Effects of variety and culture site on nutritional composition of cowpea in Burkina Faso

Morgane CHAPRON[1,2], Benoit-Joseph BATIENO[3], Youna HEMERY[1,4], Léandre PODA[3], Isabelle ROCHETTE[1,2], Guillaume GRONDIN[1,2], Claire MOUQUET RIVIER[1,2], Christèle ICARD-VERNIERE[1,2]

[1]. UMR Qualisud, Univ Montpellier, CIRAD, Institut Agro, IRD, Université Avignon, Université de la Réunion, Montpellier, France

[2]. Institute of Research for Development (IRD), Montpellier, France

[3]. Institut de l'Environnement et de Recherches Agricoles (INERA), Plant Production Department, Ouagadougou, Burkina-Faso

[4]. Institute of Research for Development (IRD), Cotonou, Benin

Correspondence : morgane.chapron@ird.fr

Abstract:

Cowpea is a legume, rich in protein, B vitamins and minerals (magnesium, zinc), but also rich in antinutritional factors such as α-galactosides and phytic acid. The nutritional composition of cowpea seeds is therefore a criterion that should be taken into account to improve varietal selection.

The nutritional composition of 13 varieties of cowpea cultivated in Burkina Faso was characterised in order to identify varietal selection criteria based on nutritional potential. Nine varieties were cultivated in Tenkodogo (T), 10 in Kamboinsé (K), and 6 in both localities. Protein content were determined by the Kjeldahl method, mineral content by ICP-OES, thiamine content by UHPLC-FLR, phytic acid content by HPAEC-CD and α-galactosides and low-molecular-weight sugars content were quantified by HPAEC-PAD. Variance analysis allowed to evaluate the effect of variety using results obtained in each site (nT=9, and nK= 10), as well as effect of locality using results from varieties cultivated in both sites.

The protein contents of the samples studied vary between 19,9 and 26,2 g/100 g DM depending on the variety. The phytate content was higher on the Kamboinsé plot (with results ranging from 0,70 to 1,17 g IP6/100 g DM) than on the Tenkodogo plot (0,42 to 0,80 g IP6/100 g DM). Thiamine equivalent contents, ranging from 0,34 to 0,73 mg/100 g DM, showed a significant variety and plot effect. The main forms of thiamine (di-phosphate and hydrochloride thiamins) were present in variable proportions depending on the variety and the plot. Iron and zinc content were mainly affected by variety and varied between 3,70 to 5,92 mg/100 g DM and from 3,30 to 5,14 mg/100 g DM respectively. The total α-galactoside content was between 3,27 and 6,09 g/100 g DM, and the sucrose content ranged from 1,29 to 5,80 g/100 g DM, both influenced by variety. All components were also influenced by the interaction between variety and plot.

Results of nutritional composition should be related to agriculture and processing practices to identify processes decreasing antinutritional factors (α-galactosides, phytic acid) while taking account consumers preferences. Phyate, iron, zinc, thiamin, α-galactoside contents could constitute additional criteria in varietal selection of cowpea, in Burkina Faso.

Keywords: phytate, α-galactoside, thiamin, iron, zinc

1. Introduction

Food security is sufficient physical and economic access to quality food for all, at all times. In 2022, the prevalence of severe or moderate food insecurity affected 18.3% of the population worldwide and 60.9% of the population in Africa (FAOStat, 2024). The prevalence of undernourishment in the world affected 735 million people in 2022, of which 282 million people living in Africa (FAOStat, 2024), it is 38% of the world's population affected by undernourishment (FAO, 2023)

Pulses are widely grown in African countries, and can therefore contribute to food security. In West Africa, 8.5 million tonnes of cowpea were produced in 2022 (FAOStat, 2024). Among the legumes grown in Burkina Faso, cowpea is the dominant species (Zinmanké et al. 2020) with 829,204 tonnes in 2022. There are a large number of cowpea varieties for a variety of uses, including human consumption as seeds or green leafy vegetables, but also as fodder for livestock.

As well as being an essential lever for food security, pulses are also important in the current ecological transition (Magrini et al. 2023) . Legumes fix nitrogen from the atmosphere, improving soil quality and the fertility of associated or following crops. Moreover, their diversity makes it possible to select varieties that are resistant to climate change (Gbaguidi et al. 2015) .

The production and consumption of pulses are therefore important for meeting nutritional needs. In fact, because of their high levels of protein, B-vitamins and several minerals such as magnesium and zinc, pulses are of important nutritional value. They also make up for the low levels of lysine and tryptophan in cereals (Ngigi et al. 2022). However, legumes are also rich in anti-nutritional compounds such as phytates and α-galactosides. Phytates, which are the seeds' phosphorus reserves, take the form of an inositol nucleus esterified with negatively charged phosphate groups, and can chelate divalent cations such as iron, zinc and calcium contained in the food, thereby reducing their intestinal absorption (Lestienne et al. 2003). This is particularly problematic in the context of vegetarian diets, or diets low in animal products, increasing the risk of mineral deficiency (Mouquet-Rivier et al. 2019). Studies have defined phytate/iron and phytate/zinc molar ratios below which absorption of these minerals is reduced, in a dose-dependent manner (Lestienne et al. 2003; Hurrell et al. 2010). Certain food processing methods, such as germination or fermentation, make it possible to reduce phytate levels (Lestienne et al. 2005) and thus reduce this mineral chelation effect. The α-galactosides are oligosides that cannot be digested by humans, as humans do not possess the α-galactosidase enzyme. They are degraded by bacteria in the intestinal microbiota in the colon, thereby playing a prebiotic role. However, in large quantities, they cause digestive problems, such as bloating or flatulence, which is impeding the consumption of legumes (Mouquet-Rivier et al. 2019) .

The aim of this study is to assess the nutritional composition of different cowpea varieties from Burkina Faso grown by breeders at the Institut de l'Environnement et de Recherches Agricoles (INERA) in order to propose additional varietal selection criteria. More specifically, the aim is to determine the levels of protein, vitamin B1 (thiamine), iron, zinc and mono- and oligo-sides, as well as anti-nutritional compounds such as phytates and alpha-galactosides. Samples of different varieties grown in the same locality were used to assess the effect of the varieties themselves. Samples of varieties grown in two different localities were used to assess the effect of locality and variety-locality interactions.

2. Materials and methods

2.1 Collection and preparation of samples

Thirteen samples of cowpea were collected from the INERA experimental stations, Burkina Faso, at Kamboinsé (9 varieties) and Tenkodogo (10 varieties) (Figure 1). These varieties, both local and improved, were sampled, within 2 to 4 different harvest years. Cowpea seeds were sorted and washed before being crushed and sieved (mesh size < 500 µm). Samples from different harvest years were pooled by mixing equal masses after grinding the seeds and stored at 4°C until analysis.

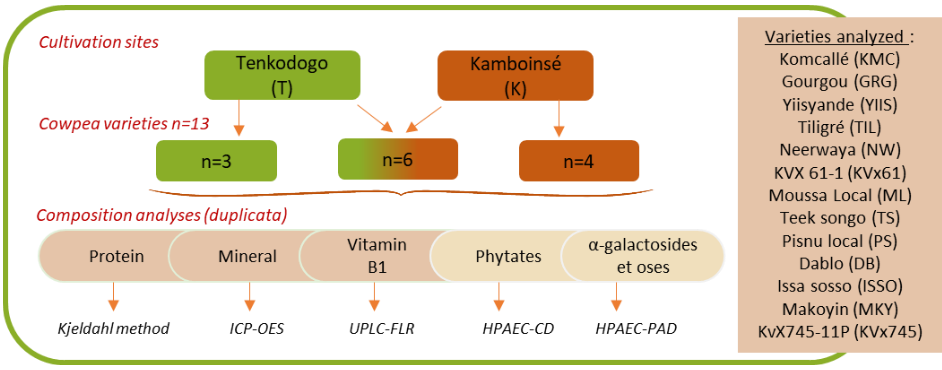

Figure 1: Sampling and analysis scheme for the study

2.2 Analysis of nutritional composition

2.2.1 Analysis of protein content

The protein content of the samples was determined by the Kjeldahl method (NF V03-050) from 0.5 g of sample, after mineralisation and distillation of the samples. A coefficient of 6.25 was used to convert Kjeldahl nitrogen into protein content.

2.2.2 Analysis of mineral content

Mineral content (Iron, Zinc) was determined by ICP-OES (5100 VDV, Agilent, France) after extraction in an Ethos Easy microwave digester (Milestone, Italy), using 0.45 g of sample in a 7:1 HNO_3 37% : H_2O_2 (v :v) mixture.

2.2.3 Analysis of vitamin B1 content

Thiamine, also known as vitamin B1, exists in various molecular forms, including mono-, di- and hydrochloride.

It was extracted using the protocol described by Akissoé et al (2021) with a few modifications: 0.5 g of sample was extracted in 0.1 M HCl under agitation for 60 minutes at room temperature. After centrifugation, 2.5 mL of supernatant was oxidized to convert thiamine to thiochrome. Chromatographic quantification was carried out as described in Akissoé et al (2021) on an Acquity HClass UPLC system (Waters, Milford, MA, USA). Thiamine mono- and di-phosphate (TMP and TDP) and thiamine hydrochloride (T-HCl) were determined using specific standard ranges. The TMP, TDP and T-HCl levels were converted to thiamine equivalents (eq-Thia, in g/100g DM) using the molar sum of the 3 forms of vitamin B1, multiplied by the molar mass of free thiamine and brought back to 100 g of dry matter.

2.2.4 Analysis of phytate content

Phytates exist in different molecular forms: formed from a myo-inositol nucleus, they are more or less phosphorylated with one to six phosphate groups. Phytic acid is the most cation-chelating phytate, as it is composed of 6 phosphate groups. Phytic acid, commonly known as IP6, is measured using the method described by Lestienne et al. (2005), with a few modifications. A 100 mg sample was dissolved in 5 mL of 0.5 M HCl. The mixture was heated to 100°C for 6 minutes with magnetic stirring. After centrifugation, the supernatant was filtered through a 0.2 µm filter and stored at 4°C until analysis. The IP6 content was determined using high-performance ion chromatography (HPIC) (Dionex, Sunnyvale, CA, USA) using a Dionex IonPac AS11 column (4 x 250 mm) and a Dionex IonPac AG11 pre-column (4 x 50 mm) combined with a 4mm AERS suppressor at 200 mA. The mobile phase used was a gradient of 200 mM NaOH and water at 1 mL/min.

From the IP6 and mineral contents, IP6/Fe and IP6/Zn molar ratios were calculated with the molar mass of IP6 (660.08 g.mol^{-1}), iron (56.85 g.mol$^{(-1)}$) and zinc (65.38 g.mol$^{(-1)}$), as follows:

$$\mathrm{IP6/Fe} = \frac{\frac{mg\ IP6}{660,08}}{\frac{mg\ Fe}{56,85}} \qquad \mathrm{IP6/Zn} = \frac{\frac{mg\ IP6}{660,08}}{\frac{mg\ Zn}{65,38}}$$

*2.2.5 Analysis of the content of **α**-galactosides and low weight sugars*

Alpha-galactosides and low molecular weight sugars were extracted in an 80% (v/v) ethanolic solution (Akissoé et al. 2021) . Quantification was performed using high-performance ion chromatography equipped with a pulsed amperometric detector (Thermo Scientific Dionex ICS-6000 HPIC System). The α-galactoside content was obtained by assaying stachyose, verbascose and raffinose. The contents of these three molecules are summed to give the total α-galactoside content. Standard calibration curves of glucose, galactose, fructose and sucrose were used to quantify each of these sugars.

2.3 Statistical analysis

Statistical analyses (analysis of variance) were carried out using RStudio software. Analyses to determine variety effects were carried out separately for each locality. 2-factor ANOVAs were performed on varieties for which we had samples grown in both localities in order to explore the effect of variety, locality and the variety-locality interaction.

3. Result

3.1 Macro- and micro-nutrient content

Protein content: The protein content of samples from both plots (n=6) showed an effect of variety and variety-plot interaction (Table 1). The values obtained at Kamboinsé were higher than those at Tenkodogo, except for the Yiisyande variety. This trend was found for all the samples: the average levels in the Tenkodogo and Kamboinsé plots were 21.5 ± 1.33 and 22.4 ± 0.96 g/100 g DM respectively. In the Tenkodogo plot, the Komcallé and KvX61-1 varieties had the lowest levels, below 20 g/100 g DM, while the KvX754-11P variety had the highest level. In the Kamboinsé plot, the varieties KvX61-1, Komcallé and Yiisyande had the lowest levels, below 22 g/100 g DM, while the variety Dablo had the highest level (Table 2). Variance analyses on both plots showed a highly significant effect of variety (Table 1) on protein content.

Table 1: Composition of the 13 cowpea varieties, and p-values of the 2-factor anova for the varieties common to both localities, and 1-factor anova for the variety effect on the Tenkodogo (T) and Kamboinsé (K) localities.

Content for 100 g DM	Averages	Min - max	Locality effect *n = 6*	Variety effect *n = 6*	Variety x locality effect *n = 6*	Variety effect in T *n = 9*	Variety effect in K *n = 10*
Protein (g)	22,5 ± 1,46	19,9 - 26,2	0,4120	0,0031	0,0116	0,0002	0,0000
Iron (mg)	4,64 ± 0,60	3,70 - 5,92	0,1078	0,0000	0,0068	0,0000	0,0000
Zinc (mg)	4,20 ± 0,60	3,30 - 5,14	0,3270	0,0210	0,0106	0,0006	0,0002
IP6 (g)	0,71 ± 0,22	0,42 - 1,17	0,0000	0,0000	0,0000	0,0000	0,0000
Thiamine eq (mg)	0,53 ± 0,11	0,34 - 0,73	0,0002	0,0000	0,0000	0,0000	0,0000
TDP (mg)	0,58 ± 0,33	0,10 - 1,01	0,0000	0,0000	0,0000	0,0000	0,0000
T-HCl (mg)	0,23 ± 0,17	0,08 - 0,67	0,0000	0,0000	0,0000	0,0000	0,0000
α-galactosides (g)	4,31 ± 0,77	3,27 - 6,09	0,2588	0,0000	0,0001	0,0002	0,0000
Stachyose (g)	3.6± 0.61	2,58 - 5,0	0,1234	0,0000	0,0001	0,0000	0,0001
Sucrose (g)	2,29 ± 1,12	1,29 - 5,80	0,5184	0,0000	0,0218	0,0000	0,0000
IP6/Fe	13.0± 3.47	8,40 - 21,8	0,0012	0,0002	0,0018	0,0120	0,0166
IP6/Zn	16.6± 4.42	10,8 - 27,	0,0006	0,0177	0,0299	0,0149	0,0083

Table 2: Protein, phytate, iron and zinc content and molar ratios of IP6/iron and IP6/zinc in cowpea samples according to variety and growing locality.

Variety	Location	Protein *g/100 g DM*	Iron *mg/100 g DM*	Zinc *mg/100 g DM*	IP6 *g/100 g DM*	IP6/Fe	IP6/Zn
KOMCALLE	T	19,9 ± 0,07 ^{a}	3,77 ± 0,29 ^{a}	3,34 ± 0,42 ^{a}	0.47 ± 0.04 ^{a,b}	10.6 ^{a,b}	13.8 ^{a,b}
KOMCALLE	K	21,6 ± 0,55 ^{A}	4,39 ± 0,52 ^{A}	4,18 ± 0,44 ^{B}	0,85 ± 0,12 ^{A}	16.7 ^{A,B}	20,2 ^{A,B,C}
GOURGOU	T	22.8 ± 0.28 ^{b,c}	4,84 ± 0,04 ^{c}	4.74 ± 0.29 ^{b,c}	0,58 ± 0,02 ^{d}	10.4 ^{a,b}	12.2 ^{a,b}
GOURGOU	K	23.2 ± 0.59 ^{B,C}	5.07 ± 0.12 ^{B,C,D}	4.49 ± 0.21 ^{B,C}	0,76 ± 0,01 ^{A}	12,9 ^{A}	16.8 ^{A,B}
YIISYANDE	T	22.7 ± 1.0 ^{b,c}	4.23 ± 0.12 ^{a,b,c}	3.88 ± 0.13 ^{a,b}	0.53 ± 0.00 ^{c,d}	10,8 ^{b}	13.6 ^{a,b}
YIISYANDE	K	21,8 ± 0,28 ^{A}	4.65 ± 0.15 ^{A,B}	4.35 ± 0.33 ^{B,C}	0,70 ± 0,01 ^{A}	12,9 ^{A}	15,9 ^{B}
TILIGRÉ	T	22,1 ± 0,21 ^{b}	4.69 ± 0.19 ^{b,c}	3.80 ± 0.05 ^{a,b}	0,52 ± 0,01 ^{c}	9.54 ^{a,b}	13.6 ^{a,b}
TILIGRÉ	K	22.7 ± 0.38 ^{A,B,C}	5.30 ± 0.04 ^{C,D}	5,06 ± 0,03 ^{C}	0,88 ± 0,01 ^{A}	14.3 ^{A,B}	17.2 ^{A,B}
NEERWAYA	T	21.6 ± 1.11 ^{a,b}	4.35 ± 0.01 ^{a,b,c}	3.82 ± 0.04 ^{a,b}	0,42 ± 0,01 ^{a}	8.40 ^{a,b}	11,0 ^{a}
NEERWAYA	K	23,8 ± 0,56 ^{C}	5,49 ± 0,08 ^{D}	4.90 ± 0.04 ^{B,C}	0,86 ± 0,01 ^{A}	13.6 ^{A,B}	17.5 ^{A,B}
KVx 61-1	T	19,9 ± 0,05 ^{a}	3,70 ± 0,03 ^{a}	3.87 ± 0.59 ^{a,b}	0,42 ± 0,00 ^{a}	9.8 ^{a,b}	10,8 ^{a}
KVx 61-1	K	21,5 ± 0,18 ^{A}	4,35 ± 0,04 ^{A}	4.36 ± 0.23 ^{B,C}	0,80 ± 0,80 ^{A}	15.8 ^{A,B}	18.1 ^{A,B,C}
MOUSSA LOCAL	K	23.2 ± 0.45 ^{B,C}	4.63 ± 0.03 ^{A,B}	4,21 ± 0,44 ^{B}	1,17 ± 0,01 ^{A}	21,8 ^{B}	27,6 ^{C}
TEEK-SONGO	K	21.9 ± 0.16 ^{A,B}	5,50 ± 0,13 ^{D}	4.37 ± 0.01 ^{B,C}	0,87 ± 0,02 ^{A}	13.6 ^{A,B}	19.6 ^{A,B,C}
LOCAL PISNU	K	22.5 ± 0.02 ^{A,B}	4,33 ± 0,22 ^{A}	3,30 ± 0,12 ^{A}	0,83 ± 0,01 ^{A}	16.5 ^{A,B}	24.9 ^{B,C}
DABLO	K	26,2 ± 0,16 ^{D}	4.82 ± 0.07 ^{A,B,C}	5,14 ± 0,02 ^{C}	1,00 ± 0,05 ^{A}	17.8 ^{A,B}	19.2 ^{A,B,C}
ISSA-SOSSO	T	22.8 ± 0.01 ^{b,c}	4.15 ± 0.01 ^{a,b,c}	3,55 ± 0,21 ^{a}	0.49 ± 0.02 ^{b,c}	10.2 ^{a,b}	13.7 ^{a,b}
MAKOYIN	T	22.8 ± 0.16 ^{b,c}	4.04 ± 0.01 ^{a,b}	3,39 ± 0,01 ^{a}	0.46 ± 0.00 ^{a,b}	9.90 ^{a,b}	13.6 ^{a,b}
KVx745-11P	T	24,4 ± 0,84 ^{c}	5,92 ± 1,14 ^{d}	5,11 ± 0,32 ^{c}	0,80 ± 0,21 ^{e}	11,7 ^{b}	15,6 ^{b}

<u>Mineral content</u>: The varieties present in the two localities showed an effect of the variety-locality interaction, with differences between the iron contents of the same variety in the two localities and significant differences between varieties (Tables 1 and 2). For example, the Neerwaya variety had the highest iron content in Kamboinsé, whereas in Tenkodogo, its iron content was rather close to the average for these 6 varieties (4.57 ± 0.55 mg/100 g DM). In Tenkodogo, KVx61-1 had the lowest iron content, while KVx745-11P had the highest. In Kamboinsé, the varieties Pisnu Local and Teek-songo had the two

highest levels. In the 2 localities, the analyses of variance showed an effect of variety (Table 1) with in general, iron levels being higher in samples from varieties grown in Kamboinsé.

With regard to zinc content, the varieties present in the 2 localities showed significant differences depending on the variety and the variety-locality interaction (Table 1). Zinc levels were higher in samples from Kamboinsé, except for the Gourgou variety (Table 2). Varieties grown in Tenkodogo and Kamboinsé showed an effect of variety (Table 1). As with iron, the KVx745-11P variety had the highest zinc concentration in Tenkodogo, while the Komcallé variety had the lowest. In Kamboinsé, the Pisnu Local variety had the lowest concentration and the Dablo variety the highest.

Vitamin B1 content: In order to better visualise the variations in vitamin B1 levels, and the locality and variety effects, certain data were repeated in figures 2.A, 2.B and 2.C. It was clearly visible that the TDP and T-HCl levels were in the majority, and that TMP was only present in small quantities. The results also showed different distributions of the TDP and T-HCl forms depending on the samples (Figures 2.A, 2.B and 2.C). Some varieties had a higher T-HCl content, while others had a higher TDP content. Moreover, these proportions also varied for the same variety depending on whether it had been grown in Tenkodogo or Kamboinsé (Figure 2.A). This was the case for the Tiligré variety, where the mean values in Tenkodogo were 0.55 ± 0.01 mg TDP/100 g DM and 0.25 ± 0.01 mg T-HCl/100 g DM, whereas in Kamboinsé they were 0.17 ± 0.01 mg TDP/100 g DM and 0.50 ± 0.01 mg T-HCl/100 g DM. Despite this difference in the proportion of forms, the thiamine equivalent content of the Tiligré variety was similar in Tenkodogo and Kamboinsé: 0.52 ± 0.01 and 0.49 ± 0.01 mg eq-Thia/100 g DM respectively. This trend was found for all varieties except Yiisyande, with significant differences in eq-Thia values from one locality to another (Figure 2.A). The variety with the lowest eq-Thia content was Neerwaya in Tenkodogo and Yiisyande in Kamboinsé (Figures 2.B and 2.C). On the other hand, the highest levels were obtained by the varieties KVx745-11P in Tenkodogo and Moussa Local in Kamboinsé. In the 2 localities, a significant variety effect was observed, and for the 6 varieties common to both localities, the locality, variety and variety-locality interaction effects were significant (Table 1).

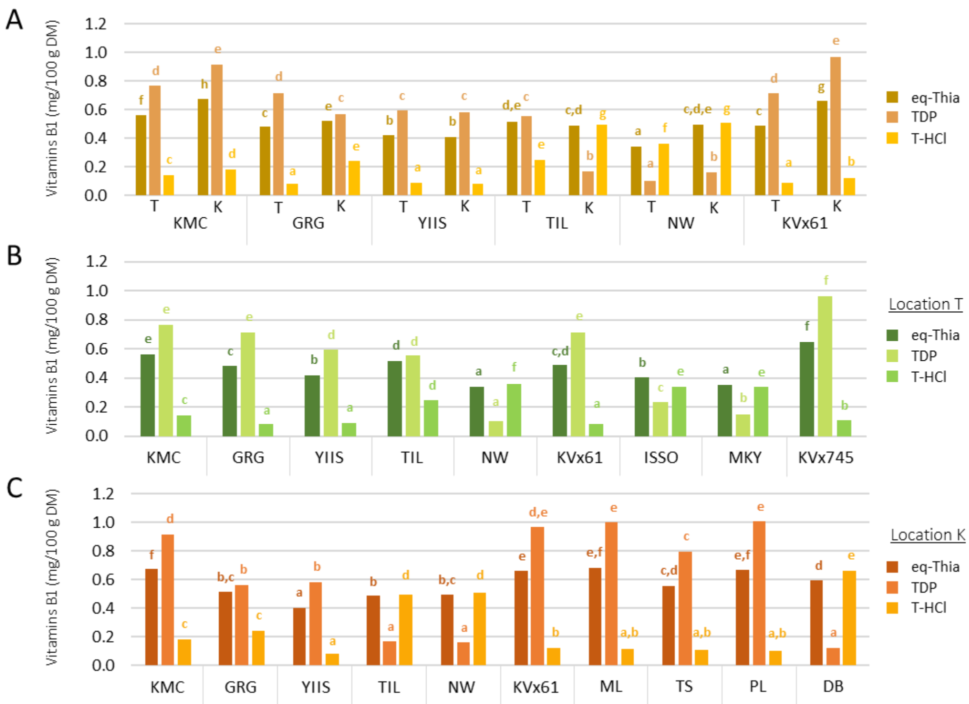

Figure 2: Profiles of thiamine forms in varieties grown (A) in the two growing localities: Tenkodogo (T) and Kamboinsé (K), (B) in Tenkodogo and (C) in Kamboinsé (KMC = Komcallé, GRG = Gourgou, YIIS = Yiisyande, TIL = Tiligré, NW = Neerwaya, KVx61 = KVX 61-1, ML = Moussa Local, TS = Teek songo, PS = Pisnu local, DB = Dablo, ISSO = Issa sosso, MKY = Makoyin, KVx745 = KvX745-11P).

Low molecular weight sugars content: The results on sugars content showed a predominant presence of sucrose compared to the other sugars measured. The average proportion of sucrose in the samples was 98.7 ± 0.4%. Analyses of variance showed a significant variety effect, as well as a significant variety-locality interaction (Table 1). The variety KVx61-1 had particularly high sucrose contents compared with the other varieties, at 5.80 ± 1.05 g/100 g DM and 4.59 ± 0.11 g/100 g DM in Tenkodogo and Kamboinsé respectively (Figure 3.A). The KVx61-1 variety also had the highest glucose and fructose contents at the 2 growing locations. The Dablo variety, grown in Kamboinsé, stood out for its highest galactose content (Figure 3.B).

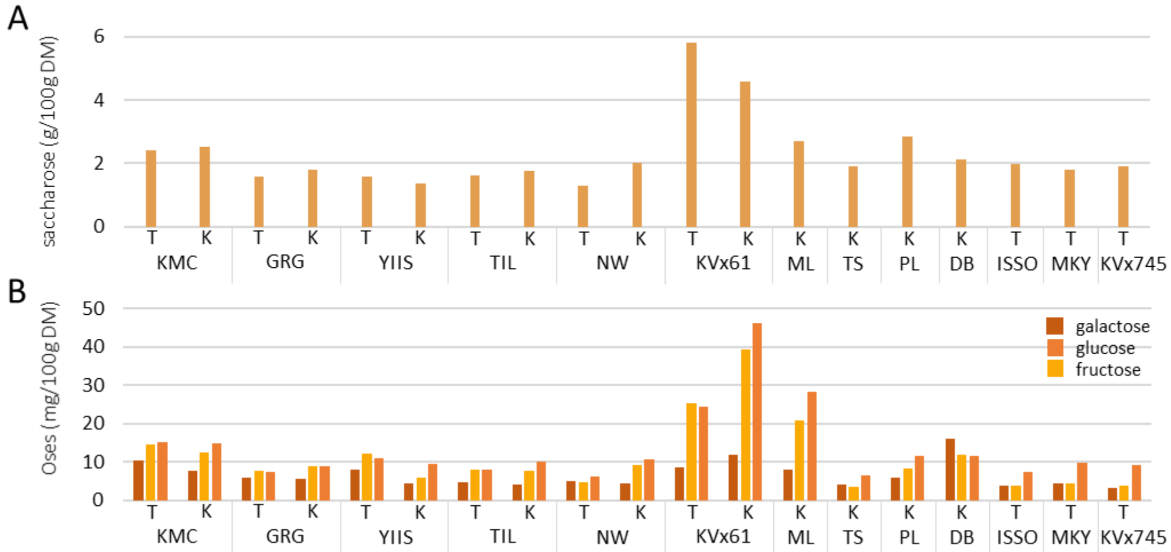

Figure 3: (A) sucrose and (B) monosaccharide (galactose, glucose and fructose) contents of the different varieties studied (KMC = Komcallé, GRG = Gourgou, YIIS = Yiisyande, TIL = Tiligré, NW = Neerwaya, KVx61 = KVX 61-1, ML = Moussa Local, TS = Teek songo, PS = Pisnu local, DB = Dablo, ISSO = Issa sosso, MKY = Makoyin, KVx745 = KvX745-11P).

3.2 Anti-nutritional compound content

Phytates: Analysis of variance showed significant locality effect (Table 1). The varieties grown in the 2 localities had IP6 levels up to 2 times lower in Tenkodogo than in Kamboinsé (Figure 4). The varieties also differed from one another, characterising the variety effect (Figure 4). The varieties Moussa Local, Dablo and Komcallé had the highest IP6 levels in Kamboinsé. In this locality, the Yiisyande variety had the lowest IP6 value and was almost 2 times higher than the lowest value obtained in Tenkodogo for the KVx61-1 variety. Similarly, the highest value in Tenkodogo was 0.80 ± 0.23 g IP6/100 g DM for the variety KVx745-11P, slightly higher than the minimum value in Kamboinsé.

The IP6/Fe and IP6/Zn ratios were higher for samples from Kamboinsé (12.9 to 21.8 for IP6/Fe and 15.9 to 27.6 for IP6/Zn) than from Tenkodogo (8.40 to 11.7 for IP6/Fe and 10.8 to 13.8 for IP6/Zn) and this was characterised by significant effects of variety, locality and variety-locality interaction (Table 1). The Moussa Local variety had the highest IP6/Fe and IP6/Zn ratios.

Alpha-galactosides: Analyses of variance on varieties common to both localities revealed a significant effect of variety and variety-locality interaction. The effect of cultivation site was not significant, although total α-galactoside levels varied for the same variety from one locality to another (Table 1, Figure 5). The variety with the highest α-galactoside content was Komcallé in both localities, and the variety with the lowest content was Tiligré in Tenkodogo and Yiisyande in Kamboinsé. The majority form of α-galactoside present in the samples was stachyose, representing on average 82.8 ± 3.0% of total α-galactosides. The distribution total α-galactoside content between verbascose, raffinose and stachyose is shown in Figure 5.

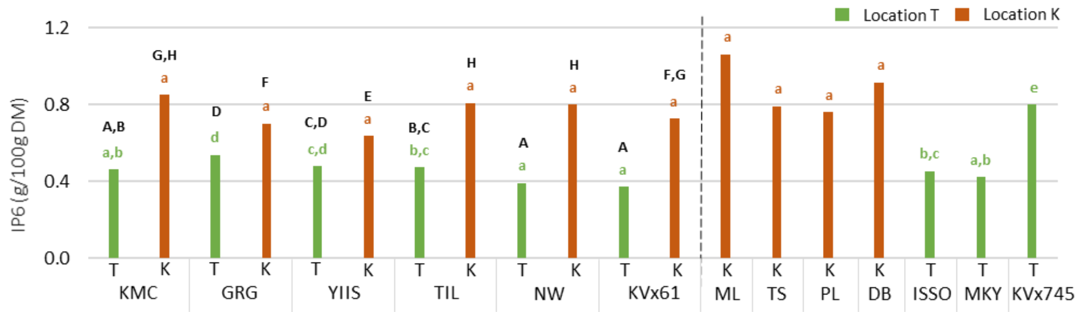

Figure 4: Phytate content of samples from different growing localities: in green, the statistical results obtained for the variety effect in Tenkodogo (T) (n=9), in orange, the statistical results obtained for the variety effect in Kamboinsé (K) (n=10), and in black, the statistical results of the variety-locality effect determined on varieties common to both localities (n=6). (KMC = Komcallé, GRG = Gourgou, YIIS = Yiisyande, TIL = Tiligré, NW = Neerwaya, KVx61 = KVX 61-1, ML = Moussa Local, TS = Teek songo, PS = Pisnu local, DB = Dablo, ISSO = Issa sosso, MKY = Makoyin, KVx745 = KvX745-11P).

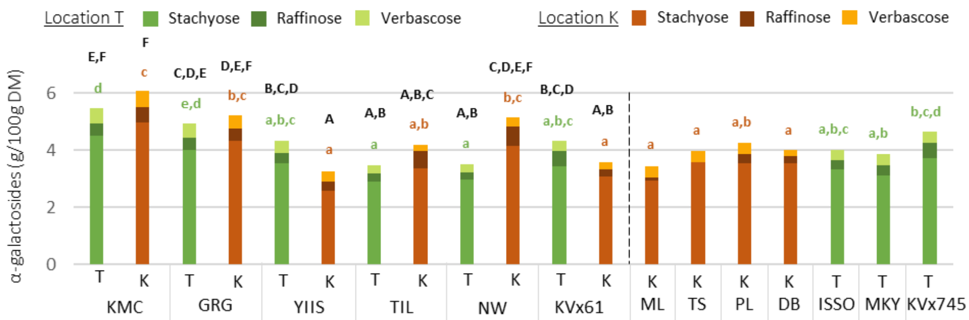

Figure 5: Levels of α-galactosides (stachyose, raffinose and verbascose) in samples from different localities: in green the statistical results obtained for the variety effect in Tenkodogo (T) (n=9), in orange the statistical results obtained for the variety effect in Kamboinsé (K) (n=10), and in black the statistical results of the variety-locality interaction determined on varieties common to both localities (n=6). (KMC = Komcallé, GRG = Gourgou, YIIS = Yiisyande, TIL = Tiligré, NW = Neerwaya, KVx61 = KVX 61-1, ML = Moussa Local, TS = Teek songo, PS = Pisnu local, DB = Dablo, ISSO = Issa sosso, MKY = Makoyin, KVx745 = KvX745-11P).

4. Discussion

With regard to the protein content of the varieties analysed, the average value obtained of 22.5 ± 1.47 g/100 g DM is in line with previous studies, which found protein contents of around 22-24% (Hama-Ba et al. 2017; Padhi et al. 2022), and with the Food Composition Table of Burkina Faso (2005), which shows 23.1 g protein/100 g dry cowpea. If we compare cowpea with other legumes, its protein value is between that of potato pea (voandzou), which has a protein content of 20.9 g/100 g DM, and that of soya, which stands at 33.7 g/100 g DM (Table de Composition des Aliments du Burkina Faso, 2005)

Komcallé and KVx61-1 have the lowest protein contents, regardless of where they are grown. For these two varieties, as well as the other varieties grown in both localities, with the exception of Yiisyande, the protein content measured was higher in Kamboinsé than in Tenkodogo. The KVx745-11P variety had the highest value in Tenkodogo and the Dablo variety the highest in Kamboinsé. The protein content of the varieties is the only nutritional quality criterion used to date by agronomists. On the basis of this criterion, these last two varieties would therefore be good parents in varietal selection programmes for the "protein" trait.

The average vitamin B1 content in our samples of 0.52 ± 0.11 mg eq-Thia/100 g DM is consistent with the value of 0.71 mg/100 g dry cowpea proposed in the West African food composition table (Stadlmayr et al. 2012) . The results obtained show that the proportions of the different forms of vitamin B1 vary from one variety and one locality to another. The results for varieties grown in the 2 localities show higher thiamine equivalent values in Kamboinsé.

From an organoleptic point of view, the KVx61-1 variety, which has the highest sucrose content, but also higher glucose and fructose contents than the other varieties, will be characterised by a sweet taste. It would therefore be interesting to combine these data with human consumption analyses to identify whether this variety is appreciated for its sweetness, and whether it is used in specific recipes. Similarly, the Moussa Local variety stands out for its glucose and fructose content and could have specific organoleptic characteristics, although the sucrose content is lower than for the KVx61-1 variety.

The average iron content obtained from our samples is lower than that available in the Burkina Faso composition table (7.6 mg/100 g dry cowpea seeds), while the average zinc value obtained is higher than that in the Burkina Faso composition table (2005) (3.8 mg/100 g dry cowpea seeds). However, the average iron and zinc levels are within the range reported by Hall et al.(2017). To estimate the bioavailability of iron and zinc in cowpea seeds, the molar ratios IP6/iron and IP6/zinc were calculated and found to be higher in Kamboinsé, with minimum ratios of 12.4:1 for iron and 15.0:1 for zinc, than in Tenkodogo. This is consistent with the fact that IP6 levels are higher in samples from Kamboinsé. Molar ratios of IP6 to iron > 1:1 and IP6 to zinc > 5:1 are considered critical values that should not be exceeded for the intestinal absorption of iron (Hurrell et al. 2010; Rahman et al. 2022) and zinc (Fredlund et al. 2006; Maares et al. 2020) in humans. These results should be treated with caution as these ratios are calculated on the basis of the content of raw seeds, and not on the basis of dishes as consumed. In fact, transformation processes such as soaking (Lestienne et al. 2005) or even germination or fermentation can modify these molar ratios by reducing the phytate, iron and/or zinc content. The IP6/Iron and IP6/Zn molar ratios could therefore be proposed as additional varietal selection criteria.

Among the α-galactosides analysed in our samples, stachyose was the most present. Indeed, it is known to be predominant in legume seeds (Njoumi et al. 2019), especially in cowpea (Akissoé et al. 2021). The values obtained are in agreement with data in the literature (Avezum et al. 2024). Consumption of foods rich in α-galactosides causes digestive discomfort that may limit the desire to consume these products. However, processing methods such as soaking, fermentation or germination make it possible to reduce concentrations of α-galactosides, for example by diffusion of these molecules into the soaking water or by enzymatic hydrolysis in the case of germination (Akissoé et al. 2021; Avezum et al. 2024). Given that the levels of these anti-nutritional compounds (phytates and alpha-galactosides) can change during pre-treatment or culinary preparation, their presence in raw seeds can be considered as a preliminary indicator of the undesirable effects they may have in the dishes as consumed. In fact, regardless of the treatment the seed undergoes before consumption, a seed very rich in phytates will see the divalent minerals of which it is made chelated. So for similar characteristics in terms of protein and agronomic aptitude, varieties that are less rich in phytates and α-galactosides would be the ones to recommend. Especially as not all cowpea transformation processes include steps that degrade phytates and/or α-galactosides and therefore their undesirable effects.

5. Conclusion

The characteristics of the localities (soil, weather conditions, exposure, etc.) seem to have an effect on some of the compounds analysed. Indeed, the Kamboinsé locality includes the samples with the highest levels of protein, vitamin B1 (TDP, T-HCl, Eq-thia), zinc, galactose, glucose, fructose, but also IP6, and α-galactosides (verbascose, raffinose, stachyose). In Tenkodogo, the samples had the highest levels of iron and sucrose, and the lowest levels of IP6.

The nutritional composition of cowpeas varies according to variety, soil type, environmental factors and cultivation techniques. This study shows that there is significant variation in nutritional compounds between varieties, as well as between variety and growing location. These results provide an encouraging basis for carrying out a study on a wider sampling with more varieties and localities. These data should be combined with agronomic data such as cycle length, yield, seed size, colour, organoleptic qualities and resistance, in order to define additional varietal selection criteria more closely linked to nutritional potential. Soil analyses and the recording of meteorological data should also be combined with analyses of nutritional composition in order to further identify the soil factors influencing the micro- and macro-nutrient content of cowpeas.

Ethics

The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models

The data supporting the results reported in this article are available on request from the corresponding author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.

The authors have used artificial intelligence-assisted technologies to translate from French to English.

Author ORCIDs

Morgane Chapron : 0009-0002-4182-0083 - Benoît-Joseph Batieno : 0000-0002-4156-7287 - Youna Hemery : 0000-0003-0408-2552 - Léandre Poda : 0000-0003-3475-6693 - Claire Mouquet-Rivier : 0000-0002-3775-4610 - Christèle Icard Vernière : 0000-0002-5626-6639

Authors' contributions

Morgane Chapron: data curation, formal analysis, research, methodology, validation, visualization, writing - original version - Benoit-Joseph Batieno: research, methodology, project administration, provision of resources, validation, writing - revision and correction - Youna Hemery: conceptualization, obtaining funding, project administration, supervision, validation, writing - revision and correction - Léandre Poda research, methodology, project administration, provision of resources, validation - Isabelle Rochette : data curation, research, methodology - Guillaume Grondin: data curation, research - Claire Mouquet-Rivier: conceptualisation, supervision, validation, writing - revision and correction - Christèle Icard-Vernière: conceptualisation, data curation, formal analysis, research, methodology, project administration, supervision, validation, writing - revision and correction

Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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