunchiness,[35] that when a product tends to be harder, expansion is more difficult. In this research it was observed that hardness increase, directly proportional to temperature, but respect to crunchiness, it was observed an increment when temperature rise from 100 to 110ºC, and then a decrement when rise from 110 ºC to 120 ºC (Figures 1C and 1D). The prediction model explained 83 % of the total variation ($p < 0.023$) for crunchiness (Table 2).

Figure (1C): Hardness

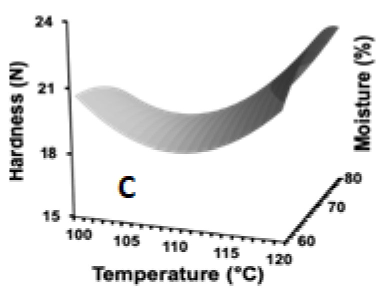
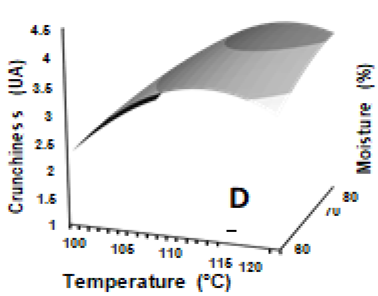


Figure (1D): Crunchiness



Water absorption index (WAI) and water solubility index (WSI)

There was not observed a clear effect of moisture on the WAI and WSI, data is shown in (Figures 1E and 1F) show a decrease in WAI and an increase in WSI when the temperature is higher [36]. Obtained values of 3.74 – 5.22 g /g for WAI and of 20.92 – 45.37 % for WSI, both of them are higher than those in this research. WAI points out the capacity of starch to retain water, and this is related to the plasticizing effect of water into a matrix of starch and some other ingredients [37], to the swelling capacity of starch [38], and to the over-gelatinization and /or melting of starch [39]. All of these phenomes occur during the extrusion process of second or third generation snacks. WSI indicates the change of the solubility of starch before and after the processing operations. A large percentage in the WSI points out that during the processing operations the starch was damaged [36. 38].

Figure (1E): Water absorption index, WAI

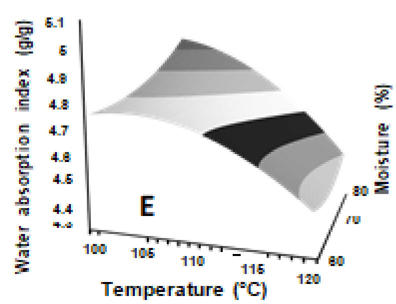
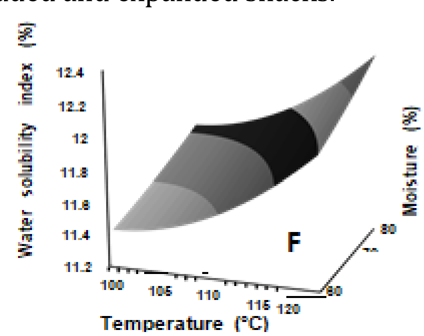


Figure (1F): Water solubility index, WSI of the extruded and expanded snacks.



Optimization

The optimal process conditions were determined maximizing the EI and minimizing the D and hardness (H) to achieve 90% of desirability. Inside the optimizing region are the following process conditions: temperature, 110 ºC and moisture 80%. The values of the physicochemical characteristics when snacks were processed at these conditions were: EI, 1.96, D, 339 kg /m3 and H 18.2 N.

Sensory evaluation

The samples tested were processed at 110ºC and at 120ºC, both of them contained 80 % moisture before extrusion. This research protocol was submitted to the Ethic Committee and obtained an ethical acceptance dictamen previously to this evaluation. Panelists evaluated hardness, crunchiness and general acceptability performing a preference randomized paired test. Statistical analysis, Friedman test (non-parametrical ANOVA) states that there were not statistical significance differences on any of the sensory attributes ($p > 0.05$). Physicochemical characteristics for the first and the second samples were EI 1.96 and 2.19, D 339 and 344 kg /m3, and H 18 and 23 N. Sensory evaluation indicated that consumer judges did not perceived differences of this attributes in those range of values. The quality characteristics of an expanded snack are low density and high expansion index, a firm and especially, a crunchy texture. The latter is the principal factor demanded by consumers [13, 35, 40-43].

Conclusion

This work showed that it is possible to obtain third generation snacks from wheat and chickpea at high moisture and low temperature with desirable quality characteristics, such as expansion index, density and crunchiness, which are the main quality characteristics of snacks. It was proved that the best processing conditions to obtain a wheat and chickpea snack with a high expansion index, a low density and a firm texture were temperature 120ºC and moisture 80%.

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