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BIOCHEMICAL RELEVANCE OF SORGHUM AND MILLET PRODUCED IN THE KASENA-NANKANA DISTRICTS OF GHANA, AND SOME OF THEIR BY-PRODUCTS TO FOOD, NUTRITION, HEALTH AND WEALTH OF THE PEOPLE

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ABSTRACT

This study was conducted in two farming seasons between 2008 and 2010. Two varieties each of millet and sorghum from the Kasena-Nankana districts of the Upper East Region of Ghana were compared. Methods used were personal interviews, proximate and micronutrient analyses, and assessment of "waste products". Results show that Pearl millet:finger millet:red sorghum:white sorghum are used respectively to make 5: 8:5:5 diets. For the first season, the highest average contents were: Crude protein(12.2%), and fibre(5.4%) in the white sorghum; carbohydrates(83.1%) in the proso millet, fat(4.2%) and ash(1.6%) in the pearl millet and moisture range from 0.3-2.1%. Also the red sorghum had the highest average of Na(548.5 mg/kg), Fe(68.8 mg/kg), and Mg(509.3 mg/kg); K(668.0 mg/kg) was highest in both red sorghum and pearl millet; Mn(16.5 mg/kg) in the pearl millet, and Ca(29.3 mg/kg) in the proso millet. In the second season, the highest average amount of crude protein(14.4%), fat(2.9%), ash(2.1%) and fibre(3.5%) were in the white sorghum, and carbohydrates(76.2%) in the red sorghum. The working moisture ranged from 8.2-17.7%. The highest average Na, Fe, and Mg were respectively 509.0 mg/kg, 70.5 mg/kg, 540.2 mg/kg all in the red sorghum. K(690.0 mg/kg) and Mn(12.8 mg/kg) were in the pearl millet, while Ca(32.0 mg/kg) was in the proso millet. The aqueous extract of the stalk ashes of pearl millet were used to flavour and de-ferment soups; stalks of sorghum served as cooking fuel, and for making baskets and sleeping mats, and the husk as cattle feed. Dusa and pito mash are food by-products from the grains used in feeding poultry and non-ruminants. Dusa had highest crude protein (21.48%) and carbohydrates(51.48%) and pito mash had 9.30% fat, fibre(11.38%) and ash(5.97%).

Keywords: Millet, Sorghum, By-products, Human, Nutrition, Health, Wealth.

1. INTRODUCTION

Over time the emerging consensus has been that insufficient agricultural output did not automatically result in reduced food insecurity, transitory food shortages or chronic hunger [1, 2]. But nutrition is rather directly related to food quality and consumption with a focus on food demand or consumption at the household level.

While farming still remains important for rural households, people are looking for diverse opportunities to increase and stabilize their incomes. Most rural livelihoods are based not solely on agriculture but on a diverse array of activities and enterprises [3]. Evidence from a sample of rural villages in Tanzania showed that, on average, only half of household income came from crops and livestock [3, 4].

For the past 20 years food production in Africa has lagged behind population growth. Thus more than 30 percent of the people in sub-Saharan Africa are chronically hungry and are small holder farmers, who, with children are also majority of the malnourished. Thus, some organizations develop staple crops bio-fortified with critical micronutrients, aimed at reducing malnutrition [5]. Rural farmers in sub-Saharan Africa, about 80 percent of whom are women [6], continue to value pursuing farming activities for home consumption. In Africa, over 60 % food production comes from the smallholder sector alone, and is mostly handy for the rural dwellers. A 2006–2007 UNICEF survey revealed acute malnutrition rates that routinely exceeded emergency thresholds. The study also showed among other things that child malnutrition is not limited to the most food insecure areas [7]. Majority of the poor and food insecure in Africa live in rural areas, and most of them depend on agriculture for their livelihoods.

Sustainability of smallholder contribution to food security and nutrition in Africa is threatened by climate change, desertification and reduced rainfall. This could increase hunger, malnutrition and poor health status, especially of women and children. There is therefore the need for a re-look into activities of peasant farmers who mainly cultivate crops and keep animals for family use. This case study was therefore conducted to investigate available rural nutrition, recognising that the cultural orientation of a people has influence on their nutrition. A large portion of the requirement for energy, protein and micronutrients of communities in these two Kasena-Nankana districts is suspected to be derived from cereals such as millet and sorghum.

Cereals are the most important and largest source of the world's food and have a significant impact in human diet throughout the world. Cereal products generally comprise about 80% or more of the average diet in India and Africa, 50% in central and Western Europe, and between 20-25% in the U.S [8]. Millet is a potentially, productive high-quality [9, 10] grain or silage crop that appears superior to sorghum bicolor in establishment and production under limited soil moisture. It is the principal grain crop in the Sahel (Niger and Senegal, West Africa) and is grown under low input management conditions such as non-crusting, sandy soils with little fertilizer and limited water [11]. Millets are adapted to climate of the savanna zones of the tropics because they are drought and heat tolerant crops [12]. Application of fertilizer on farm fields is able to improve grain yield and protein content of pearl, finger and column millet working on poor tropical soils [13]. Sorghum is a staple food in more than fifteen countries in East and West Africa and Arabia. It is rated the fifth most important cereal crop grown in the world. The cereal out-performs other cereal under various environmental stresses and is thus generally more economical to produce [14]. In recent years, sorghum has been used as a substitute for other grains in gluten-free beer. In China, sorghum is the most important ingredient for the production of distilled beverages such as Moatai and Kaoliang. In Nigeria, Ghana, Lesotho and South Africa, sorghum is used to produce beer, including the local versions of Guinness.

Agro-industrial by-products have been evaluated in Ghana as potential alternative feed sources for non-ruminant farm animals [15]. Studies have involved brewers spent grains [15], cocoa pod husk and dried coffee pulp [16], mango kernel meal [17], and oil palm sherry [18].

Millets differs from one another by their appearance, taste, grain quality and morphological behaviour, thus their biochemical composition is also different in a broad sense [19]. Typically millets contain higher quantities of essential amino acids methionine and cysteine and are higher in fat content than maize, rice and sorghum [19]). Food products from millet vary depending on people's taste and cultural preference [20]. What we eat plays an important role in the development of a variety of chronic diseases such as coronary heart disease, diabetes, high blood pressure, osteoporosis, obesity, and various cancers [21]. Therapeutically, the wax surrounding the sorghum grain contains the compound policosanol which can reduce cholesterol level. It is also gluten-free and therefore safe for persons with celiac diseases [22].

The Upper East region in northern Ghana has some of the highly poor communities of the country. It is largely made up of peasant farming communities in which millet and sorghum are cultivated and consumed and appear to constitute an important nutritional component to the people in the form of staple food crops. A large portion of the requirements for energy, tissue building and repair, as well as vitality in the communities are suspected to be derived from the two cereals. Grain quality is affected by factors such as genotype, climate, soil type and fertilization, among others, which can affect the chemical composition and nutrient value [23]. Notwithstanding these facts, this work assessed the contribution of the two cereals to nutrition and health of the people. The amount of crude protein, carbohydrate, fats, fibre, ash, moisture, and micronutrient (Ca, Fe, Mg, Mn, K, Na) composition of the grain were evaluated, and the nutritional value of the grains compared. Also, the food by-products of the grains were investigated for use as non-ruminant feed. The results were used to compare the grains in terms of their local use in making different meals in homes of peasant farmers, their parameters of nutritional relevance, as well as value added uses of their waste and food by-products. The work provided information on the contribution of the grains to the improvement of food security, nutrition and health, and the possibilities of using the food by-products of the grains for production of farm animals to supplement income and nutrition.

2. MATERIALS AND METHODS

2.1. Materials

Samples of two varieties of millet (pearl and proso) and two varieties of sorghum (red and white) were collected from farm fields from the Upper East region of Ghana. Also, two by-products ("dusa" and "pito mash") of food products of the cereals were also collected from the communities. In all twelve (12) samples of the grains were collected randomly from the farms in the 2008 and 2009 farming seasons. The collected grains were bagged separately in polyethene bags and brought to the laboratory for processing and analyses.

Equipment used in the work included a Thermo Scientific ICE 300 series brand AAS, and PFP 7 flame Jenulay brand Flame Photometer. Other materials included oven, magnetic stirrer, water bath, balance, crucibles, desiccator, muffle furnace, and Kjedahl apparatus. All chemicals used were of food grade.

2.2. Methods

2.2.1. Sample Preparation

Collection of the grains was done randomly from farms that did not have any special treatment beyond the application of cultivation methods that the indigenes do on their small holder farms. In this way, the grains represented the exact forms that were consumed in the communities. Unwholesome grains and other unwanted materials among the grains were picked out. The grains were powdered separately using porcelain mortar and pestle. They were then transferred into separate plastic bags, tied, labeled and stored in a cool dry place for further work.

Processing included grinding to pass through 0.05 mm mesh sieve using a stainless steel 'willey' mill. The ground material was weighed (5.00g into a porcelain dish and put into a muffle furnace and the temperature set at 500^{o} C for 24 hours to ash. Concentrated HCl (5ml) was then added to the ash in the porcelain dish and heated in a sand bath for 15 minutes, transferred and filtered into a 100 ml volumetric flask using distilled water and topped up to the mark.

Personal interviews were conducted to get information on uses of the grains in making diets. Proximate as well as micronutrient analyses were also done on the samples. Six (6) proximate and micronutrient parameters each were investigated in each cereal, dusa and pito mash sample. In addition, assessment of "waste products" from the crops and grains was carried out.

Proximate analyses were done for the crude protein, fat, moisture, ash, fibre, and carbohydrates. Minerals analysed were calcium, iron, magnesium and manganese were analysed from the ashed sample prepared above using Atomic Absorption, while potassium, and sodium were analysed using the Flame Photometer.

Moisture content determination was done in a hot-air oven thermostatically controlled at a temperature of 105°C for 5 hours and crude ash content was determined in a muffle furnace preheated to 600°C for 2 hours.

Determination of crude fat content, crude fibre, crude protein were done using methods of AOAC [24], and AOAC [25] which has also been used by Odedeji and Oyeleke [26]. The total carbohydrate content was determined by difference.

ie. %carbohydrates = 100 – (%moisture + %ash + %fat + %fibre + %protein).

2.2.2. Mineral Analysis

About 1.0g of each powdered sample was weighed and transferred into a 100ml volumetric flask. 10ml of an acid mixture of nitric acid and perchloric acid in the ratio 9:4 was added, mixed and swirled. The flasks were placed on a hot plate in the fume hood and heated at an initial temperature of 90°C. This temperature was then raised to 180°C, and heating continued until the production of red NO_2 fume ceased. The content of each flask was further heated until the volume of the content was reduced to 4ml and it became colorless. The contents were cooled and the volumes were made up with distilled water and then filtered. These solutions were used for the mineral estimation using the Atomic Absorption Spectrometer and Flame Photometer.

3. RESULTS

Table-1. Proximate results of analyses of the cereals in the first year of the study

Sample	Percentage (%)					
	Protein	Fat	Ash	Fibre	Moisture	Carbohydrates
Pearl millet	11.1	4.2	1.6	2.2	1.2	79.7
Proso millet	10.5	3.3	1.3	1.5	0.3	83.1
Red sorghum	11.5	3	1.2	1.5	1.1	81.8
White sorghum	12.2	4.1	1.4	5.4	2.1	74.6

The proximate results for the first farming season of the study indicated that the highest average crude protein(12.2%), and fibre(5.4%) were in the sorghum bicolor; carbohydrates(83.1%) in the proso millet; fat(4.2%) and ash(1.6%) in the pearl millet and moisture range from 0.3-2.1%.

Table-2. Micronutrient results of analyses of the cereals in the first year of the study

Samples	Na (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Ca (mg/kg)	K (mg/kg)
Pearl Millet	288.7	51.7	216	16.5	9	668
Proso Millet	115.4	52.8	345	12	29.3	595
Red Sorghum	548.5	68.8	509.3	16	21	668
White Sorghum	125.1	39.8	498.7	15.7	8	608.8

For the micronutrients, the sorghum bicolor had the highest average amount of Na(548.5 mg/kg), Fe(68.8 mg/kg), and Mg(509.3 mg/kg); K(668.0 mg/kg) was highest in both sorghum bicolor and pearl millet; Mn(16.5 mg/kg) in the pearl millet, and Ca(29.3 mg/kg) in the proso millet.

Table-3. Proximate results of the analyses of the cereals in the first year of the study

Sample	Percentage (%)					
	Protein	Fat	Ash	Fibre	Moisture	Carbohydrates
Pearl Millet	9.5	2.1	1.9	2	8.7	75.8
Proso Millet	10	2.5	1.8	1.6	8.2	75.9
Red Sorghum	9	2.8	1.6	1.6	8.8	76.2
White Sorghum	14.4	2.9	2.1	3.5	17.7	59.4

In the second year of the study, the highest average amount of crude protein(14.4%), fat(2.9%), ash(2.1%) and fibre(3.5%) were in the white sorghum; and carbohydrates(76.2%) in the sorghum bicolor, all working in the moisture ranged from 8.2-17.7%.

Table-4. Micronutrient results of analyses of the cereals in the first year of the study

Samples	Na (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Ca (mg/kg)	K (mg/kg)
Pearl Millet	208.2	49.6	216.8	12.8	11	690
Proso Millet	175.4	62.6	530.2	12	32	520
Red Sorghum	509	70.5	540.2	10	31.8	668
White Sorghum	145.6	40.8	500.7	10.7	18	609

Also in the second season, highest average amounts of Na, Fe, and Mg were respectively 509.0 mg/kg, 70.5 mg/kg, 540.2 mg/kg all in the sorghum bicolor. That of Mn(12.8 mg/kg) and K(690.0 mg/kg) were in the pearl millet, while Ca(32.0 mg/kg) was in the proso millet.

Table-5. Proximate results of analyses of dusa and pito mash in the first year of the study

Sample	Percentage (%)				
	Protein	Fat	Ash	Fibre	Carbohydrates
Dusa	21.48	6.6	1.7	9.91	51.48
Pito mash	20.9	9.3	6	11.38	47.2

Table-6. Proximate results of analyses of dusa and pito mash in the second year of the study

Sample	Percentage (%)				
	Protein	Fat	Ash	Fibre	Carbohydrates
Dusa	22	6.4	6	9.8	58.88
Pito mash	18.4	9.2	5.6	10.92	56.4

Proximate analyses of dusa and pito mash, in the first year (Table 5), working with a moisture range from 0.9- 6.0% identified, among others, the highest average amount of crude protein(21.48%) and carbohydrate(51.48%) in dusa while highest average fat (9.30%), fibre(11.38%) and ash(6.00%) was in pito mash. The proximate results of dusa and pito mash in the second year (Table 6) did not vary much from those of the first year, working with a moisture range of 5.3 to 6.0%

Table-7. Micronutrient results of analyses of dusa and pito mash in the first year of the study

Samples	Na (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Ca (mg/kg)	K (mg/kg)
Dusa	3.24	4.83	12.87	9.12	11.75	9.42
Pito mash	2.98	33.6	10.86	3.62	4.92	11.2

Table-8. Micronutrient results of analyses of dusa and pito mash in the second year of the study

Samples	Na (mg/kg)	Fe (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Ca (mg/kg)	K (mg/kg)
Dusa	4.23	1.71	8.37	2.66	16.63	7.62
Pito mash	4.2	13.14	14.64	3.87	14.73	9.32

4. DISCUSSION

The results compared well with those found in previous works [27]. There was no specific trend to the variations in the various proximate and micronutrient results, but there was a general increase in most of the micro nutrient levels moving on to the second year of study. Micro nutrient levels could easily have been influenced by soils' chemical content, fertilizer application and available plant debris in the soil.

Human mineral deficiency is a worldwide problem, especially in developing countries. Therefore, food analyses are important in order to assess the quality of existing food and estimate dietary intake of various nutrients [28]. Nutrients such as Calcium contribute to optimal bone mass, which can reduce the risk of fractures and osteoporosis [29]. The proso millet had the highest calcium content of 29.3mg/kg and 31.0mg/kg in the second year. Calcium is essential for growth of bones and teeth. The red sorghum had the highest level of sodium (548.5 mg/kg) far in excess of that in the white sorghum (125.1 mg/kg) and the other samples. The level of sodium in the pearl millet was also higher than that in the white sorghum and the proso millet. The iron level was found to be very high in the red sorghum (68.8 mg/kg) compared to the other cereals. The proso millet had the second highest level of iron with a composition of 52.8 mg/kg which is slightly higher than that of the pearl millet and much higher than that in the white sorghum. Iron contributes to the building of heam group in blood. The level of potassium was the same (668.0 mg/kg) for the pearl millet and red sorghum. This was higher than that obtained in the white sorghum (609 mg/kg) and the proso millet (600 mg/kg). Potassium has been found as a vital element in kidney function and ultra filtration. Level of magnesium was found to be highest in the red sorghum than in the white sorghum as well as the proso and pearl millets, both of which had much less magnesium. The pearl millet had the least magnesium content. The pearl millet had very high manganese content than the proso millet. Lower manganese content was found in the red sorghum and white sorghum. The results are consistent with other works which state that the total mineral (ash) content of all millets is often higher than that of sorghum [30]. Values for individual minerals in pearl millet vary widely and are dependent to a large extent on the mineral composition of the soils in the growing areas [30]. 12.2% crude protein, and 5.4% fibre in sorghum, and 83.1% carbohydrates 4.2% fat and 1.6% ash in the proso millet are good levels to contribute to nutrition and health of consumers. Also, 509.0 mg/kg, 70.5 mg/kg, 540.2 mg/kg respectively of Na, Fe, and Mg in the red sorghum, 690.0 mg/kg of K and 12.8 mg/kg of Mn are also valuable amounts of the respective minerals for nutrition and health. Studies have shown that eating whole grains such as millet and sorghum have been linked to protection against clinical conditions such as atherosclerosis, ischemic stroke, obesity, insulin resistance, and diabetes [31]. Magnesium in millet at such levels has been shown to be capable of reducing the severity of asthma and the frequency of migraine attack as well as lower high blood pressure and the risk of cardiac arrest especially in people with atherosclerosis [31]. Magnesium is also a mineral that acts as a co-factor for enzymes, including enzymes involved in the body's use of glucose and insulin secretion.

The human body needs iron to make the oxygen-carrying proteins such as hemoglobin and myoglobin. Iron also makes up part of many proteins in the body. Babies require good levels of iron from their mothers' breasts, and young children may obtain the required iron from appropriate iron-fortified foods or iron supplements. Children between age 1 and 4 grow rapidly, which uses up iron in the body. Adolescents are more prone to low iron levels because of rapid growth rates and inconsistent eating habits. Women's iron requirements are up to 15 mg/day and 18 mg/day for those between ages 19 to 50 years. Based on the uses of the cereal grains analysed, it was found that most of the household nutrition in the districts is derived from these cereals. Pearl millet was used for making eight different diets; finger millet five different diets; red sorghum and white sorghum five different diets each.

Also, eating foods such as millet which is high in insoluble fibre could help women avoid gallstone. Dietary fibre though edible, resists the hydrolysis by alimentary tract enzymes. Fibre is however not totally unavailable because a portion of it is metabolised to volatile fatty acids in the gastrointestinal tract. Dietary fibre also provides therapeutic effects [32]. It was found that a diet rich in fiber from whole grains, such as millet, and fruit offered significant protection against breast cancer for pre-menopausal women. Antinutrients found in grains include digestive enzyme inhibitors, phytic acid, haemagglutinins, and phenolics and tannins. Cereals and legumes are often rich in fibre-associated anti-nutritional factors (namely phytate, polyphenols, oxalate) [33] that reduce the bioavailability of minerals. Some antinutrients such as phenolics and saponins have health advantages as they have been shown to reduce the risk of cancer of the colon and breast in animals [34]. Phytic acid, lectins, phenolics, amylase inhibitors and saponins have also been shown to lower plasma glucose, insulin and/or plasma cholesterol and triacylglycerols [35]. Levels of antinutrients in the grains were not assessed, but certainly it is understood that presence of nutrients in the grains does not necessitate their bioavailability, the proportion of the total nutrient content in a food, meal or diet that is utilized for normal metabolic functions. Many minerals and trace elements are inefficiently and variably absorbed from the diet, but from these reasonably large quantities, larger amounts of the minerals are expected to be bioavailable.

The value added uses included the use of the aqueous extract of the ashes of stalks of the millet to flavour soups as well as prevent microbial fermentation of food products; the use of the ashes to preserve leguminous seeds; use of the stalks of sorghum as cooking fuel and for making baskets, and mats as beddings; use of the husk of sorghum to feed cattle in the dry season when most fodder has dried; use of two food by-products ('dusa' and pito mash) in feeding poultry and non-ruminants.

In the first year of the study, the pearl millet recorded the highest percentage ash composition (1.6%), fat composition (4.2%), manganese content (16.5mg/kg) and a least magnesium composition of 216mg/kg. Also, the proso millet was found to have the highest carbohydrates composition and calcium level, and the lowest fibre, moisture, protein, sodium, potassium and manganese levels. Proso millet will therefore be a good source of energy though with the shortest storage life due to presence of moisture. The white sorghum had the highest moisture, fibre and protein compositions. It also had the lowest carbohydrate, calcium and iron levels. This indicate that the white sorghum will have the shortest shelf-life due to presence of moisture after drying, and could also have a high nutritional quality but may not be good for persons who require high levels of calcium and iron in their diet. The red sorghum had the lowest ash content which indicates that it is of the highest quality. It also had the highest concentration of sodium, iron, potassium and magnesium and the lowest fat and fibre content. Red sorghum therefore appears to contain the essential nutrients for growth of an individual.

The determination of food composition is fundamental to the establishment of the nutritional value and the overall acceptance of the food from the consumer's stand point. This work will further influence the acceptability of the cereals as food.

5. CONCLUSION

White sorghum was found to have the highest protein and fiber composition of 14.4% and 3.5% respectively. However, it has high fat and ash compositions of 2.9% and 2.1% respectively. The red sorghum contained the lowest ash content in both years of study (1.2% and 1.6% respectively) and thus has the lowest mineral concentration amongst the grain analysed. White sorghum has high moisture (17.7%), high protein (14.4%) and fibre (3.5%), and low carbohydrate content (59.4%).

From the results and discussion, the grains are used in making at least 23 different diets and would have been making major contribution to food security, nutrition and health of the people in the two districts. The crop and food by-products are relevant for use in the production of farm animals to further provide nutrition and income, alongside the growing of crops. Both dusa and pito mash contained enough good nutrients that can support growth of poultry and non-ruminants. The utilisation of the ashes, ash extract, husk and straw of the millet and sorghum contribute to income and wellbeing of producers and users of millet and sorghum. Millet and sorghum therefore have relevant biochemical contribution to nutrition, health and wealth of the people.

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