EFFECT OF EXTRUSION ON THE PHENOLIC COMPOUND CONTENT, ANTIOXIDANT CAPACITY AND PHYSICAL PROPERTIES OF SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH) AND PEARL MILLET (*PENNISETUM GLAUCUM* (L.) R.BR) BRAN

André L. SANTOS[1]; Monique B. SANTOS[2]; Davy W. H. Chávez[3]; Luiz H. FASOLIN[4]; Carlos W. P. CARVALHO[5]

ABSTRACT

Sorghum and pearl millet are cereals widely cultivated in Brazil, but little used in the human diet. These grains can provide several nutrients, especially bran, which, in addition to minerals and dietary fiber, has a high content of phenolic compounds beneficial to human health due to its high antioxidant capacity. This study investigated the effect of the extrusion process on the total phenolic content, antioxidant capacity and physical properties of sorghum and pearl millet bran. The extruded sorghum bran showed higher content of total phenolics and antioxidant activity, demonstrating the positive effect of processing on the availability of phenolic compounds. The decorticated grains had the lowest content of phenolic compounds, indicating that the highest content of these compounds were present in the pericarp of the grain. The content of phenolic compounds and antioxidant activity showed a high positive correlation with specific volume and a high negative correlation with density.

INTRODUCTION

Pearl millet, botanical species *Pennisetum glaucum* (L.) R. Br, is the sixth most produced cereal, with a production of 27.8 million tons (SRIVASTAVA; SAINI; SINGH, 2020). Sorghum (*Sorghum bicolor* (L.) Moench), is the fifth cereal crop in the world, with a production of 58,70 million tons in 2020 (FAOSTAT, 2022). Pearl millet and sorghun grains are a gluten-free cereal, rich in dietary fiber and polyphenols that can reduce the occurrence of lipid disorders, cardiovascular disease and hyperglycemia. Despite these benefits, it is still an underused cereal for human consumption in many countries, especially in Brazil (SRIVASTAVA; SAINI; SINGH, 2020).

The most important anatomical parts of a cereal grain are endosperm, bran, and germ. The bran represents about 14-19% of the grain's weight. Despite being a rich source of vitamins, minerals, phytochemicals and dietary fiber, bran is usually discarded during primary processes such as peeling, grinding and polishing (PATEL, 2015).

Bioactive compounds such as phenols, anthocyanins and tannins are present in the bran fraction. Recent studies show the use of extrusion as a pretreatment positively affects phenolic compounds and the antioxidant capacity of sorghum bran (ORTIZ-CRUZ et al., 2020). Extrusion is a thermomechanical process that combines moisture, pressure, temperature and shear. According to the literature, some physical properties, such as particle size and density influence this process (CARVALHO et al., 2010).

In order to add bioactive compounds, dietary fiber and satisfy the demands of increasingly health-conscious consumers, many studies have been carried out with the aim of adding bran in food formulations. However, for this to be possible, it is necessary to study the physical and chemical properties of the materials, directing to the appropriate product and technology process

[1] Doctoral student, Program in Food Science and Technology (PPGCTA – UFRRJ);
[2] Postdoctoral, FAPERJ project No. E_26/204.595/2021 (Brazil);
[3] Postdoctoral, FAPERJ project No. E_26/204.328/2021 (Brazil);
[4] Teacher, Postgraduate Program in Food Engineering (PPGEA – UNICAMP);
[5] Researcher, Embrapa Agroindústria de Alimentos

OBJECTIVE

Investigate the effect of the extrusion process in the pearl millet and sorghum bran. Evaluate the content of total phenolic compounds, antioxidant activity and physical properties of pearl millet and sorghum bran, extruded bran and decorticated grains, and verify the correlation between the physical and chemical properties studied.

MATERIALS AND METHODS

1. Samples preparation

The Pearl millet and sorghum grains were kindly donated by Atto Sementes (Rondonópolis, MS). Whole grains were cleaned in a Clipper Office Tester 400/B mechanical separator (A.T. Ferrell Co., Bluffton, USA). After cleaning, the grains were decorticated in a rice bench testing machine, model MT-97, nº 3788-5 (Suzuki, Brazil) at a flow rate of 150 g for 10 min. for millet and 05 min for sorghum. The brans and decorticated grains were then ground in a hammer mill model 3100 (Perten Instruments AB, Huddinge, Sweden). The decoticated grains were stored for future analysis. A part of the sorghum and millet bran was stored and another part went to the extrusion process.

2. Extrusion conditions

Sorghum and pearl millet were conditioned with 14% moisture. A 19/20 DN single-screw laboratory extruder (Brabender, Duisburg, Germany) equipped with a 2:1 compression screw was used; 6 mm circular matrix; three heating zones from supply to output set to: 40, 80 and 100 °C; screw speed was set to 200 rpm and a feed rate of ~2.0 kg/h (TOLEDO et al., 2020). After extrusion, the samples were dried in an oven at 105 ºC for 4 hours and ground again, as described above.

3. Antioxidant capacity (AC-ABTS) and total phenolic compounds (TPC)

The analyzes were carried out following the methodology proposed by (RUFINO et al., 2010) and (GEORGE et al., 2005).

4. Particle size distribution (PZD), density and specific volume

The PZD of the raw flours was determined in duplicates, using a S3500 series particle size analyzer (Microtrac Inc., Montgomeryville, USA) with deionized water, using three size ranges: <0.1 mm, from 0.1 to 0.5 mm and from >0.5 to 2 mm. For density and specific volume analysis, the particulate material were determined by the gas displacement method in a pycnometer system AccuPyc II 1340 (Micromeritics, Norcross, USA), using helium as displacement medium.

5. Statistical analysis

Analysis of variance 2x3 (two-way ANOVA), Tukey's test at 5%, Principal Component Analysis (PCA), Pearson's coefficient (r) and Hierarchical Clustering on Principal Components (HCPC) were performed. All analyzes were performed using R software version 3.2.4 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS AND DISCUSSION

The results of the analyzes are shown in Table 1. The values for TCPs were in the range of 99.78-1240.94 µgGAE/100g while AC ranged from 4.55 to 55.51 µmol TE/g. The lowest TCPs and ACs were observed in DSG and DMG, which was expected since decortification essentially removes the outer pericarp of the grain, mainly non-starch polysaccharides and phenolic compounds (BARBHAI; HYMAVATHI, 2022).

Significant increases were identified in TPCs levels in SEB when compared with SB, the same behavior reported by Ortiz-Cruz et al., (2020) his increase can be explained by the structural modification of cell walls under high temperature, pressure and shear conditions (SALAZAR LOPEZ et al., 2016).

In AC analyses, extrusion caused a significant increase for all treatments, the highest AC was observed in ESB (55.51 µmol TE/g). The AC in cereals has been mainly related to phenolic acids and non-starch polysaccharides present in the cell wall (TAKOUDJOU MIAFO et al., 2022). The breakage of covalent bonds caused by the extrusion process reflects the increase in AC and TPCs (TAYLOR; DUODU, 2015).

The volumetric mean D[4.3], arithmetic D[3.2] and span are shown in Table 1 and Figure 1ab. The hierarchical classification (Figure 1b) formed 4 groups (SDG-SB, MDG, MEB-MB and SEB). Significant differences were observed between M (Millet) and S (Sorghum) for D[4,3], D[3,2] and span, these results may be related to the chemical composition of the outer layers of the grains, which decrease the hardness, making the decortication process easier (EARP; MCDONOUGH; ROONEY, 2004). The highest D[4,3] was observed in SB (161.30µm) and the lowest 81.31µm was observed in EMB.

The highest D[4,3] was observed in SB (161.30µm). Extrusion significant reducted of 24.82% in SB when compared to ESB and a reduction of 16.46% in MB. As for D[3,2], the DMG and DSG fractions showed the lowest values 21.32 and 32.10µm, respectively. The span index in SB was reduced by 11.44% which indicates a greater homogeneity of the sample after extrusion. This same behavior, after extrusion, was reported by Cao et al., (2021).

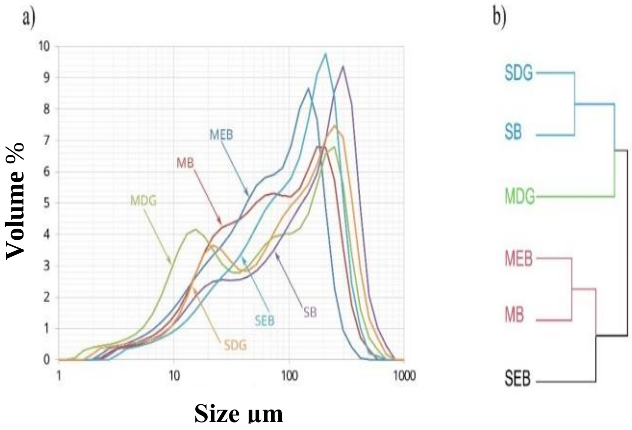

Figure 1: Particle sizes for bran, extruded bran and decorticated grain. (a) Particle size distribution (b) Hierarchical classification.

The sorghum and millet fractions were subjected to density and specific volume analysis (Table 1). The highest densities were observed in the DMG and DSG fractions. For specific volume, the lowest values were found in the DMG and DSG fractions. These results corroborate with Vargas-Solórzano et al., (2014).

Principal component analysis (PCs), hierarchical clustering on principal components (HCPC) and Pearson's correlation coefficient are shown in Figure 2. The two principal components (PCs) explain ~96.3% of the data variance (Dim1 67%, Dim2 29.3%). PCs analysis (Figure 2a) showed the differences between decorticated fractions (DMG and DSG) and bran with and without extrusion (MB/EMB and SB/ESB). The main variables that characterized the raw and extruded meals were the physical properties, SV and D[3,2] and the functional properties AC-ABTS and TPC, while the decorticated fractions showed higher D[4,3]. PCs were used to apply HPCP (Figure 2b), resulting in 3 groups depending on the treatment applied, being decorticated grain (MDG and SDG), millet bran and extruded bran (MB and MEB) and sorghum bran and extruded bran. (SB and SEB). Pearson's correlation coefficient (Figure 2c) showed a high positive correlation ($0.90 > r \leq 0.99$) between TPC - AC-ABTS, AC-ABTS - SV and TPC-SV and a high negative correlation ($0.70 > r \leq 0.90$) between span-D[3,2], Density -SV, TPC-Density and Density-AC-ABTS.

Table 1: SV, Density, D[4,3], D[3,2], span, TPC, and ABTS for millet and sorghum, in the bran, extruded bran and decorticated grain fractions.

Grain	**Fraction**	**SV** (cm³/g)	**Density** (g/m³)	**D[4,3]** (µm)	**D[3,2]** (µm)	**Span** (%)	**TPC** (µgGAE/100g)	**AC-ABTS** (µmol TE/g)
M	B	0,72±0.0^{Aa}	1.39±0.0^{Bb}	97.37±10.2^{Ab}	32.26±3.08^{Ab}	3.00 ± 0.1^{Ba}	1225.72±79.83^{Aa}	41.1±0.97^{Bb}
M	EB	0,72±0.0^{Aa}	1.39±8.8^{Bb}	81.31±4.2^{Bb}	29.2±2.19^{Ab}	2.81 ± 0.0^{Ba}	1240.90 ± 20.0^{Aa}	44.89±0.4^{Ab}
M	DG	0,70±0.0^{Bb}	1.43±0.0^{Aa}	105.84±6.6^{Ab}	21.32±1.64^{Bb}	3.81 ± 0.2^{Aa}	272.30 ± 27.71^{Ba}	9.57±0.7^{Ca}
S	B	0,71±0.1^{Bb}	1.40±0.0^{Bb}	161.3±5.8^{Aa}	41.98±2.62^{Aa}	2.36 ± 0.0^{Bb}	1023.86 ± 8.1^{Bb}	49.22±1.47^{Ba}
S	EB	0,72±0.1^{Ab}	1.39±0.0^{Bb}	121.25±12.0^{Ba}	44.8±4.03^{Aa}	2.09 ± 0.1^{Cb}	1106.87 ± 2.65^{Aa}	55.51±0.72^{Aa}
S	DG	0,69±0.0^{Cb}	1.45±0.0^{Aa}	132.9±2.4^{Ba}	32.10±2.0^{Ba}	2.82 ± 0.2^{Ab}	99.78 ± 2.65^{Cb}	4.55±0.35^{Cb}

Capital letters in the same column indicate differences between fractions within the same grain ($p<0.05$), by tukey test.

Lower case letters in the same column indicate difference between grains within each fraction ($p<0.05$), by tukey test.

Values expressed as mean ±standard deviation.

M: pearl millet. S: sorghum, SV: specific volume, D[4,3]: arithmetic average, D[3,2]: volumetric average, Span: particle polydispersity index, TPC: total phenolic compounds and AC – ABTS: antioxidant capacity.

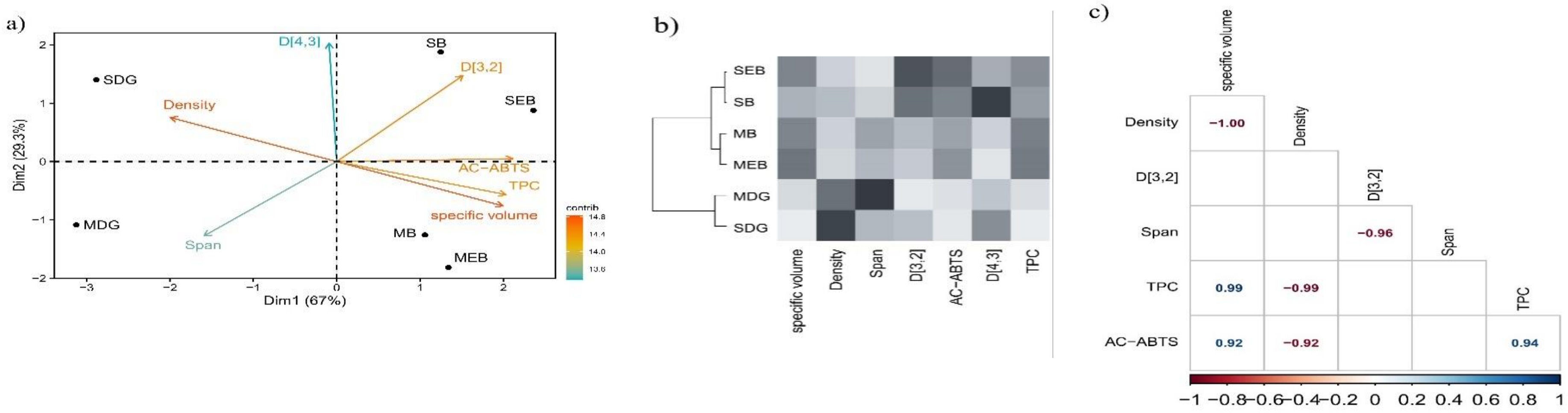

Figure 2: (a) Principal component analysis (PCs), (b) hierarchical clustering on principal components (HCPC) and (c) Pearson's correlation coefficient for bran, extruded bran and decorticated grain.

CONCLUSION

The highest concentrations of TPC were observed in bran and extruded millet bran. The highest antioxidant capacity was reported in extruded sorghum bran. The decorticated sorghum grain had the highest density and the lowest antioxidant capacity, whereas the decorticated millet grain had the lowest arithmetic mean. The data from PCs and HCPC showed that the extrusion process is able to increase the homogeneity of the particles, antioxidant capacity and the phenolic compounds present in the samples.

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