Comparative Study of Nutritional Value of Wheat, Maize, Sorghum, Millet, and Fonio: Some Cereals Commonly Consumed in Côte d'Ivoire

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Abstract

This paper focuses on providing a useful database for the decision-makers for adequate food security policy. It involves making a comparative study of the nutritional values of wheat, maize, sorghum, millet and fonio, which are the five cereals largely consumed in Côte d'Ivoire. In conducting this study, physicochemical analysis were performed. The results reveal that wheat, maize, sorghum, millet, and fonio have an acidic pH. These cereals contain relatively little amount of water and a large proportion of fibers. Carbohydrates represent the highest proportion of the dry matter of the cereals, while maize contains the most important rate. Maize, sorghum, and millet contain more lipids. Wheat, maize, and millet have lower ashes. Wheat and millet contain more proteins. Millet, sorghum, and fonio are the richest cereals in iron. Wheat is rich in calcium but has a lower content of potassium, phosphorus, and Magnesium. Fonio is rich in zinc. Cereals are rich in phytochemical compounds such as phenolic acid, flavonoids, and tannins. It is also important to take into cognizance the presence of antinutritional compounds such as phytates and oxalates. The results show that all the cereals studied represent potential sources of energy in Ivorians food but also has significant sources of fibers and minerals.

Keywords: Cereals, Nutritional Value, Energy, Antinutritional Compounds, Côte d'Ivoire

Introduction

Cereals include plants from the family of Poaceae and are grown especially for their grains. They are often ground into refined flour with more or less whole, but also as whole grains (Ballogou, 2012; Chaib et al., 2015;

Barkiyou, 2017). For centuries, cereals have represented the basic food in the tropical and semi-arid areas of Africa and Asia (Echendu, 2009; Defan et al., 2015). Their energy contribution in the food intake of West African Sahelian countries represents 63 % on average. In Côte d'Ivoire, they contribute to about 32.6 % of the energy intake per inhabitant and per day. This makes cereals one of the main energy sources and nutrients for populations (ReSAKSS, 2011). The increase in cereal consumption is also attributable to the increase in the consumption of rice. This has led to the detriment of other cereals such as maize, wheat, sorghum, millet, and fonio (ReSAKSS, 2011). Furthermore, the calorific contribution of rice in the daily food consumption of cereals is 19% on average from 2004 to 2008, which is against 6.4% and 5% from corn and wheat respectively (ReSAKSS, 2011). As for millet, sorghum, and fonio, they are not part of the food habits of most people from Côte d'Ivoire. However, those cereals, which are less popular, are rich in nutrients and could positively contribute to the improvement of health and living standards. Therefore, this study could be a useful database for decision-makers in adequate food security policy. Also, it focuses on comparing the nutritional values of wheat, maize, sorghum, millet, and fonio.

Materials and Methods

Food Material

Whole and dry grains of white maize (Zea mayze), white sorghum (Sorghum bicolor), grey millet (Pennisetum glaucum), white fonio (Digitaria exilis), and tender wheat (Triticum aestivum) were used. These grains were bought in the big market of Korhogo. This city, in the north of Côte d'Ivoire, is known as the largest supply and production center of cereals in Côte d'Ivoire. Whole grains of wheat were also offered by the Grand Moulin d'Abidjan (The Flour Factory of Abidjan), a private cereals distributor located in Abidjan, in the south of Côte d'Ivoire. Whole and dry cereals grains were separated, sieved and washed with distilled water, then dried with an oven (MMM Medcenter Gmbh, D-82152, Germany) at a temperature of 60 °C for 48 hours. After that, it was turned into flour by means of a mechanic crusher (Rutsch GM 300, Germany). The subsequent flours were sieved with a sieve of 500 µm as diameter.+

Methods for Assaying Cereal flours

a) pH Determination

The determination of the pH was carried out with the principle of the AOAC (1990), based on the potentiometric method, using the electrode of the pH counter (WT pH 302). The assaying helped to determine the total concentration of natural acid of the product.

b) Determination of Titratable Acidity

The titratable acidity was determined by means of the method proposed by the AOAC (1990). The titratable acidity was measured with a standard solution of sodium hydroxide (NaOH) in the presence of phenolphtalein which served as a colored indicator.

c) Moisture Content

The moisture content was determined by using a standard procedure of the AOAC (1990). The principle is based on the mass loss of the sample till it reaches a constant mass at 105 °C.

d) Proteins Content

Crude proteins are determined from the assaying of total nitrogen by using the method of Kjeldhal (AOAC, 1990). The nitrogen of the dry matter is dosed according to the Kjeldhal's method after the sulphuric mineralisation in the presence of selenium, which is used as a catalyst. The nitrogen content was multiplied by the conversion coefficient of nitrogen into proteins. However, this conversion coefficient varies depending on cereals. More especially, the coefficient is 6.25 for sorghum and fonio, 5.83 for wheat and millet, and 5.6 for maize (FAO, 1998).

e) Lipids Content

The lipids content was determined by means of the method of AFNOR (1986) using the Soxhlet as extractor. The extraction of oils is obtained by the hexane with Soxhlet type extractor (Unit Tecator, System, HT2, 1045, Sweden). This was done after the evaporation of the solvent and the drying of the capsule in the oven, at a temperature of 105 °C for 30 min. The difference in weight provides lipid content of the samples.

f) Digestible Carbohydrates Content

The digestible carbohydrates content is determined by calculation (FAO, 1998). The sugars content is determined following the method with sulfuric phenolic as described by Dubois et al. (1956). The starch content is determined by using the formula recommended by FAO (1947): Starchy content = 0.9 (% total carbohydrate - % total sugars).

g) Fibers Content

The fibers content is determined by using the Van Soest's method (1963). The method used to determine the ash is the one described by AOAC (1990), which consists of burning a sample till white ashes is gotten. The cap containing the sample is put in a muffle furnace (PYROLABO) and submitted at a temperature of 550 °C for five hours. Then the cap is taken out of the muffle furnace and kept cooled in a dryer. Thereafter, it is weighed.

h) Energy Value

The energy value of the sample is calculated with specific coefficient of Atwater (1899) for the proteins, the lipids, and the carbohydrate.

i) Minerals Contents

Calcium, copper, iron, potassium, magnesium manganese, sodium, phosphor, and zinc have been measured out in the ash with electronic scanning. This is coupled with an energy-dispersive spectroscopy (MEB/EDS), which is an electronic scanning Microscope/energy-dispersive-spectroscopy.

j) Polyphenols Contents

The polyphenols are determined based on the method of Singleton et al. (1999) using Folin-Ciocalteu's reactant on the methanolic extract. The optic density is read with a spectrophotometer (PG INSTRUMENT) at 725 nm against a blank.

k) Flavonoids Contents

The content in flavonoids is determined with the method of Meda et al. (2005), on the methanolic extracts, using the aluminum trichloride and sodium acetate as reactant. The absorbance is read with a spectrophotometer (PG INSTRUMENT) at 415 nm against a blank.

l) Tannins Contents

The assaying of tannins was carried out based on the method described by Bainbridge et al. (1996), and vanilin was used as reactant on the methonolic extracts. The absorbance is read with a spectrophotometer (PG INSTRUMENT) at 500 nm against a blank.

m) Phytates Contents

Phytates are quantified based on the methods described by Latta and Eskin (1980) under magnetic agitation which is associated with the reactant of Wade. The absorbance is read with a spectrophotometer (PG INSTRUMENT) at 490 nm against a control.

n) Oxalates Contents

Oxalates are measured out by using the method of Day and Underwood (1986). The sample is homogenised in the soda under magnetic agitation, which is a filtered mixture on Wathman paper. It is also titrated immediately with a solution of potassium permaganate.

Statistical Analysis

The results are reported under the form of average standard deviation. The comparisons of the values of the physico-chemical parameters are carried out with the STATISTICA software, version 6.1. Analysis of variance followed by the Newman Keuls test is carried out. The significance of the differences of average is obtained with a risk error of $\alpha \leq 0.05$.

Results

Physicochemical Values of Different Cereals

The study of the physico-chemical composition is assessed by dry matter (DM) (Table 1). The results reveal that all the cereals under study have an acidic pH. The pH values are between 4.80 ± 0.01 for fonio and 6.83 ± 0.01 for wheat. Values of titratable acidity (AT) vary from 2.49 ± 0.0 mEq/10 g DM (wheat) to 7.25 ± 0.28 mEq/10 g DM (fonio). Moisture rate is lower (10.72 ± 1.05 % FM) in wheat and higher (11.72 ± 0.20 FM) in fonio. The results of the analysis also show that protein values are between a rate of 12.24 ± 0.94 % DM for wheat and 7.10 ± 0.96 % DM for maize. The lowest content in lipids is obtained with wheat (1.73 ± 0.42 % DM) and fonio (1.62 ± 1.11 % DM). Maize is richer in carbohydrates (75.48 ± 2.89 % DM) and in total sugars (3.66 ± 0.66 % DM). The highest rate of starch is obtained with wheat (68.24 ± 2.16 % DM) and the lowest with sorghum (61. 20 ± 4.25 % MS). Maize (6.69 ± 0.15 % MS) and sorghum (8.14 ± 1.07 % MS) have higher values of fibers than those of wheat (2.81 ± 0.26 % MS), millet (3.89 ±0.51 % MS), and fonio (3.38 ± 1.04 % MS). Fonio has the greater value (8.22 ± 0.49 % DM) of ashes and wheat has the lowest (1.41 ± 0.57 % DM). The calculated energy value of maize (321.79 ± 18.03 Kcal / 10 g DM) is higher than that of the other cereals under study.

Table 1. Physicochemical composition of cereals

Parameters	Cereals				
	Wheat	Maize	Sorghum	Millet	Fonio
pH	6.83 ± 0.01^{e}	6.57 ± 0.01^{c}	6.63 ± 0.01^{d}	6.45 ± 0.01^{b}	4.80 ± 0.01^{a}
TA (mEq / 100 g DM)	2.49 ± 0.00^{a}	4.48 ± 0.00^{c}	3.97 ± 0.00^{b}	5.46 ± 0.00^{d}	7.25 ± 0.28^{e}
Moisture (%FM)	10.72 ±1.05^{a}	11.51 ±0.82^{c}	11.57 ±0.75^{c}	11.31 ± 0.42^{b}	11.72 ± 0.20^{d}
Proteins (% DM)	12.24 ± 0.94^{d}	7.10 ± 0.96^{a}	8.99 ± 1.86^{b}	11.09 ± 0.12^{c}	8.12 ± 1.12^{b}
Lipids (% DM)	1,73 ± 0.42^{b}	4.18 ± 1.15^{d}	3.65 ± 0.70^{c}	4.58 ± 0.43^{e}	1.62 ± 1.11^{a}
Carbohydrates (%DM)	73.91 ± 3.56^{c}	75.48 ± 2.89^{d}	71.82 ± 3.89^{b}	71.82 ± 3.62^{b}	70.40 ± 3.95^{a}
Sugar (% DM)	2.91 ± 0.30^{c}	3.66 ± 0.66^{e}	2.56 ± 0.55^{b}	3.31 ± 0.75^{d}	2,01 ± 0.75^{a}
Starch (% DM)	68.24 ± 2.16^{d}	65.69 ± 5.09^{c}	61.20 ± 4.25^{a}	64.80 ± 3.51^{b}	65.12 ± 2.65^{c}
Fibers (% DM)	2.81 ± 0.26^{a}	6.69 ± 0.15^{d}	8.14 ± 1.07^{e}	3.89 ±0.51^{c}	3.38 ± 1.04^{b}

Ashes (% DM)	1.41 ± 0.57 [a]	1.79 ± 0.09 [b]	4.16 ± 0.58 [d]	2.16 ± 0.71 [c]	8.22 ± 0.49 [e]
EV (Kcal / 100 g DM)	308.22 ± 14.36 [b]	321.79 ± 18.03 [d]	308.84 ± 15.13 [b]	319.39 ± 17.67 [c]	284.72 ± 19.65 [a]

The variance of analysis is followed by Newman-Keul's multiple comparison test on the verge of 5 %. On the same line, the averages followed by different letters are significantly different ($p \leq 0.05$); TA: Titratable acidity. EV: Energy value. . DM: Dry Matter. FM: fresh matter. The averages are from three samples per cereal

Minerals Contents in Cereals

The mineral contents are assessed as mg for 100 g of ashes (Table 2). This shows that fonio (19.60 ± 1.45 mg / 100 g of ashes) and wheat (18.11 ±1.23 mg / 100 g of ashes) contain more calcium than the other cereals under study. Millet contains the greatest amount of copper (1.98 ± 0.33 mg / 100 g of ashes). The iron content in wheat (2.25 ± 0.25 mg / 100 g of ashes) and maize (2.92 ± 0.06 mg / 100 g of ashes) are lower than those found in sorghum (10.05 ± 0.45 mg / 100 g of ashes), millet (15.29 ± 0.01 mg / 100 g of ashes), and fonio (10.00 ± 0,08 mg / 100 g of ashes). The highest potassium contents are found in maize (276.17 ± 9.34 mg / 100 g of ashes), sorghum (283.80 ± 34.41 mg / 100 g of ashes), millet (283.74 ± 28.41 mg / 100 g of ashes), and fonio (277.08 ± 22.78 mg / 100 g of ashes). On the other hand, wheat (120.75 ± 2.66 mg / 100 g of ashes) and maize (126.12 ± 0.67 mg / 100 g of ashes) have the lowest rate of magnesium. Sorghum contains more manganese (3.47 ± 2.20 mg / 100 g de ashes), sodium (9.04 ± 1.26 mg / 100 g of ashes), and phosphorus (293.42 ± 48.61 mg / 100 g of ashes). The lowest rate of zinc is found in maize (0.83 ± 0.04 mg / 100 g of ashes) and millet (0.95 ± 0.08 mg / 100 g of ashes).

Table 2. Cereal minerals composition

Parameters (mg / 100 g A)	**Cereals**				
	Wheat	**Maize**	**Sorghum**	**Millet**	**Fonio**
Ca	18.11 ±1.23 [d]	10.68 ± 2.12 [c]	9.92 ± 2.28 [b]	7.57 ± 1.51 [a]	19.60 ± 1.45 [e]
Cu	0.74 ± 0.01 [b]	0.64 ± 0.08 [a]	0.74 ± 0.13 [b]	1.98 ± 0.33 [d]	0.82 ± 0.01 [c]
Fe	2.25 ± 0.25 [a]	2.92 ± 0.06 [b]	10.05 ± 0.45 [c]	15.29 ±0.01 [d]	10.00 ± 0.08 [c]
K	112.19 ± 1.91 [a]	276.17 ± 9.34 [b]	283.80 ± 34.41 [c]	283.74 ±28.41[c]	277.08 ± 22.78 [b]
Mg	120.75 ± 2.66 [a]	126.12 ± 0.67 [b]	179.37 ± 1.21 [d]	155.13 ±1.59 [c]	156.60 ± 0.95 [c]
Mn	1.86 ± 0.13 [b]	1.36 ± 0.01 [a]	3.47 ± 2.20 [d]	2.65 ±0.22 [c]	1.84 ± 0.07 [b]
Na	5.15 ± 0.01 [d]	3.74 ± 0.64 [c]	9.04 ± 1.26 [e]	2.04 ±1.24 [b]	1.85 ± 0.08 [a]
P	242.80 ± 0.60 [a]	284.68 ± 29.51 [c]	293.42 ± 48.61 [e]	267.08 ± 62.42 [b]	289.08 ± 26.07 [d]
Zn	1.23 ± 0.06 [c]	0.83 ± 0.04 [a]	1.40 ± 0.24 [d]	0.95 ± 0.08 [b]	2.27 ± 0.07 [e]

The variance of analysis is followed by Newman-Keul's multiple comparison test on the verge of 5 %. On the same line, the averages followed by different letters are significantly different ($p \leq 0.05$); A: Ash.

Phytochemical Contents in Cereals

Phytochemical screening of phenolic acids, flavonoids, and tannins (expressed in mg per 100 g of DM) are high for all the cereals under study (Table 3). Maize (173.70 ± 3.36 mg /100 g DM) and millet (173.26 ± 0.72 mg /100 g DM) contain more phenolic acids than wheat (136.59 ± 0.99 mg /100 g DM), sorghum (107.25 ± 1.13 mg /100 g DM), and fonio (134.42 ± 2.81 mg /100 g DM). Sorghum (1.51 ± 0.30) contains the lowest amount of flavonoids, while millet has the highest content in tannins (78.26 ± 0.35).

Table 3. Average content of phytochemical compounds in cereals

Parameters (mg / 100 g DM)	Cereals				
	Wheat	Maize	Sorghum	Millet	Fonio
Phenolic acids	136.59 ± 0.99 ^{b}	173.70 ± 3.36 ^{c}	107.25 ± 1.13 ^{a}	173.26 ± 0.72 ^{c}	134.42 ± 2.81 ^{b}
Flavonoids	4.76 ± 0.12 ^{d}	5.07 ± 0.15 ^{e}	1.51 ± 0.30 ^{a}	2.40 ± 0.37 ^{b}	3.79 ± 0.06 ^{c}
Tannins	23.73 ±1.61 ^{a}	48.60 ± 1.66 ^{c}	66.68 ±1.56 ^{d}	78.26 ± 0.35 ^{e}	34.65 ±0.43 ^{b}

The variance analysis is followed by Newman-Keul's multiple comparison test on the verge of 5 %. On the same line, the averages followed by different letters are significantly different ($p \leq 0.05$); DM: dry matter

Antinutritional Contents in Cereals

The values of antinutrional compounds are expressed in mg / 100 g DM (Table 4). The results show that the content in phytates is higher than the content in millet (28.14 ± 0.43 mg / 100 g of DM). Meanwhile, sorghum contains more oxalates (136.67 ± 2.89 mg / 100 g of DM).

Table 4. Average content of antinutritional compounds in cereals

Parameters (mg / 100 g of DM)	Cereals				
	Wheat	Maize	Sorghum	Millet	Fonio
Phytates	12.01 ±0.49 ^{a}	17.93 ± 0.21 ^{c}	15.99 ± 0.19 ^{b}	28.14 ± 0.43 ^{e}	19.48 ± 0.32 ^{d}
Oxalates	84.99 ± 0.30 ^{b}	116.40 ± 1.05 ^{c}	136.67 ± 2.89 ^{e}	130.95 ± 2.67 ^{d}	80.10 ± 1.43 ^{a}

The variance analysis is followed by Newman-Keul's multiple comparison test on the verge of 5 %. On the same line, the averages followed by different letters are significantly different ($p \leq 0.05$); DM: dry matter

Discussion

The analysis of the study shows that the pH of the cereals such as wheat, maize, sorghum, and millet significantly differs from one another and are close to neutrality. The pH for fonio also largely differs. These values are different from the ones proposed by N'Guessan (2014) for the flour of maize. Additionally, these values offer an indication on the type of microbiota likely to be contaminated of fonio by moisturing. Most of the batteries better develop with pH close to seven (7). Moreover, moisture develops when the pH is lower. The increase in moisture implies enzymatic reactions which will influence the titratable acidity (N'Guessan, 2014). This is why the titratable acidity of fonio is high.

Wheat, maize, sorghum, millet, and fonio contain relatively little amount of water. These contents are lower than those identified by FAO (2012) with white rice. This quality reduces the risk of damage and microbial growth, and thus favours a good conservation of cereals (Echendu et al., 2009). The protein contents of wheat and millet are greater than those of maize, sorghum, and fonio. The values obtained for the proteins are also close to the ones reported by Békoye (2011) on millet. However, these values are inferior to the content reported for millet, sorghum, and fonio by FAO (2012). Nonetheless, they are inferior to the content reported by Padulosi et al. (2009) for sorghum and maize as indicated by Echendu (2009) on fonio. The values obtained for maize, sorghum, and fonio are comparable to that of rice obtained by Saleh et al. (2013). However, this is inferior to the white rice reported by FAO (2012). There are lots of variations in the cereals composition which is related to the genetic factors, environmental factors, and farming practices. In sorghum, the protein content changes according to the place where they are farmed (Jeuffroy & Oury, 2012). The combination of winter peas and wheat allows an increase in wheat protein content (Pierreux & Bodson, 2018). In maize, the protein content increases with sandy soils compared to clay and loamy soil (Nyiraneza et al., 2012). In addition, cereals have an unbalanced amino acid composition which is essential with limiting rate, particularly in lysine. Nutrition based on a great consumption of cereals and a low supply of protein must be considered as risky (Smith et al., 2013).

Furthermore, the analysis revealed that among the cereals studied, maize, sorghum, and millet contain more lipids than wheat and fonio. The values obtained for maize, sorghum, and millet are in line with that of FAO (2012) on millet, maize, sorghum, and fonio. These contents can also be compared with those mentioned by Defan (2015) on the variety of maize MDJ, EV8728 and GMRP18 produced in Côte d'Ivoire. The values obtained for fonio are inferior to the content found by Glew et al. (2017). Also, the values obtained for lipids are greater than those indicated by FAO (2012) with white rice. Generally, cereal grains are low in lipids concentrated in the germ and the aleurone (Barkiyou, 2017).

Carbohydrates represent the highest proportion of the dry matter of the cereals under study. Maize contains the most important rate. These values are close to the ones found by Békoyé (2011) for maize. More so, these values are inferior to the content reported by FAO (2012) for the white rice. In fact, cereals essentially consist of carbohydrates. Most come from starch and lower proportions come from total sugars (Defan, 2015). These carbohydrates make up the main source of energy in cereals (Fardet, 2015). This high amount of carbohydrates is in relation with the higher content in starch and in energy, which is noted in this study. The fact that cereals grains contain a relatively high amount of carbohydrates is an advantage which is related to the use of their flour for trade products such as starch, glucose, and alcohol (Defan, 2015).

Sorghum and maize have fibers rate superior to those of wheat, millet, and fonio. In addition, all the rates of fibers found in the present study are great and superior to those reported by FAO (2012) with white rice. Such rates were mentioned by FAO (1995), especially with sorghum, due to the presence of bran. Food fibers consist of bioactive compounds which contribute to the prevention of coronary diseases, gastrointestinal tract trouble, and diabetes (Fardet, 2010; Shobana et al., 2010).

Wheat, maize and millet have lower ashes value compared with sorghum and fonio. These values are comparable to those of Defan (2015). The values are also comparable to the ones obtained by Padulosi et al. (2009) which showed that such ash contents, especially for the maize are acceptable. On the other hand, the values obtained for fonio are superior to the ones reported by FAO (2012). A large number of variances in the content of the ashes from cereals grains were reported, especially for pearl millet and sorghum. Genetic and environmental factors play a major role in the determination of this composition (Gamuyao et al., 2012).

The major minerals present in the grains of cereals under study are the sodium, iron, potassium, calcium, phosphorus, and magnesium. The trace elements noted are copper, manganese (Mn), and Zinc (Zn). These are the minerals found in most of the cereals (Békoyé, 2011; Ikram, 2013). Millet, sorghum, and fonio are the richest cereals in iron (Fe). These results resemble those of Padulosi1et al. (2009) and Glew et al. (2015). Wheat is rich in calcium but has a lower content of potassium, phosphorus, and Magnesium. The mineral contents of cereals studied are different from those obtained by Platel et al. (2010). The mineral salts content of the cereals studied are extremely variable and depend on the content in sulphured fertiliser. Therefore, they are influenced by the farming environment (Belaid, 2013). Other factors such as plant population density, season, and hydric constraint also contribute to the variation of the minerals (Gamuyao et al., 2012).

The analysis further revealed that wheat, maize, sorghum, and fonio are rich in phytochemical compounds such as flavonoids and tannins. The values found in this study are higher than the ones reported by Defan et al. (2015) for maize and inferior to the content reported by N'Dri et al. (2012) for sorghum, millet, and fonio after cooking. The presence of phenolic compounds in the grains of cereals prevents losses due to premature germination. Thus, this makes a longer conservation possible (N'Guessan et al., 2014). Besides these considerations, those compounds give cereals some therapeutic properties, especially anti-inflammatory, antibacterial, anti-oxidant, antithrombotic, heart protection, and vasodilatory (Fardet, 2010;

Banerjee et al., 2012; Shahidi & Chandrasekara 2013; Kaddafi et al., 2015; Udeh et al., 2017).

In addition to the phytochemical compounds, this study also revealed the presence of some nutritional inhibitors which are likely to reduce the nutritional value of the cereals. These are the phytates and the oxalates. The values obtained are in harmony with the ones obtained by Ikram et al. (2013). Phytates have a strong binding capacity and can make up insoluble complexes with proteins and some minerals such as iron and zinc. However, they are not available for the body. Nevertheless, the bioavailibilty of proteins and minerals can be improved by some methods of treatment mentioned such as malting, germination, soaking, milling, and cooking (Platel et al., 2010; Udeh et al., 2017). These treatments reduce the quantity of the antinutritional substances present in the cereals and therefore improve the bioavailability of minerals and proteins.

Conclusion

The analysis of the physiochemical composition revealed that wheat, maize, millet, and sorghum are rich in carbohydrates and energy. They contain a significant quantity of fibers, minerals, low proteins, and lipids content. Their lower quantity of water and the presence of phytochemical compounds provide the capacity to be conserved over a long period of time. However, the presence of nutritional inhibitors affects the nutritional property of the cereals by reducing the bioavailability of proteins and minerals. The high carbohydrate content of these cereals could have the ability to increase post prandial blood glucose. It would therefore be important to analyse this elevation of blood glucose in terms of blood glucose control as part of the prevention of obesity and diabetes.

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