Proximal analysis and profile of fatty acids on six varieties of white grain sorghum with potential use in human consumption

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ABSTRACT

In Mexico, corn is the most widely used cereal, however, in arid areas it is not possible to cultivate it, so white sorghum represents an alternative. However, it is important to know the varieties nutritional content. Therefore, this study the proximal profile and fatty acids of six white sorghum varieties grown in Mexico were evaluated. Proximate analysis was carried out based on AACC methods and gas chromatography had been used for fatty acid analysis. Mazatlán and Sureño varieties showed the highest content of proteins (12%), fiber (7%), and ash (1.65%); regarding fat content, the highest values were found in Mazatlán and Costeño (4%). For fatty acid profile, saturated and unsaturated fatty acids were detected, including Omega 6 and 9. Sorghum represents an alternative, specially for arid and semiarid regions. The results indicate that these varieties are a viable source to produce foods for human consumption.

Análisis proximal y perfil de ácidos grasos de seis variedades de sorgo de grano blanco con uso potencial en el consumo humano

RESUMEN

Si bien el maíz es el cereal más utilizado en México, no es posible cultivarlo en zonas áridas, por lo que el sorgo blanco representa una alternativa al mismo. Debido a esto resulta importante conocer el contenido nutricional de las variedades. Por ello, el presente estudio se propuso evaluar el perfil proximal y los ácidos grasos presentes en seis variedades de sorgo blanco cultivadas en México. El análisis proximal se realizó con base en métodos de la AACC, mientras que para el análisis de ácidos grasos se utilizó cromatografía de gases. A partir de dichos análisis se pudo constatar que las variedades Mazatlán y Sureño poseen el mayor contenido de proteínas (12%), fibra (7%) y cenizas (1,65%); en cuanto al contenido de grasa, los valores más altos se encontraron en las variedades Mazatlán y Costeño (4%). En lo que respecta al perfil de ácidos grasos, se detectaron ácidos grasos saturados e insaturados, incluyendo Omega 6 y 9. El sorgo representa una alternativa, especialmente para las regiones áridas y semiáridas. Los resultados permiten concluir que estas variedades son una fuente viable para producir alimentos destinados al consumo humano.

1. Introduction

Sorghum seed was moved to western Africa, and it was introduced in the Americas in the 18th Century (Pérez et al., 2010). In the region of Central America and the Caribbean, production is led by Mexico (90%), and in South America, it is concentrated in Argentina (60%) and the dry areas of Brazil, northern Colombia and Venezuela (FAO, 2016). Sorghum is an important source of nutrients and energy in Africa, especially in semiarid region, the grains are used for making different foods (breads, pasta, porridges). Sorghum grains can be white, yellow, Brown, Red or black; all sorghums contain compounds like flavonoids, phenolic acids and tannins. Despite the beneficial effect of antioxidants, high levels of tannins in brown, read or black sorghums are considered anti-nutritional component, the effects include reduction in voluntary feed intake and diminished digestibility. White grain sorghum has very low or null levels of tannin, thus white grain is preferred for human feeding (Etuk et al., 2012; Pezzali et al., 2020; Xiong et al., 2019). The proximate compositions analysis show that sorghum grain contains important nutrients that complement diets. Sorghum nutritional composition is like other major cereals, is a good source of energy, macronutrients and micronutrients, also it is rich in polyunsaturated fatty acids, these are present mainly in the germ of the grain. Therefore, its quality, availability, storage, use and consumption contribute to food security and nutrition wherever required, and it is also considered an adequate food for people with pathologies such as diabetes and obesity, due to its high vitamin, mineral and fiber contents (Chavan et al., 2016; Hadebe et al., 2017; Mehmooh et al., 2008).

In Mexico, the production of sorghum-based foods improves the market and incomes for farmers, due to its
low costs required to produce the grain, ensuring a lower reliance on the purchase of grain from abroad, and it can minimize the ongoing food crisis. Mexico accounts for 33.7% of imports and it has production ranges of 2, 249,079 Ton, with the state of Tamaulipas as the main producing state (1, 687,602) (SIAP, 2019). The food industry seeks new alternatives to cereals such as wheat, which has generally been totally or partially replaced in some products with maize, rice or oat. However, white sorghum is a cheaper and equally nutritious alternative. In addition, this plant displays a high resistance to temperature changes, a short planting cycle and low production costs (McGinnis & Painter, 2020; De Morais Cardoso et al., 2017). In Mexico, sorghum is used for feeding animals, and mostly red grains are planted. However, white grain varieties have been developed or introduced for potential use in human nutrition. Therefore, the aim of the present study was to analyze the proximal and fatty acid profile in six varieties of white sorghum adapted to planting areas in Mexico.

2. Materials and methods

Six varieties of white sorghum were used: RB-Paloma, Mazatlán, Istmeño, Gaviota, Sureño and Costeño, planted in Rio Bravo, Tamaulipas in Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) experimental field, harvested during 2019. The process to produce flour consisted in washing the grain with drinking water to remove excess dust, drying in an oven at 55°C for 24 h (Zenith lab, Dry Oven DHG-9240A); later, the grains were ground with an electric grain grinder (BI-DTOOL 3000A), and the flour was stored in airtight plastic container at 4°C until use.

2.1. Proximal analysis

The proximate analysis was carried out based on official AACC methods. The total protein content was determined using crude protein micro Kjeldhal’s method (official method 46–13.01), along with moisture (official method 44–15.02), ash (official method 08–03.01), fats (official method 30–10.01) and crude fiber (official method 32–10.01). Carbohydrates (total starch) were calculated by difference (American Association of Cereal Chemists (AACC), 1995). All determinations were made in triplicate.

2.2. Determination of the profile of fatty acids

Fatty acids were extracted according to Ramos-Ramos et al. (2019), Sigma Aldrich extraction kit (Cat. No. MAK174) was used for fatty acids extraction; boron trifluoride-methanol was used for the preparation of the fatty acid methyl ester (FAME). Fatty acids were analyzed an Agilent Technologies 6890 N gas chromatograph, equipped with an HP-88 capillary column (100 m x 0.25 mm x 0.2 μm, Agilent Technologies) and a flame ionization detector. The temperature of the injection port and of the detector was 250°C and 260°C, respectively. The initial temperature of the oven was set to 100°C for 5 min and was then increased by 4°C every minute until it reached 240°C, where it was kept for 15 min, the carrier gas was helium and the injection Split 100:1. A calibration curve with Supelco 37 FAME mix pure standard by Sigma Aldrich (CRM47885) was used to calculate the concentration of fatty acids.

2.3. Statistical analysis

The statistical analysis was carried out using the program IBM SPSS Statistics V20, a variance analysis (ANOVA) was applied, the differences between varieties were evaluated using a Tukey’s test for means comparison (p ≤ 0.05).

3. Results and discussion

3.1. Proximal analysis of the six sorghum varieties

The proximal composition of sorghum grains varieties studied is shown in Table 1; regarding ash contents, the variety RB-Paloma was found to have the highest value, yet it presented no differences with Mazatlán, Sureño and Gaviota; this parameter depends on the genome of the variety and the planting conditions. A study carried out by López Ortiz et al. (2011) evaluated the proximal content of native varieties and varieties germinated in Cali, Colombia, and they found similar results with the present study: 1.50% for native and 1.48% in the germination. Determining ash is important since it is a general measurement of the minerals present (Verma & Srivastav, 2017). The moisture content of the cereals is of great importance, since its shelf life depends largely on this; it is a quality indicator, along with grain handling, cereal grains must contain less than 14% (Mex-Álvarez et al., 2016), and in this case, all varieties are below this value. On the other hand, a large concentration of fiber was found, mainly in the Mazatlán and Paloma varieties. These values were high in comparison to Sultan et al. (2019), they reported 2.3% crude fiber in white sorghum grain from Pakistan. Several investigations have studied the effect of fiber in foods, beneficial effects include the regulation of intestinal transit, the prevention of colon cancer.

| Variety                  | Ash (%) | Moisture (%) | Crude fiber (%) | Fat (%)    | Protein (%) | CH (%)   |
|--------------------------|---------|--------------|-----------------|------------|-------------|---------|
| Costeño-201              | 1.35 ± 0.06   | 8.69 ± 0.2    | 6.86 ± 0.3     | 4.14 ± 0.09 | 10.41 ± 0.12 | 66.86 ± 1.22 |
| RB-Gaviota               | 1.49 ± 0.11 | 8.79 ± 0.72   | 7.07 ± 0.26  | 2.9 ± 0.02  | 12.48 ± 0.24 | 67.31 ± 0.72 |
| Istmeño                  | 1.46 ± 0.15 | 9.13 ± 0.27   | 6.07 ± 0.66  | 3.14 ± 0.02 | 10.58 ± 0.12 | 69.59 ± 1.23 |
| Mazatlán-16              | 1.65 ± 0.04 | 8.74 ± 0.08   | 9.09 ± 0.66  | 4.01 ± 0.05 | 12.48 ± 0.12 | 63.99 ± 0.92 |
| RB-Paloma                | 1.67 ± 0.10 | 8.15 ± 0.28   | 7.68 ± 0.68  | 3.63 ± 0.02 | 10.06 ± 0.37 | 68.78 ± 1.44 |
| Sureño                   | 1.62 ± 0.12 | 9.01 ± 0.04   | 7.25 ± 0.34  | 2.60 ± 0.11 | 12.93 ± 0.26 | 66.86 ± 0.77 |

*Columns with different letters indicate significant statistical differences according to Tukey’s test (p ≤ 0.05). CH: Carbohydrates. The average of three repetitions and the SD are shown.

Table 1. Proximal composition in varieties of white sorghum (%).
maintenance of the microbiota, prevention of cardiovascular diseases, and others (Cai et al., 2020; Weickert & Pfeiffer, 2018).

Regarding fat content, Costeño and Mazatlán varieties were found to display values of over 4%, higher than the rest of the varieties (Table 1). The amounts for sorghum varieties range between 2.6% and 4%, like reports by Abdulrahman and Omoniyi (2016) in sorghum varieties in Nigeria, in which values between 3.58 and 4.47% of fat were found. The fat present in cereal grains is attributed the energy value, which is why whole grain cereals are recommended, due to their high content of unsaturated fats, which help prevent cardiovascular diseases, obesity and diabetes (Laskowski et al., 2019). On the other hand, Mazatlán variety displayed the highest content of protein, being statistically different (p < 0.05) to the other varieties, except for Sureño. Calero et al., (2017) reported a lower protein content in maize grains (8.07%), this result suggests that the white sorghum grain can be used in combination with maize or other gluten-free cereals, or the flours of these grains can be used to produce foods with high protein contents. The highest amount of carbohydrates was found in the Istmeno and Paloma varieties (69.59 and 68.78 respectively); on average, sorghum grain has about 72.1% carbohydrates (Xiong et al., 2019). The differences between varieties may be due to genetic factors, factors related to the environment or to agronomic conditions during growth (Adeniyi & Ariwoola 2019).

3.2. Determination of fatty acids

In all the varieties studied, 15 saturated and 10 unsaturated fatty acids were found; the saturated fatty acids found included butanoic, hexanoic, capric, undecenoic, dodecanoic, tridecanoic, miristic, pentadecanoic, palmitic, heptadecanoic, stearic, arachidic, heneicosanoic, behenic, tricosanoic acids. Unsaturated fatty acids found included palmitoleic, oleic, linoleic, gamma linoleic, eicosanoic, linolenic, erucic, and docosadienoic acids (Table 2). In Mazatlán, Gaviota and Paloma varieties, a greater number of fatty acids were detected, along with the presence of polyunsaturated oils, such as omega 6 (linolenic) and omega 9 (Oleic and Erucic) (Table 2). Mehmood et al. (2008) determined fatty acids content; they reported oleic, palmitoleic, linoleic, linolenic, stearic, palmitoleic and palmitic acids; also, PUFA were higher than MUFA.

Fatty acids consumed are not only considered as nutrients that provide energy, but also as regulating agents for the metabolism, providing many functions that are beneficial for human health, particularly polyunsaturated fatty acids such as linoleic acid, which has found do reduce cholesterol and triglyceride concentrations by up to 50% when eaten by patients with hypercholesterolemia. The consumption of fatty acids such as eicosapentaenoic acid (EPA, C20: 5, n3) or a-linolenic acid (ALA, C18: 3, n-3) has been related to beneficial effects on longevity (Román et al., 2019). Sureño variety had a higher concentration of oleic and linoleic acids, in comparison with the other varieties (Table 2). The sorghum grain has been reported to essentially contain fatty acids such as oleic, linoleic and palmitoleic, octadecanoic (C08) and azelaic acids (C:9) (Stefoska-Needham et al., 2015). However, the two latter were not found in the varieties analyzed in the present study, possibly due to begin varieties that are grown in different geographic regions.

Pontieri et al. (2018) evaluated the profile for fatty acids in sorghum varieties from Argentina and Bolivia, grown in Italy, and they found that around 40% of the fatty acids corresponded to polyunsaturated fats, linoleic acid having the highest concentration. High concentrations of these fatty acids were found in the analyzed varieties; therefore, these varieties can even be considered for other purposes, apart from foods. A high

Table 2. Content of unsaturated and saturated fatty acids in the six varieties of Sorghum bicolor (L) Moench flour (mg/100 g).

| Fatty acids          | Istmeno | Mazatlán | Gaviota | Sureño | Costeño | Paloma |
|----------------------|---------|----------|---------|--------|---------|--------|
| Palmitoleic          | ND      | ND       | 1.6 ± 0.1 b | 2.3 ± 0.7 a | 1.8 ± 0.1 a | ND     |
| Oleic                | 1.6 ± 0.1 b | 6.6 ± 2.3 b | 2.3 ± 0.1 b | 20.3 ± 11.5 b | 8.6 ± 1.0 b | 1.0 ± 0.1 b |
| Linoleic             | 2.4 ± 0.1 b | 10.0 ± 3.4 b | 16.9 ± 5.1 b | 27.3 ± 15.6 b | 12.6 ± 3.5 b | 11.1 ± 13 b |
| y-Linolenic          | ND      | ND       | ND      | ND     | ND      | ND     |
| cis-11-Ecosenoic     | ND      | ND       | 2.7 ± 1.0 b | 1.9 ± 0.1 b | ND      | ND     |
| Linolenic            | ND      | ND       | 7.7 ± 2.6 b | ND      | ND      | ND     |
| Erucic               | ND      | ND       | ND      | ND     | ND      | ND     |
| cis-13,16 Docosadienoic | ND     | 2.40 ± 0.34 | ND      | ND     | ND      | ND     |
| Butanoic             | ND      | ND       | 19.84 ± 1.8 b | 20.76 ± 0.9 b | ND      | ND     |
| Hexanoic             | ND      | ND       | 13.4 ± 0.1 b | 14.6 ± 1 a  | ND      | ND     |
| Capric               | ND      | ND       | 1.20 ± 0.2 | ND      | ND      | ND     |
| Undecanoic           | ND      | ND       | 0.5 ± 0.1 a | ND      | ND      | ND     |
| Dodecanoic           | ND      | ND       | 0.2 ± 0 b  | ND      | 0.1 ± 0 b | ND     |
| Tridecanoic          | ND      | ND       | ND      | ND     | 1.4 ± 0.01 | ND     |
| Miristic             | ND      | 2.4 ± 0.4 | ND      | ND     | ND      | ND     |
| Pentadecanoic        | ND      | 6.34 ± 2.3 | ND      | ND     | ND      | ND     |
| Palmitic             | 1.7 ± 0.1 b | 4.5 ± 1.4 b | 0.8 ± 0.1 c | 5.9 ± 2.9 b | 0.8 ± 0.1 c | 2.3 ± 0.1 b |
| Heptadecanoic        | ND      | 16.3 ± 5.7 | ND      | ND     | ND      | ND     |
| Estearic             | 1.5 ± 0.1 b | 9.4 ± 3.2 | 1.5 ± 0.1 b | 3.1 ± 1.2 b | 1.7 ± 0.1 b | 1.4 ± 0.1 b |
| Arachidic            | ND      | 5.40 ± 1.66 | ND      | ND     | ND      | ND     |
| Heneicosanoic        | ND      | 1.60 ± 0.1 | ND      | ND     | ND      | ND     |
| Behenic              | ND      | 1.9 ± 0.6 a | ND      | 0.4 ± 0.1 b | ND      | ND     |
| Tricosanoic          | ND      | ND       | 2.0 ± 0.2 a | 3.8 ± 1.6 b | ND      | ND     |

^a,b,c^ Row with different letters indicate significant statistical differences according to Tukey’s test (p ≤ 0.05). The average of five repetitions and the SD are shown.
ND: Not detected
^a,b^ Las columnas con letras distintas indican diferencias estadísticas significativas según la prueba de Tukey (p ≤ 0.05). Se indican la media de cinco repeticiones y la DE.
ND: No detectado.
concentration of saturated fatty acids and the deficit of polyunsaturated fats are known to be related with different diseases, including cancers, heart diseases, cognitive disorders and imbalances, cognitive and psychological imbalances, complications in pregnancy and fetal development, and others (Rodríguez-Cruz et al., 2005; Pontieri et al., 2018). It is important to mention that unsaturated fatty acids of cereals are lower than in fish, but cereals also are a good source of these nutrients.

4. Conclusions

The results indicate that the six varieties of white sorghum have a good proximal content for human food development, Mazatlan-16 variety was highest protein, crude fiber and fat. All varieties showed fatty acids, including Omega 6 and 9; linolenic acid was present in Mazatlan and Paloma, euric acid in Paloma, while oleic acid was found in all varieties. These results suggest that expanding the production of these varieties of white sorghum in Mexico and developing food products for human consumption with a high nutritional value, is feasible. The six studied varieties are an alternative, especially in arid areas of Mexico.

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Disclosure of potential conflicts of interest

No potential conflict of interest was reported by the author.

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