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Sensory and nutritional evaluation of popcorn kernels with yellow, white and red pericarps expanded in different ways

Ricardo Tadeu Paraginski [a], Nelisa Lamas de Souza [b], Gabriela Hornke Alves [b], Valmor Ziegler [b,*], Maurício de Oliveira [b], Moacir Cardoso Elias [b]

[a] Federal Institute Farroupilha, Campus Alegrete, 97555-000, Alegrete, RS, Brazil
[b] Department of Agroindustrial Science and Technology, Federal University of Pelotas, 96010-900, Pelotas, RS, Brazil

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Abbreviations:
ABTS*
(2,2 azino-bis (3 ethylbenzothiazoline-6-sulfonic acid) diammonium salt)
DPPH*
(1,1-diphenyl-2-picrylhydrazyl)
HCl
Hydrochloric acid
PA
Pattern analytical

ABSTRACT

The objective of this study was to evaluate the effects of pericarp color and expansion process on the sensorial and nutritional quality of popcorn kernels. Popcorn kernels with red, white or yellow pericarps underwent expansion using one of these methods: in a pan with oil, in a microwave with oil, in a microwave without oil, in an electric popcorn popper with oil, or in an electric popcorn popper without oil. The pericarp color and method of processing primarily affect the sensory quality of corn popcorn grains after the expansion. The best sensory evaluations were observed in the popcorn grains expanded in a pan with the presence of oil; these suffer the greatest physicochemical and structural changes, represented by viscoamylographic properties, indicating that in this form of processing, starch undergoes further expansion. However, this form of processing features the highest energy value compared to other forms of processing without compromising the amount of compounds with antioxidant potential present in these grains.

1. Introduction

The popcorn grains of maize (*Zea mays everta*) are mainly produced in the Americas and used exclusively for human consumption. In Brazil, the annual production of popcorn is 80,000 tons (Miranda et al., 2011). Recent years have seen an increase in consumption and consumer demand for a better quality product. The quality is mainly related to the nutritional and functional properties, such as the increase or maintenance of bioactive compounds, the increase of resistant starch during the expansion process and the development of desirable sensory characteristics.

Popcorn is consumed as a nutritious snack with excellent functional properties, and it has increased in popularity over time. It is a dish made from a special variety of corn that is distinguished by a glassy endosperm, by being thicker than normal and by having hard grains of maize (*Zea mays*) (Quinn et al., 2005). When we heat the popcorn kernels quickly and evenly, the structural components of the cell wall, such as the arabinoxylans and the pulp, undergo molecular changes that leave them more rigid and crystalline (Tandjung et al., 2005). Likewise, the inner water is converted into steam, and at a certain point, the internal pressure causes an expansion of the pericarp that changes the small amount of oil inside and the starch and fiber, resulting in a format larger than the original grain (Soylu and Tekkanat, 2007). The physical

* Corresponding author. Rua Gomes Carneiro, 1671, Apartamento 301, Centro, CEP 96010-610, Pelotas, RS, Brazil.
E-mail address: vamgler@hotmail.com (V. Ziegler).

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characteristics developed in the expansion are directly related to the desirable attributes of consumption, which include texture and better consumer acceptability (Ceylan and Karababa, 2002).

The consumption of foods with pigmentation has been encouraged over the years because of the importance of these compounds, which are considered to be precursors of vitamin A and essential retinoid compounds with anticarcinogenic activity associated with the inhibition of colon, esophagus, lung, liver, breast and skin cancers (Rodriguez-Amaya, 2001). Popcorn grains exhibit great genetic variability, and some possess these features; further studies should be conducted to evaluate the performance of these grains during processing.

Popcorn, although it is a product consumed during leisure time, has good nutritional quality due to its average dietary fiber content of 17.79% and also its low calories (Park et al., 2000); if it is prepared without oil or fat, it has from 25 to 55 kcal in a volume of 250 ml. The types of grains that are more accepted commercially are round, pearl-like, and have an orange endosperm, though this may vary according to the consumption region. For domestic use, the grains are generally small (76–105 grains 10 g) and yellow, and the popcorn is the butterfly type, which is softer (Sweley et al., 2012b).

Studies have been conducted on the properties of the grains and the volume expansion in various genotypes of popcorn (Soylu and Tekkanat, 2007); other studies have evaluated the effect of cultivation, the addition of oil and the power of microwaves on the morphological properties of the grains (Sweley et al., 2012a), but there is little information on the properties of popcorn based on the different ways that consumers might process it. Therefore, considering the growth in the consumption of popcorn and pigmented products, combined with consumers' search for foods with higher nutritional quality that retain sensory quality, the study aimed to evaluate the effects of pericarp color and expansion process on the parameters of sensory and nutritional evaluation of popcorn kernels.

2. Material and methods

2.1. Materials

Popcorn kernels with yellow, white and red pericarps were used that were grown in Passo Fundo, Rio Grande do Sul, Brazil, latitude S 28°15′40″, longitude W 52°24′30″ and at an altitude of 680 m. To assess the effects of processing on the sensory and nutritional quality, the grains were subjected to 5 expansion methods in triplicate for each method: (1) pan with oil; (2) microwave with oil; (3) microwave without oil; (4) electric popcorn popper with oil; and (5) electric popcorn popper without oil (Fig. 1). The process of expansion in a pan without oil was excluded because it was observed in preliminary testing that it would not be possible to expand the popcorn under these conditions. For those expansion processes in which oil was used, it was added at 4% the soybean oil. To the oil mixture, grains and oil were placed in a glass Becker, and then mixed with the aid of a glass rod until the entire surface of the grains were covered by the oil. In all expansion processes investigated in this study, the discontinuation of expansion was standardized by using a 5 s (second) time interval between the expansion of one grain to the next. The expansion of grains occurs when the pressure and the internal temperature of the grains reach at least 135 *psi* and 177 °C, respectively (Hoseney et al., 1983). To evaluate the nutritional properties and binders (RVA), the expanded and non-expanded grains were ground in a Perten 3100 mill (Perten knife grinder, model Laboratory Mill 3100, Huddinge, Sweden) with a sieve of number 35 mesh to achieve a uniform grain size for the samples and to perform the analysis.

2.2. Methods

2.2.1. Sensory evaluation

The sensory evaluation of the popcorn was performed as described by Minin (2010), who describes various forms of sensory evaluation in consumers. The evaluation was performed with 50 untrained judges, including employees, students and visitors of the Federal University of Pelotas. Participation was based on interest and availability to participate in the sensory tests; the assessors were not trained, were of both sexes, and were between the ages of 15 and 45. The evaluation in a panel containing the samples was conducted immediately after preparation as shown in Fig. 1. This was a preference-ranking test regarding the color and size of the popcorn grain flowers for each type of pericarp (red, white and yellow) and for the various processing forms (pan with oil, microwave with oil, microwave without oil, electric popcorn popper with oil and electric popcorn popper without oil). To obtain the final result, a score of 1 is assigned to the least preferred sample, with a gradually increasing preference leading to an increasing preference score to 5 for the most preferred sample. The end result is obtained by summing the scores of 50 judges. The results were processed by determining the critical values of the difference of the sum of orders for comparing the treatments with each other ($p \leq 0.05$) based on the Friedman test. In addition, the Purchase Intent test was performed for the three colorations of pericarp in every form of expansion, and the evaluators were asked to observe the global attributes (color, brightness, size and shape). For each attribute, the evaluators used a structured, 5-point scale, in which "sure would buy" is indicated by (1), "probably would buy" is indicated by (2), "perhaps would buy" is indicated by (3), "probably would not buy" is indicated by (4), and "sure would not buy" is indicated by (5).

2.2.2. Paste properties

The pasting properties of the maize flour (3.0 g, 14% moisture basis) were determined with a Rapid Visco Analyser (RVA-4; Newport Scientific, Warriewood, Australia) using the RVA profile Standard Analysis 1. The viscosity was expressed in rapid visco units (RVU). The sample was held at 50 °C for 1 min, heated to 95 °C in 3.5 min and held at 95 °C for 2.5 min. The sample was then cooled to 50 °C in 4 min and held at 50 °C for 2 min. The rotating speed was held at 960 rpm for 10 s and then maintained at 160 rpm during the process. The parameters, including the pasting temperature, peak viscosity, breakdown, final viscosity and setback, were recorded.

2.2.3. Nutritional composition and energy value

The moisture content of the popcorn was determined using a drying oven set at 105 ± 3 °C with natural air circulation for 24 h following the recommendations of the American Society of Agricultural Engineers (ASAE, 2000). The moisture content was expressed as a percentage (%). The fat content was determined following the 30-20 method of the American Association of Cereal Chemists (AACC, 1995). The nitrogen content was determined according to the AACC 46-13 method (AACC, 1995), and the protein content was obtained using a conversion factor of nitrogen to protein of 6.25. The mineral content was determined according to the AACC 08-01 method (AACC, 1995). The total carbohydrate content was determined by the difference. The fiber content was determined following the analytical protocol described by Angelucci et al. (1987). The calculation of the energy value was determined considering the energy value of 4 kcal g^{-1} (Protein), 9 kcal g^{-1} (lipids), 2 kcal g^{-1} (crude fiber) and 4 kcal g^{-1} (carbohydrates).