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RESEARCH ARTICLE

Nutritional Profile of Selected Flood-Recession Sorghum Cultivars from Chad

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Abstract

Flood-recession sorghum, known in Chad as berbéré, cultivated at the end of the rainy season, represents a quarter of the total cereal production. Surveys, collections of cultivars, and agronomic trials have been carried out, but no physicochemical constituents have been analyzed. For this study, major mineral and tannin content of four main cultivars were evaluated. Morphological traits of the panicles and seeds were determined using the sorghum descriptor. The mineral content was determined by classical chemical analysis methods. The cultivars are distinctly characterized by the color of their seeds. Their panicles are compact. The glumes are all black and cover a quarter of the seeds. Their endosperm is mainly starchy. For mineral components, the gaps between the minimum and maximum values are high for tannin but relatively low for protein, ash, and fiber, and moderate for others. The coefficients of variation range from 2.50 to 24.10 %. Significant to highly significant differences are observed for all variables. The yellow-grained Djiressé Asfar cultivar has the highest protein (11.17 %), ash (2.07 %), iron (7.21 mg / 100 g), and zinc (8.92 mg / 100 g) contents. The white-grained Djiressé Beïda presents high starch (64.26 %), fiber (2.74 %), and calcium (17.07 mg / 100 g) concentrations. The red-grained Djiressé Ahmar has low protein (9.67 %), starch (60.32 %), ash (1.71 %), fiber (2.61 %), iron (4.37 mg / 100 g), tannin (26 mg ETA/100 g) concentrations, and medium calcium (13.61 mg / 100 g), zinc (5.64 mg / 100 g) concentrations. Gagnan cultivar has low protein (9.67 %), starch (61.91 %), fiber (2.39 %), calcium (12.22 mg / 100 g), zinc (4.99 mg / 100 g) and intermediate ash (1.91 %), iron (5.35 mg / 100 g) contents. Tannin content varies between 25 and 42 mg ETA/100 g.

Practical application

These results show that the flood-recession sorghum cultivars are an important source of nutrients diversity. These nutritional values can be used to develop high-quality nutritional products. The morphological traits and mineral components highlighted can be integrated in a national breeding program.

Keywords: Physicochemical value, flood-recession sorghum, cultivar, berbéré, Chad.

1. Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most widely cultivated cereals in the world. Global production is estimated at 61,364,997 tons, with 26,280,475 tons in Africa (FAOSTAT, 2021). In certain sub-Saharan regions of West and Central Africa, there are three main sorghum cultivation systems; sorghum grown in rainy conditions, irrigated sorghum, and flood-receded or transplanted sorghum. Their production areas are relatively different. Flood-receded sorghum is

cultivated at the end of the rainy season in fairly humid areas after the water has receded. As reported by Chantereau *et al.* (2013), these production areas are those flooded by rivers such as Senegal, Niger, Benoue in Cameroon, or Lake Chad. Additionally, this type of sorghum is also grown on vertisols in the northeastern part of Nigeria during the dry season under residual moisture conditions (Tabo *et al.*, 2002). In Chad, besides the areas around Chad Lake, the main production basin is in the Salamat province after the retreat of a watercourse called Barh Azoum.

Depending on the countries and cultivation areas, local name have been attributed to flood-receded sorghum. In West and Central Africa, many authors have reported that this type of sorghum is called "muskuwaari" in Fulfulde, cultivated in the extreme north of Cameroon, "masakwa" in Kanuri in Nigeria (Raimond, 2005; Chantereau *et al.*, 2013). In Chad, it is named "berbéré" (Bezot, 1963; Raimond, 2005; Chantereau *et al.*, 2013), which derives from Chadian Arabic language (Raimond, 2005). According to this author, "berbéré" originally referred to the black soil where sorghum transplanting is done. This meaning was then extended to the plant itself. Seignobos (2000) also reported that "Berbéré" was spread in the regions of Guéra and Salamat in Chad by the Showa Arabs, ethnic groups from Cameroon and Chad. However, according to Raimond (2005), it is difficult to specify the origins of transplanted sorghum cultivation. Indeed, archaeological research has not provided precise answers, and this author stated that its dissemination was done by different peoples.

In Chad, cereals, particularly millet and sorghum, constitute the staple diet of the population. "Berbéré" is cultivated in both the Sudanian and Sahelian zones. The main production basin is the Salamat province. However, this cultivation is also practiced in the provinces of Chad Lake, Guéra, Baguirmi, Batha, and part of Mayo-Kebbi. Over the past three years, the average production of cereals is estimated at 2,714,796 tons on 3,256,128 hectares sown. The average production of rain sorghum is 914,513 tons, and for "berbéré", it is 527,723 tons. During the last 2022-2023 campaign, the areas sown with "berbéré" are estimated at 486,333 hectares for a production of 552,286 tons, of which 344,655 tons or 62.41 % are in the Salamat province alone (DPSA/ANADER/SODELAC, 2023).

Compared to traditional varieties of transplanted sorghum, surveys conducted in certain regions of Chad and in the North and Extreme North provinces of Cameroon have identified a great diversity of varieties divided into five major regional groups (Raimond, 2005). They are generally classified in the durra or caudatum races (Seignobos, 2000; Saïdou *et al.*, 2014). Specifically in Chad, on the flood-receded lands in the South, transplanted sorghums belonging to the durra species are cultivated, and the caudatum species in the North (Bezot, 1963). However, Seignobos (2000) noted that in the southwestern Chad, the durra race is found in part of Baguirmi, and in the Bongor area, the caudatum race dominates.

Consequently, it appears that the diffusion of flood-receded sorghum races has occurred over vast territories where this sorghum cultivation system is practiced by rural communities. Furthermore, Chantereau (2001) reported that the Center for International Cooperation in Agronomic Research for Development (CIRAD) had 35 genotypes of "berbéré" from Chad in its germplasm bank. Recent surveys conducted in the Guéra province and in the Dababa and Fitri departments also collected 37 cultivars of transplanted sorghum in the form of panicles and

seeds (Nadjiam *et al.*, 2017). Similarly, 95 cultivars were collected in the departments of Baguirmi, Aboudeia, East and West Batha (Nekouam *et al.*, 2021). This indicates the importance of this crop in Chad.

Looking at the agronomic aspects, trials were conducted in the 1980s by the Agronomic Research Bureau in Chad. Currently, work on ethnobotanical aspects, cultivation systems, and genetic diversity of accessions is noted (Gapili *et al.*, 2016; 2019). These accessions were mainly collected in the Sudanian zone of Chad. Their sensitivity to photoperiodism and the effects of sowing dates were also evaluated (Naoura *et al.*, 2023).

Concerning the nutritional profile, many studies have been conducted worldwide on rain sorghum varieties (Songre-Ouattara *et al.*, 2015; Belay *et al.*, 2017; Nazal *et al.*, 2023). These studies have shown that nutritional values vary from one variety to another (Songre-Ouattara *et al.*, 2015). Additionally, Belay *et al.* (2017) indicated that the physicochemical compositions of sorghum varieties of Ethiopia were significantly different in various agro ecologies zones and even within the same agro ecological area. Gajmal *et al.* (2021) reported that the chemical composition of two sorghum cultivars was also vital and important in the development of high nutritional value products. Stella *et al.* (2021) showed that the physicochemical properties of starches extracted from sweet sorghum grains are comparable to standard starches from maize and other sources.

In addition to these components, many studies have been conducted on tannin levels in sorghum. Tannins in plant species are sometimes considered as antinutritional factors. Since the 1990s, varieties cultivated in France can only be registered in the official catalogue if they have a low tannin content, which must be less than 0.30 % based on dry matter (Metayer, 2011). However, it should be noted that some results indicate differences, especially concerning the link between this content and seed colour. The evaluation of nutritional components of sorghum varieties cultivated in Hungary showed that the type of sorghum, variety, and seed colour influence tannin and antioxidant levels. Red varieties have higher tannin levels than white varieties (Nagy *et al.*, 2021). In contrast, Boren and Waniska (1992) showed that seed colour is an inappropriate indicator for assessing tannin content in sorghum seeds. Sedghi (2012) specified that more research is needed to better determine tannin levels in sorghum seeds based on their coloration. This author indicates that estimating tannin concentrations from colour can vary depending on sorghum varieties.

In contrast, the physicochemical constituents of "berbéré" have not been analysed in Chad. Only the taste qualities such as the taste of the dough, stems and seeds were collected from producers and consumers. Raimond (2005) noted that these traditional varieties are appreciated for the sweet taste of the dough and stalks, the satiating effect, and the seeds in the milky state. However, there are many cultivars of this type of sorghum, of which four are widely spread and cultivated in production areas. They are highly valued by farmers. These include different morphotypes of "Djiressé," also called "Am Djiressé," and the "Gagnan" cultivar. These cultivars were reported by Raimond (2005) under the names "Djiressa" and "Gagnan." Currently, three variants of "Djiressé" have been identified and registered in the “Catalogue National des Espèces et Variétés Végétales” of Chad (CNEV, 2015).

To preserve and enhance these cultivars, the study aims to evaluate the morphological traits of

their panicles and seeds, major nutritional components and tannin content.

2. Materials and Methods

2.1. Materials

The materials consist of four genotypes widely cultivated in the flood-receded sorghum production basin. The first three were collected in the Salamat region (10°58'N and 20°15'E), and the last in the Guéra province (11°84'N and 18°97'E). Except for the "Gagnan" cultivar, the "Djiréssé" are listed in the « Catalogue National des Espèces et des Variétés Végétales » (CNEV, 2015). The agronomic characteristics of these genotypes are presented in Table 1.

Table 1. Major agronomic traits of flood-receded sorghum cultivars

N°	Code	Local name	Plant height (cm)	Days to maturity	Yield (t/ha)	Grain Color
1	Dsf	*Djiressé Asfar	185	125	3.00	Yellow
2	Dah	*Djiressé Ahmar	195	125	3.50	Red
3	Dbe	*Djiressé Beïda	205	130	4.00	White
4	Gga	Gagnan	194	126	3.50	Buff

*Source : Catalogue National des Espèces et des Variétés Végétales au Tchad (CNEV, 2015)

2.2. Methods

2.2.1. Determination of qualitative traits

The traits of panicles and seeds were determined using the sorghum descriptor (IBPGR, ICRISAT, 1993). These include panicle shape, seed type, endosperm texture, glume coloration and seed coverage.

2.2.2. Physicochemical analyses

The nutritional profile and the mineral content levels were determined using classical chemical assay methods. The moisture content was determined using the NF V 03-707 method (AFNOR, 2000). Ash content was measured using the NF V 03-760 method (AFNOR, 1981a). Protein content was measured by the Kjeldahl method according to the NF V 03-050 standard (AFNOR, 1970). The NF V 03-041 method (AFNOR, 1981b) was used for fiber content. Starch content was determined according to the Luff-Schoorl method. Mineral element content was measured by X-ray fluorescence spectrometry. Tannins were measured using the Folin-Denis colorimetric method described by Joslyn (1970).

2.2.3. Statistical analyses

The cultivars were described using the sorghum morphological trait descriptors (IBPGR, ICRISAT, 1993). The chemical data were analyzed using the XLSTAT-Pro software version 2013.5.01. These data were subjected to descriptive analyses and variances (ANOVA). Duncan's tests at the 5 % threshold were performed for the variance analyses.

3. Results and discussion

3.1. Results

3.1.1. Morphological characteristics of panicles and grains

The four genotypes analyzed have compact panicle. Three of them have elliptic panicle shape except for Djiressé Beïda which is oval. Their grains colors are different. White grains for Djiressé Beïda, red grains for Djiressé Ahmar, yellow grains for Djiressé Asfar and buff grains for Gagnan (**Figure 1**). The glumes are all black and cover a quarter of the grains. Their endosperm is mainly starchy (**Table 2**).

Figure 1. Morphological traits of four selected sorghum "Berberé"

3.1.2. Descriptive analysis of physicochemical components

The values of the different variables indicate significant variations in the different mineral components among the seeds of the cultivars. The gaps between the minimum and maximum values are notably high for tannin content. They are relatively low for protein, ash, and fiber, and moderate for other constituents. The coefficients of variation ranged from 2.50 to 24.10 %, respectively for starch and moisture contents. The other variables such as fiber (5.40 %), protein (6.50 %), ash (8.10 %), calcium (13.50 %), tannin (15.90 %), iron (18.10 %) and zinc (22.70 %) fall within the interval between these two values (**Table 3**).

3.1.3. Variances analysis of physicochemical constituents of grains

Significant differences were observed for the variables moisture, protein, starch, tannin, ash and fiber contents (**Tables 4**). And highly significant differences for calcium, iron and zinc (**Table 5**). Among the cultivars, only the Gagnan cultivar has the highest moisture content.

Two cultivars stand out clearly in terms of protein for Djiressé Asfar (11.17 %) and starch content for Djiressé Beïda (64.26 %), and three for tannin concentrations for Djiressé Asfar (34 %), Djiressé Beïda (35.5 %) and Gagnan (41 %). In case of the other variables such as moisture, fiber, calcium, iron and zinc, the cultivars have quite different concentrations except for ash, where Djiressé Beïda and Djiressé Ahmar have statically the same value. The analysis of each individual shows that the yellow-grained Djiressé Asfar has the

highest protein (11.17 %), ash (2.07 %), iron (7.21 %), and zinc (8.92 %) contents. The white-grained

Table 2. Main traits of the panicles and grains of cultivars

Code	Local name	Panicle compactness	Panicle Shape	Glume color	Grain covering (%)	Grain color	Endosperm texture
Dbe	**D.[1]Beïda**	Compact	Oval	Black	25	White	Ms[2]
Dah	**D. Ahmar**	Compact	Elliptic	Black	25	Red	Ms
Dsf	**D. Asfar**	Compact	Elliptic	Black	25	Yellow	Ms
Gga	**Gagnan**	Compact	Elliptic	Black	25	Buff	Ms

[1]Djiressé : D. ; [2]Mostly starchy : Ms

Djiressé Beïda presents high starch (64.26 %), fiber (2.74 %), and calcium (17.07 %) concentrations. The Gagnan cultivar has the highest moisture content (10.59 %) and is richer in tannin (41 mg ETA/100 g) than all other cultivars. In addition, protein, starch, fiber, calcium, and zinc values are low in Gagnan. In contrast, Djiressé Ahmar has nutritional values that most often fall within low to medium concentration ranges. This cultivar presents low values for 6 of the 9 constituents analyzed.

Table 3. Descriptive analysis of physicochemical components of the grains

Variables	Minimum	Maximum	Average	SD	CV (%)
Moisture (%)	5.69	10.60	7.50	1.93	24.10
Protein (%)	9.58	11.17	10.04	0.70	6.50
Starch (%)	60.15	64.32	61.91	1.63	2.50
Tannin (mg ETA/100 g)	25.00	42.00	34.12	5.82	15.90
Ash (%)	1.70	2.10	1.86	0.16	8.10
Fiber (%)	2.37	2.74	2.55	0.15	5.40
Ca (mg/100 g)	12.20	17.10	14.83	2.14	13.50
Iron (mg/100 g)	4.37	7.22	5.77	1.12	18.10
Zn (mg/100 g)	4.97	9.00	6.60	1.60	22.70

SD : Standard Deviation ; CV : Coefficient of Variation

3.2. Discussion

Flood-recession sorghum, also known as transplanted or berbéré sorghum, is one of the most cultivated cereals in Chad. Its production represents 19.44 % of the total cereal production and 36.59 % of the entire sorghum production over the past three years (DPSA/ANADER/SODELAC, 2023).

Due to its specificity of being cultivated in humid areas at the end of the rainy season,

berbéré complements agricultural production. This crop is characterized by extensive polymorphism and great plasticity in different environments and seasons (Saïdou *et al.*, 2014). Flood-recession sorghum in the regions of Chad and the northern and far northern provinces of Cameroon are generally classified in the durra or caudatum races (Seignobos, 2000; Saïdou *et al.*, 2014).

In addition to its importance in the diet of the Chadian population, the variability of nutrients indicates the quality of this crop. Although few studies have been conducted on the specific nutritional profile of berbéré, many data on the physicochemical composition exist for the same species.

Table 4. Analysis of variances of biochemical constituents of grains

Code[1]	Grain color	Moisture (%)	Protein (%)	Starch (%)	Tannin (mg ETA/100 g)	Ash (%)	Fiber (%)
Dsf	Yellow	6.120^{a}	11.170^{b}	61.160^{a}	34.000^{b}	2.070^{b}	2.465^{b}
Dbe	White	6.590^{a}	9.665^{a}	64.260^{b}	35.500^{b}	1.730^{a}	2.740^{d}
Dah	Red	6.720^{a}	9.665^{a}	60.315^{a}	26.000^{a}	1.710^{a}	2.605^{c}
Gga	Buff	10.585^{b}	9.665^{a}	61.910^{a}	41.000^{c}	1.910^{ab}	2.385^{a}
	P-value	**0.001**	**0.0003**	**0.016**	**0.003**	**0.021**	**0.001**

Values with same letters and in the same column are not significantly different according to the Duncan test at 0.05.
[1]Dsf : Djiressé asfar ; Dbe : Djiressé beïda ; Dah : Djiressé Ahmar ; Gga : Gagnan.

Table 5. Analysis of variances of physicochemical constituents of grains

Code	Local name	Ca (mg/100 g)	Iron (mg/100 g)	Zn (mg/100 g)
Dsf	Djiressé Asfar	16.440^{c}	7.210^{d}	8.915^{d}
Dbe	Djiressé Beïda	17.070^{d}	6.140^{c}	6.870^{c}
Dah	Djiressé Ahmar	13.605^{b}	4.370^{a}	5.640^{b}
Gga	Gagnan	12.215^{a}	5.345^{b}	4.985^{a}
	P-value	**<0.0001**	**<0.0001**	**<0.0001**

Values with same letters and in the same column are not significantly different according to the Duncan test at 0.05.

The results of the study show a small variation in the morphological traits of panicles and grains of the cultivars. Their panicle is essentially compact type. In terms of shape, only the panicle of the cultivar Djiressé Beïda is oval while the other three are elliptic. The studied cultivars have grains of which a quarter is completely covered by black glumes with an endosperm mainly starchy. In his work, Raimond (2005) pointed out that for flood-recession sorghum cultivars, the criteria for

distinguishing traditional varieties are mainly based on the colour traits of the grains and glumes, compactness and growth of the panicle. For Songré-Ouattara *et al.* (2016), physical traits such as the colour of the grains and endosperm and the shape of the grain appear less discriminatory. In this study, the trait that allowed for this clear distinction is the coloration of the seeds.

Descriptive analyses revealed variable gaps between constituents. They are low, medium, or significantly high. Specifically for protein content, the average obtained of 10.04 % is similar compared to the results reported by Rihacek *et al.* (2020) which the mean reached 9.6 to 11.3 % of dry matter but lower to 12.85 % found by Desta *et al.* (2023). Similarly, the coefficient of variation which is 6.50 % against 12.20 % for the work of Desta *et al.* (2023) is also lower. This is an indication of the small variation for this parameter in the study. For starch content, the difference between cultivars in terms of minimum and maximum values is small. Three cultivars have statistically the same values. Only Djiressé Beïda with 64.26 % starch is significantly above the average content of 61.91 % of all cultivars. The differences of tannin content are high. This is confirmed by the value of the standard deviation which is 5.82 %, the highest of all parameters studied. A larger difference was even reported by Nagy *et al.* (2021) in a study conducted on white-grained and red-grained varieties. Indeed, this work revealed tannin values of 1470 mg/100 g and 148 mg/100 g for two red-grain varieties and 193 mg/100 g for a white-grain variety. For fiber, the average of 2.55 % is higher than the 1.26 % reported by Desta *et al.* (2023). The coefficient of variation of 5.40 % is also satisfactory, as the same authors report a coefficient of 22.19 %.

The coefficients of variation of the physicochemical constituents are among the highest values in this study, namely 13.50 % for calcium, 18.10 % for iron and 22.70 % for zinc. The calcium content values of Djiressé Beïda (17.07 %) and Djiressé Asfar (16.44 %) are well above the average (14.83 %). Regarding iron contents, only Djiressé Ahmar with 4.37 % and Gagnan with 5.35 % have values below the average of 5.77 %. Compared to the work of Songre-Ouattara *et al.* (2016), whose iron content is 14.4 mg/100g, all these cultivars evaluated in this study are really poor in iron. Djiressé Beïda and Djiressé Asfar have zinc contents of 6.87 % and 8.92 %, respectively. These concentrations are higher than the general average of 6.60 %. However, they are lower for Djiressé Ahmar whose concentration is 5.64 % and Gagnan who has 4.99 %. Songre-Ouattara *et al.* (2016) reported significantly lower levels of about 1.9 mg/100 g zinc in sorghum flours used in the manufacture of enriched sorghum biscuits.

The analysis of variances of physicochemical and nutritional constituents revealed significant differences between cultivars. The moisture content ranging from 6.12 % to 10.59 % is close to the results reported by Gajmal *et al.* (2021) on two sorghum cultivars. However, these values were lower than 15 % the codex norms and standards (Codex alimentarius, 1989). Nevertheless, the moisture content of the Gagnan cultivar was 10.59 %, despite identical treatment conditions. This shows that this cultivar naturally contains much more water than others. Two cultivars stood out distinctly concerning protein and starch contents. Djiressé Asfar cultivar was richer in protein, while Djiressé Beïda had the highest starch content. Compared to previous studies, Ojediran *et al.* (2018) reported similar protein values (10.50 %) for two sorghum varieties, one with red grains and the other with white grains. Rihacek (2020) on the

nutritional evaluation of sorghum varieties showed that the average crude protein content reaches 9.60 to 11.30 % of dry matter. Lower average protein contents were also observed in fifteen cultivars from Burkina Faso (Bazié *et al.*, 2023). For the starch content, it was slightly lower than the results reported by Treviño-salinas *et al.* (2021) on the evaluation of white-grained sorghums from Mexico but similar to the results of Martino *et al.* (2012). However, they were still significantly lower compared to millet cultivars (Adeoti, 2017). Two individuals with similar values, one intermediate and another high for ash content were identified. Djiressé Asfar cultivar presented the highest value. On the other hand, the Djiressé Ahmar had the lowest concentration. Compared to the work of Belay (2017), except for Djiressé Asfar, the values of the other genotypes were similar to the results reported by this author. These ash contents were similar to red-grained sorghum but lower than those of white-grained sorghum reported by Ojediran *et al.* (2018). Looking at the fiber, even though the cultivars had distinctly different contents, they were similar to the work of Ojediran *et al.* (2018) but lower than those of Treviño-salinas *et al.* (2021). For Ojediran *et al.* (2018), the fiber content for two sorghum varieties analyzed are respectively 2.05 % for red and 2.11 % of white grain. In the second case, Treviño-salinas *et al.* (2021) after evaluating six white grain sorghum varieties grown in Mexico, revealed that the fiber content ranged from 6.07 to 9.09 %.

Tannin content varies between 26.00 and 34.00 mg ETA/100 g. The Gagnan cultivar had the highest tannin content, while Djiressé Ahmar presented the lowest concentration. Numerous previous studies have been conducted on sorghum cultivars. Kaufman *et al.* (2013) showed that the tannin content of 14 cultivars varies from 2.30 to 67.20 catechin equivalents. Similarly, these authors reported that the tannin content and composition play an important role in determining their functionality. Nagy *et al.* (2021) evaluated tannin content using the vanillin-HCl method, as well as antioxidant capacity in five sorghum varieties, including two with white grains and three with red grains. Comparing the values of the present study to these results, the reported condensed tannin content is significantly higher and important. These authors also indicated that the sorghum type, variety and colour influence their tannin and antioxidant contents in general. Furthermore, Ojediran *et al.* (2018) determined condensed tannin concentrations of two sorghum varieties, around 0.062 g/100 g for red grains and 0.016 g/100 g for white grains.

For the iron, calcium and zinc, significant differences between cultivars were observed in their composition. These contents were different from one cultivar to another. The Gagnan cultivar presents the lowest values in calcium and zinc. Djiressé Asfar was richer in iron and zinc than all the cultivars studied. The highest calcium content was obtained in the Djiressé Beïda cultivar. For Djiressé Ahmar, the calcium and zinc contents were moderate and low in iron. In comparison, the evaluation of the mineral composition of eight sorghum genotypes from Brazil showed that the values in iron and zinc are lower than those of the present study. For calcium, they were within the range of values reported by Martino *et al.* (2012).

Referring to FAO and WHO recommendations (Codex alimentarius, 1989) some of the results obtained in this study are consistent. The moisture content is below 15 %, the protein contents are above the minimum acceptable of 8.5 % and the tannin contents are below the maximum threshold of 0.3 %. On the other hand, the contents in ash and fiber are not compliant because the maximum permitted are respectively

1.5 % and 1.8 % (Codex alimentarius, 1989). The different physicochemical constituents can be used in correcting deficiencies in micronutrients such as iron, calcium and zinc.

4. Conclusion

In Chad, the production of flood-recession sorghum significantly contributes to the population's diet. The evaluation of the most favored cultivars by producers showed low diversity in agro morphological traits except for a clear distinction in seed colour. However, there is a significant variability in the physicochemical parameters. The evaluated cultivars have different nutritional profiles for certain variables. Based on physicochemical traits, Djiressé Asfar and Djiressé Beïda have been identified as the most promising cultivars. In contrast, Djiressé Ahmar offers unattractive nutritional values for their valorization. For the Gagnan cultivar, the tannin content is significantly higher. The study did not only provide additional information on flood-recession sorghum but also showed the importance and diversity of local plant genetic resources. The nutritional potential of these cultivars is an asset for further work. These cultivars can be used to develop high-quality nutritional products. However, since flood-recession sorghum is under-exploited by research in Chad, the present study can be extended to a wider range of cultivars in order to better value and integrate them into the national breeding program.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Ethics

This Study does not involve Human or Animal Testing.

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