Food Chemistry 263 (2018) 225–231

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Hydrothermal treatment of maize: Changes in physical, chemical, and functional properties

Verónica Rocha-Villarreal[a], Jessica Fernanda Hoffmann[b], Nathan Levien Vanier[b,*], Sergio O. Serna-Saldivar[a], Silverio García-Lara[a]

[a] Centro de Biotecnología FEMSA, Escuela de Ingeniería y Ciencias, Tecnológico de Monterrey, Campus Monterrey, Eugenio Garza Sada 2501, Monterrey, NL C.P. 64849, Mexico
[b] Departamento de Ciência e Tecnologia Agroindustrial, Universidade Federal de Pelotas, 96010-900 Pelotas, Brazil

ARTICLE INFO

Keywords:
Parboiling
Maize
Hydrothermal
Nutrition
Processing
Functionality

ABSTRACT

The objective of this work was to assess the effects of a traditional parboiling treatment on physical, chemical and functional properties of yellow maize kernels. For this, maize kernels were subjected to the three main stages of a traditional parboiling process (soaking, steaming, and drying) at different moisture contents (15%, 25%, or 35%), and different pressure steaming times (0, 15, or 30 min). Kernels were evaluated for physical and chemical changes, while manually generated endosperm fractions were further evaluated for nutritional and functional changes. The parboiling process negatively altered the maize kernels properties by increasing the number of kernels with burst pericarp and decreasing the total carotenoid content in the endosperm by 42%. However, the most intense conditions (35% moisture and 30 min steam) lowered the number of broken kernels by 41%, and the number of stress cracks by 36%. Results also demonstrated that soaking enhanced the nutritional value of soaked yellow maize by increasing the thiamine content and the bound phenolic content in the endosperm fraction up to 102%. The proper implementation of this hydrothermal treatment could lead to significant enhancements in nutritional and functionality of maize products.

1. Introduction

Maize (*Zea mays*) is the most produced cereal crop in the world, with over 1 billion tons produced yearly (USDA, 2017). The major chemical component of the maize kernel is starch, which constitutes up to 73% of the kernel weight. Starch is made up of two glucose polymers: amylose, an essentially linear molecule, and amylopectin, a branched form. The next largest chemical component is protein, varying in common varieties from 8 to 11% of the kernel weight (Gyori, 2016). However, while most corn protein (75%) comes from the endosperm, it is in the germ that the proteins with the best amino acid profile are concentrated (Naves, De Castro, De Mendonça, Santos, & Silva, 2011). The oil content of the maize kernel is mainly associated to the germ, with values ranging from 3 to 18%, and is valuable because of its fatty acid distribution (FAO, 1998).

The maize kernel also contains carotenoids, found mainly in yellow genotypes, mostly in the hard endosperm and on small amounts in the germ (FAO, 1998). On the contrary, phenolic acids are generally covalently bound to cell walls with approximately 75% being localized in the aleurone layer and pericarp (García-Lara & Bergvinson, 2014).

The most common maize processing method in the food industry is dry-milling, which grinds the maize and removes much of the bran and germ to produce more refined products, that can store longer and have better appearance and texture (Kiple & Ornelas, 2000). The germ of kernel is high in fat, enzymes, and nutrients essential for growth and development. It is also particularly high in polyunsaturated fatty acids, which are subject to oxidation, resulting in objectionable flavors (Gwirtz & Garcia-Casal, 2014). Hence, the removal of the germ assists in protecting the finished maize product from oxidative rancidity (Culbertson, 2014). However, populations that consume degermed maize benefit less in terms of oil and fatty acids than others which consume whole-kernel products. Moreover, the proteins with the best amino acid profile are also lost, decreasing the nutritional quality of maize (FAO, 1998).

Alternatively, pericarp is a high-fiber semipermeable barrier surrounding the kernel (Gwirtz & Garcia-Casal, 2014). It appears that its removal is important for reducing mycotoxins in food products (Voss, Poling, Meredith, Bacon, & Saunders, 2001). Moreover, it is removed in maize processing because the variety of fibers interfere with many procedures, altering the appearance and texture (Culbertson, 2014).

* Corresponding author.
E-mail addresses: nathanvanier@hotmail.com (N.L. Vanier), sserna@itesm.mx (S.O. Serna-Saldivar), sgarcialara@itesm.mx (S. García-Lara).

https://doi.org/10.1016/j.foodchem.2018.05.003
Received 22 January 2018; Received in revised form 30 April 2018; Accepted 1 May 2018
Available online 03 May 2018

Pericarp removal results in the loss of crude fiber content (FAO, 1998) but also phenolic compounds (García-Lara & Bergvinson, 2014). Moreover, the removal of these structures results in the loss of water soluble vitamins (Nuss & Tanumihardjo, 2010), where milling alone, is responsible for the loss of 72% of thiamin (Suri & Tanumihardjo, 2016).

Losses of nutrients during processing can be mitigated by encouraging consumption of whole-grain maize products over degermed, refined products. However, these products present other challenges, such as poor product stability and unconventional organoleptic properties (Culbertson, 2014). Because of the great importance of maize as a basic staple food for large population groups, many efforts have been made to improve the bioavailability of the nutrients it contains. Three main approaches have been tried: genetic manipulation, fortification, and processing; each one of them presenting significant challenges.

Parboiling is a hydrothermal treatment commonly used in rice that partially gelatinizes the starch, sealing fissures and improving the milling yield. Parboiling also facilitates the migration of nutrients from outer grain structures such as bran into inner structures like the endosperm (Rocha-Villarreal, Serna-Saldívar, & García-Lara, 2018).

Moreover, changes have been reported in the physicochemical properties of cereal grains, such as changes in the solubility, swelling and pasting properties, which could alter the functionality of the treated grains (Zavareze & Dias, 2011) and thereby modify their applications.

In maize, like in many other cereals different from rice, the effects of parboiling are scarcely studied and poorly reported. Therefore, the objective of this study was to evaluate the physicochemical and nutritional effects of a traditional parboiling treatment in commercial yellow maize kernels.

2. Material and methods

Yellow dent hybrid maize (*Zea mays*), mainly used for industrial purposes in the south region of Brazil, was supplied by Puro Grão Indústria e Comércio de Grãos, located in Pelotas, RS, Brazil. Broken kernels and foreign material or dockage were removed using a 6164-inch round sieve and damaged kernels were removed manually. Initial moisture content of 15% was determined using a moisture tester (G810, Gehaka, Brazil).

2.1. Hydrothermal treatment

Sample of 1350 g was divided into three categories for the hydrating stage, according to the final desired moisture: low (15%), medium (25%), and high moisture (35%) (Agarry, Afolabi, & Akintunde, 2014). Samples with final moisture content at 25% and 35% were soaked for 1 h and 10 h, respectively, in distilled water at 45 °C (Dubnoff Microprocessed – Q226M, Quimis, Brazil). After soaking and achieving the desired final moisture, one sample of each moisture level (15%, 25% and 35%) was steamed in a vertical autoclave (AV-75, Phoenix, Brazil) set at 110 °C and 5 psi for 15 or 30 min; whereas a set of samples remained without steaming (0 min). All samples were dried in an air flow oven (400-2ND, Nova Ética, Brazil) set at 37 °C until 13% moisture content (wb) was achieved. Whole dried kernels were used to evaluate physical properties. To assess nutrients and fumonisin content, a fraction of the kernels from each treatment was manually dissected to obtain the clean endosperm structure. For this, tip cap was removed with a scalpel and kernels were soaked in distilled water at room temperature for one minute. Using tweezers, pericarp was peeled off and germ was removed with the assistance of a scalpel. Clean endosperm samples were collected and ground to a 70-mesh size (210 μm) powder using an electric coffee grinder (B55, Grupo Botini-Botimetal, Brazil) and a laboratory mill (Perten 3100, Perten Instruments, Sweden). Same milling procedure was applied for remaining whole corn kernels, which were used to evaluate starch properties, chemical effects, and functionality. Flour from both sample types was stored in sealed plastic containers at 4 °C until needed.

2.2. X-ray diffraction and relative crystallinity

X-ray diffractograms of whole kernel flours were obtained with an X-ray diffractometer (XRD-6000, Shimadzu, Japan). The scanning region of the diffraction ranged from 3° to 45° with a target voltage of 30 kV, current of 30 mA and scan speed of 1°/min. The relative crystallinity (RC) of the starch granules was calculated using Origin software (OriginLab Corporation, Massachusetts, USA) and the area on the X-ray diffractograms (Paiva et al., 2014).

2.3. Swelling power and solubility

Swelling power (g/g) and water solubility (%) of ground whole kernels (four replicates per sample) at 90 °C where determined according to the method described by (Kusumayanti, Handayani, & Santosa, 2015).

2.4. Grain defects quantification: broken pericarp kernels, open pericarp kernels and stress cracked kernels

The kernels physical effects caused by the different treatments were visually identified and classified as broken, burst pericarp, and cracked (internal fissures or stress crack) kernels as shown in the Fig. S1. The visual inspection was performed in 6 replicates of 50 kernels each and the results were expressed as percentages.

2.5. Colorimetric analysis and total carotenoids content

A photoelectric colorimeter (CR-410, Konica Minolta, NJ, USA) was used for color determination of the flour obtained from the endosperm fraction. Color for each sample (10 measurements per sample) was recorded in terms of the L^*, a^*, b^* values; and the hue angle values were calculated (McLellan, Lind, & Kime, 1995). A picture of whole kernels is presented in Fig. S2.

Total carotenoid content analysis in ground endosperm was carried out according to the AOAC method 970.64 (AOAC, 2005b) in triplicate. Absorbance was read in a UV/Vis spectrophotometer (6705, Jenway by Cole-Parmer, UK) at 450 nm and total content in β-carotene equivalents was estimated using the methodology described by Rodriguez-Amaya (2001).

2.6. Crude protein, fat, and thiamine contents

In ground endosperm, the moisture content was determined using the drying oven at 105 °C, with natural air circulation for 24 h (FAO, 1993) and expressed as percentage (%). Fat content was determined following method 30-20 of the American Association of Cereal Chemists (AACC International, 2000). Nitrogen content was determined according to AACC method 46-13, and the protein content was obtained using a conversion factor of nitrogen to protein of 6.25 (AACC International, 2000). All analysis was performed in triplicate.

Thiamine content was determined in selected samples from 15% moisture content (whole non-treated kernel, endosperm fraction of non-treated kernel, and endosperm fraction of 30 min-pressure steaming treatment) and from endosperm fraction of 35% and 30 min-treated kernels, following the fluorometric method 953.17 of the American Organization of Analytical Chemists International (AOAC, 2005a) in triplicate.

2.7. Free and bound phenolics contents

The extraction of free and bound phenolics for endosperm flour was performed according to the Folin-Ciocalteu method described (Alves et al., 2016). Absorbance was measured at 725 nm (UV 17000