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PHYSICOCHEMICAL PROPERTIES, PROXIMATE AND FUNCTIONAL PROPERTIES OF DIFFERENT SORGHUM VARIETIES PRODUCED/ADAPTED UNDER SORPARI AND MARKETED/LOCAL SORGHUM IN SOMALI REGIONAL STATE




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Executive Summary

Sorghum is one the staple food or crop that widely consumed in Somali community. The study was conducted in Somali Regional state with objective to analyze proximate, functional and physical of different sorghum varieties produced in Somali reginal state. Six different types of samples such as *Dekeka, AdoKaye, ESH-1, Melkam, ASSO-1* and JLM control as control sample were collected. The collected sorghum samples were individually grounded to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis. Proximate composition such as crude Protein, crude Fat, crude fiber, moisture content, carbohydrate, total energy, different minerals like Calcium, Iron, Magnesium and Total phosphorous were determined by AOAC. The functional and physical properties of the sorghum were determined different standard procedures. Based on the result all locally adapted those sorghum varieties adapted by the Somali region research institute were better in both macro and micro nutrients especially when it comes fiber, total ash, moisture content as compared to the control sample with brand name *JLM control* which imported from abroad. All samples's protein content is very loaw which in the range 5.23 to 6.50%. There is significant different in different components of rice between different varieties at $p<0.05$. Significance difference were also observed at $p<0.05$ in minerals content such as Calcium, zinc, iron and Total Phosphorous. The functional and physical properties of different sorghum varieties under study are almost not significantly different at $p<0.05$. Overall, from the finding we conclude that, almost all locally adapted sorghum varieties have better in nutritional content especially moisture, ash and fiber and very poor in protein content. Therefore, all actors on sorghum should apply fortification especially bio-fortification to enhance the nutrient content in particular the protein content as sorghum is one of the staple crops in Somali region.

Key words: Sorghum, Proximate composition, Functional Properties, Physical properties.

CHAPTER ONE

1. INTRODUCTION

1.2. Background

Judging from the 2017 available data from FAOSTAT, Africa is the largest contributor to world sorghum production, with a production quantity of approximately 29.7 million tonnes [1]. Sorghum grains are a widely adaptable species and mostly cultivated in tropical, subtropical and temperate regions [4]. As a drought tolerant and a climate-smart crop under the prevailing realities of climate change, its utilization is spread across diverse industries, including for animal feed, biofuels, forage, ethanol production and fodder preservation [5,21]. It remains one of the most versatile food crops in Africa.

Sorghum belongs to the Andropogoneae tribe and Poaceae family and is a known C4 crop (i.e., it uses the C4 carbon fixation pathway to increase its photosynthetic efficiency), particularly adapted to hot, drought-prone and semi-arid tropical environments with less rainfall. It is said to have originated from the Northeast quadrant of Africa [7]. Millet, barley, teff and wheat are also members of the Poaceae family [8] and are likewise known for their ecological dominance in many ecosystems, as well as their capacity to grow in low rainfall and harsh environmental extremes conditions [9]. As indicated by Ratnavathi and Komala [10], over 20 sorghum species are known and these include: Sorghum almum, Sorghum amplum, Sorghum angustum, Sorghum arundinaceum, Sorghum bicolor, Sorghum brachypodum, Sorghum bulbosum, Sorghum burmahicum, Sorghum ecarinatum, Sorghum exstans, Sorghum grande, Sorghum halepense, Sorghum interjectum, Sorghum intrans, Sorghum laxiflorum, Sorghum leiocladum, Sorghum macrospermum, Sorghum matarankense, Sorghum nitidum, Sorghum plumosum, Sorghum propinquum, Sorghum purpureosericeum, Sorghum stipoideum, Sorghum timorense, Sorghum trichocladum, Sorghum versicolor, Sorghum verticiliflorum and Sorghum vulgare var. technicum. Notable among these is S. bicolor, known for its food use. Sorghum grains can typically be white, pale orange, tan, red, dark brown and brownish-red [2,11,12], but the major commercially available ones are the black, white and red. The color of the testa (seed coat or pericarp) are genetic characters controlled by the R and Y genes [7,13].

In developing countries, especially in Africa, over 78% of the sorghum produced is used for food, with about 14% for animal feeding and 7% for other uses [14]. Extensive studies on the composition of sorghum have indicated that the grain is a good source of energy, carbohydrates, polyunsaturated fatty acids (PUFAs), minerals, vitamins and some essential amino acids [12,13,15]. Proximate composition of sorghum from earlier studies has indicated that its protein content ranges from 6.2% to 14.9%, carbohydrates (54.6%–85.2%), fat (1.3%–10.5%), ash (0.9%–4.2%) and fibre (1.4%–26.1%). The variations in these values might possibly be related to the genotypes of the grains and growth conditions, as well as other cultivar specific differences. As indicated by previous authors [12,16], starch, including dietary fiber derived from cellulosic cell wall carbohydrates, is a major component of sorghum, constituting about 75% of the grain. The presence of non-starch polysaccharides (NSPs) in sorghum grains could be suggestive of their potential ability to improve bowel function and lower cholesterol levels [17,18].

Sorghum contains both some of the essential and non-essential amino acids, including alanine (7.34–9.62 g/100 g), aspartic acid (4.83–7.06 g/100 g), glutamic acid (17.5–28.12 g/100 g), leucine (12.02–14.48 g/100 g), phenyalanine (4.03–5.62 g/100 g), proline (6.66–12.34 g/100 g) and valine (4.22–6.86 g/100 g), but limited in lysine and tryptophan. It does, however, have beneficial bioactive peptides and protein fractions, including 2-kDa antiviral peptide, α-kafirin, karifin, protease, amylase and xylanase inhibitors, as well as cationic peroxidase, which exerts anticancer, antiviral, antioxidant, cholesterol-lowering and antihypertensive effects [19–22].

Available studies have also indicated that sorghum contain minerals and vitamins, both of which constitute part the essential nutrients required by humans to perform the functions necessary to sustain life. Sorghum contains fairly high levels of potassium (K) (900–6957.67 mg/kg), and phosphorus (P) (1498–3787.25 mg/kg), minerals known to assist with muscle movement, keeping the nervous system healthy and building strong bones and teeth. Vital vitamins reported in sorghum also include the B-vitamins (0.1–19.9 mg/100 g), vitamin E (1.38 mg/100 g). Trace amounts (maximum of 0.01 mg/100 g) of β-carotene (a vitamin and precursor of vitamin A) have also been reported [23,24], an indication that sorghum cannot be considered a good source of β-carotene and vitamin A. Considering the nutrient deficiencies in under-developed and developing countries in Africa, the limitation of some of these vital nutrients could be addressed by complementing sorghum with legumes (a plant source), as well as animal products. This will

contribute to ensuring a nutritional balance of these nutrients, and assist in alleviating and counteracting micronutrient deficiencies.

1.2. Statement of the problem

Sorghum (*Sorghum bicolor* L) Mönch is the world's fourth major cereal in terms of production with annual production volume of about 60million MT from land cover of over 40million hectares. Sorghum is a staple food for over 500 million people in Africa, Asia and Latin America [25].

Ethiopia is one of the major producers of sorghum, ranking 7th in the world and third in Africa contributing 12% and 5% of African and world annual production respectively. Sorghum in Ethiopia accounts for about 18% of annual production and 16% of land cover allocated for the entire grain crops including cereals, pulses and oilseeds [26]. Sorghum is a staple food for millions in Ethiopia and is also widely used for making different local beverages. Its stalks are used as feed and as construction material. In recent years sorghum has also become an important export item, mainly to middle-eastern market.

Sorghum (Sorghum bicolor L. Moench) is the sixth most planted crop in the world, and it is one of the most important cereals used as a staple food for those primarily living in arid and semiarid areas [27]. In Africa, it is the second most important cereal in which around 500 million people depend on it as their daily consumptions (1). It is consumed mostly in northern China, India, and southern Russia, where about 85% of the crops are consumed directly as human food [28]. Sorghum has greater drought tolerance, soil toxicities, and temperature variation than other cereals and requires minimal fertilizers for cultivation, thus playing a critical role for food security in some semiarid areas of Asia, Africa, and Latin America [29]. It is considered one of the potential crops to alleviate the challenges of recurrent drought in Africa.

In Ethiopia, sorghum is the third (3rd) most important staple cereal crop after teff and maize [30]. Sorghum crop is grown in almost all regions of Ethiopia and used as a staple food crop on which the lives of millions of poor Ethiopians depend on it. Sorghum is used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, Nifro, infant food, syrup, and also, the leaf and stalk are used for animal feed, and further, the stalks are used for the construction of houses and fences and as fuelwood. Different research centers under Somali

region pastoral and Agro-pastoral research institute have been working on the sorghum over the last many years; during this period, varieties of sorghum have been released. The released varieties had different specific qualities such as disease resistance, malt quality, and earliness. However, none of the varieties had no comprehensive nutritional profile data let it be macro-nutrient, micronutrient and other content, since the quality of sorghum produced worldwide is affected by biotic and abiotic constraints [31]. Therefore, the aim of the present study was to profile the nutritional value, mineral contents, functional and physical properties of sorghum varieties adapted and released by SoRPARI and grown in different parts of Somali region of Ethiopia. Knowing the sorghum nutritional diversity would have a direct impact on the improvement of sorghum for quality breeding and for food product development to reduce the prevalence of food insecurity, malnutrition, and mineral deficiency, especially for those low-income communities.

1.3. Objective

1.3.1. General Objective:

The general objective of the study is to profile the nutritional, minerals, anti-nutritional content functional and physical properties of different sorghum varieties grown under SoRPARI and other local or marketed one.

1.3.2. Specific objective

The specific objectives of the research were;

- To assess the proximate (macronutrient and micronutrient) composition of different sorghum varieties grown in study area
- To evaluate the functional properties of different sorghum varieties flour
- To assess the physical properties of different sorghum varieties grown in study areas.

1.4. Significance of the study

This study is so important as it is the 1st in its nature to conduct such study on different sorghum varieties proximate composition, and physico-chemical properties of different variety adapted by SoRPARI and some grown in Somali regional state (SRS). The outcome of the study will be important to get up to date data on the nutritional composition, physical, functional and anti-nutritional properties of the different sorghum varieties grown in SRS. The result obtained from

this study will further be important for future researcher as baseline information to conduct their research. Based on the recommendation come out from this study, policy maker, government, non-Government organization and other interested institutions working on the area will expected to get up to date information from the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Origin, Description and Agro-Ecology of Sorghum

The crop sorghum originated in northeastern Africa, where large variability in wild and cultivated forms remains (32). It is a self-pollinating summer plant classified under the family Poaceae (grass family), tribe and Aropogoneae, species, Sorghum bicolor (L.) Moench. It is the fifth most important cereal crop in the world, after wheat, maize, rice and barley (33) and the second major crop (after maize) across all agro-ecologies in Africa (34; 35). Domesticated in North Africa, possibly in the Nile or Ethiopian regions around 1000 BC. Its cultivation likely spread from Ethiopia, where it is believed domestication occurred, to Africa, the Middle East, and India along trade and shipping routes over 3,000 years ago (32, 36).

Sorghum used as a source of food, feed, fiber and fuel and is one of the most important cereal crops grown in arid and semi-arid areas of the world, receiving 400 to 800 mm of rainfall annually (37). Sorghum known under a variety of names: great millet and guinea corn in West Africa, kaffir corn in South Africa, durra in Sudan, Mtama in East Africa, johaalacholam in India and kaoliang in China. Cultivated sorghum divided into five groups namely bicolor, guinea, caudatum, kafir and dura. Sorghum varieties have used for many years for poultry and human consumption, especially in Africa and Asia, and have been shown to vary in physical and chemical characteristics (38). Sorghum is cultivated as a major food crop in several countries in South Asia, Africa, and Central America. The crop is mainly grows in tropical and subtropical areas that are marginal and stress prone. Sorghum known as guinea-corn, dawa, or sorgho in West Africa, durra in the Sudan, Mashelia in Ethiopia and Eritrea, Mtama in East Africa, Kaffircorn, Mabele, or Amabele in southern Africa, and as jowar, jonna, cholam or jola in the Indian subcontinent. Sorghum is a major cereal crop in arid and semi-arid areas of the world. It is a staple crop of semiarid sub-Saharan Africa. Sorghum is a major food and nutritional security crop to more than 100 million people in Eastern horn of Africa, owing to its resilience to drought and other production constraints (39). Sorghum is indigenous to Africa and accounts for 43% of all major food staples produced in sub-Saharan Africa considered sorghum as a traditional crop

in much of Africa and Asia and an introduced and hybridized crop in the Western hemisphere (40).

Sorghum (Sorghum bicolor) is one of the most widely grown cereal crops in Ethiopia. It is a main food crop on which the lives of millions of poor Ethiopians depend. It has tremendous uses for the Ethiopian farmer and no part of this plant is ignored. Sorghum grows in a wide range of agro-ecologies most importantly in the moisture stressed parts where other crops can least survive and food insecurity is rampant. The primary and most important source of sorghum germplasm introduction for Ethiopia has been the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). From the very beginning of sorghum research in Ethiopia, a significant number of sorghum germplasm lines have been introduced from ICRISAT and evaluated annually for various desirable traits. The second most important source has been the International Sorghum and Millets (INTSORMIL) collaborative research support program (41).

Sorghum used in various ways in our country; the grain is used for human foods such as injera, bread, porridge, Nifro, infant food, syrup, and local beverage known as “Tella” and “Arekie.” In addition, the leaf and stalk used for animal feed, and further, the stalks used for the construction of houses and fences and as fuel wood (42).

2.2. Overview of Global Sorghum Production

2.2.1. Production

Sorghum (*Sorghum bicolor* L.) Mönch is the world’s fourth major cereal in terms of production. In recent years, annual world production of sorghum averaged at about 60 million tons with only a slight net declining trend. As Fig. 2.1 shows, the area covered by sorghum seems to remain more or less the same.

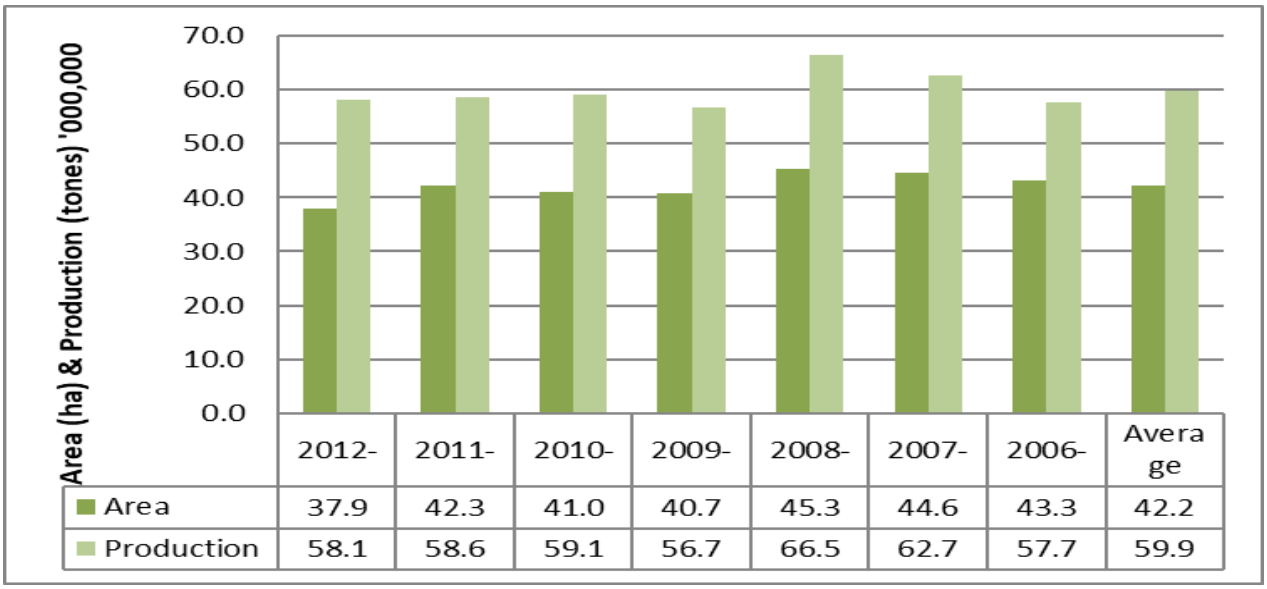


Figure 2.1: World Sorghum production and area cover trend. (Source: FAOSTAT 2006-12)

The crop is mainly produced in Africa, Asia and the Americas. With an average annual volume contribution of 24.5 million tons, Africa has emerged as the leading sorghum producer in the years between 2006 and 2012. Moreover, higher number of hectares of sorghum is cultivated in Africa than in any other continents (Table 2.1). However, the yield per unit area for Africa was significantly lower than yields in both the Americas and Asia.

Table 2.1: Sorghum production in major production continents

Region	Area (000'000 ha)	Production (000'000 MT)	Yield (MT/ha)
Africa	25.69	24.51	0.95
Americas	6.18	21.90	3.54
Asia	8.25	10.54	1.28
World	42.15	59.91	1.42

Source: Compilation from FAOSTAT 2006-2012

The United States of America is the leading sorghum producer accounting for about 15% of the world total annual production. Nigeria and India follow in 2nd and 3rd position contributing about 13% and 12% of the world annual production, respectively. Over 77% of the total annual world sorghum production is produced by ten countries, with the United States, Nigeria, India and Mexico together contributing about 50 %. (Fig. 2.2). Ethiopia contributes almost 5% of total world production.

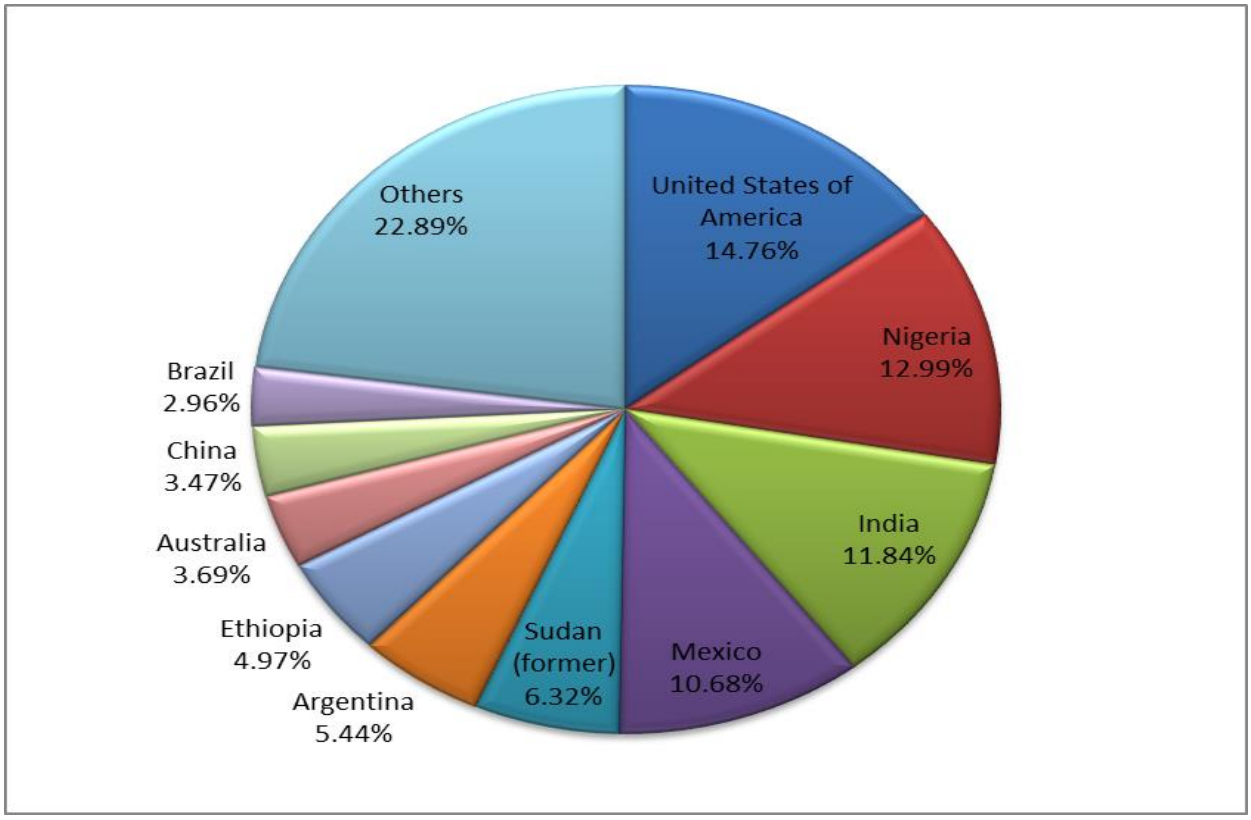


Figure 2.2: World sorghum producers (averaged 2006-2012) (Source: FAOSTAT 2006-12)

2.2.2. Global Sorghum consumption

Sorghum is used as human food, animal feed, and in the production of alcohol and other industrial products. The larger proportion which is estimated to account for about 55% of the annual total production is used for human food (43). There is an increasing trend of sorghum consumption as human food, which was earlier reported to be about 35% of total annual production (44). Sorghum is assumed to be a staple food for more than 500 million people in Africa, Asia and Latin America (25). Sorghum is consumed as whole grain or processed into

flour. As stated earlier, Mexico and Nigeria in this order, take the first and second position of sorghum consuming countries. Over 99% of Ethiopian production is consumed domestically.

2.3. Sorghum Production and Productivity in Ethiopia

The presence of wild and cultivated sorghums in Ethiopia reveals that Ethiopia is the primary center of origin and center of diversity (45). The diversity of sorghum, studying genetic diversity and biochemical composition of sorghum germplasm from Ethiopia is very important for several reasons (46).

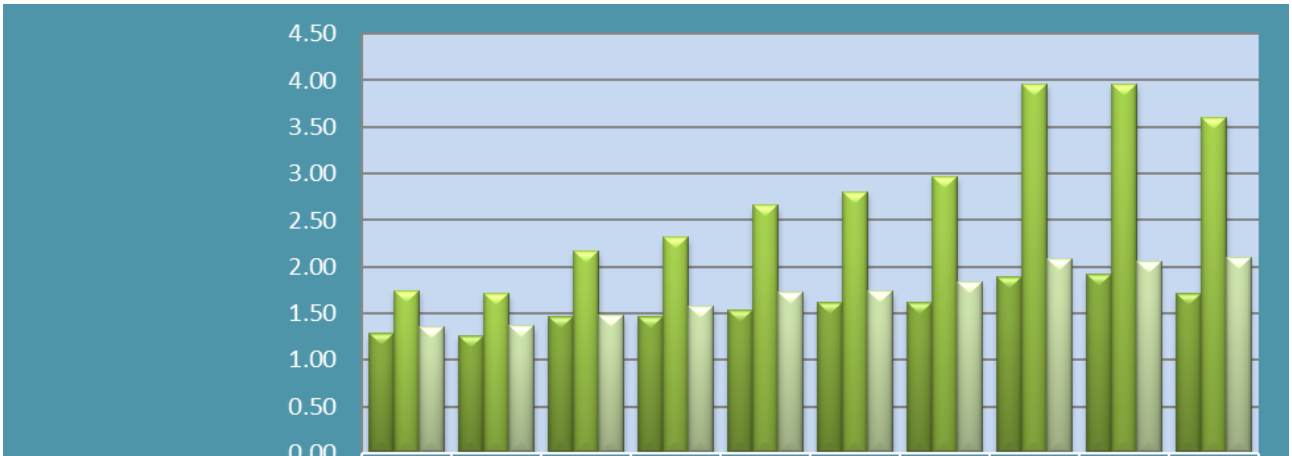
In sub-Saharan Africa, agricultural production is dominated by cereal-based systems. Ethiopia is the third largest sorghum producer in Africa after Nigeria and Sudan (47). In Ethiopia, sorghum is the third most important crop in area of production after tef and maize, and third in volume of production following maize and teff (48). It is the third most important cereal crop after maize and rice in sub-Saharan Africa (49).

The growth and yield of sorghum, one of the major crops in these dry land regions of Africa, is often limited by drought. In the dry land environments, drought is not only the result of limited annual rainfall, but is also due to the rainfall characteristics, mainly the delay in the onset and early cessation of the main rainfall. The authors (49) reported that the potential of sorghum production affected by abiotic and biotic factors and socio-economic constraints. Diseases, insect pests and weeds are key biotic impediments to yield and quality losses in sorghum production.

In Ethiopia, the sorghum varieties that have officially promoted and sourced from other countries, or locally bred using externally sourced genetic resources and landraces (49). Ethiopia has a diverse wealth of sorghum germplasm adapted to a range of altitudes and rainfall conditions. From the five morphological races of sorghum (bicolor, guinea, caudatum, durra and kafir), all, except kafir, are all grown in Ethiopia. Important traits reported from the Ethiopian sorghum include cold tolerance, drought resistance, resistance to sorghum shoot fly, disease and pest resistance, grain quality and resistance to grain mould, high sugar content in the stalks, and high lysine and protein content. Ethiopian often regarded as the centre of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wild forms (50).

2.4. Production volume and land cover of sorghum in Ethiopia

According to the Central Statistical Agency of Ethiopia (51) of the entire grain crops (cereal, pulses, oilseeds) production in the country, sorghum accounts for 18% and 16% volume produced and land cover respectively. Sorghum was produced over an area of 1.9 million hectares in 2011/12 cropping season (26), which slightly reduced to 1.71 in 2012/13 cropping season (51). Accordingly, the volume also reduced from 3.95 million MT in 2011/12 cropping season to 3.6 million MT in 2012/13. However slight increase of yield per unit area of land was observed. Both area cover and production of sorghum showed a net increase of 50% and 127% respectively between 2003/4 and 2012/13 (Fig. 2.3). The yield per unit area also increased from about 1.36 MT in 2003/4 to 2.11 MT in 2012/13.



	2003/4	2004/5	2005/6	2006/7	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13
Area '000,000 (ha)	1.28	1.25	1.47	1.46	1.53	1.62	1.62	1.90	1.92	1.71
Prodution '000,000 (MT)	1.74	1.72	2.17	2.32	2.66	2.80	2.97	3.96	3.95	3.60
Yield/ha (MT)	1.36	1.37	1.48	1.58	1.73	1.74	1.84	2.09	2.05	2.11

Figure 2.3: Area (ha) and production (MT) trend of sorghum in Ethiopia. ***Source: CSA 2004-13***

2.5. Uses of sorghum in Ethiopia:

The crop is a staple food and a major source of energy for millions of Ethiopians (52). Sorghum is an important food security crop particularly for the growers, consuming over 87% of what they produce. It has high carbohydrate content (76.5%), is fairly rich in fat (3.1%), but has low levels of essential amino acids (poor quality protein). Moreover, anti-nutritional factors phytates and tannis which can reduce bioavailability of proteins, starch and minerals have been reported in sorghum such as (53).

Sorghum grain is traditionally used as main ingredient in different food products such as Enjera, Nifro , genfo (porridge), Kitta (flat bread from unfermented dough), Kollo(rosted grain), bread and weaning foods. It is consumed by all age classes. Children start consuming sorghum in the form of thin porridge and soup. The best grain for the preparation of such food stuffs is the bold and creamy white colored sorghum grains. Traditional homemade beverages are also prepared from sorghum, including Areke, Bordie and Tella. Generally, creamy white, yellow and red grain types are used for making Injera and other food recipes. The brown and chalky white color groups with high polyphenol content are mostly preferred to make local beverages. Sorghum is the second most important crop for Enjera quality next to teff. The stalk is also used for animal feed, for construction of houses and fences and as fuel. The current average annual per-capita consumption is estimated to be about 40Kg. Owing to its drought resistance, sorghum promises to be a food security crop in many parts of the country (54, 55). In recent years sorghum has also become an important export commodity.

2.6. **Proximate chemical composition of sorghum**

2.6.1 Moisture content:

Osman, (56) analyzed four Sudanese sorghum genotypes and found the moisture content to range from 6.36 to 6.67%. The moisture content of two sorghum cultivars (African and Indian) was found to be 7.49% and 6.77% respectively (57). The moisture content of different cultivars of sorghum was reported between 8 and 12% (58). Generally, the moisture content varies according to the humidity, cultivar, area and environment, as claimed by, (59).

2.6.2 Ash content

The ash content of food stuffs represents the inorganic residue remaining after the organic matter has been burned. Dickoet al. (58) reported that the ash content of different cultivars of sorghum ranged between 1 and 4%. Awadelkareem, (57) found that the ash contents of two sorghum (African and Indian) cultivars were 2.29% and 1.54% respectively. Osman, (56) who studied the ash content of four Sudanese sorghum genotype reported a range from 1.77% to 1.96%. Yousif and Magboul (60) determined the ash content of different cultivars of dura (sorghum), grown in different parts of Sudan, to range from 1.2 to 2.0%.

2.6.3 Protein content:

Yousif and Magboul (60) who analyzed fifteen different cultivars of dura (sorghum) grown in different parts of Sudan, found that their protein ranged from 6.9 to 12.8%. The protein content of two cultivars of sorghum (African and Asian) was found to be 14.00 and 10.02% respectively (57). Elsayed (61) analyzed Tabat, Mugud and Fetarita and found that their protein contents were 6.64, 9.11 and 12.71% respectively. Sastryet al, (62) reported a range of 10.1 – 16.8% for eight sorghum genotypes. Osman (56) reported that the protein content of four Sudanese sorghum genotypes ranged from 12.24% to 13.67%. reported that the crude protein content of different cultivars of sorghum was between 7 and 15% Dickoet al. (58).

Waggle et al. (63) reported that the average protein content of sorghum varies according to a number of factors, including planting date, cultivars, seed size and temperature. The quality of protein is primarily a function of its essential amino acids composition; the function of dietary protein is to satisfy the body needs for nitrogen and essential amino acid (64).

2.6.4 Fiber content

The term dietary fiber was used to describe a variety of indigestible plant polysaccharides including cellulose, hemicellulose, pectin and various lignified compounds (64). Klobfensteinet al.(65) compared several sources of cereal fiber and found that sorghum bran was effective in lowering serum and liver cholesterol level in guinea pigs. Yousif and Magboul (60) reported the crude fiber content in fifteen different cultivars of dura (sorghum) grown in different parts of the Sudan, ranged from 1.4 to 2.6%. However, the fiber content in several sorghum cultivars was found to be between 1.2 and 6.6% (66).

2.6.5 Fat content:

The lipids of sorghum are important nutritionally and also influence the flavor and storage characteristic of sorghum, (67). Yousif and Magboul (60) studied fifteen different cultivars of Dura (sorghum) grown in different parts of Sudan and found that the fat content ranged between 3.0 and 4.1%. Dickoet al. (58) reported that the fat content of different cultivars of sorghum were between 1.5 and 6.0%. According to Shadad (68), fat content of twenty varieties of dura (sorghum) grown in different parts of Sudan ranged from 1.5 to 4.6%.

2.6.6 Carbohydrate content:

According to Yousif and Magboul (60) carbohydrate contents of fifteen different cultivars of dura (sorghum) grown in different parts of Sudan, were ranged from 72.4 to 78.7%. Osman (56) reported that the carbohydrate content of four sorghum genotypes ranged from 72.31 to 73.88%. Dickoet al. (58) reported that the carbohydrate contents of different cultivars of sorghum were between 65 and 80%.

2.7 Minerals content:

The term mineral usually refers to elements other than C, H, O and N that are present in foods, these four non-mineral elements are present primarily in organic molecules and water, and constitute about 99% of the total number of atoms living systems. Although minerals are normally found in relatively low amount in food, their importance in this food is use known. The daily requirement of the elements of the calcium, sodium and potassium as follows: calcium (1000mg/day), Sodium (3000mg/day), Potassium (1500mg/day) and magnesium (350mg/day). In the sorghum kernel the mineral matter is unevenly distributed and is more concentrated in the germ and the seed-coat (69). Minerals from plant sources, particularly those from plant seeds, are less bio accessible than those from animal source due to the phytic acid, tannin and fiber present in the plant. Bioavailability of minerals can be defined (70) as the proportion of the total minerals in food meal or diet that is utilized for normal body function (metabolic processes).

2.7.1 Sodium content:

Sodium content in two cultivars of sorghum (African and Indian) was found to be 6.18 and 5.83mg/100g respectively, Awadelkareem (57). Raihanatu et.al. (71) who studied the sodium content of different sorghum cultivars reported a range between 3.07 and 5.01%.

2.7.2 Potassium content:

Awadelkareem, (57) found that total potassium contents in two cultivars of sorghum, African and Indian, were 225.23 and 367.51 mg/100g respectively. The potassium content of four sorghum cultivars ranged from 3.00 to 12.03% according to Raihanatu et al. (71).

2.7.3 Calcium content:

Calcium content in two cultivars of sorghum (African and Indian) was found to be 2.43 and 3.33%, respectively, (57). The calcium content of three cultivars of sorghum (Wad Ahmed, Winter white and Winter red) were found to be 10.27, 14.40 and 5.43mg/100g respectively (75). The calcium content of two cultivars of sorghum (Tabat and Wad Ahmed) was found to be 9.34 and 75.7% respectively (72). Dickson, et al (73) reported that the calcium content of six cultivars of sorghum ranged from 5.2 to 38.1mg/100g. Raihanatuet al. (71) reported calcium content between 6.19 to 12.6% in four sorghum cultivars.

2.7.4 Magnesium content:

Dickson et al.(73) who studied six cultivars of sorghum found that their magnesium content ranged between 109.8 and 224.1mg/100g. Magnesium content of four sorghum cultivars ranged between 2.12 to 4.81% was reported by (71). The magnesium content of four new sorghum lines was reported between 120 and 135mg/100g (74).

2.7.5 Phosphorus content:

Abdelseed (74) who determined the phosphorus content of four sorghum genotype reported a range from 331.46 to 388.75 mg/100g. Awadelkareem (57) who studied the minerals content of two sorghum cultivars (African and Indian), found phosphorus contents of 263.3 and 314.15 mg/100g, respectively. The phosphorus contents in two sorghum cultivars (Tabat and Wad Ahmed) reported by Mohammed (2009) were 287.05 and 296.55 mg/100g respectively. Nour, (75) reported phosphorus content of 422.45mg/100g (Wad Ahmed), 410.28 mg/100g (Winter white) and 423.66mg/100g (Winter red).

CHAPTER THREE

3. MATERIALS AND METHOD

3.1. Structure of the experiment work

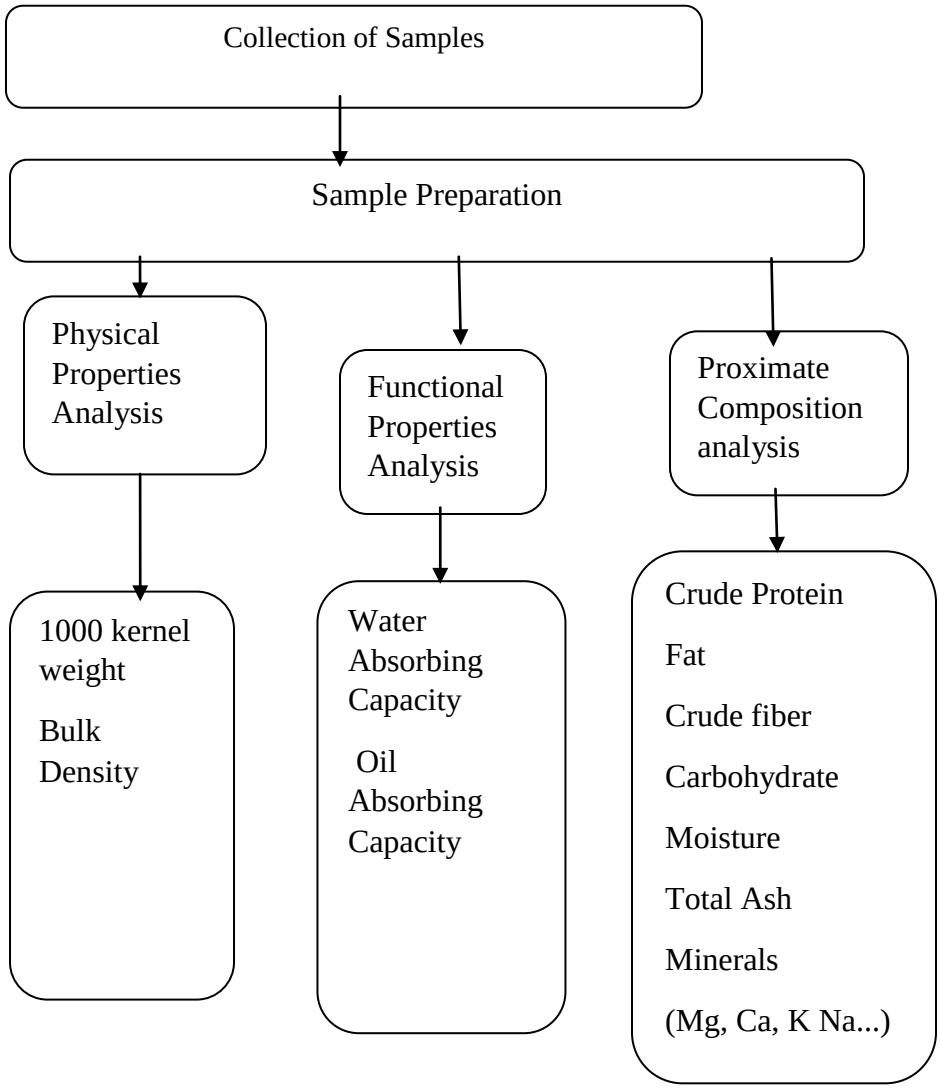


Fig 3.1: Experimental structure

3.2. Materials and Equipment Used

Five different sorghum varieties produced/adapted under SoRPARI were collected from Dolo-Ado research center and one popular widely marketed variety as a control was purchased from the local market in Jigjiga. The five varieties produced or adapted under SoRPARI that were

going to use for this study includes *Dekeka, AdoKaye, ESH-1, Melkam, ASSO-1*, whereas the control sorghum type might be the one with most likely used by local community named *JLM-Control* for this particular study. Only whole sorghum grains without any physical damage or insect infestation were selected for analysis. All equipment used in sample preparation were expected to be obtained from SoRPARI laboratories and missed equipment can be used from local institutes Further, after bringing to the laboratory, sorghum samples were individually ground to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis.

3.3. Physical properties

A. Hundred (100) kernel weight and bulk density

One hundred sorghum kernels were randomly selected and weighed separately. For bulk density, 50 g of sorghum grains was weighed and will be dropped into a graduated glass measuring cylinder from a constant height (approximately 30 cm). The volume occupied by sorghum samples were recorded and bulk density were calculated as g/ml ratio [76, 77].

3.4. Proximate Composition

3.4.1. Moisture content

The moisture content of the samples was determined by drying 10g of sample in an air oven at 105^{o}C to constant weight (16 -18 h).

3.4.2. Protein content of the flours

Protein content was determined according to [78] using the official method 979.09, which comprised three major steps: digestions, distillation and titration, and quantification.

Digestion

Fresh samples (in duplicate) of each 0.5g was added into Tecator tubes and 6ml of acid mixture (5parts of concentrated ortho-phosphoric acid and 95 parts of concentrated sulfuric acid) was added into each tube and mixed, and 3.5ml of 30% hydrogen peroxide was added step by step, resulting in violent reaction. Following the cessation of violet reaction, the tubes should be shaken and placed back to the rack. Catalyst mixture (ground 0.5g of selenium metal with 100g of potassium sulfate) of 3g was added into each tube and was allowed to stand for about 10 minutes before digestion. Following the attainment of digester temperature at 370^{o}C, the tubes

was low ill bed into the digester. The digestion was continue until a clear solution will be obtained (~ after 4 hours). The tubes in the rack should be cooled in a fumehood. 25 ml of de-ionized water will be added and the mixture should be shaken to avoid precipitation of sulfate in the solution.

Distillation and titration

The digested and diluted sample solution was distilled using boric acid and the distillate was subjected to titration using 0.1N hydrochloric acid until reddish color appeared.

Quantification of crude protein concentration

$$\text{Nitrogen } \% = \frac{\text{VHCl} * [\text{HCl}]}{\text{Wo}} * 14 * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\text{Protein } \% = 6.25 * \% \text{ Nitrogen} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where; V is the volume of HCl consumed in liter, N is the normality of HCl (0.1N), W_O is the sample weight on dry mass basis and 14 is the molecular weight of nitrogen.

3.4.3. Experimental analysis of fat

The fat content of the complementary food samples (flours) was determined using a semi-continuous solvent extraction method (Soxhlet method) following the procedures of AOAC 960.39 [32]. In this method, the solvent builds up in the extraction chamber for 5-10 minutes and completely surrounds the sample and then siphons back to the boiling flask.

The crude fat content (percent weight by weight) was calculated as follows:

$$F = \left(\frac{W2 - W1}{W}\right) * 100\% \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where;

F= Crude fat content in percent weight by weight

W_1 = Weight of the extraction flask in gram (g)

W_2 = Weight of the extraction flask and the dried crude fat in gram (g)

W = Weight of sample in gram (g)

3.4.4. Experimental analysis of ash content

The ash content was determined based on AOAC [32] using the official method 923.03. Briefly, porcelain crucible that is will behind using distilled water was placed in a muffle furnace at 550^{o}C for 30 minutes. Then, the crucibles were cooled by placing it in desiccators for 30 minutes at room temperature. Following this step, they were weighed to the nearest milligram (M_1) using the dried, cooled and weighed crucible, 2.5g of fresh sample together (M_2). Then the sample was thoroughly char in fume-hood by placing it on a hot plate, and increasing the temperature slowly until smoking ceases. After the completion of charring, the sample was placed into the muffle furnace at 550^{o}C for 5 hours. The ignition was continue by cooling for 1hour and weighing until a clean and white ash was obtained, which was then measured to the nearest milligram (M_3).

$$\text{Total ash(in \% weight by weight)} = \left(\frac{M3-M1}{M2-M1}\right) * 100 \ldots\ldots\ldots\ldots\ldots (5)$$ Where:

(M_2-M_1) is the weight of sample in gram (g) on dry basis
(M_3-M_1) is the weight of ash in gram (g)

3.4.5. Experimental analysis of carbohydrates

The total available carbohydrate concentration was determined by difference according to AOAC official method, (922.02, 925. 05).

% Carbohydrate = 100% - (%moisture + %protein + %fat + %ash + % crude fiber)…. (6)

3.4.6. Experimental analysis of the crude fiber content

The crude fiber content of the complementary foods (flour) was determined by using the official method of AOAC [78]. The method involved the digestion of a fresh sample, filtration, will behing, drying and combustion. Following these steps, the crude fiber was calculated using the following formula:

$$\text{Crude fiber in } \left(\frac{g}{100g}\right) = \frac{[(W2-W3)*100]}{W1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where;

W_1 = weight of the fresh sample
W_2 = weight of crucible with the sample after oven draying
W3 = weight of the crucible with the sample after ashing

3.4.7. Gross energy (total calorie)

Gross energy was determined by calculation from fat, carbohydrate and protein contents using the Atwater's conversion factors: 16.7 KJ/g (4 kcal/g) for protein, 37.4 KJ/g (9 kcal/g) for fat and 16.7 KJ/g (4 kcal/g) for carbohydrates and expressed in calories.

3.4.8. Mineral analysis

Mineral composition of the samples was determined according to methods recommended by Association of Official Analytical Chemists [78]. Fe, and Zn content of complementary food samples was determined by atomic absorption spectrophotometer (AAS) following standard procedures.

Sample preparation for Fe and Zn

The complementary food samples were ashed following the procedure described above in the total ash analysis section. 7 mL of 6N HCl solution was added to the ash of each sample and heated on a low temperature hot plate until it dried. Then, 15 mL of 3N HCl solution was added and the mixture was heated on the hot plate till it just boils. After the solution cooled down, it was filtered through a filter paper into a volumetric flask (50 mL). Ten mL of 3N HCl was added and the crucible was heated until the solution boiled. The solution was allowed to cool and filtered through a filter paper into the volumetric flask. The crucible and filter paper were hed thoroughly and the will behings was collected into the flask. Finally, 2.5 mL of lanthanum chloride was added into the solution and the volume was made up to the 50 mL mark with deionized water. Blank sample was also run by taking the same amount of reagents. The solutions was transferred to polyethylene bottles and stored in cool place until analysis.

Calibration curve and AAS reading

In order to fit calibration curves, a series of standard solutions of the minerals was prepared from stock solutions of 20 ppm for Fe (0, 0.5, 1, 2, 3, and 4) and Zn (0, 0.5, 1, 2,3 and 4 ppm). The flame AAS was calibrated with the prepared standards for the respective minerals and the sample solutions and also the blank was run to correct the obtained values. Finally, the mineral content of the samples was calculated by using the following formula.

$$\text{Mineral content } (mg/100g) = \frac{[(cs-cb)x\,v\,x\,D]}{10\,x\,W}$$

Where,

Cs = concentration sample, Cb = Concentration of the blank, V = volume (mL) of the extract and W = weight of samples, D= dilution factors.

$$\text{Fe content } (mg/100g) = \frac{(c-D)x\,200}{w\,x\,10}$$

$$\text{Zn content } (mg/100g) = \frac{(E-F)x\,2000}{wx\,10}$$

W = weight (g) of sample

C and E = Concentration of the sample

D and F = Concentration of blank

The mineral contents were determined by the procedure of AOAC [79]. Calcium, iron, and zinc was determined according to AOAC 2000 official methods of 985.35 using an Atomic Absorption Spectrophotometer while phosphorous was determined by official method of 986.24 using calorimetric method using ammonium molybdate. After removal of organic material by dry ashing, the residue will be dissolved in dilute acid. The solution was sprayed into the flame of Atomic Absorption Spectrophotometer (Varian SpectraAA-20Plus, Varian Australia Pty., Ltd., Australia) and the absorption of the metal to be analyzed was measured at a specific wavelength.

The stock standard solutions of minerals (iron, zinc and calcium) was diluted with 0.3 N HCl to concentrations that fall within the working range (0, 0.6, 1.0, 1.4, 1.8, μg/ml for zinc analysis; 1.0, 1.5, 2.5, and 3.0 μg/ml for calcium analysis and 0, 2.0, 6.0, 10.0 12.0 μg/ml for iron analysis). The Atomic Absorption Spectrophotometer (AAS) used for mineral determination was calibrated using standard solutions and the reagent blank solution was run with the sample.

Ashes was obtained from dry ashing. The ash was wetted completely with 5ml of 6N HCl, and dried on a low temperature hot plate. A 7ml of 3N HCl will be added to the dried ash and heated on the hot plate until the solution just boils. The ash solution was cooled to room temperature at open air in a hood and filtered through a filter paper (Whatman 42, 125mm) into a 50ml graduated flask. A 5ml of 3N HCl will be added into each crucible dishes and heated until the solution just boil, cooled, and filtered into the flask. The crucible dishes was again will behed three times with de-ionized water; the will behings was filtered into the flask. A 2.5mL of 10% Lanthanum chloride solution was added into each graduated flask. Then the solution will be cooled and diluted to the mark (50ml) with deionized water. A blank was prepared by taking the same procedure as the sample.

Calculation:

Mineral content (mg/100g) = [(a-b) x V]/10W

Mineral content (mg/Kg) = [(a-b) x V]/W

Where, W = weight in grams of samples

V = Volume in ml of extract

A = concentration in micro gm/ml of sample solution

B = concentration in micro gm/ml of blank solution.

Phosphorous determination

Phosphorous was determined by the colorimetric method using ammonium molybdate [78]. It was converted to phosphomolybdate, which was reduced to a blue molybdenum compound by aminonaphtholsulphonic acid to give a blue molybdenum compound. A sample solution was obtained from mineral analysis (determination of Fe, Zn and Ca). 1 ml of the clear extract was taken from the sample solution and diluted to 100 ml with distilled water in a 100 ml volumetric flask.

A 5ml of the sample dilution was added into test tubes. A 0.5ml of molybdate and a 0.20ml aminonaphtholsulphonic acid was added into the test tube (sample solution) and mixed thoroughly step by step. A 0.20ml aminonaphtholsulphonic acid was added into the test tube repeatedly each time until the solution becomes clear. The solution was allowed to stand for 10 minute. The absorbance (reading A) of the solution was measured at 660 nm against distilled water. Simultaneously with sample phosphorous, standard and blank analysis was carried out. Standard and blank solutions was prepared as above but 5 ml of working standard (reading AS) and 5 ml of distilled water (reading AB) in place of the sample dilution was used respectively. A standard curve was made from absorbance versus concentration and the slope was used for calculation.

Calculation:

First A_B will be subtracted from all other readings

P mg/100g = (A-A_B) x 50 x 100 x /slope x W_F x 10

Where: A = Reading of the sample solution

A_B = Reading of the blank solution

W_F = Weight of fresh sample.

Determination of phytate and non-phytate phosphorus

Phytate and phosphorous was determined by the above methods. Phytate phosphorus was calculated with the following formula.

Phytate phosphorous (mg/*100g) = (A*28.18)/100*

Where; A = phytate content (mg/100g)

Non-phytate phosphorous will be calculated as a difference between the total phosphorus and phytate phosphorous.

Determination of molar ratio of phytate/mineral (Bioavailability)

The mole of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (phytate: 660g/mol; Fe: 56g/mol; Zn: 65g/mol; Ca: 40 /mol). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of minerals.

3.5. Determination of functional properties

3.5.1. Oil and Water Absorption Capacity Determination

2g of the samples was mixed with 10ml of distilled water for 5 minutes respectively on a magnetic stirrer. The mixture was centrifuged at 3500rpm for 30minutes and the volume of the supernatant was measured by using 10ml measuring cylinder on each of the sample. The water density was taken to be 1g/ml.

$$\text{WAC}=volume of water absorbed/\text{Weight of the sample used}\times 100$$

3.6. Statistical analysis

All the analysis was performed in duplicate (unless stated otherwise) and presented as mean ± standard deviation. Statistical significance of the data obtained was analyzed by One-way analysis of variance (ANOVA) followed by Duncan test by using Genstat version 18.0. The level of significance was considered at $P < 0.05$.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1: RESULT

Table 4.1: Proximate composition of different Sorghum Varieties

Varieties	Results in (%) (100g)						
	Moisture	**Ash**	**C.Fiber**	**C.Protein**	**C.Fat**	**CHO**	**Energy**
JLM Control	11.61±0.24^{cd}	2.330±0.01^{a}	2.720±0.11^{b}	6.320±0.24^{bc}	6.570±0.14^{c}	70.45±0.31^{ab}	366.2±0.55^{b}
AdoKaye	12.51±0.11^{d}	2.910±0.02^{b}	2.840±0.02^{bc}	6.210±0.23^{b}	5.500±0.23^{b}	70.03±0.46^{a}	354.5±0.98^{a}
Dekeka	9.63±0.22^{ab}	3.110±0.11^{bc}	2.410±0.03^{a}	6.490±0.11^{c}	5.165±0.31^{a}	73.19±0.34^{c}	365.2±0.87^{b}
ESH-1	10.65±0.12^{bc}	3.260±0.21^{cd}	2.410±0.12^{a}	6.240±0.12^{bc}	8.270±0.25^{f}	69.17±0.12^{a}	376.1±0.94^{c}
Asso-1	10.07±0.31^{ab}	3.410±0.08^{d}	2.910±0.03^{bc}	6.500±0.21^{c}	7.270±0.34^{e}	69.84±0.48^{a}	370.8±0.84^{bc}
Melkam	9.36±0.23^{a}	3.830±0.10^{e}	3.000±0.14^{c}	5.230±0.14^{a}	6.940±0.26^{d}	71.64±0.51^{b}	369.9±0.96^{bc}

Key: Same letter in the same column is not significantly different from each other at p<0.05
JLM: The control sorghum sample
CHO: Carbohydrate,
Energy: Energy in Calory unit obtained from consuming 100g of these sorghum varieties

The proximate composition of different sorghum varieties has been depicted in table 4.1 above. Melkam variety has the lowest in moisture content while Adokaye is the highest. No significance difference was observed between Melkam, Asso-1, Dekeka varieties of sorghum under study for moisture content. There is also no significant difference in between Asso-1, Esh-1 & Dekeka and the same is true Adokaye and JLM control at p<0.05. The moisture content is significantly different between Melkam & Esh-1, Adokaye and JLM control at P<0.05. The same is true for Asso-1 & Adokaye and JLM control sample at P<0.05. The Ash content of different sorghum varieties were also indicated in table 4.1 above. JLM control has the lowest in ash content while Melkam has the highest. No significance difference was observed between Adokaye & Dekeka and in between Esh-1 & Asso-1 at P<0.05. The ash content is significantly different between Melkam and Asso-1, Esh-1, Dekeka, Adokaye & JLM control at P<0.05. The same is true for varieties of Asso-1 and Dekeka, Adokaye & JLM control sample.

When it comes crude fiber content, Melkam has the highest while (Ash-1 and Dekeka) has the lowest in crude fiber content as shown in table 4.1 above. The crude fiber content was significantly different between Melkam and (Ash-1 and Dekeka) & JLM control sample at $P<0.05$. There is no significant difference between Dekeka & Esh-1 and between Asso-1, Adokaye & Melkam varieties of sorghum. The same is true for others samples too at $P<0.05$. With respect to crude protein content, Melkam has the lowest while Asso-1 variety has the highest in crude protein content. There is no significance difference in between JLM control, Adokaye and Esh-1 samples at $P<0.05$. There is also no significance difference in between JLM control, Dekeka, Esh-1 and Asso-1 samples at $P<0.05$. The crude protein content is significantly different in between Melkam and Asso-1, Esh-1, Adokaye, Dekeka and JLM control samples at $P<0.05$. The same is true in between Dekeka and Adokaye & Asso-1 as shown above. The crude fat content of different sorghum varieties was also indicated in table 4.1 above. Dekeka has the lowest while Esh-1 has the highest in crude fat content. The crude fat content was significantly different among all varieties of sorghum under study at $P<0.05$.

When it comes carbohydrate content, all sorghum varieties have high amount of carbohydrate as shown in table 4.1. Dekeka variety has the highest while Esh-1 has the lowest in carbohydrate content. There is no significant difference in carbohydrate among Asso-1, Esh-1, Adokaye and JLM control samples at $P<0.05$. There is also no significance difference in between Melkam and JLM control samples. The carbohydrate content is significantly different in between Dekeka and the rest of other sorghum samples under study at $P<0.05$. Significance difference were also observed in between Melkam & Asso-1, Esh-1 and Adokaye at $P<0.05$. The energy in calory unit were also calculated and depicted as shown in table 4.1 above. Adokaye variety has the lowest while Esh-1 has the highest in energy obtained from consuming 100g of each sample. Almost all samples have comparable in terms of their energy content. The energy obtained is significantly different in between Esh-1 and Adokaye at $P<0.05$. Significant difference was also in between (Esh-1 & Adokaye) varieties and the rest of others sorghum varieties under study at $P<0.05$. There is no significant difference in energy obtained from the sorghum varieties of Melkam, Asso-1 and JLM control sorghum samples at $P<0.05$. The same is true for other varieties as shown in table 4.1 above.

Table 4.2. Minerals content of different Sorghum varieties

Varieties	Results in (mg/kg)			
	Calcium	**Zinc**	**Iron (Fe)**	**Total Phosphorous**
JLM Control	900±2.50[a]	32.39±0.98[a]	67.9±0.92[a]	2600±8.85[a]
AdoKaye	1200±3.65[b]	34.83±0.96[b]	100.4±0.98[b]	3300±8.95[b]
Dekeka	900±4.24[a]	34.16±0.86[b]	127.4±1.24[c]	3600±7.95[c]
ESH-1	1401±6.55[d]	37.50±0.94[c]	160.7±1.55[d]	4100±9.96[e]
Asso-1	1300±6.75[c]	33.45±0.92[ab]	175.8±2.08[e]	3800±9.02[d]
Melkam	1400±7.01[d]	40.42±0.97[d]	180.1±2.21[f]	4200±9.13[f]

Same letter in the same column is not significantly different from each other at $p<0.05$

JLM: The control sorghum sample

Minerals are important in fighting against hidden hunger or micronutrient deficiency. The minerals contents of different sorghum varieties are indicated in table 4.2 above. The calcium content in the range of 900mg/Kg to 1401mg/kg for sorghum sample JLM control and Eshi-1 respectively. No significant difference in calcium content between JLM control & Dekeka samples, Esh-1 & Melkam samples at $P<0.05$ respectively. The calcium content is significantly different between Asso-1 and the rest of others sorghum varieties under study at $P<0.05$. The same is true for sample Adokaye and the rest of other sorghum samples under study. When it comes zinc content different sorghum varieties, it is in the range of 32.39 mg/Kg to 40.42 mg/Kg for JLM control and Melkam sample respectively. No significant difference in zinc content were observed in between Adokaye, Dekeka and Asso-1 varieties at $P<0.05$. There is also no significance difference in between JLM control sample and Asso-1 in their zinc content. The zinc content is significantly different for Melkam variety and the rest of other samples at $P<0.05$. The same is true that, significant difference was observed in between Esh-1 and the rest of the sorghum samples at $P<0.05$.

The iron content of different sorghum varieties is also indicated in table above. The iron content in the range of 67.9mg/Kg to 180.1mg/Kg for JLM control sample and Melkam sorghum sample respectively. Significant difference was observed in iron content in all sorghum varieties under study at $P<0.05$. The total phosphorous content is also indicated in table 4.2 above. In a similar

fashion JLM control has the lowest (2600mg/Kg) while Melkam sorghum sample has the highest in total phosphorous sample which is 4200mg/kg. Significant difference was observed in total phosphorous content of all sorghum varieties under study at P<0.05.

Table 4.3 Functional Properties of different Sorghum varieties

Varieties	Results	
	Water Absorbing Capacity	**Oil Absorbing Capacity**
JLM Control	1.640±0.02[b]	0.9150±0.03[a]
AdoKaye	0.875±0.04[a]	0.6050±0.05[a]
Dekeka	1.080±0.03[a]	0.6900±0.04[a]
ESH-1	1.075±0.03[a]	0.6250±0.06[a]
Asso-1	0.850±0.02[a]	1.0500±0.09[a]
Melkam	0.930±0.04[a]	1.1900±1.01[a]

Key: Same letter in the same column is not significantly different from each other at p<0.05
JLM: The control sorghum sample
WAC= Water Absorbing Capacity OAC= Oil Absorbing Capacity

The functional properties of different crops or food types are important in determining the integration food with oil, water and other ingredients. The functional properties of different sorghum varieties are indicated in table 4.3 above. Water absorbing capacity in the range of 1.075 to 1.640 for Esh-1 and JLM control samples respectively. No significant difference was observed in water absorbing capacity among all sorghum samples except JLM control samples which is significantly different at P<0.05 as indicated above. When it comes to oil absorbing capacity, it is in the range from 0.6050 to 1.1900 for Adokaye and Melkam sorghum samples respectively. The oil absorbing capacity is not significantly different among all sorghum samples as indicated above at P<0.05.

Table 4.4. Physical properties of different sorghum varieties

Varieties	Results in	
	100 seed weight	**Bulk density (g/ml)**
JLM Control	3.645±0.23[b]	0.760±0.01[b]
AdoKaye	3.045±0.31[a]	0.695±0.02[a]
Dekeka	2.800±0.24[a]	0.750±0.02[b]
ESH-1	2.975±0.26[a]	0.770±0.03[bc]
Asso-1	2.855±0.30[a]	0.685±0.01[a]
Melkam	3.005±0.34[a]	0.785±0.03[c]

Same letter in the same column is not significantly different from each other at $p<0.05$
JLM: The control sorghum sample

The different physical properties are also important as quality indicators for different crop types. The physical properties of different sorghum varieties are indicated in table above. The 100 seed weight is in the range of 2.800g to 3.645g for Dekeka and JLM control sorghum samples respectively. No significant difference was observed in all sorghum samples under study for 100 seed weight except JLM control sample which is significantly different in 100 seed weight at $P<0.05$. When it comes bulk density, it is in the range of 0.685g/ml to 0.785g/ml for Asso-1 and Melkam sorghum samples respectively. No significance difference was observed in bulk density for the samples JLM control, Dekeka & Esh-1 and also for the samples Adokaye & Asso-1 at $P<0.05$ respectively. The bulk density of Melkam sample is significantly different as compared to other sorghum samples under study except Esh-1 sample at $P<0.05$.

4.2. DISCUSSION

4.2.1. Proximate composition/Macronutrient/ of different sorghum varieties

The proximate composition different sorghum varieties indicated in table 4.1. above. The moisture content in the range of 9.36 to 12.51%. The moisture content is very important in determining the shelf stability of food products. The moisture content is significantly different among some sorghum samples. The difference in moisture content is might be due difference in variety, farm management, agro-ecology, soil fertility and some other reasons. The result

obtained is in line with the research done by Mesresha et.al. for the sorghum grown in Ethiopia. The result is in contradict with the research done in Sudan by Nefisa 2002 and Mexico by Miria et.al in 2021. The findings confirm that varieties of sorghum tested were not exposed to deterioration due to mold growth or any damage related to wetness. This could be attributed to a moisture level of less than 15% [80].

The ash content of different sorghum varieties in the range of 2.33 to 3.83%. Significant difference was observed among some sorghum varieties as indicated in table 4.1 above. The difference is due to the fact that being difference in variety, farm management, soil fertility and some other reasons. The result is in contradict with the research done in Sudan by Nefisa (81), in Mexico by Miria et.al in (82) and with the research done by Mesresha et.al [83]. for the sorghum grown in Ethiopia. This might be virginity and fertility of Somali region soil which expected to contributed to higher ash content of sorghum samples.

Food with high fiber content is recommended to fight against constipation and other diseases. The fiber content in the range 2.410 to 3.00% as indicated in table 4.1. Significant difference in fiber content was observed among different sorghum varieties. The difference might be being different in varieties type and farm management during farming. The fiber content of the six varieties under this research were lower as compared to the other research done in Sudan by Nefisa [81], in Mexico by Miria et.al [82] and with the research done by Mesresha et.al. [83] for the sorghum grown in Ethiopia. This maybe due to the high in ash, moisture and carbohydrate content of these varieties. The protein content in the range of 5.23 to 6.50% is significantly different among different sorghum sample in this research as indicated in table 4.1 above. The difference in protein content might be due being different in varieties, farm management and some other cases. The protein contents of these six varieties in this research is relatively lower as compared to the other research done in Sudan by Nefisa [81], in Mexico by Miria et.al [82] and with the research done by Mesresha et.al. [83] for the sorghum grown in Ethiopia. This indicates, these sorghum and the other sorghum varieties need some kind of interventions like bio-fortification.

The fat content in the range of 5.165 to 8.270% as indicated in table 4.1. The fat content is significantly different among all sorghum varieties under study at $P<0.05$. The difference due to the fact that being different in variety types, origin of the seed, farm management and some other

reasons. The result obtained for fat content is in line with the research done by Mesresha et.al. [83] for the sorghum grown in Ethiopia. The result is in contradict with the research done in Sudan by Nefisa [81] and Mexico by Miria et.al [82]. The carbohydrate content of different sorghum depicted in table 4.1 above. There is significant difference in carbohydrate content among some sorghum varieties under study. This is mainly contributed due to being difference in variety type and especially the difference in other macro components such as protein, fat, moisture, fiber and ash of sorghum under study. The result of carbohydrate is in line with or comparable with the research done by Mesresha et.al. [83] for the sorghum grown in Ethiopia and with the research done in Sudan by Nefisa [81] while it is in contradict with the research done in Mexico by Miria et.al [82].

Energy is calculated with standard factors designed for carbohydrate, fat and protein. The energy was calculated in calory unit and is in the range of 354.5Kca; to 376.1Kcal. Significance difference was observed in energy content among some of the sorghum varieties in this research at $P<0.05$. This difference come as result of being different in macro component (Protein, fat and CHO) which in turn due to being different in variety and some other reasons.

4.2.2. Mineral's content of different sorghum varieties

The mineral content of different sorghum varieties is indicated in table 4.2 above. The calcium content is the range of 900mg/Kg to 1401mg/Kg. There is significant difference in calcium content among some sorghum varieties under this research at $P<0.05$. This might be due to being different in variety, soil fertility, farm management. The result obtained is comparable to the with the research done in Sudan by Nefisa [81]. The Zinc content of different sorghum varieties are in the range of 32.38mg/kg to 40.42mg/Kg as indicated in table 4.2. The zinc content is significantly different among some sorghum varieties at $P<0.05$. This might be due to being different in variety, soil fertility, farm management.

The iron content of different sorghum varieties is also indicated in table 4.2 above. The iron content in the range of 67.9mg/Kg to 180.1mg/kg and it is significantly different among all sorghum varieties in this research. This might be due to being different in variety, soil fertility, farm management. The phosphorous content also indicated in table 4.2. It is in the range of 2600mg/Kg to 4200mg/kg. The phosphorous content significantly different among all sorghum

varieties in this research. This might be due to being different in variety, soil fertility, farm management. The result obtained is in contradict with the research done in Sudan by Nefisa [81]. This might be the fact that, the difference in ash content, agro-ecology difference, soil fertility and some other reasons.

4.2.3. Functional Properties

The functional properties of different Sorghum varieties indicated in table 4.3 above. The water and oil absorbing capacity of the sorghum varieties shows no differences in their association with oil and water except the control sample. Water absorption capacity (WAC) is the capacity of the flour to absorb water and swell for enhanced consistency in food (84). The WAC of a food product measures the water holding ability by the starch after the swelling in excess water, which corresponds to weight of the gel formed, and therefore is an index of degree of starch gelatinization. It depends on the availability of the hydrophilic groups which bind the water molecules and also on the gel-forming capacity of the macromolecules (84).

Water absorption capacity is an important functional property required in food formulations especially those involving dough handling. The observed mini variation in water absorption capacities between different sorghum varieties maybe attributed to different protein concentrations, their degree of interaction with water and their conformational characteristics (85). This effect could be as a result of the loose association of amylose and amylopectin in the starch granules and weaker associative forces maintaining the granular structure. Water absorption capacity is important in bulking and consistency of products as well as in baking applications. Thus, the sample with the highest water absorption capacity is best accepted in baking applications.

Oil absorption capacity (OAC), also called oil absorption, is the binding of fat by the proteins' non-polar side chain. Oil absorption capacity (OAC) is mainly attributed to the entrapment of oils physically. It is an indication of the rates at which proteins bind to fat in food formulations (84). Oil absorption capacity is an important functional property that enhances the mouth feel while retaining the flavors of food products which intron important in food formulation (85). The oil absorption capacities of the flours were different among the different sorghum varieties as shown in table 4.3 above. From statistical analysis, there was no significant

difference ($p < 0.05$) in the oil absorption capacity of the flour samples. Absorption of oil by food products improves mouth feel Physical properties and minimum cooking time.

4.2.4. Physical properties

The physical properties among different sorghum varieties are depicted in table 4.4. There is more or less some significance difference between different sorghum varieties with respect bulk density. The bulk density ranged from 0.685 to 0.785 as shown in table 4.4. The difference in bulk density may be due to the intrinsic characteristics of each variety. Density values are useful in design of silos and storage bins. Hundred seed weight showed significant difference and varied from 2.855 to 3.645 g. Low hundred seed weight may due to the low moisture content which increases the probability of more damaged grains during milling.

4.3: Limitation of the research

The study was better enough in conducting the macronutrients content analysis but shows limitation in considering to analyze extra minerals content as it considers only four minerals in this research. The study also limited in considering the Sorghum samples from different research centers under institute. The research didn't consider about analyzing the vitamins content of the sorghum varieties. The anti-nutritional content of the sorghum varieties was planned but not investigated because of facility problem during the study period. Some of the functional properties and other important parameters were also skipped because of facilities related problem.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1: Conclusion

The research was done on six sorghum varieties of which one is a control sample. From the data obtained we conclude that, the moisture content of all varieties below 15% which is an indication for their better shelf stability. The ash content of all sorghum varieties is high which an indication for their high mineral content. The fiber, carbohydrate and fat content of all sorghum varieties are also high enough. But the protein content of all sorghum varieties is very low. When it comes to minerals content, all varieties of sorghum have high amount calcium, iron, zinc and total phosphorous. Significant different were observed in all varieties for both macro and micro nutrients.

5.2: Recommendation

Based on the data obtained from this research we forward the following recommendation;

- Biofortification or other means of fortification should be applied as all variety's protein content is very low.
- Sorghum is one the stables crop when it comes to Somali region, all stakeholders should put their effort in providing high quality seed in terms of maturity, drought resistant, nutrient content.
- Further detail research should be done on these and other varieties of sorghum grown in the region by expanding the parameters such antinutritional content, more minerals, vitamins, functional properties and some others.
- Platform should be established which put all sorghum actors like researchers, investors, government bodies and NGOs.
- May be better to establishment is recommended to have sorghum research center, Institute or others for the better result that can be obtained from sorghum.

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Pictures during Lab demonstration





