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Grains production in high climate change impacted regions and its potential for the supply of critical nutrients for humans nutritional well being

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Abstract

Climate change affects most remarkably Savannah regions in ways that alter agricultural productivity. In addition, these regions are marked by high prevalence of malnutrition and mortality related to undernourishment in children under 5 years old. One of the most promising solutions to sustainably fight malnutrition is to design programs that will consider locally produced foods and production approaches that protect the soil. The present study was designed to evaluate the nutritional quality of grains produced in the Savannah in order to provide data that will be used to make recommendations for nutrition and sustainable farming. Farmers in the Savannah region in Togo were interviewed about their productions and their produced grains were sampled for biochemical characterization. All producers exploit family lands and mainly produce grains. More than 98% of producers breed poultry by only at the family level. Biochemical characterization of the sampled foods shows that pulses present a relative high level of sand, fatty matters and proteins. Results show that both cereals and pulses contain sufficient energy, fatty matters, vitamins and minerals that are necessary for human wellbeing. Foods formulations could be made especially for children under food substitution. In addition, pulses production is encouraged for sustainable soil preservation.

Keywords Savannah, Cereals production, Pulses production, Nutritional value, Soil preservation

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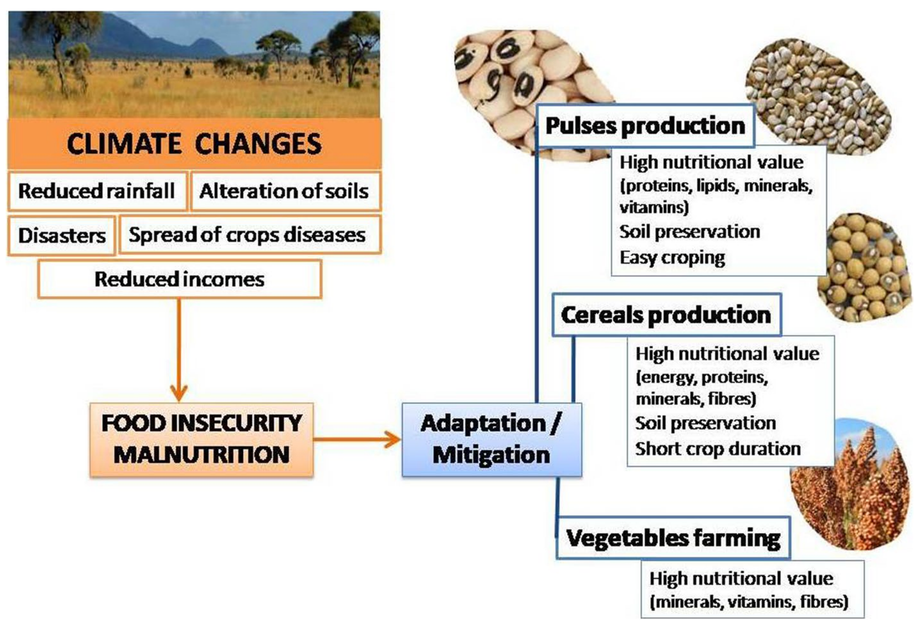
Graphical abstract



Introduction

Climate change is now an indisputable situation that affects lives of billions of people worldwide through natural disasters, spread of harmful biotic elements, socio-economic and even political destabilizations (Zhao et al. 2022). It affects food systems with a particular intensity in food production systems where new challenges are faced almost in every production cycle as farmers and breeders have to fight with drought, wildfire, floods, elevated CO_2 level, soil acidification, pests and spoiling microbes' proliferation, etc. … (Filho et al. 2022; Misiou & Koutsoumanis 2022; Zhao, Yu et al. 2022). All these environmental disorders also impact the composition of the raw foods produced in the particular context of climate change. Several authors showed the impact of climate change on the nutritional quality of some foods using experimental models (DaMatta et al. 2010; Ebi & Loladze 2019; Gomez-Zavaglia et al. 2020). In fact, agricultural productions in controlled environment enriched with carbon dioxide and/or heat resulted in raw foods with reduced quantity of proteins and minerals such as iron and magnesium (Beach et al. 2019; Taub & Wang 2013). These results show that climate change could be a factor with a serious risk of hampering the efforts to food and nutritional security in some regions because the supply in these critical nutrients could be reduced in the population (Helldén et al. 2021).

Among the most exposed areas to climate change are the tropical savannah and the arid regions in Africa where the most perceived change is the modification in the rainfall quantities and periods (Amponsah et al. 2022; Derbile et al. 2022; Incoom et al. 2020). These regions present in most cases economic systems mainly based in agriculture and livestock farming and people mostly consume locally produced foods. Up to now, information about the nutritional value of the locally produced foods in the Sub-Saharan region is rare making it difficult to formulate dietary guidelines that could be helpful to the whole population. Moreover, the climate change that affects the region implies a dynamic in produced food composition rendering it necessary to perform biochemical studies to keep updated regarding the composition of these foods.

Given the importance of climate in the quality as well as the quantity of nutrients in raw foods, people in these regions present a high risk of malnutrition. As an illustration, global data indicate that undernourishment is much more prevalent in African countries even if it decreased globally (FAO, 2021). In these countries, the undernourishment is much more observed in under 5 years old children with high levels of stunting, acute severe malnutrition, micronutrient deficiencies, anaemia, and protein deficiency (Alfani et al. 2019). All these forms of undernourishment are factors that expose people to severe forms of wide spreading infections such as COVID19 (Kurtz et al. 2021). Authorities have conceived several programs including school cantinas and nutritional management of undernourished children in hospitals (Chadare et al. 2022; Mizéhoun-Adissoda et al. 2022). One of the realities in these countries is that parents often abandon healthcare centres and most children could not undergo effective and complete medical management in well designed facilities (Compaoré et al. 2021). In addition, given that very few is known about local food composition, most interventions depend on food produced abroad. Such systems have shown their weakness in the last 4 years with the COVID19 pandemic but also with the conflict between Russia and Ukraine. In fact, several studies have shade light on the threat of insecurity in African countries especially in the supply of grains like wheat because of this war (Jagtap et al. 2022; Santeramo & Kang 2022; Zhou et al. 2023). In fact, the current war worsened the food and nutritional insecurity related to COVID19 pandemic which initially lead to inflation and altered many food supply chains in Africa (Amare et al. 2021; Manyong et al. 2022).

The alternative to achieve an effective fight against undernourishment in under-five children is to propose a set of guidelines for an appropriate use of locally produced foods that can be used for children feeding outside medical facilities. Indeed, a dietary guideline based in local food would provide practical recommendations to each individual so that everybody could be able to get appropriate food for his family. For this reason, it is important to gather data on the nutritional quality of locally produced foods. The present study was focused on the biochemical characterization of locally produced grains in the Togolese Savannah in order to collect data necessary for the design of guidelines for the optimal utilization of locally produced foods in the fight against undernourishment.

Materials and methods

Data and samples collection

The project and the protocols of all steps in this study were subjected to an evaluation at Kara University. An authorization was also provided by administrative authorities in the studied region. After ethical procedures and authorizations acquired, a survey using a structured questionnaire was realized in rural areas in the Savannah region in the northern Togo (Fig. 1). The selected villages were Bogou and Moumoane in the Prefecture of Tandjouare, Borgou, Gbantchal and Ogaro in the Prefecture of Kpendjal, Fare and Sadori in the Prefecture of Oti, and, Pana and Toaga in the Prefecture of Tone. The survey was administered by trained interviewers in households selected randomly in these rural areas. The questionnaire was designed to collect data on the households, agricultural productions, source of foods consumed, destination of produced speculations, main health problems, and major issues regarding food security and safety.

After data collections, raw foods produced in the region were sampled in most popular markets attended by producers in the region. The study was performed from July 2020 to September 2021. Collected food samples were taken to the laboratory for biochemical analyses.

Biochemical analyses

All the collected food samples were subjected to analyses of water content, rate of sands, protein level, whole sugar content, fatty matter, and vitamin C.

Water, sands, and dietary fibre contents

The water content of each food sample was assessed using the standard procedure described by the Association of Official Analytical Chemists (AOAC)(A.O.A.C. (1990) Official Methods of Analysis. 15th Edition). Samples were dried in a stove at 95 °C and weighed every 30 minutes until weight stability. The water content was then calculated as the percentage of water mass in the wet raw sample. In order to quantify sands, each sample was dried and grinded to flour. The flour was burned in an oven at 550 °C for 6 h. The sands were then weighed and the obtained value was used to calculate the percentage in the dry mater. The crude fibre in the samples were quantified using the Weende method using sulphuric acid to chemically digest all compartments in food samples excepting fibres (Van Soest & McQueen 2007).

Quantification of macronutrients

Fatty matters were quantified after extraction in petroleum ether or hexane. Around 20 g of the flour obtained by grinding the grains are mixed with the solvent and incubated 12 hours under agitation at room temperature to allow the complete extraction of fatty matters. By the end of agitation, the suspended particles were discarded after decantation. The obtained liquid composed of fatty matter in the solvent is consequently subjected to a gentle evaporation à 60 °C. The preparation is weighed every 30 minutes until the mass remains stabilized. The final mass represents the mass of fatty matter in the sample.

The total carbohydrates moiety was determined using a phenol-sulphuric acid reaction proposed by DuBois et al. 1956 (DuBois et al. 1956). Around 0.1 g of the flour is treated with 5 ml of concentrated hydrochloric acid for 30 minutes at 100 °C. By the end of this hydrolytic reaction, the mixture is neutralized by bicarbonate. The supernatant (0.5 ml) of the reaction is sampled and added to 0.5 ml of phenol under stirring during 10 minutes at

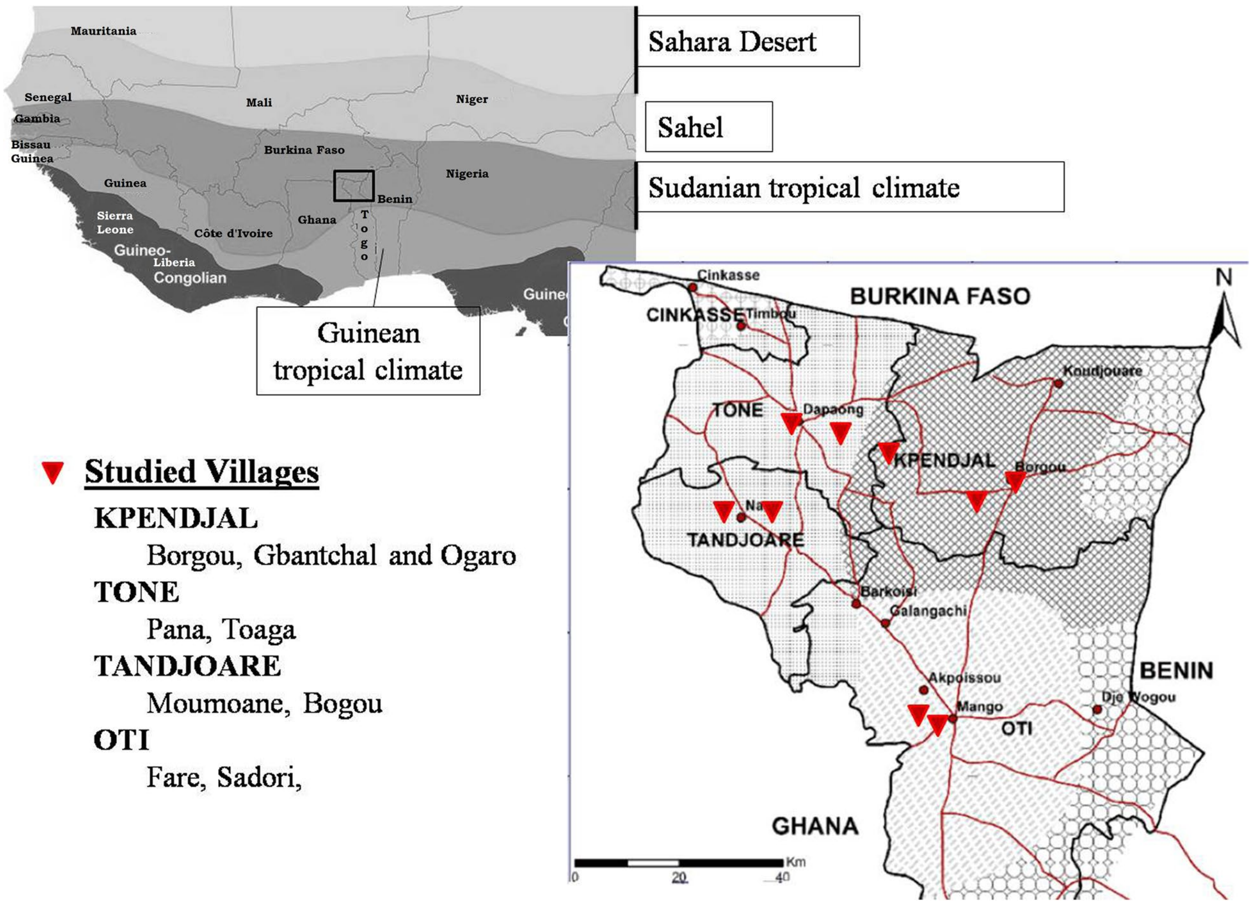


Fig. 1 Map of the studied region

room temperature. Sulphuric acid (5 ml) is added to the reaction and incubated 30 minutes in a bath at 30 °C. Colorimetric measures are made in a spectrophotometer at 490 nm. Absorbance values were used to determine the corresponding concentrations using standard curves made using glucose.

The protein content was determined using the total nitrogen titration based on the Kjeldhal method as described by the AOAC (A.O.A.C. (1990) Official Methods of Analysis. 15th Edition; Devani et al. 1989). Briefly, the method is based in nitrogen mineralization, distillation and titration. The total nitrogen content obtained is finally multiplied to the factor 6.24 to obtain the total protein content in the analyzed sample.

Quantification of vitamin C

The content in vitamin C was determined by redox titration using iodine (Bogdanski 1958). For each test, a sample of 3 g of the dried floor was suspended in 25 ml of distilled water. After a long agitation, 10 ml of the supernatant were mixed with 10 ml of iodine at 0,005 M with a drop of starch at 5% and phosphoric acid. The titration was performed with thiosulfate at 0.005 M until the disappearance of the colour. The same test is performed with distilled water without sample to establish the value for the blank.

Data analysis

The energetic value of each tested sample was calculated using the Atwater and Bryant's model (Smit et al. 2004). All the collected field data as well as laboratory data were computed and analyzed using the IBM SPSS Statistics 20.0. All the laboratory data are expressed as mean ± SD of triplicate tests. Statistical tests were made with a significance cut-off set at $p < 0.05$.

Results

Households and production

A total of 385 producers' households with agriculture as the main source of income were included in the study. The household's head who is also the one who decides the speculation to be produced is a man in most households (353 vs 32 households headed by a woman). The mean age of households' heads is 47.43 years old. According to

Table 1 Characterization of the studied population

	N	Percentage
Gender of the household's head		
Female	32	8.31
Male	353	91.69
Age of the head of household		
< 30 years old	21	6.10
30–39 years old	76	22.02
> 40 years old	248	71.88
Education of the head of household		
Analphabetic	202	52.74
Primary school	100	26.10
High school	78	20.36
University level	3	0.8
Food menu decision maker		
Male alone	55	15,94
Female alone	140	40,58
Male after discussion with the family	71	20,58
Female after discussion with the family	79	22,9
Produced speculations		
Zea mays (white colour)	325	94,2
Zea mays (yellow colour)	107	31,01
Sorghum bicolour S1 (red colour)	159	46,08
Sorghum bicolour S2 (orange colour)	35	10,14
Sorghum bicolour S3 (yellow colour)	56	16,23
Sorghum bicolour S4 (white colour)	66	19,13
Sorghum bicolour S5 (brown colour)	53	15,4
Pennisetum glaucum Var P1	45	13,04
Pennisetum glaucum Var P2	137	39,71
Rice (*Oryza sativa*)	87	25,21
Glycine max	134	38,84
Cowpea (*Vigna unguiculata*) H1 (white colour)	110	31,9
Cowpea (*Vigna unguiculata*) H2 (black colour)	103	29,86
Cowpea (*Vigna unguiculata*) H3 (red colour)	86	24,93
Peanut (*Arachis hypogaea*) A2 (big grains)	94	27,25
Peanut (*Arachis hypogaea*) A1 (small grains)	87	25,21
Bambara groundnut (*Vigna subterranean*) V1 (white colour)	71	20,57
Bambara groundnut (*Vigna subterranean*) V2 (black colour)	64	18,55
Sesame (*Sesamum indicum*) S1 (small grains)	36	10,43
Sesame (*Sesamum indicum*) S2 (big grains)	34	9,86
Main children health problems		
Malaria	341	98,84
Diarrhea	234	67,82
Stomach ache	239	69,27
Hip pain	83	24,05
Anemia	125	36,23
Breeding activity		
Poultry breeding	341	98,84
Goats breeding	127	36,81
Cattles breeding	243	70,43
Consumption of the breeding products		
Volailles 20–35	341	100
Caprins 10–15	57	45
Bovins 3–9	24	10

their education level, 52.74% of heads of households in the studied population have never attended school. Those who attended school went to primary school, secondary school or university at 26.11, 20.36, and 0.8% respectively. All these producers exploit family lands that are transmitted through generations. The characteristics of the surveyed households and their heads are summarized in Table 1.

Given the climatic conditions and the relatively weak fertility of lands in the region, producers in the region have adapted their production methods to the production of edible grains including cereals and pulses. Almost generally, crops are made in co-culture associations of cereals and pulses. Main produced grains include cereals such as maize (*Zea mays*), sorghum (*Sorghum bicolour*), rice (*Oryza sativa*), pearl millet (*Pennisetum glaucum*). Cereals are cropped in association of the following pulses: soy bean (*Glycine max*), peanut (*Arachis hypogaea*), cowpea (*Vigna unguiculata*), bambara groundnut (*Vigna subterranean*), and sesame (*Sesamum indicum*). Two to three varieties of each speculation are identified in the region and distinguished only by their phenotype (grain colour, grain size).

Regarding the origin of seeds used in the production, 219 (56.88%) producers exclusively use their own seeds selected from previous seasons. The remaining 43.12% buy seeds developed and sold by specialized institutions in Togo. These seeds are mainly maize and soybean.

Perception of climate change

During the interviews, producers were asked about how they perceive some climatic parameters. The results are summarized in Table 2. It appears from this table that a high number of producers (42.08%) feel that the drought affects more and more lands. Besides, 29.35% of producers feel that the temperature is getting higher. 44.67% of the interviewed producers think that there is no delay in the beginning of the rain season during the last 3 years.

Table 2 Producers' perceptions regarding climate change

	Perception of the producer regarding climatic factors' evolution during the last 3 years			
	Reduced	**Increased**	**Not changed**	**Don't know**
Flooding	86	95	156	48
Drought	98	162	99	26
Delay in the beguining of rain season	172	95	81	37
Long rain season	78	50	160	97
Short rain season	38	56	199	92
Strong winds during the production season	107	88	136	54
High temperature	43	113	164	65
Cold temperature during the production season	92	64	153	76

Biochemical characterization of raw food

Grains' water, ashes and crude fiber content

The sampled grains presented water contents in ranges below 9%. Among cereals, rice samples showed highest water content values (8.21% for the coloured rice) whereas maize samples were the driest cereals (5.21 and 5.71% for the orange *Zea mays* and the white one respectively). Among pulses, the white *Vigna subterranean* presented the lowest water content (2.93%). Concerning the level of mineral matters measured by quantifying sands, there is a significant difference between cereals and pulses. All cereals contain less than 2% sands whereas pulses contain sands in ranges from 3.66% in red *Vigna unguiculata* to 6.44% in *Sesamum indicum* with relatively big grains. The crude fiber as determined using the chemical method was found to be more abundant in white *Zea mays* variety (7.33%) but the lowest level of crude fibre among cereals was found in white grain *Oryza sativa* (5.16%). The values of water, sands and fibre content of sampled cereals and pulses are presented in Table 3 and Fig. 2.

Table 3 Grains content in moisture, sands and crude fibre

	Varieties	Moisture %	Sands content %	Crude fibre level %
Maize (*Zea mays*)	M1 (orange colour)	5.21	1.31	6.94
	M2 (white colour)	5.71	1.15	7.33
Pearl millet (*Pennisetum glaucum*)	Var P1	7.02	1.45	6.36
	Var P2	6.68	1.52	7.10
Rice (*Oryza sativa*)	R1 (white colour)	7.31	0.66	5.16
	R2 (yellow colour)	8.21	0.77	5.20
Sorghum (*Sorghum bicolour*)	S1 (red colour)	7.06	1.54	7.09
	S2 (orange colour)	7.13	1.13	6.69
	S3 (yellow colour)	6.96	1.12	6.78
	S4 (white colour)	6.23	1.06	8,08
	S5 (brown colour)	7.26	1.61	7.38
Soy bean (*Glycine max*)		5.25	6.08	9.10
Bambara groundnut (*Vigna subterranean*)	V1 (white colour)	2.93	3.85	9.06
	V2 (black colour)	4.12	4.33	9.33
Peanut (*Arachis hypogaea*)	A1 (small grains)	4.52	4.54	5.45
	A2 (big grains)	4.44	4.80	6.34
Sesame (*Sesamum indicum*)	S1 (small grains)	4.53	6.44	7.02
	S2 (big grains)	3.76	4.32	6.57
Cowpea (*Vigna unguiculata*)	H1 (white colour)	6.45	3.93	11.02
	H2 (black colour)	4.96	3.97	11.14
	H3 (red colour)	6.19	3.66	11.44

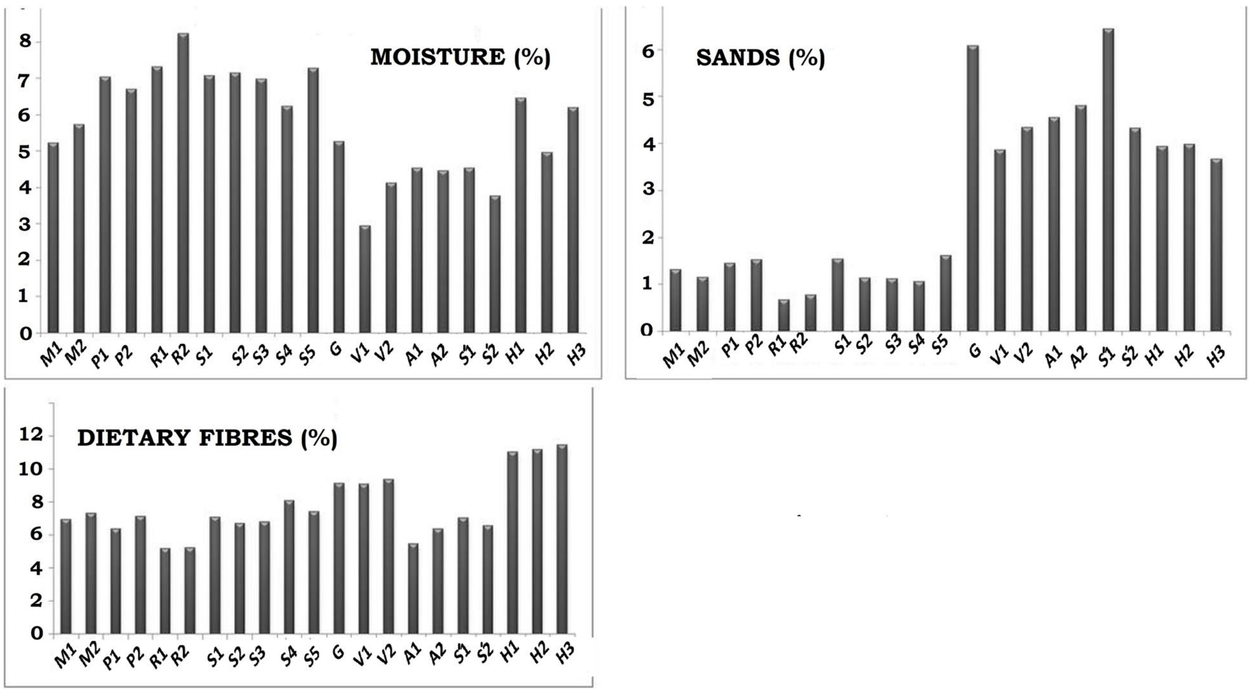


Fig. 2 Level of Moisture, Sand and Dietary fibres in studied grains. M1:Maize (*Zea mays*) M1 (orange colour); M2:Maize (*Zea mays*) M2 (*white colour*); P1:Pearl millet (*Pennisetum glaucum*) Var P1; P2:Pearl millet (*Pennisetum glaucum*) Var P2; R1:Rice (*Oryza sativa*) R1 (white colour); R2:Rice (*Oryza sativa*) R2 (yellow colour); S1:Sorghum (*Sorghum bicolour*) S1 (red colour); S2:Sorghum (*Sorghum bicolour*) S2 (orange colour); S3:Sorghum (*Sorghum bicolour*) S3 (yellow colour); S4:Sorghum (*Sorghum bicolour*) S4 (white colour); S5:Sorghum (*Sorghum bicolour*) S5 (brown colour); G:Soy bean (*Glycine max*); V1:Bambara groundnut (*Vigna subterranean*) V1 (white colour); V2:Bambara groundnut (*Vigna subterranean*) V2 (black colour); A1:Peanut (*Arachis hypogaea*) A1 (small grains); A2:Peanut (*Arachis hypogaea*) A2 (big grains); S1:Sesame (*Sesamum indicum*) S1 (small grains); S2:Sesame (*Sesamum indicum*) S2 (big grains); H1:Cowpea (*Vigna unguiculata*) H1 (white colour); H2:Cowpea (*Vigna unguiculata*) H2 (black colour); H3:Cowpea (*Vigna unguiculata*) H3 (red colour)

Carbohydrates, fatty matter and proteins

The composition of sampled grains regarding carbohydrates, fatty matters and proteins is shown in Table 4. As shown in Table 2, cereals contain the highest levels of carbohydrates but pulses present the most elevated levels of fatty matters and proteins. More than 60% of dry matters in all cereals are made of carbohydrates. The highest values are obtained in rice followed by sorghum varieties and pearl millet. Among pulses, *Vigna subterranean* varieties contain the highest levels of carbohydrates (Fig. 3).

Regarding fatty matters, cereals contain very low levels. The two varieties of *Zea mays* (3.13 and 4.36%) and those of *Pennisetum glaucum* (3.15 and 3.2%) present highest levels of fatty matters among cereals. The lowest values of fatty matters are recorded in *Oryza sativa* varieties with 0.65 and 0.7% of dry matters. *Sorghum bicolour* varieties present fatty matters levels ranging from 2.66 to 2.99%. Among pulses, *Vigna subterranean* (3.7% for the white variety and 4.13% for the black one) and *Vigna unguiculata* (0.97% for the white variety, 1.01% for the black one and 0.67% for the red one) are the samples with the lowest value of fatty matter content. The remaining pulses contain high values of fatty matter content. In terms of importance, *Arachis hypogaea* contain the highest value of fatty matters (>40%) followed by *Sesamum indicum* (31.14 and 37.97%) and *Glycine max* (14.66%).

All cereals contain less the 10% of proteins (Fig. 3). The highest levels of proteins among cereals are recorded in *Sorghum bicolour* varieties followed by *Pennisetum glaucum* one. The orange coloured *Zea mays* presented protein levels comparable to those of Sorghum bicolour and *Pennisetum glaucum* but the white *Zea mays* shows relatively low levels of proteins content. Pulses are particularly riche in proteins in comparison to cereals. The highest value of protein content was recorded with *Glycine max* (34.43%) followed by the *Sesamum indicum* variety with big grain (31.87%).

Content in vitamin C

Vitamin C was quantified in the selected grains and found to be present in levels below 2% of dry matters (Fig. 2). The highest value (1.68%) was recorded in *Arichis*

Table 4 Grains composition in macronutrients and energetic value

	Varieties	Total carbohydrates (% of dry matter)	Fatty matters (% of dry matter)	Proteins (% of dry matter)	Energetic value (Kcal/100 g)
Maize (Zea mays)	M1 (orange colour)	61.77 ± 1.29	4.36 ± 0.77	7.36 ± 0.30	315.76 ± 13.29
	M2 (white colour)	60.17 ± 0.94	3.13 ± 0.11	6.47 ± 0.16	294.73 ± 5.39
Pearl millet (*Pennisetum glaucum*)	Var P1	62.27 ± 0.48	3.15 ± 0.17	7.68 ± 0.77	308.15 ± 6.53
	Var P2	62.27 ± 1.42	3.20 ± 0.27	7.17 ± 0.11	306.56 ± 8.55
Rice (*Oryza sativa*)	R1 (white colour)	62.02 ± 0.52	0.65 ± 0.34	6.47 ± 0.64	279.81 ± 7.7
	R2 (yellow colour)	63.14 ± 1.18	0.70 ± 0.36	6.38 ± 0.55	284.38 ± 10.16
Sorghum (Sorghum bicolour)	S1 (red colour)	60.23 ± 0.80	2.66 ± 0.02	7.58 ± 0.26	295.18 ± 4.42
	S2 (orange colour)	61.29 ± 0.47	2.82 ± 0.17	7.17 ± 0.12	299.22 ± 3.89
	S3 (yellow colour)	62.27 ± 0.74	2.99 ± 0.21	7.72 ± 0.97	306.87 ± 8.73
	S4 (white colour)	61.17 ± 0.82	2.81 ± 0.13	8.09 ± 0.13	302.33 ± 4.97
	S5 (brown colour)	62.32 ± 0.49	2.68 ± 0.41	7.51 ± 0.28	303.44 ± 6.77
Soy bean (*Glycine max*)		22.57 ±0.27	14.66 ±1.33	34.43 ± 1.35	359.94 ± 18.45
Bambara groundnut (Vigna subterranean)	V1 (white colour)	42.25 ± 1.07	3.7 ±0.37	15.69 ± 1.43	265.06 ± 13.33
	V2 (black colour)	44.56 ± 0.39	4.13 ± 0.27	16.16 ± 0.11	280.05 ± 4.43
Peanut (*Arachis hypogaea*)	A1 (small grains)	24.35 ±1.28	40.32 ± 1.06	28.95 ± 0.63	576.08 ± 17.18
	A2 (big grains)	27.30 ± 0.88	41.30 ± 0.67	23.95 ± 0.23	576.7 ± 10.47
Sesame (*Sesamum indicum*)	S1 (small grains)	19.92 ±0.86	37.97 ± 0.35	19.72 ± 1.19	500.29 ± 11.35
	S2 (big grains)	13.49 ± 0.23	31.14 ± 0.12	31.87 ± 1.15	461.7 ± 6.6
Cowpea (Vigna unguiculata)	H1 (white colour)	42.42 ± 0.51	0.97 ± 0.11	21.78 ± 1.02	265.53 ± 7.11
	H2 (black colour)	36.60 ± 0.78	1.01 ± 0.31	21.35 ± 0.05	240.89 ± 6.11
	H3 (red colour)	48.15 ±0.86	0.67 ±0.26	20.87 ± 1.06	282.11 ± 10.02

hypogaea and the lowest values recorded in Sorghum bicolour varieties (Table 5 and Fig. 3).

Discussion

Semi arid regions in Africa are highly impacted by climate change and food productions systems challenge a lot of threats (Filho et al. 2022; Misiou & Koutsoumanis 2022). Moreover, the ongoing COVID19 pandemic and the war between Russia and Ukraine exacerbate the food system fragilities in African countries (Amare et al. 2021; Manyong et al. 2022; Santeramo & Kang 2022; Zhou et al. 2023). In such contexts, resilience and adaptive practices are necessary to ensure local production of high quality food in sufficient quantities and effective food distribution chains. Several governmental programs are designed to increase food availability in these areas but very few is actually known about the nutritional quality of locally produced food in these areas. In the present study, a particular focus was given to the biochemical composition of cereals and pulses produced in the savannah region in Togo.

Interviews show that all the producers involved in this study produce several types of grains that are the main components of all their meals. Cereals are produced because of their importance and appreciation in food preparation. Besides, pulses are more and more produced because they do not require the use of fertilizers. In effect, the inflation related to the COVID19 pandemic as well as the war between Russia and Ukraine has lead to a substantial increase in the cost of synthetic fertilizers making it necessary for producers to reduce their use of these fertilizers (Rivera-Ferre et al. 2021). Investigations about producers' perceptions show that most of them are aware of climate change and therefore look for mitigation approaches in order to continue their activity. Similar results were found with mango seedling producers in Ghana as well as with wheat farmers and apple producers in South Africa (Asare-Nuamah et al. 2022; Theron et al. 2022).

Producers in the present study adopt association cultures by producing concomitantly cereals and pulses in the same fields. This practice enhances the agricultural yield and helps in preserving soils (O'Hara et al. 2002). Indeed pulses are generally in symbiotic interactions with nitrogen fixing bacteria allowing their development without fertilizers and increasing the biomass that could be a soil protective factor for next season crops (Zhao et al. 2022). It is therefore important to mention that biological nitrogen fixation is a determinant factor for soil preservation and agriculture sustainability in the savannah. It is then necessary to preserve soil microbes so that nitrogen

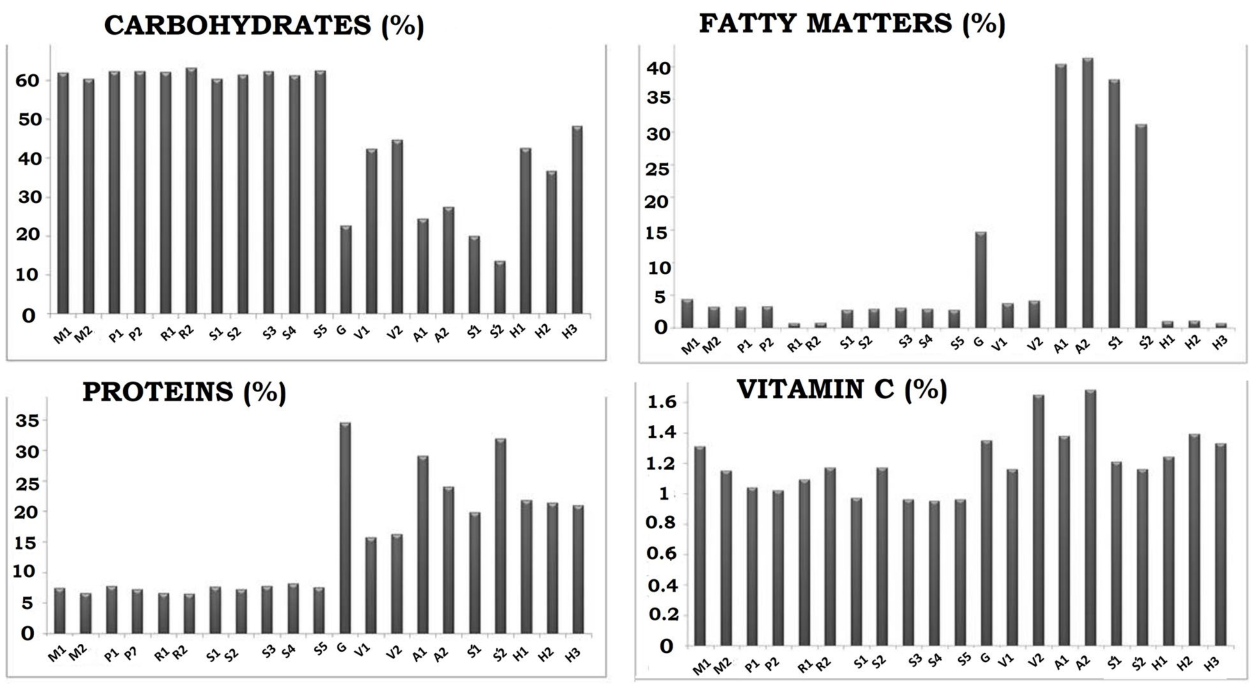


Fig. 3 Content of major macronutrients and Vitamin C in studied grains. M1:Maize (*Zea mays*) M1 (orange colour); M2:Maize (*Zea mays*) M2 (*white colour*); P1:Pearl millet (*Pennisetum glaucum*) Var P1; P2:Pearl millet (*Pennisetum glaucum*) Var P2; R1:Rice (*Oryza sativa*) R1 (white colour); R2:Rice (*Oryza sativa*) R2 (yellow colour); S1:Sorghum (*Sorghum bicolour*) S1 (red colour); S2:Sorghum (*Sorghum bicolour*) S2 (orange colour); S3:Sorghum (*Sorghum bicolour*) S3 (yellow colour); S4:Sorghum (*Sorghum bicolour*) S4 (white colour); S5:Sorghum (*Sorghum bicolour*) S5 (brown colour); G:Soy bean (*Glycine max*); V1:Bambara groundnut (*Vigna subterranean*) V1 (white colour); V2:Bambara groundnut (*Vigna subterranean*) V2 (black colour); A1:Peanut (*Arachis hypogaea*) A1 (small grains); A2:Peanut (*Arachis hypogaea*) A2 (big grains); S1:Sesame (*Sesamum indicum*) S1 (small grains); S2:Sesame (*Sesamum indicum*) S2 (big grains); H1:Cowpea (*Vigna unguiculata*) H1 (white colour); H2:Cowpea (*Vigna unguiculata*) H2 (black colour); H3:Cowpea (*Vigna unguiculata*) H3 (red colour)

fixing bacteria could remain in place. Bushfires should then be avoided and strategies developed to prevent wildfires (Ondik et al. 2022).

Laboratory characterization of raw grains samples from local markets revealed the all have less than 8% water content. These low values show that the grains could be stored for long periods with relatively reduced damage rates (Manu et al. 2019). Given that producer do not use sophisticated equipments to dry their producers, it is obvious that they profit from the relatively high drought of the environment to increase their storage potential.

In order to evaluate the level of mineral matters in the samples, these were subjected to sand quantification. It can be noted from the recorded results that pulses contain higher levels of sands. All cereals presented less than 2% sand content whereas pulses show values above 3%. Similar tendencies were observed for crude fibre content with pulses more doted in fibre in comparison to cereals. Previous studies in different regions also showed these comparisons especially for dietary fibres (Langyan et al. 2022). The highest values of sand were recorded in *Sesamum indicum* and *Glycine max* but highest values of crude fibres were recorded in *Vigna unguiculata* varieties.

Regarding major macronutrients, cereals presented the highest levels of total carbohydrates with yellow coloured *Oryza sativa* showing the most elevated content in carbohydrates (63.14%). The lowest values of total carbohydrates were recorded in two oilseeds (*Arachis hypogaea* and *Sesamum indicum*). These oilseed contained the highest levels of fatty matters (40.32 and 41.30% for *Arachis hypogaea* varieties, and 37.97 and 31.14% for *Sesamum indicum* species) but *Glycine max* was the third specie in terms of fatty matter content (14.66%). Among pulses, *Vigna unguiculata* is the specie with the lowest level of fatty matters. Cereals in general contained reduced levels of fatty matters but *Zea mays* is the cereal with the highest level of lipids (4.36 and 3.13%) followed by *Pennisetum glaucum* varieties (3.15 and 3.20%). *Oryza sativa* varieties contained less than 1% of lipids.

Like for fatty matters, proteins were found to be generally abundant en pulses in comparison to cereals. *Glycine max* contains the highest level of proteins (34.43%) followed by the *Sesamum indicum* variety with bigger grains (31.87%) and the two varieties of

Table 5 Level of vitamin C in sampled grains

	Varieties	Vitamine C (% of dry matters)
Maize (Zea mays)	M1 (orange colour)	1.31 ± 0.14
	M2 (white colour)	1.15 ± 0.04
Pearl millet (*Pennisetum glaucum*)	Var P1	1.04 ± 0.12
	Var P2	1.02 ± 0.07
Rice (*Oryza glaberrima*)	R1 (white colour)	1.09 ± 0.13
	R2 (yellow colour)	1.17 ± 0.06
Sorghum (Sorghum bicolour)	S1 (red colour)	0.97 ± 0.11
	S2 (orange colour)	1.17 ± 0.32
	S3 (yellow colour)	0.96 ± 0.05
	S4 (white colour)	0.95 ± 0.08
	S5 (brown colour)	0.96 ± 0.26
Soy bean (*Glycine max*)		1.35 ± 0.09
Bambara groundnut (Vigna subterranean)	V1 (white colour)	1.16 ±0.11
	V2 (black colour)	1.65 ±0.13
Peanut (*Arachis hypogaea*)	A1 (small grains)	1.38 ± 0.22
	A2 (big grains)	1.68 ±0.06
Sesame (*Sesamum indicum*)	S1 (small grains)	1.21 ± 0.05
	S2 (big grains)	1.16 ± 0.12
Cowpea (Vigna unguiculata)	H1 (white colour)	1.24 ± 0.06
	H2 (black colour)	1.39 ± 0.27
	H3 (red colour)	1.33 ± 0.23

Arachis hypogaea (28.95 and 23.95%). The three *Vigna unguiculata* varieties present comparable protein contents between 20 and 22%. The two *Vigna subterranean* varieties are pulses containing the lowest level of proteins. All cereals possessed proteins in proportions under 9% with the lowest levels of proteins observed in *Oryza sativa* and white coloured *Zea mays*. When considering the total energetic value, oilseeds varieties *Arachis hypogaea* (576.08 and 576.7 kcal/100 g) and *Sesamum indicum* (500.29 and 461.7 kcal/100 g) present the highest values. *Vigna subterranean* and *Vigna unguiculata* are the less energetic pulses and this is due to the fact that they contain very few lipids but relatively high levels of dietary fibres'.

It appears from biochemical results that locally produced grains have the potential for providing major nutrients to the population. However, there should be information strategies to show best practices to benefit from these foods in order to reduce malnutrition in the savannah without introducing new foods. Practical recommendations should be given regarding priority speculations to be produced in order to save soils but also regarding food choices for each age group. As an example, *Arachis hypogaea*, *Sesamum indicum* and *Glycine max* are good sources of fatty matters and proteins and therefore have the potential of providing liposoluble vitamins such as vitamin A as well as other active compounds as found in other studies (Çiftçi & Suna 2022; Mili et al. 2021; Ponka et al. 2015). Besides Vigna subterranean, *Vigna unguiculata* and *Glycine max* among pulses and cereals such as *Sorghum bicolour*, *Pennisetum glaucum* and *Zea mays* are excellent sources of dietary fibres. These foods could be of great added value regarding gut microbiota, metabolism and the reduction of obesity (Delzenne et al. 2020; Prokopidis et al. 2022). Another group of nutrients that are of importance in the regional public health is minerals, particularly iron and zinc. The present study did not specifically quantified these minerals but it can be seen from sand contents that *Glycine max*, *Vigna subterranean*, *Arachis hypogaea*, *Sesamum indicum* and *Vigna unguiculata* are good providers of minerals. This finding was also noticed in other studies (Abebe & Alemayehu 2022; Dravie et al. 2020; Udeh et al. 2020). Given the importance of anaemia in the studied region and the need for vitamin C to increase the bioavailability of iron, we investigated the potential for the grains to provide this vitamin (Shubham et al. 2020). It appears from the results that both pulses and cereals contain vitamin C in proportions around 1% of dry matters. However, thermal treatments during food processing will eliminate a part of this vitamin. It is therefore recommended for people in this region to add to grains in their foods fruits and green leafy vegetables. It is important to mention that the climate in the Savannah region does not allow the proliferation of green leafy vegetables during all the year. It is therefore necessary to promote vegetable farming by improving mater management. During the study, several households have mentioned vegetable farming as a source of vegetable for their own consumption but also as a source of additional incomes.

Conclusion

The present study was realized in order to evaluate the potential for locale food production to provide sufficient nutrients to people living in the Savannah Region in Togo where climate is seriously altered leading to many challenges for food production. Results show that most producers are aware of climate changes and therefore look for mitigation solutions to continue their activity. The main produced speculations are cereals and pulses. One of the most promising mitigation approaches used by producers is the association of cereals and pulses in the same fields. This association presents the benefit of preserving soils fertility but also ensures the provision of added value nutrients to consumers. The biochemical composition of these grains shows that they contain sufficient energy, fatty matters, vitamins and minerals that are necessary to reduce the level of malnutrition in general and the under-5 years old chronic and acute malnutrition. It is therefore recommended to inform the population with practical advices for a better utilization of these grains and soils. Apart from grains it will be of great impact to foster vegetables farming and their consumption to increase the nutritional supply of minerals and vitamins.

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Authors' contributions
Conception and study design: TS, MP, SKA. Data collection: TS, DB, MP. Data analysis: TS, DB, EWRC, AAE, BO, MK, RRAY, SKA. Manuscript drafting: All authors contributed to the manuscript drafting. The author(s) read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Due to the fact that the study includes data collection from individuals through interviews, the whole protocol and analysis methods were submitted for ethical approval at Kara University de Kara. Upon approval, details of the study were forwarded to the four studied Prefectures (Oti, Tone, Tandjouare, and Kpendjal). Administrative authorisations were obtained before field operations. Before each interview, the respondent was first informed about the study, its aims, expected results and possible outcomes. The interview begins only after the consent.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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