LWT - Food Science and Technology 71 (2016) 316–322

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Physicochemical properties of sorghum and technological aptitude for popping. Nutritional changes after popping

E.E. Llopart [a, b], S.R. Drago [a, b, *]

[a] Instituto de Tecnología de Alimentos, Facultad de Ingeniería Química, Universidad Nacional del Litoral, Santiago del Estero 2829, Santa Fe, Argentina
[b] CONICET, Godoy Cruz 2290, Buenos Aires, C1425FQB, Argentina

A R T I C L E I N F O

Article history:
Received 26 August 2015
Received in revised form
23 February 2016
Accepted 7 April 2016
Available online 9 April 2016

Keywords:
Whole grain
Sorghum
Popping
Antioxidants

A B S T R A C T

The aims were to characterize 28 hybrids of red (RS) and white (WS) sorghum by physicochemical analysis, relate them with their technological aptitude for popping, and asses nutritional changes after popping in selected samples. Through principal component analysis it was observed that the higher the grain hardness, the higher apparent volume of popped product was, and performance was higher for WS. An indicator of the ability of sorghum hybrids to pop was developed. Comparing precooked samples with their native flours, no significant difference for protein and fat content was observed, but ash, dietary fiber, and minerals were reduced by popping. Protein digestibility increased but available lysine decreased (WS:1.3 and RS:1.2 times). Phytic acid, polyphenols and antioxidant capacity were reduced (WS: 1.3 and RS: 1.5; WS: 1.3 and RS: 1.8; WS: 1.3 and RS: 1.7 times, respectively), but whole flour precooked by popping can be considered an important source of antioxidants. Popped sorghum is an interesting alternative as food itself, or as ingredient for making other foods such as cereal bars.

1. Introduction

Dietary recommendations of the World Strategy for populations (CODEX, 2006) recommend the consumption of whole grains (WG). The beneficial effects of WG on health is due to fiber, micronutrients and phytochemicals present in the outer layer of the grain and germ (Raninen, Lappi, Mykkänen, & Poutanen, 2011) as well as WG are an important source of antioxidants (Miller, Rigelhof, Marquart, Prakash, & Kanter, 2000). Epidemiological studies suggest that consumption of WG, including sorghum, reduces mortality from cardiovascular disease, which is probably related to its antioxidant properties (Awika & Rooney, 2004).

Incorporating WG into the diet is low by the lack of habits, problems due to higher cooking times and limited amounts of processed foods based on them, due to technological difficulties of incorporating WG in foods (Drago et al., 2010).

One possibility is to expand the grains by popping, which is a traditional, simple, inexpensive and rapid method (González, Torres, De Greef, Tosi & Re, 2002). During popping, grains are exposed to high temperature for short time, which leads to explosion of the grain with the consequent transformation of cereal, changes in nutritional profile and lifetime of the product, and inactivation of undesirable microorganisms and certain antinutrients (Nath, Chattopadhyay, & Majumdar, 2007). In addition, this process develops flavors and therefore, improves acceptability (Sreerama, Sasikala, & Pratape, 2008).

The optimum conditions for popping depend on the method used and the characteristics of the grains such as the proportion of horny endosperm and pericarp resistance. It is also know, that some properties of the grains can predict or explain the behavior in different processes such as hectoliter weight, percentage of flotation, density and milling ratio (De Dios, Puig, & Robutti, 1992) thus it is important to define the parameters that distinguish sorghum hybrids suitable for popping.

The aims of the study were to characterize 28 hybrids of sorghum by physicochemical analysis, assess their technological aptitude for popping, determine the relationship among them and

Abbreviations: AV, apparent volume; AP, aptitude for popping; BD, bulk density; BPC, bound polyphenol content; d.b., dry basis; DCa%, calcium bio-accessibility; DFe%, iron bio-accessibility; DZn%, zinc bio accessibility; F%, percentage of flotation; F, fine fraction; FPC, free polyphenol content; MR, milling ratio; PA, phytic acid; AC, antioxidant capacity; PCA, principal component analysis; PP, popping performance; T, thick fraction; TPC, total polyphenol content; TW, test weight; WG, whole grains; WS, white sorghum; RS, red sorghum.

* Corresponding author. Instituto de Tecnología de Alimentos, Facultad de Ingeniería Química, Universidad Nacional del Litoral, Santiago del Estero 2829, Santa Fe, Argentina.

E-mail address: sdrago@fiq.unl.edu.ar (S.R. Drago).

http://dx.doi.org/10.1016/j.lwt.2016.04.006
0023-6438/

evaluate some nutritional changes after popping in selected samples.

2. Material and methods

2.1. Raw material

28 sorghum hybrids: 14 white (WS) and 14 red (RS) were evaluated. The Research Program Pannar Sorghum Seed Company RSL donated some of them and others were from commercial sources.

2.2. Methods

2.2.1. Proximate composition

Moisture, ether extract, protein and ash were determined according the AACC methods (AACC, 2000).

2.2.2. Minerals

Mineral content was measured by atomic absorption spectroscopy using an Atomic Absorption Spectrophotometer (Analyst 300 Perkin Elmer) after dry ashing. To determine Ca content, lanthanum chloride was used at a final concentration of 0.5% in order to minimize the effect of phosphates.

2.2.3. Total polyphenols (TPC)

Free (FPC) and bound (BPC) phenolic compounds were extracted according to Qiu, Liu, and Beta (2010). Then, phenolic compound content was determined by the Folin-Ciocalteau method (Singleton, Orthofer, & Lamuela-Raventos, 1999) using gallic acid as standard.

2.2.4. Physical properties

2.2.4.1. Test weight (TW). A 0.25 L Hectoliter Weight Schlopper type scale was used. The results were expressed in kg/hL according to Maxson, Fryar, Rooney, and Krishnaprasad (1971).

$$TW\ [kg/hL] = W\ (g/0.25\ L) * 100\ L\ /\ 1\ hL * 1\ kg\ /\ 1000\ g$$

Where W is the weight in g of 0.25 L.

2.2.4.2. Milling ratio (MR). 50 g sample were ground and sieved. The remaining material in the 1 mm sieve was considered the thick fraction (T) and the material that passed through the 0.5 mm sieve was the fine fraction (F). The milling ratio was calculated as: T/F (De Dios, Puig & Robutti, 1992).

2.2.4.3. Percentage of flotation (F%). It is the percentage of grains that float in carbon tetrachloride (CL_4C) (Hallgren & Murthy, 1983).

2.2.4.4. Bulk density (BD). It was determined by volume displacement in a graduated cylinder and calculated as: BD (g/cm^3) = seed weight/(final volume - initial volume) (Chandrashekar & Kirleis, 1988; De Dios, Puig & Robutti, 1992).

2.2.5. Popping process

Adapted fluidized bed VP Model Dryer equipment (Bench Scale Equipment Co., Inc., Dayton, Ohio) was used. Based on previous studies with sorghum hybrids, the following conditions were defined for popping: 250 °C temperature for 1 min, 14% and 18% moisture content.

The following parameters were evaluated on popped samples:

2.2.5.1. Apparent volume (AV). Apparent Volume of popped sorghum was calculated as: AV (cm^3/g) = popped grain volume (cm^3)/popped grain weight (dry basis) (d.b.) (g).

2.2.5.2. Popping performance (PP). It was calculated on a dry basis as: (%) = popped grain weight (d.b.) (g)/initial weight (d.b.) (g).

2.2.5.3. Ability for popping (AP). An indicator of the ability of sorghum hybrids to pop was developed, which integrates the information provided by TW, AV and PP as follow:

$$AP = TW * AV * PP\ /\ 10000$$

Where, TW: test weight (kg/hL), AV: apparent volume (cm^3/g grains exploited), PP: popping performance.

2.2.6. Nutritional assessments

Selected hybrids (PEX 40730 W and PAN 8918) flours and precooked popped flours were milled with a Ciclotec mill (UD Corp Boulder Colorado–USA) using a 1 mm sieve and were analyzed regarding to:

2.2.6.1. Proximate composition. It was determined as was mentioned before.

2.2.6.2. Available lysine. The method of Carpenter modified by Booth (1971) was used.

2.2.6.3. Protein digestibility. The *in vitro* method according to Rudloff and Lonerdal (1992) was used.

2.2.6.4. Mineral bio-accessibility. The method of dialyzability according to Drago, Binaghi, and Valencia (2005) was used to estimate iron, zinc and calcium bio-accessibility (DFe%, DZn% and DCa %, respectively).

2.2.6.5. Total polyphenols (TPC). It was determined as was mentioned before.

2.2.6.6. Phytic acid content (PA). AOAC (1995) method was used.

2.2.6.7. Antioxidant capacity (AC). It was determined by the method of inhibition of the radical cation ABTS+• according to Cian, Luggren, and Drago (2011).

2.2.7. Statistical analysis

All determinations were performed in duplicate. Normality test (Chi-Square, Shapiro–Wilks, Z for skewness and Curtosis Z) were performed for analysis the data. When p-value was higher than 0.05, in two or more of the test, the distribution was considered normal and the mean and standard deviation (SD) were reported. ANOVA was used to determine significant differences among samples. For not normal population, Kruskal–Wallis test was performed and the median and interquartile range (IR) were reported. Multiple regression was applied to correlate AP with physicochemical results. Statistical software (Statgraphics plus 3.0) was used to perform normality test (Chi-Square, Shapiro–Wilks, Z for skewness and Curtosis Z), analysis of variance, multiple regression and principal component analysis (PCA).

3. Results and discussion

3.1. Physicochemical characteristics of sorghum hybrids

The results of chemical composition and mineral content of sorghum hybrids are presented in Tables 1 and 2, respectively. All of them were normally distributed, except TPC, FPC, and BPC. The