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

DOI: 10.3303/CET1757288

Texture on Extruded Snack: Correlation between Instrumental and Sensory Analysis

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One of the most popular food produced by extrusion process are the snacks. The quality of this product is related to sensory factors such as appearance and taste, with emphasis on texture. However, it is very difficult to find studies with correlations between descriptive and instrumental analyses for texture. The objective of this study was to perform extruded snacks instrumental and sensory analysis, crossing the obtained data and enabling correlations between them. Corn snacks were extruded on equal parameters in a complete IMBRA RX50 extrusion line (INBRAMAQ, Ribeirão Preto SP, Brazil), and then, the snacks were divided into four treatments modifying the moisture contents. These four treatments were also flavoured and stored for later physical analysis of moisture, water solubility, water absorption, water activity, colour, expansion ratio, specific volume, apparent density, retraction index and texture, the last one both instrumental and sensorial. Sensorial evaluation was performed by hedonic scale with 112 panellists, evaluating snacks texture, flavour and overall appearance. The snacks were analysed in Texture Analyzer TAXT2 Plus, using five different probes and varying the test speeds. Through the obtained results, it was possible to accomplish an excellent correlation between the data since the R values found varied between -0.91 and -0.99. Conclusively, the instrumental tests can replace sensory evaluation for texture attribute in extruded snacks.

1. Introduction

Extrusion process has become relevant and more popular in food industry by expanding the products range, in addition, being efficient and a versatile type of process (CARVALHO, R., 2000; MONTEIRO et al, 2016). As an extruded products example widely consumed, is possible to mention snacks and breakfast cereals (CHINELLATO et al, 2016).

Snacks are generally corn based products and their stability is relative to sensory characteristics such as texture, appearance and flavour (GUERREIRO, L., 2007). Texture can be considered one of the main attributes of this food type being a critical factor of its quality (GUERREIRO, L., 2007; PAULA, A. M. and CONTI-SILVA, A. C., 2014). Processing conditions by extrusion and packed product moisture content directly influence the snacks texture, according to Guerreiro (2007).

According to Szczesniak (1963) and Bourne (2002), quantifying foods texture is very important in order to satisfy quality control parameters and to evaluate advantages and disadvantages of products and processes, adjusting them in order to obtain an end product acceptable to consumers. Moreover, in order to develop generalizations and theoretical hypotheses, texture is a sensorial property, so it must be perceived and described by humans. When measured by test instruments, the results should be interpreted in terms of sensory attributes (SZCZESNIAK, 2002). A high level of sensory assessments predictability should be achieved by instrumental readings (BOURNE, 2002).

Please cite this article as: Berwig K., Marques D.R., Silva D.M.B., Mendes M., Raniero G., Monteiro C.C.F., Monteiro A.R.G., 2017, Texture on extruded snack: correlation between instrumental and sensory analysis, Chemical Engineering Transactions, 57, 1723-1728 DOI: 10.3303/CET1757288

In order to interpret sensorial quality attributes and establish limits for certain acceptable characteristics, the results obtained by instrumental texture analyses can be correlated with these (Andrade et al., 2007, FEITOSA et al, 2013).
Texture is, in several foods, the most determinant quality factor in consumer acceptability, however broadly the objective and subjective results are discussed individually. The aim of this study was to assess the extruded snacks texture, both by objective methods (instrumental analysis) and by subjective methods (sensory evaluation), crossing the obtained texture data and performing a correlation between them.

2. Material and Methods

2.1 Raw material

Snacks were manufactured from corn grits, provided by Caramuru Alimentos, located in Apucarana PR, Brazil**.**
For extruded snacks coating, a mixture containing 1 % fine herbs seasoning (All-Flavors, Brazil) and 1 % refined salt (Cristal, Brazil) was used, as well as, 15 % soybean oil (Liza, Brazil). These products were local purchased in Maringá PR, Brazil. The added ingredients mass was calculated relating to total extruded snack mass.

2.2 Particle size distribution

Grits for snacks production was characterized in terms of granules sizes, according Abimilho (2003) methodology, in duplicate. A corn grits fraction of 100 g was deposited in a 14, 16, 24, 28, 60 and 100 mesh overlapping sieve system and subjected to shaking until a constant mass was trapped in each sieve. The results are expressed as a percentage.

2.3 Snacks manufacturing

Extrusion cooking was performed in the IMBRA RX50 (INBRAMAQ, Ribeirão Preto, Brazil), equipped with a single screw of 50 mm in diameter and 200 mm in length. The die plate used has two 3 mm diameter holes and the parameters were fixed by motor amperage at 20 A and the cutting speed at 50 rpm. Grits feed rate was 18 $g.s^{-1}$.
The corn grits used in extrusion were humidified by adding 2.5 % water to its total weight and preconditioning for 24 hours at 5 °C.
After extrusion, all snacks were oven dried with forced air circulation at 60 °C for 15 minutes to standardize the moisture in all samples.

2.4 Sample preparation

Four samples were prepared by changing moisture of each of them through assembled system, sprinkling water vapour on the snacks surface. Each sample preparation details are described in Table 01. Humidification and homogenisation occurred in stainless steel coating pan with 20 litres capacity and 40 rpm rotation.

Table 01: Description of the snack samples preparation

Sample	Preparation
U0	15 min drying
U2.5	Sample U0 + 2.5 min humidification + 2.5 min homogenization
U5.0	Sample U2.5 + 2.5 min humidification + 2.5 min homogenization
U7.5	Sample U5.0 + 2.5 min humidification + 2.5 min homogenization

After preparation altering snacks moisture content, all four samples were flavoured by pulverizing first 15 % soybean oil on total snacks weight, followed by a mixture of 1 % fine seasoning herbs and 1 % salt, leaving in the coating pan for 15 minutes to complete homogenization.

2.5 Moisture content

Moisture content determination of the different snack samples were carried out by AOAC (2005) methodology, in triplicate, using oven-dry at 105 °C.

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

Water absorption index (WAI) and water solubility index (WSI) were determined according to the methodology described by Anderson et al (1970). Evaluation was performed in triplicate for each sample and consisted of weighing 1.25 g of ground sample in a tared centrifuge tube, followed by 15 mL addition of distilled water. Tubes containing samples were kept under constant stirring for 30 minutes then centrifuged at 3000 rpm for 10 minutes. Supernatant was placed in tared petri dish, dried in a circulation/renewed forced air oven at 105 °C until constant weight. The tube with the residue was also weighed and Eq (1) and Eq (2) were used for WAI and WSI calculation.

$$\mathrm{WAI} = \frac{\mathrm{MR}}{\mathrm{MS}-\mathrm{MER}} \ (1)$$

Where: WAI = water absorption index; MR = mass of the centrifuge residue (g); MS = sample mass (dry basis) (g); MER = mass of the supernatant evaporation residue (g).

$$\mathrm{WSI} = \frac{\mathrm{MER}}{\mathrm{MS}} \times 100 \ (2)$$

Where: WSI = water solubility index; MER = mass of the supernatant evaporation residue (g); MS = sample mass (dry basis) (g).

2.7 Water activity

Water activity was performed in triplicate, in each sample, using digital equipment AQUALAB.

2.8 Colour

Colour was evaluated using digital colorimeter, with readings in three extruded samples for each treatment. Results are expressed by CIELAB system, in L*, a* and b* values. Values of L* vary from black (0) to white (100), values of a* ranges from green (-60) to red (+60) and b* values, from blue (-60) to yellow (+60) (BIBLE and SINGHA, 1993).

2.9 Expansion ratio

Expansion ratio (ER) was calculated according to Mercier et al. (1998), by the ratio between the average diameter of 10 different expanded products and the diameter of extruder die. Diameter was checked using a Vernier calliper and the ER calculation is represented by Eq. (3).

$$\mathrm{ER} = \frac{\text{sample diameter}}{\text{extruder die diameter}} \ (3)$$

2.10 Specific volume, apparent density and retraction index

To specific volume determination, a 200 mL container was used adding a mass between 2 and 4 grams of snacks then completing with millet seeds, the reading was carried out by checking the seeds volume occupied by the snacks through 50 mL graduated cylinder. Dividing the volume displaced by the mass employed, according to Eq (4), it is possible estimate the samples specific volume.

$$\mathrm{SV} = \frac{\text{displaced seed}}{\text{sample mass}} \ (4)$$

For the apparent density determination, snacks were added in a 500 mL container and then weighed. The apparent density (in $g.mL^{-1}$) is given as Eq (5).

$$\mathrm{AD} = \frac{\text{sample mass}}{\text{container volume}} \ (5)$$

Retraction index was calculated based on the decrease of the specific volume as a function of time, according to Eq (6), after seven days.

$$\mathrm{RI} = \frac{\text{final specific volume}}{\text{initial specific volume}} \ (6)$$

2.11 Instrumental texture analysis

Instrumental texture analysis was performed on Texture Analyzer TAXT2 Plus (Stable Micro Systems, England), according to Dischsen et al. (2013) and Chinellato et al (2016) with modifications, where the samples were arranged horizontally on the platform using four different probes and changing pre-test and test speeds. For each probe or parameter altered, 20 determinations were performed for each of the four samples.
The first probe used (P1) was the 12 x 7 cm Probe Warner Bratzler (HDP / BS), at 5 kg maximum load, which breaks the sample like a guillotine**.** The second probe (P2) was a HDP / BSW model, with grooved blade insertion. The third probe (P3) was a P / 36R model, cylindrical 75 % compression, with 36 mm of diameter. The fourth probe (P4) was A / BE type with 45 mm diameter, 50 % compression. For this probe, 30 snacks were placed in each measurement and similarly, the pre-test and test speed rates were altered.
In all of this probes was used 20 repetitions with pre-test and test speed of 1.0 $mm.s^{-1}$ were performed (V1), followed by a further 20 repetitions with pre-test and test speed of 10.0 $mm.s^{-1}$ (V10).

2.12 Sensory evaluation

Sensory evaluation was carried out at State University of Maringá (UEM), with 112 untrained panellists, of both genders and ranging in age from 17 to 43 years. The analysis was approved by the Research Ethics Committee of the State University of Maringá (CAAE 18718013.3.0000.0104).
The four samples were randomly coded, presented with three assorted digits and differently positioned for each panellist, as described by Monteiro and Cestari (2013). In order to check the consumer acceptance and opinion, a hedonic scale of nine points (ranging from 1 = extremely disliked to 9 = extremely liked), was used and the attributes evaluated were texture, flavour and overall appearance.

2.13 Statistical Analysis

Evaluated characteristics results were submitted to correlation analysis and analysis of variance (ANOVA) with subsequent analysis of the means, compared by Tukey test at the significance level of 5 % through the software Assistat 7.7.

3. Results and discussion

The particle size of the grits was 19 %, 27 % and 54 % retained respectively on sieves mash 24, 28 and 60, same range found by Mikalouski et al (2014).
As the different samples were prepared by modifying the snacks humidification, the moisture content and water activity (a_w) presented significant differences between the samples. Table 2 shows moisture and water activity results of the samples assessed.

Table 2: Moisture content and water activity (a_w) of the processed snacks

Sample	Moisture Content (%)	a_w
U0	5.10^d±0.13	0.308^d±0.004
U2.5	5.71^c±0.05	0.362^c±0.003
U5.0	6.68^b±0.13	0.423^b±0.006
U7.5	7.84^a±0.02	0.477^a±0.002

Equal lower-case letters in the same column do not differ by Tukey test at 5 % probability.

Regarding water absorption, water solubility and expansion, the samples did not differ significantly. Expansion ratio is directly related to the raw material moisture content (PINTO et al, 2015). The extruded snacks were manufactured in the same way, with the same raw material, justifying the fact that there is no significant difference between their expansion ratio. The results were lower than those found by Mikalouski et al (2014), ranging from 3.99 to 4.73, but the same authors manufactured snacks with humidified grits at 20 % of their weight. Borba (2005), when extruding sweet potato flour, varied moisture between 13 and 23 %, finding ER values ranging from 1.85 to 2.60, just as the smallest expansions occurred mainly at low humidity.
Furthermore, as for the colour attribute, the treatments did not differ significantly. Extruded samples had high luminosity values, between 64.18 and 68.72, predominantly in yellow colour (b*), being this colour characteristic of the raw material, originated from corn.
Specific volume (VE) varied from 11.430 to 13.177 mL.g^{-1}, showing no significant differences between them. The apparent density (AD) ranged from 0.050 to 0.055 g.mL^{-1}, with only U0 sample differing significantly. Retraction index (RI) represents a specific volume reduction as a function of time, in this case, calculated related to seven days. During this time, samples did not present significant differences of retraction. Monteiro et al. (2016), studying corn extruded snacks, also did not find significant differences among samples for SV, AD and RI. The results found for specific volume, apparent density and retraction index for all samples are shown in Table 3.

Table 3: Results of the specific volume (SV), apparent density (AD) and retraction index (RI) analyses

Sample	SV (mL.g^{-1})	AD (g.mL^{-1})	RI
U0	12.524^a±0.441	0.055^a±0.001	0.978^a
U2.5	11.917^a±0.800	0.052^b±0.002	1.120^a
U5.0	11.430^a±0.949	0.051^b±0.001	1.167^a
U7.5	13.177^a±0.370	0.050^b±0.001	1.030^a

Equal lower-case letters in the same column do not differ by Tukey test at 5 % probability.

As the objective of this study was to correlate the values found for instrumental and sensorial texture, the fact that most of the cited parameters showed no difference between samples does not interfere with the desired aim.
Table 4 shows the scores obtained by each sample in the sensorial analysis. It is possible to verify, for the texture attribute, that the samples differed significantly, and snacks with lower moisture content (Table 3) presented higher scores. Mendonça et al. (2000) obtained similar results varying humidity and temperature of extrusion and reported that the most important variable in the sensorial evaluation was the humidity.

Table 4: Punctuation of sensory attributes evaluated with 9 points hedonic scale (varying from 1 = extremely dislike to 9 = extremely like)

Sample	Texture	Flavour	Overall Appearance
U0	7.46^{a}±1.24	6.86^{a}±1.51	7.12^{a}±1.30
U2.5	7.27^{ab}±1.15	6.92^{a}±1.32	7.08^{ab}±1.25
U5.0	6.78^{b}±1.48	6.65^{ab}±1.43	6.63^{b}±1.43
U7.5	5.63^{c}±1.79	6.21^{b}±1.53	6.04^{c}±1.55

Equal lower-case letters in the same column do not differ by Tukey test at 5 % probability.

Values obtained for snacks instrumental texture are presented in Table 5, with all forces in kilo (kg).

Table 5: Instrumental texture results of extruded snacks (kg), where P1 = probe HDP/BS; P2 = probe HDP/BSW; P3 = probe P/36R; P4 = probe A/BE

Sample	Probe and test speed (mm/s)							
	P1 V1	P1 V10	P2 V1	P2 V10	P3 V1	P3 V10	P4 V1	P4 V10
U0	0.78b±0.20	0.83b±0.35	1.14c±0.29	0.98b±0.35	3.50c±0.76	2.80c±0.51	18.47d±1.06	17.24d±1.07
U2.5	0.97^{b}±0.33	0.79^{b}±0.22	1.53^{bc}±0.44	1.13^{b}±0.33	4.06^{c}±0.64	3.34^{c}±0.82	20.92^{c}±1.40	19.55^{c}±1.36
U5.0	1.49^{b}±0.46	1.06^{b}±0.29	1.89^{b}±0.51	1.53^{b}±0.39	4.85^{b}±0.95	4.30^{b}±0.67	23.77^{b}±1.34	22.84^{b}±1.15
U7.5	3.42^{a}±1.77	2.53^{a}±1.00	4.26^{a}±1.41	3.10^{a}±1.41	6.88^{a}±1.32	6.23^{a}±1.05	25.53^{a}±1.45	24.99^{a}±1.26

Equal lower-case letters in the same column do not differ by Tukey test at 5 % probability.

The main snack texture property is crunchiness (Caprils and Araas, 2012) and factors such as hardness and fracture are significantly affected by moisture (Mendelezia et al, 2000). In the present study, as found by Mendonça et al (2000), values for instrumental texture raised as moisture increased in snacks. Monteiro et al (2016), evaluating snacks texture throughout their shelf life, realized that with increasing moisture, the necessary force to break the snacks increased. The vapour added to the samples caused humidity gain and the snacks became more withered and plastics (GATES et al, 2008).
Instrumental forces derived from performing different tests (Table 5) were correlated with the scores obtained by sensorial texture attribute (Table 4) and correlation coefficients R values are shown in Table 6.

Table 6: Correlation coefficients R of the instrumental and sensorial texture data results

Instrumental Texture	P1V1	P1V10	P2V1	P2V10	P3V1	P3V10	P4V1	P4V10
Correlation with Sensory texture	-0.994	-0.973	-0.988	-0.993	-0.998	-0.997	-0.911	-0.927

Sensorial texture correlates negatively with all probes used, demonstrating that the greater force required to cut or compress the snacks, the lower is consumer acceptance. In addition, R coefficients ranged from -0.911 to -0.998, values higher than those reported by Paula and Conti-Silva (2014). It was possible to observe that the probes P1, P2 and P3 was performed better than P4, and the velocity of testing (1 or 10 mm/s) did not matter to correlation results, thus faster tests is better because it is easier to carry out.

4. Conclusion

Instrumental forces resulted from tests performed with different probes (particularity Warner Bratzler HDP/BS, HDP/BSW and P/36R) correlated strongly with texture sensorial attribute. Since measurement and controlling physical properties are faster, easier and cheaper than sensorial analysis this is an interesting alternative for industries to predict consumer responses and have a better understanding of texture perceptions, as well as facilitate comparisons between scientific studies that evaluate this attribute.

Acknowledgment

To Comissão de Aperfeiçoamento de Pessoal do Nível Superior - CAPES, Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq, Complexo de Centrais de Apoio à Pesquisa – COMCAP/UEM and Fundação Araucária de Apoio ao Desenvolvimento Científico e Tecnológico do Paraná for granting scholarships and support this project.

References

ABIMILHO (Associação Brasileira das Indústrias Moageiras de Milho), 2003. Manual de amostragem, métodos físico-químicos e microbiológicos para análise de produtos derivados de milho. Associação Brasileira das Indústrias Moageiras de Milho, Apucarana, Brasil.

Andrade A.A., Rodrigues M.C.P., Nassu R.T., Neto M.A.S, 2007. Medidas instrumentais de cor e textura em queijo de coalho. Congresso Latino Americano de Analista de Alimentos, ed. 15. Fortaleza, Brasil.

Anderson R.A., Conway H.F., Peplinski A.J., 1970. Gelatinization of corn grits by roll and extrusion cooking. Cereal Science Today, v.1 4, n.1 , p.4-7 e 11-12.

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

Bible B.B., Singha S., 1993. Canopy position influences CIELAB coordinates of peach color. HortScience, v. 28, n. 10, p. 992-993.

Borba A.M., 2005. Efeito de alguns parâmetros operacionais nas características físicas, físico-químicas e funcionais de extrusados da farinha de batata-doce (*Ipomoea batatas*). Dissertação de mestrado, Universidade de São Paulo. Piracicaba, SP. Jul.

Bourne M.C., 2002. Food texture and viscosity: concept and measurement. Elsevier Science & Technology Books, ed. 2. Mar.

Capriles V.D., Arêas J.A.G, 2011. Redução da razão comprimento/diâmetro da extrusora e aumento da aceitabilidade de snacks à base de amaranto. Brazilian Journal of Food Technology, v. 14, n. 1, p. 19-26. Campinas, SP. Jan./mar.

Carvalho, R.V, 2000. Formulações de snacks de terceira geração por extrusão: caracterização texturométrica e microestrutural. Universidade Federal de Lavras (UFLA). Lavras, MG.

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, v. 49, p. 403-408, DOI: 10.3303/CET1649068.

Dischsen A.E., Monteiro A.R.G., Fukuda G.T., Marques D.R, 2013. Development of a breakfast cereal using waste from cassava processing industry. Acta Scientiarum. Technology, Maringá, v. 35, n. 1, p. 157-161.

Feitosa, L.R.G.F., Maciel J.F., Barreto T.A., Moreira R.T, 2013. Avaliação da qualidade do pão tipo francês por métodos instrumentais e sensoriais. Semina: Ciências Agrárias, v. 34, n. 2, p. 693-704. Londrina, PR. Mar./abr.

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, v. 47, p. 239-244.

Guerreiro L, 2007. Dossiê técnico: produtos extrusados para consumo humano, animal e industrial. Rede de Tecnologia do Rio de Janeiro. Ago.

Mendonça S., Grossmann M.V.E., Verhé R, 2000. Lebensmittel-Wissenschaft & Technologie, v. 33, n. 1, p. 6-8.

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, v. 17, n. 1, p. 28-32. Campinas, SP. Jan./mar.

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

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

Paula A.M., Conti-Silva A.C, 2014. Texture profile and correlation between sensory and instrumental analyses on extruded snacks. Journal of Food Engineering, v. 121, p. 9-14.

Pinto L.A.M., Tavares F.O., Pinto M.M., Hirata A.K., Mateus G.A.P, 2015. Desenvolvimento e caracterização de salgadinho produzido a partir de gritz de milho nixtamalizado. Revista Verde de Agroecologia e Desenvolvimento Sustentável, v. 10, n. 4, p. 12-16. Pombal, PB. Out./dez.

Szczesniak A.S., 1963 Objective measurements of food texture. Journal of Food Science. v. 28, p. 410-420.

Szczesniak A.S, 2002. Texture is a sensory property. Food Quality and Preference, v. 13, p. 215-225.