NUTRITIVE VALUE OF WHITE KAURA SORGHUM (*SORGHUM BICOLOR L.Moench*) GRAINS AND SPROUTS AND THEIR UTILIZATION BY GOATS

BY

SULE Sale

DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

NOVEMBER, 2015

NUTRITIVE VALUE OF WHITE KAURA SORGHUM (*SORGHUM BICOLOR L. MOENCH*) GRAINS AND SPROUTS AND THEIR UTILIZATION BY GOATS

BY

SULE Sale, B. AGRIC (KUST) 2010
(M.Sc/AGRIC/15264/2011-2012)

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,
AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN ANIMAL SCIENCE.

DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY, ZARIA

NOVEMBER, 2015

DECLARATION

I hereby declare that this thesis entitled "Nutritive value of white kaura sorghum (*Sorghum bicolor L. moench*) grains and sprouts and their utilization by goats" was written by me in the Department of Animal Science under the supervision of Dr. D. D. Dung and Prof. J. T. Amodu. And it is a record of my own research work. It has not been presented in any previous application for a higher degree. All borrowed ideas have been duly acknowledged by means of references and quotation marks.

____

Sale Sule

Date…………………………...............

CERTIFICATION

This thesis titled **"NUTRITIVE VALUE OF WHITE KAURA SORGHUM (*SORGHUM BICOLOR L. MOENCH*) GRAINS AND SPROUTS AND THEIR UTILIZATION BY GOATS"** by Sule, Sale meets the regulations governing the award of the Degree of Master of Science in Animal Science of Ahmadu Bello University, Zaria, and approved for its contribution to scientific knowledge and literary presentation.

Dr. D. D. Dung

____________________ ____________ ____________

Chairman, Supervisory Committee Signature Date

Prof. J. T. Amodu

____________________ ____________ ____________

Member, Supervisory Committee Signature Date

Prof. S. Duru

____________________ ____________ ____________

Head, Department of Animal Science Signature Date

Prof. K. Bala

____________________ ____________ ____________

Signature Date

Dean, School of Postgraduate Studies
Ahmadu Bello University, Zaria.

DEDICATION

This dissertation is dedicated to all members of my family and to my late father. May his gentle soul rest in perfect peace, Amen.

ACKNOWLEDGMENTS

I give thanks to God who gives us knowledge and life to live. I would like to express my sincere great thanks to my supervisors, Dr. D. D. Dung and Prof. J. T. Amodu for supervision, encouragement, guidance and help throughout this study.

My gratitude and special appreciation goes to the following persons Mr. Danjuma Sule, Musa U. Garba, Umar Abubakar, Idi Adamu, Godwin, Abubakar Sule, Yahuza, Idi and Mohammed Sule for their various contributions to this work. To my colleagues, I also thank Ahmed Dahiru, Yau Musa, Hassan Baba, Audu, Hassan Tanko, Mamman Isa, Haruna Hamza and Musa Umar.

I also thank my parents: Late Alhaji Suleiman and Hajiya Ramatu for their prayers and continuous support. The encouragement and support given by my brothers, sisters, friends and colleagues in the Animal Science Department is highly appreciated. Many thanks also go to all lecturers and supporting staff of the Department of Animal Science, Ahmadu Bello University, Zaria for their help, in particular Dr. M. R. Hassan, Dr. S. B. Abdul, and Prof. J. J. Omage for their guidance in laboratory analyses.

ABSTRACT

Trials were conducted to determine the nutrient profile of hydroponic white kaura sorghum sprouts as compared to the grains and the performance of Red Sokoto goats fed the experimental diets. The measurement of the animal response at experimental level was performed in order to test the hypothesis that sprouting gives rise to hydroponic sprouts that give higher animal performance. In the first part of the experiment, white kaura sorghum was sprouted hydroponically for 7 days duration. Daily sampling of the sprouts was done to determine the dry matter (DM) concentration and also to determine the nutrient concentration on day 7 in comparison to the unsprouted grain. The result shows a 24.6% loss ($P<0.05$) in DM from the seed after sprouting for a period of 7 days. The CP, ash and lipid (4.9, 1.12, 2.15%) respectively, were higher ($P<0.05$) in concentration in sorghum sprouts than in the sorghum grains on a DM basis. This was considered to be a reflection of a loss in DM after sprouting, causing a change or shift in concentration of these nutrients. The level of vitamin A, C and E (10.00, 12.10, and 0.45) respectively, were higher ($P<0.05$) in concentration for the sprouts than the grains. The level of Nitrogen intake, Nitrogen absorbed and total nitrogen loss (24.24, 19.43 and 4.82) were lower ($P>0.05$) in sprouted when compared to the grains. The second phase of the experiment involved feeding of hydroponic white kaura sorghum sprouts and the grains to Red Sokoto goats. Ten Red Sokoto goats were randomly allocated to the two experimental diets in a completely Randomized Design. There was significant difference ($P<0.05$) in nutrient digestibility in grains compared with hydroponic sorghum sprouts. The level of crude fibre, ether extract and organic matter were (26.10, 6.18, and 44.73) respectively, were also higher ($P<0.05$) for the diet containing sprouted fodder when compared to the control diets, therefore there is advantage of fodder over the control diet. The level of Nitrogen ammonia (NH_3-N), Total volatile fatty acid (TVFA) and the pH were significantly higher $P<0.05$ for the animals fed sprouted fodder diet when compared to the control diet (33.29, 20.91, and 6.50) respectively. It was then concluded that the 24.6% loss of DM followed 7 days of sprouting, however, did not allow the animals the chance to utilize such energy for useful purposes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

CHAPTER ONE

1.0 INTRODUCTION

Sorghum sprout as non-conventional feedstuff is relatively new in the feed industry. Sorghum (*Sorghum bicolor*), locally called guinea-corn, is the most extensively grown cereal grain in the country after maize (Aba *et al.*, 2004).The crop is environmentally friendly as it is water efficient, requires little or no fertilizer or pesticides and is biodegradable (Dogget,1989). In the savanna and semi-arid regions of Nigeria, millions of people consume sorghum in their daily diets as food (Obilana, 2005). This food is high in energy, and is therefore recommended for the infant, pregnant and lactating mothers (Obilana, 2005). Sorghum is also used as raw material for lager beer brewing (Aisien and Muts, 1987).

About 50% of the total land area devoted to cereal crops in Nigeria is occupied by sorghum. The area is estimated at 6.86 million hectares and extends north-wards from latitude 8^0N to latitude 14^0N (Aba *et al.*, 2004). The total sorghum production in Nigeria is estimated at 4.8 million tons (Obilana, 2005). Consequently, Nigeria has become the highest sorghum producer in West African sub- region, accounting for 71% of the regional total sorghum output. Globally the country leads in sorghum production for human consumption and has risen from fifth position in 1995 (FAO, 1995) to the third largest producer of sorghum in the world, after USA and India, where more than 90% of their sorghum harvested is used for animal feeds (Obilana, 2005).

Sorghum sprouting has a lot of prospect as a feeding stuff in livestock industry. It is currently being turned out in large quantities by breweries, food and allied industries. Ikediobi (1989) reported that sorghum sprout have increases nutritive values and increased level of lysine, methionine and tryptophan, when compared to unsprouted seeds. There are a range of chemical and structural changes that take place within the cereal grain through the hydroponic growing process. Activation of enzymes within the grain leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components (Sneath and McIntosh, 2003).

Chavan and Kadam (1989) stated that, sprouting grains causes increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins, and a decrease in dry matter, starch and anti-nutrients. The increased contents of protein, fat, fiber and total ash are only apparent and attributable to the disappearance of starch. However, improvements in amino acid composition, B-group vitamins, sugars, protein and starch digestibility and decrease in` phytates and protease inhibitors are the metabolic effects of sprouting process. Shipard (2005) stated that, the metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting. The reserve chemical constituents, such as protein, starch and lipids, are broken down by enzymes into simple compounds that are used to make new compounds (Sneath and McIntosh, 2003).

Research on hydroponically sprouted sorghum has shown an increase in fresh weight over the sprouting duration as well as change in dry matter (Peer and

Leeson, 1985; Trubey *et al.*, 1969). The gain in fresh weight has been mainly attributed to imbibitions of water constituting up to 80-90% of the fresh weight (Dung *et al.,* 2010). Change in dry matter occurs as a result of enzymatic activities as well as in dry matters losses (Salunkhe *et al.,* 1984; Sneath and McIntosh, 2003).

The enzymes also cause the inter-conversions of these simple components leading to increase in quality of amino acids as well as increase in concentrations of vitamins (Plaza *et al*., 2003). Early research on hydroponic sprout reported the presence of a grass juice factor that improved livestock performance (Elvehjen*et et al.*, 1934). More recent research has also indicated that hydroponic sprouts are a rich source of nutrient and they contain the grass juice factor that gives an improved performance to livestock (Nutrigrass, 2007).

Research on increased performance for both ruminants and monogastric animals has been reported (Finney, 1982).Workers using cattle, also reported an improvement in performance due to the feeding of hydroponic grain sprouts when compared to the original grains (Tudor *et al*., 2003). Some reports however showed there was no advantage with regards to animal performance when supplementary feeding of hydroponic grain sprouts was done (Tudor *et al.,* 2003). There are a range of chemical and structural changes that take place within the cereal grain through the hydroponic growing process. Activation of enzymes within the grain leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components (Dung *et al*., 2010). This hydrolysis increases the concentrations of amino acids, soluble sugars and fatty acids within the grain and resulting shoot (Chavan and kadam, 1989).

1.1 Justification

In Nigeria, there is little information on sorghum sprouts as a feed for goats. most reports on sorghum sprouts as a feed for goats emanated from research institute and universities. Studies carried out on sorghum sprout are few. Information from the research was good alternative to the conventional method of improved feed based on performance records, and it would also improve our knowledge of feeding goats with sorghum sprouts. Finney (1982) showed that hydroponic sprouts are a good source of nutrients, contains a grass juice factor that leads to improved animal performance. Fazaeli *et al*. (2011) found no significant difference in live weight gain or feed conversion efficiency between a fodder diet and a control diet, consisting of barley grain. Tudor *et al*. (2003) have found that steers supplemented with hydroponic barley sprouts performed higher than expected. Sneath and McIntosh (2003) stated that hydroponic sprouts may have profitable application in intensive, small-scale livestock situations with high value outputs, where land and alternative feed costs are high, and where the quality changes (for example, less starch, more lysine, vitamins, protein, amino acid), due to sprouting are advantageous to the livestock.

1.2 Objectives of the study

This study was designed to achieve the following objectives

- To compare the nutrient profile of hydroponic white kaura sorghum sprouts and sorghum grains.
- To compare the performance of Red Sokoto goats fed diet containing sorghum grains and sorghum sprouts.

1.3 Hypotheses

Ho_1: Feeding concentrate diets containing sorghum sprouts and grains have no effect on growth and nutrient digestibility in Red Sokoto goats

H_{A1}: Feeding concentrate diets containing sorghum sprouts and grains meal have effect on growth and nutrient digestibility in Red Sokoto goats

Ho_2: The sequence of feeding white kaura sorghum sprouts will increase performance

HA_2: The sequence of feeding white kaura sorghum sprouts will not increase performance

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution of Sorghum

Sorghum, (*Sorghum bicolor*) is a tall, coarse annual (of the family Gramineaes (grass family), somewhat similar in appearance to corn (but having the grain in a panicle rather than an ear) and used for much the same purposes (Watson, 1970). Sorghum probably indigenous to Africa is one of the longest cultivated plants of warm regions and also in Asia-especially in India and China. This is due to extreme drought resistance (because of the unusually extensive branching root system) and its ability to withstand hotter climates than corn (FAO, 1995).

Wild relatives of sorghum are currently confined to Africa south of the Sahara, (Zohary and Hopf, 2000), Yemen and Sudan- indicating its domestication. However, the archaeological exploration of sub-Saharan Africa is yet in its early stages, and we still lack critical information for determining where and when sorghum could have been taken into cultivation (FAO, 1995). Although rich finds of *S. bicolor* have been recovered from Qasr I brim in Egyptian Nubia, the wild examples have been dated to circa 800–600 BC, and the domesticated ones no earlier than 100 CE. The earliest archeological evidence comes from sites dated to the second millennium BC in India and Pakistan-where *S. bicolor* is not native. These incongruous finding have been interpreted, according to Zohary and Hopf, (2000), as indicating: (i) an even earlier domestication in Africa, and (ii) an early migration of domestic sorghum, from East Africa into the Indian subcontinent. This interpretation got further support because several other African grain crops, namely: pearl millet (*Pennisetum glaucoma*) (L.) cowpea (*Vigna unguiculata)* (L.) Walp and hyacinth bean (*Lablab purpureus)* (L.), Sweet show similar patterns. Their wild progenitors are restricted to Africa (Zohary and Hopf, 2000).

Most cultivated varieties of sorghum can be traced back to Africa, where they grow on savanna lands. During the Muslim Agricultural Revolution, sorghum was planted extensively in parts of the Middle East, North Africa and Europe. The name "sorghum" comes from Italian "sorgo", in turn from Latin "Syricum (granum)" meaning "grain of Syria". Despite the antiquity of sorghum, it arrived late to the Near East (Watson, 1970). It was unknown in the Mediterranean area into Roman times. Tenth century records indicate it was widely grown in Iraq, and became the principal food of Kirman in Persia. In addition to the eastern parts of the Muslim world, the crop was also grown in Egypt and later in Islamic Spain. From Islamic Spain, it was introduced to Christian Spain and then France (by the 12th century). In the Muslim world, sorghum was grown usually in areas where the soil was poor or the weather too hot and dry to grow other crops (Dogget, 1988).

Sorghum is well adapted to growth in hot, arid or semiarid areas. The many subspecies are divided into four groups-grain sorghums (such as milo), grass sorghums (for pasture and hay), sweet sorghums (formerly called "Guinea corn", used to produce sorghum syrups), and broom corn (for brooms and brushes). The name "sweet sorghum" is used to identify varieties of *Sorghum bicolor* that are sweet and juicy (FAO, 1999).

In Nigeria, the most widely used varieties for this purpose are: SK5912, KSV8 and ICSV400 (Ogbonna, 2002). Large-scale beer production with these varieties was however hampered due to some biochemical problem including inadequate proteolysis resulting in low extract yields (Ogbonna *et aI,* 2003), Ogbonna and Okolo, 2005) Sorghum is presented as an environmentally-friendly, fodder, food and industrial grain in Nigeria.

2.2 Production Trends of sorghum

FAO reported, that the United States of America was the top producer of sorghum in 2009, with a harvest of 9.7 million tones. The next four major producers of sorghum in decreasing quantities were India, Nigeria Sudan and Ethiopia. The other major sorghum producing regions in the world by harvested quantities were: Australia, Brazil, China, Burkina Faso, Argentina, Mali, Cameroon, Egypt, Niger, United Republic of Tanzania, Chad, Uganda, Mozambique, Venezuela and Ghana. (APWW, 2009 and FAOSTAT, 2010).

The world harvested 55.6 million tones of sorghum in 2010. The world average annual yield for the 2010 sorghum crop was 1.37 tones per hectare. The most productive farms of sorghum were in Jordan, where the national average annual yield was 12.7 tons per hectare. The national annual average yield in world's largest producing country, the USA, was 4.5 tons per hectare (CPWW, 2010, and FAOSTAT, 2011). The allocation of farm area to sorghum crops has been dropping, while the yields per hectare have been increasing. The biggest sorghum crop the world produced in the last 40 years was in 1985, with 77.6 million tons harvested that year. (FAO, 2010)

The United States Department of Agriculture (**USDA**) estimates that the **World Sorghum Production 2014/2015** will be 62.81 million metric tons, around 2.67 million tons more than the previous month's projection.

Sorghum Production last year was 60.13 million tons. This year's 62.81 estimated million tons could represent an increase of 2.68 million tons or a 4.46% in sorghum production around the globe.

Table 2. 1. Production World Sorghum by Country, 2014 production year

Country	Quantity Produced (Values in Metric Tons)
United States:	9,144,000
Others:	7,170,000
Mexico:	7,000,000
Nigeria:	6,500,000
India:	6,000,000
Argentina:	4,800,000
Ethiopia:	4,000,000
Sudan:	3,800,000
China:	2,800,000
Brazil:	2,400,000
Australia:	2,050,000
Burkina:	1,900,000
Mali:	1,200,000
Niger:	1,200,000
Chad:	900,000
Tanzania:	800,000

Source: Worldsorghumproduction.com

2.3 Varieties of sorghum

Sorghum belongs to the tribe *Andropogonae* of the grass family, *Poaceae*. Sugar cane (*Saccharum officinarum*) is a member of this tribe and a close relative of sorghum. In 1753, Linnaeus described in his species plantarum, three species of cultivated sorghum: *Holcus sorghum, Holcus saccaratus* and *Holcus tricolour*. In 1794, Moench distinguished the genus sorghum from the genus *Holcus* and in 1805;

Person suggested the name *Sorghum bicolor (L)* Moench as the correct name for cultivated sorghum (FAO, 1995). *Sorghum bicolour (L) Moench* is 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, joha ala cholam in India and kaoliang in China. Grain sorghum grown primarily for food can be divided into milo, kafir, hegari, feterita and hybrids (Norman *et al*., 1995). Hartland *et al*. (1972) divided cultivated sorghum into five groups namely *bicolor, guinea, caudatum, kafir* and *dura*. Seven agronomic groups have also been described by (Norman *et al.*,1995) *viz* kaffir sorghums originally from South Africa; milo sorghums originally from East Africa; feterita sorghums from Sudan; durra sorghum from the Mediterranean area, Near East and Middle East; sballu sorghum from India; koaliang sorghum grown mainly in China, Manchuria and Japan and the hegari sorghums also from Sudan.

Table 2. 2.sorghum varieties and area of dominance

Sorghum varieties and area of dominance Varieties	Area of Dominance
Bicolor	African savannah, South East Asia
Guinea	West Africa Savannah, India, South East Asia
Caudatum	Tropical Africa
Kaffir	Africa, South of Equator
Durra	Near East and India

Source: Harland and de Wet (1972); Norman *et al*. (1995)

The most abundant variety of sorghum in Nigeria is *Sorghum guineense*; other varieties include *Sorghum durra, Sorghum caudatum* and *Sorghum margaritiferum* (IAR, 1999). Several cultivars have, however, been developed through sustained breeding. Maunder (2002) reported that the single most important technology change in sorghum since the 1950's has been the development and use of hybrid seeds. Several improved varieties have been developed and released to farmers in Nigeria since the 1970's mainly by the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria and the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Kano Centre. Some of these cultivars have been developed from the local varieties, namely Fara-fara, Farida, and Kaura and from the ICRISAT lines of the Sudan zone. (IAR, 1999; National Centre for Genetic Resources and Biotechnology (NCGRB), 2004). Among these are the ICSV 111 and ICSV 400 released by ICRISAT in 1996, SAMSORG series developed and released in the 1970's and 1980's; others are the NR series developed from the Sudan zone ICRISAT line (NCGRB, 2004), L-187, L-243 and L-333 and SK-5912, which have pale yellow to yellow grains and L-1499, which have white coloured grains (Maunder, 2002).

2.4 Distribution and Habitat of sorghum

Sorghum bicolor is an African crop, which is widely distributed throughout the world. Different cultivars are found in different regions depending on the climate. It is adapted to a wider range of ecological conditions. It is mostly a plant of hot, dry regions; but also survives in a cool weather as well as waterlogged habitat (Amsal *et al.,* 1998). According to People's Plants (2000) the most common cultivar in South Africa has compact elongated heads and was previously known as S .*cafferorum*. A form (previously known as *S. dochna*) with more sparse open heads is often grown for its sweet canes which are chewed like sugar cane.

2.5 Growing *Sorghum bicolor.*

Sorghum is usually grown as a field crop. In Africa there are two basic types: white sorghum which is sweeter and used as a grain crop and red sorghum, which is less tasty to but is not as badly attacked by birds and makes good beer. Sorghum is also planted for cattle fodder and other purposes (Van wyk, 2000).

Amsalu *et al.* (1998), reported that, Sorghum is planted from seed, usually in rows in spring. As it is a little more frost hardy than maize it can be planted up until midsummer if the rains are late. Sorghum grows in a wide variety of soils and is drought resistant, but it will do better if the soil is enriched with compost or fertilizers prior to planting. Cultivars have also been selected to suit different soil and climate conditions (Van *et al.,* 2000). After harvesting the stalks can be used for cattle food or fuel. It is best to practice crop rotation and only grow sorghum on the same land every 4 years.

Sorghum is prone to various pests, including birds and in some parts of Africa parasitic witch weed (Striga). Crop rotation and early weeding by hand helps with the latter. American bollworm, aphids and borer will need to be controlled with pesticides. Birds will need to be kept from ripening grain sorghum (FAO, 1995).

2.6 Cultivation of Sorghum in Nigeria

About 50% of the total area devoted to cereal crops in Nigeria is occupied by sorghum. The area estimated at 6.86 million hectares extends north-wards from latitude 8^0 N to latitude 14^0N (Aba, *et al*., 2004). In 1978, the total sorghum production in Nigeria was estimated at 4.8 million tones (Obilana, 1981). This figure has risen to about 7.0 million tons annually (Obilana, 2005). Consequently, Nigeria has become the highest sorghum producer in the West African sub-region, accounting for 71% of the regional total sorghum output. Globally also, the country leads in sorghum production for human consumption and has risen from its fifth positiosn in 1995 (FAO, 1995) to be the third largest producer of sorghum in the world after the USA and India where more than 90% of their sorghum harvest is used for animal feed (Obilana, 2005).

2.7 Adaptation to Environmental Condition

Sorghum is adapted to a wide range of environmental conditions, particularly, drought. Hence, it is widely grown in different ecological zones of Nigeria (Showemimo *et al*., 2000). It has a number of morphological characteristics that contribute to its adaptation to dry conditions. These include: an extensive root system, waxy bloom on the leaves that reduce water loss, ability to stop growth in periods of drought and resume when conditions are favorable as well as tolerance to waterlogging (Dogget, 1988). The crop equally grows on a wide range of soils: sand, loam, saline and alkaline soils with a pH range of 4-8.5 (Aba *et al*., 2004).

2.8 Environmental impact

2.8.1 Water efficiency and salt-tolerance

Doggett (1988), reported that sorghum have high water efficiency and require less total water to reach their production potential. In environments where water is limited due to drought or declining aquifers and where it is necessary to conserve or reallocate available water, forage sorghums are promoted as a substitute for more water-consuming crops, particularly forage maize. Sorghums will be extremely valuable forage wherever water becomes a scarce and precious resource due to global climate change (USDA, 2004, Reddy *et al.,* 2004). The combination of drought-tolerance and salt-tolerance makes sorghum a very interesting feed resource under arid and semi-arid conditions in saline lands.

2.8.2 Toxic soil reclamation

Sorghum is tolerant of many pollutants and it thrives in toxic soils that kill most plants. Sorghum can take up excess soil N due to its penetrating root system and this ability has been useful to reclaimed fallow lands where soil N was up to 400 kg/ha, (Reddy, 2004). Sorghum also thrives on salty irrigated soils: it restores the porosity of the soil and makes new wheat crop possible in only one season while it yields very high (NRC, 1996).

2.8.3 Cover crop and soil improver

According to FAO (1996), Sorghum can be used as a cover crop during fall and winter: sown during fall, it covers more than 60 % of the soil surface before winter and protects it from wind erosion. It also helps sparing more water than other cover crops because it dies quickly after first frost and does not withdraw water from the soil. After harvest, ploughing down the stubbles can improve the organic status of the soil and limit erosion (NRC, 1996).

2.8.4 Weed and pest control

Sorghum has detrimental effects on broad-leaf weeds and this effect is still effective after its death. This could be due to the release of phenolic and cyanogenics by the roots (NRC, 1996).

2.8.5 Crop support

Dead stalks of sorghum grain can provide support to climbing legumes several months after the grain is harvested (NRC, 1996).

2.8.6 Regeneration of native pastures

Sweet sorghum has been used successfully in attempts to revegetate severely degraded Queensland bluegrass (*Dichanthium sericeum*) pastures in Australia (Harlan *et al.,* 1972). Sorghum was only one of the species involved: it was added to the mixture to give extra competition to volunteer weeds and as a safety measure to ensure cattle had fodder in the paddock. It indeed provided fodder four to five months after sowing and cattle preferred it to the other sown species (Seshu, 1991).

2.9 Sorghum Breeding and Selection

The most common landraces of sorghum in Nigeria are: Kaura, Farafara, and Guinea (Curtis, 1967). They are variously tolerant to striga (a parasitic weed) in all savanna zones and are agronomically alike. Sorghum improvement by breeding started in Nigeria in 1956, however, years of selection at the Institute for Agricultural Research (IAR), Samaru, Nigeria, have resulted in the development and release of sorghum varieties suited to specific ecological zones (Aba *et al*., 2004). Varieties have equally been developed with suitable qualities for industrial uses.

2.10 Harvesting

Sorghum is usually harvested when the grain moisture content has fallen below 20%, and the grain has become hard. Harvesting is done by hand using a knife to cut the panicles, which are temporarily stored in sacks before being taken to the threshing floor for further drying to a moisture content of 12–13% (FAO, 1995). Alternatively, the whole plant is cut or pulled up and the panicle removed later. Combine harvesting is possible, but many small farmers cannot afford to buy the machinery. In South Africa, combine harvesting is more common (NRC, 1995). For dye production, leaf sheaths are harvested when the plant comes to maturity, about 4–6 months after sowing. They can be used immediately or dried and stored. Rain fed forage sorghum is usually cut only once, soon after flowering. Reddy *et al*. (2004). Forage sorghum crops grown under more favourable conditions, often with irrigation and high levels of fertilizer, can be harvested and then left to regrow (ratoon). Broomcorn is harvested by hand as mechanical harvesters are not available. Sweet sorghum is harvested when the seed is in the soft dough stage when the sugar content of the stalk is highest (Harland *et al*., 1997).

2.11 Sorghum Processing and Utilization

2.11.1 Processing method

Sorghum is the most amenable cereal grain to different processing technologies including primary, secondary and tertiary methods (Obilana, 2005). Primary processing involves: fermentation, malting, wet dry boiling, roasting and popping. Secondary processing involves: brewing, beverage and drinks production, baking and confectionery making, steaming, extension (for pastes and noodles) while tertiary processing involves: composite flours (mixing of cereal flours, cereals legume flours, cereal cassava flours), bio-fortification and chemical additives. The different processing levels and their technologies are achieved using different agro-industrial equipment and machinery. These results in diversified end-products for foods, feeds, beverages, alcoholic and non-alcoholic drinks.

2.11.2 Utilization of sorghum

The uses of sorghum in Nigeria can be grouped into two: traditional and industrial. The traditional uses include a variety of traditional foods, beverages and drinks while its non-food traditional use includes: thatching of roofs and fencing of compounds (Showemimo, 2000). Sorghum consumptions for food are mainly in the form of flour or paste processed in to two main dishes: "OGI" or "AKAMU", a thin porridge and "TUWO", a thick porridge. Other dishes that are sometimes made from sorghum include a number of deep fried snacks, steamed dumplings, etc (Obilana, 1981). Of all cereal crops, sorghum contributes about 50% of the calories in Nigeria generally and about 73% in the savanna regions of the country in particular (Simons, 1976). Sorghum foods are also high in minerals, vitamins and some essential amino acids which are further enhanced through bio fortification thus, making them superior to other cereal foods. Sorghum, contributes more energy and digestible protein in the diets of the majority of the people in the sub-Saharan regions than those obtained from root and tuber crops (Aba *et al.,* 2004). In addition, its polyphenol (mostly tannin) contents are used as antioxidants just as the slow digestibility of sorghum starch and make its foods useful in diabetic treatments.

2.11.3 Use of sorghum as fodder

FAO (2004) reports that 440,000 square kilometers were devoted worldwide to sorghum production in 2004. In the US, sorghum grain is used primarily as a maize (corn) substitute for livestock feed because their nutritional values are very similar. Some hybrids commonly grown for feed have been developed to deter birds, and therefore contain a high concentration of tannins and phenolic compounds, which causes the need for additional processing to allow the grain to be digested by cattle. Sorghum forage can be used in different ways, as pasture, green chop, hay, silage and crop residues (straw, stubble and leaves). Due to its relatively low protein content, it usually requires protein supplementation as well as minerals and vitamins (Heuze *et al.*, 2012). Sorghum has a higher fibre digestibility that makes them competitive with maize (FAO, 2011).

For forage sorghum, intake is good at the beginning of the cycle but decreases rapidly as soon as the inflorescence grows. Intake is higher for regrowth: for instance, intake at bolting stage in the 1st cycle is 21.5 g DM/kg LW while intake at regrowth is 24.0 g DM/kg (Heuze *et al.*, 2012). When compared to maize silage, sorghum silage is more fibrous and less digestible. Whole crop sorghum silage has a nutritive value higher than that of fodder grasses and legumes, and close to that of medium-quality maize silage (Nutrigrass, 2007). It has been noted that equations based solely on ADF for predicting digestibility are likely to underestimate the value of sorghum (Plaza *et al*., 2003).

It has been reported that 51% of sorghum crops is used to feed livestock while 49% is for human food and other uses (Maunder, 2002). Smith (1995) agreed and indicated that sorghum compares well with other feed grains in total carbohydrate, indicating its suitability as a feed grain.

NRC (1996) reported that the stems of sweet sorghum types are chewed like sugar cane and, mainly in the United States; sweet syrup is pressed from them. In North America and Eastern Europe, special types with very long, fibrous and few-seeded inflorescences, known as ‘broomcorn’, are grown to make brooms. Sorghum plant residues are used extensively as material for roofing, fencing, weaving and as fuel. The stems can be used for the production of fibre board. Danish scientists have made good paneling using stem chips of sorghum. FAO (1995) reported that the stover remaining after harvesting the grain is cut and fed to cattle, sheep and goats, or may be grazed. Some farmers grind harvested stover and mix it with sorghum bran or salt to feed livestock. Sorghum is also grown for forage, either for direct feeding to ruminants or for preservation as hay or silage. Sorghum flour is used to produce an adhesive in the manufacture of plywood (Balole, 2001). Sweet sorghum is suitable for the production of alcohol, while the bagasse is a suitable source of paper pulp for the production of kraft paper, newsprint and fibre board. Sorghum has various applications in African traditional medicine: seed extracts are drunk to treat hepatitis, and decoctions of twigs with lemon against jaundice; leaves and panicles are included in plant mixtures for decoctions against anemia (ICRISAT, 2000). The Salka people in northern Nigeria use sorghum in arrow-poisons. The red pigment is said to have antimicrobial and antifungal properties and is also used as a cure for anaemia in traditional medicine (IAR, 1999).

2.12 Properties of sorghum grain

The composition of sorghum grain per 100 g edible portion is: water 9.2 g, energy 1418 kJ (339 kcal), protein 11.3 g, fat 3.3 g, carbohydrate 74.6 g, Ca 28 mg, P 287 mg, Fe 4.4 mg, vitamin A IU, thiamin 0.24 mg, riboflavin 0.14 mg, niacin 2.9 mg and ascorbic acid mg. The essential amino acid composition per 100 g edible portion is: tryptophan 124 mg, lysine 229 mg, methionine 169 mg, phenylalanine 546 mg, threonine 346 mg, valine 561 mg, leucine 1491 mg and isoleucine 433 mg. The principal fatty acids are per 100 g edible portion: linoleic acid 1305 mg, oleic acid 964 mg and palmitic acid 407 mg (USDA, 2004). Sorghum grain is first limiting in lysine, then in methionine and threonine. Much of the protein in sorghum is prolamine (39–73%), which is poorly digestible. As a result, maximum available protein in sorghum grain is usually 8–9%, (Balole, 2001).

The tannin content of sorghum also affects its nutritional value. High- and low-tannin sorghum types are distinguished. High-tannin sorghum types (sometimes called ‘brown sorghums’, although the grain may also be white, yellow or red) have less nutritional value but have agronomic advantages, including resistance to birds, insects, fungi and decreased sprouting in the panicle (Murty *et al*., 2001). Sorghum types without a pigmented grain wall (‘white sorghums’) do not contain condensed tannins and have a nutritional value similar to that of maize. Decortication, parboiling, malting or steeping in alkali solutions significantly reduce the tannin content of sorghum grain (Rooney *et al*., 2000).

In general, the endosperm accounts for 82–84% of the grain weight, the germ for 9–10% and the grain wall for 6–8%. The starch granules in the endosperm have a diameter of 4–15 μm. Ogwemike (2002) reported that the starch normally contains 70–80% amylopectin and 20–30% amylose, although some types contain 100% amylopectin and others up to 62% amylose. The gelatinization temperature ranges from 68–75°C. Taylor (2003) reported that Sorghum grain does not contain gluten and cannot be used for leavened products unless mixed with wheat.

The composition of the green plant varies according to age and cultivar but it normally contains 78–86 g of water per 100 g of fresh material. On a dry basis it contains per 100 g: protein 12 g, carbohydrate 40–50 g and fibre 20–30 g (Chantereau *et al*., 1977). The glycoside dhurrin occurs in the aerial parts of most sorghum. Dhurrin is hydrolyzed to hydrocyanic acid (HCN), which is highly toxic and can kill grazing animals. It is particularly concentrated in the young leaves and tillers and in plants that are suffering from drought (Balole, 2001). HCN content usually declines with age, reaching non-toxic levels 45–50 days after planting, and HCN is destroyed when the fodder is made into hay or silage.

The red pigment in sorghum dye cultivars is composed of anthocyanic compounds, particularly rich (95%) in the stable apigeninidin chloride (3-deoxyanthocyanidin) and tannins of the condensed proanthocyanidins group (producing phlobaphen reds), (De vries *et al.,* 2001). Balole (2001) stated that red pigment in the sorghum leaf sheath makes up to over 20% of the dry weight. The role of the non-pathogenic fungus *Bipolaris maydis* in the production of apigeninidin in these cultivars deserves further research. Used without a mordant, the dye obtained from sorghum gives a dark red that is fairly colour fast and still much used in eastern Africa, particularly Sudan and Ethiopia, for dyeing leather, cotton and the grasses and reeds used for woven matting (Sanders *et al*., 2000).

Sorghums used for forage fall in four categories (Heuze 2012, FAO, 2012):

- **Grain sorghums**. Dual purpose varieties can be used directly as fodder, and livestock can eat the straws or stubble after grain harvest for all grain varieties. Many sorghums used for forage in the tropics belong to the tall (2 to 4 m), thick-stemmed landrace types and are used as dual purpose (grain and forage) crops (Magness *et al.*, 1971).
- **Sweet sorghums**. Etuk *et al.* (2012) reported that their stems contain a sweet juice used on a small scale for sugar making. They are grown as fodders, especially in the USA, and are used in the development of fodder hybrids. In more intensive production, fodder cultivars are usually crosses between grain and sugar sorghums. These have higher sugar content than ordinary sorghums and are less liable to cause HCN poisoning. They can also be used for silage or hay (USDA, 2004).
- **Sudan grass** (*Sorghum × drummondii)* and Columbus grass (*Sorghum × almum).* These species are described in their respective datasheets.
- **Commercial hybrid fodder sorghums** are usually based on Sudan grass and grain sorghum. They retain the multi-cut qualities of Sudan grass but have a much higher

yield potential. They are becoming popular for green fodder in some developing countries and seed is widely available internationally (Etuk *et al.*, 2012).

The germplasm of sorghum is extensive. For instance, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Patancheru, India keeps a collection of 36,000 accessions from all the major sorghum-growing regions of the world (Balole *et al*., 2006). This datasheet is about *Sorghum bicolor* forage but will occasionally concern sorghum hybrids.

Particularly notable are the brown midrib sorghum which have been specifically developed for forage. The stems and leaves of *bmr* phenotypes are less lignified, resulting a higher cell wall digestibility (Heuze *et al.*, 2012, FAO, 2012). Unfortunately, the *bmr* trait is associated to negative ones for plant health, survival, environmental fitness and biomass yield, which tends to limit the adoption of *bmr* varieties by farmers **(**Heuze *et al.*, 2012)**.** In dual purpose sorghums, the nutritive value of the forage has seldom been taken into account in the past. However, cultivars that have both an enhanced grain yields and a higher forage value are now being developed, notably in India (CGIAR, 2010).

Forage sorghum is a valuable fodder: it is relished by ruminants, it is outstandingly drought resistant and it grows where maize is not able to grow because of high temperatures or dry conditions. Forage sorghum can be grazed (young or as deferred fodder), cut fresh, made into hay or ensiled (Smith *et al*., 2000**).**

2.13 Nutritional profile of Sorghum bicolor

Sorghum is about 70% starches, so is a good energy source. Its starch consists of 70 to 80% amylopectin, a branched-chain polymer of glucose, and 20 to 30% amylose, a straight-chain polymer (Watson, 1970). The digestibility of the sorghum starch is relatively poor in its unprocessed form, varying between 33 and 48%. Processing of the grain by methods such as steaming, pressure cooking, flaking, puffing or micronization of the starch increases the digestibility of sorghum starch. This has been attributed to a release of starch granules from the protein matrix, rendering them more susceptible to enzymatic digestion (Trinder, 1998).

On cooking, the gelatinized starch of sorghum tends to return from the soluble, dispersed and amorphous state to an insoluble crystalline state. This phenomenon is known as retro gradation; it is enhanced with low temperatures and high concentrations of starch (Van wyk, 2000). Amylose, the linear component of the starch, is more susceptible to retro gradation.

Certain sorghum varieties contain antinutritional factors such as tannins. The presence of tannins is claimed to contribute to the poor digestibility of sorghum starch. Processing in humid thermal environments aids in lowering the antinutritional factors (Sneath *et al.,* 2003).

Sorghum starch does not contain gluten. This makes it a possible grain for those who are gluten sensitive (US. G.C. 2005). After starch, proteins are the main constituent of sorghum. The essential amino acid profile of sorghum protein is claimed to depend on the sorghum variety, soil and growing conditions. A wide variation has been reported. For example, lysine content in sorghum has been reported to vary from 71 to 212 mg per gram of nitrogen (Roger *et al.,* 2003). Some studies on sorghum's amino acid composition suggest albumin and globulin fractions contained high amounts of lysine and tryptophan and in general were well-balanced in their essential amino acid composition. On the other hand, some studies claim sorghum's prolamin fraction was extremely poor in lysine, arginine, histidine and tryptophan and contained high amounts of proline, glutamic acid and leucine. The digestibility of sorghum protein has also been found to vary between different varieties and source of sorghum, ranging from 30 to 70% (Van der Walt, 1956).

A World Health Organization report suggests the inherent capacity of the existing sorghum varieties commonly consumed in poor countries was not adequate to meet the growth requirements of infants and young children. The report also claimed sorghum alone may not be able to meet the healthy maintenance requirements in adults. A balanced diet would supplement sorghum with other food staples.

Chavan and Kadan (1989) reported that sorghum's nutritional profile includes several minerals. This mineral matter is unevenly distributed and is more concentrated in the germ and the seed coat. In milled sorghum flours, minerals such as phosphorus, iron, zinc and copper decreased with lower extraction rates. Similarly, pearling the grain to remove the fibrous seed coat resulted in considerable reductions in the mineral contents of sorghum. The presence of antinutritional factors such as tannins in sorghum reduces its mineral availability as food. It is important to process and prepare sorghum properly to improve its nutrition value.

Sorghum is a good source of B-complex vitamins. Some varieties of sorghum contain ß-carotene which can be converted to vitamin A by the human body; given the photosensitive nature of carotenes and variability due to environmental factors. Scientists claim sorghum is likely to be of little importance as a dietary source of vitamin A precursor. Some fat-soluble vitamins, namely D, E and K, have also been found in sorghum grain in detectable, but in sufficient quantities. Sorghum as it is generally consumed is not a source of vitamin C (Gontzea and Sutzea, 1958 as cited in Chavan and Kadam, 1989).

2.14 Sprouting and hydroponic fodder production

Hydroponic fodder production involves supplying cereal grain with moisture and nutrients, all outside a growing medium such as soil, and then harvesting the resulting green shoots and root mat (Merisco, 2009). The grain responds to the supply of moisture and nutrients by sprouting and then producing a 200 – 250mm long vegetative green shoot with interwoven roots over a period of 5 to 7 days. At the end of the growing period the fodder is fed to livestock as a supplement in the same way that hay and silage are currently used (Merisco, 2009).

Sprouting grains for human consumption has been used for centuries in Asian countries to improve food value. Hydroponics and sprouting cereals for livestock fodder has a shorter history. In 1699 an English scientist, Woodward attempted to grow plants in various sources of water (Myers, 1974). In the mid-1800s, the French chemist Jean Boussingault verified nutritional requirements of plants grown without soil and by 1860 the techniques of "nutriculture" were being perfected by Sachs and

Knop working independently in England (Hoagland and Arnon, 1938). About this time European farmers also began sprouting cereal grasses feed to dairy cows during winter. In the 1920s and early 1930, Gericke developed procedures to grow plants in nutrient solution on a large scale (Myers, 1974).

In 1939 Leitch reviewed a range of experiments using sprouted fodder for dairy cows, beef cattle, calves, pigs and poultry. The introduction to Leitch's thesis commences "The present lively interest in sprouted fodder has arisen from the commercial exploitation of processes of water culture of plants to produce stock fodder". Leitch referred to five commercial hydroponic fodder systems. Two British commercial systems, "Cabinet Culture" (also called "Crop-a-day") and "The Sprout Process", two German patents and interestingly an electrically heated cabinet in Australia called "Vitaplant" which was marketed by "British Cultivations, Ltd." In the 1950s fodder sprouting chambers had moved from Europe to the USA. From the early 1970s a range of units were designed and manufactured in Europe and the USA. One Irish company manufactured a machine to produce hydroponic barley grass in 1973 in South Africa. Harris (1973) estimated that "no more than 400 units of all types of fodder sprouting chambers are in use in South Africa" and also raised the question of the economics of such a production system. Meanwhile in 1974 in Arizona, John Myers commented, "Thus it is that we find nothing but contradictory and conflicting research reports in a literature search today" (Myers 1974). Fodder sprouting chambers have been used in Britain, Europe, Canada, USA, Mexico, Ireland South Africa, India, Russia, New Zealand, Australia and no doubt many more countries.

In Australia in 1992, 1997 and 2003 journalists reported that 'The Fodder Factory' was the answer to drought for livestock producers. In March 2003 in Western Australia Tudor *et al,* (2003) found conflicting results feeding cattle with sprouted barley. Today a range of commercial hydroponic systems are marketed in Australia for sprouting cereal grains for livestock production. There are a range of chemical and structural changes that take place within the cereal grain through the hydroponic growing process. Activation of enzymes within the grain leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components (sneath and McIntosh, 2003).

Dung *et al*. (2010) reported that ruminant animals prefer diets that are leafy and non-stemmy and the leaves have to be of a low to intermediate tensile strength. In one of the latest fodder studies, Dung *et al*. (2010) found crude protein, ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain. This illustrates an advantage to the fodder.

In a trial looking at the performance of feedlot calves fed on fodder, Fazaeli *et al*. (2011) found no significant difference in live weight gain or feed conversion efficiency between a fodder diet and a control diet, consisting of barley grains.

2.15 Treatment of sorghum seeds for sprouting

Chavan et al. (1989) reported that cereals seeds were cleaned from debris and other foreign materials. Then the cleaned seeds were surface sterilized by soaking for 4 hours in a 0.1% sodium hypochlorite solution (Clorox bleach) to prevent the formation of mold. Planting trays and the growing cabinet also were cleaned and disinfected. Seeds were sown in the plastic trays lined with black plastic sheets and have holes at the bottom to allow drainage of excess water from irrigation. (Chavan and Kadam, 1989).

2.16 The sprouting process

Producing sprouts involves soaking the grain, most commonly sorghum, in water until fully saturated, followed by draining and placing it in trays or troughs for sprouting, usually for 5 to 7 days. The grain is kept moist during this period. Pre-soaking is important as there is a rapid uptake of water which facilitates the metabolism of reserve material and the utilization of these reserves for growth and development (Thomas and Reddy, 1962).

Grain is often soaked or washed with a sterilizing solution to help minimize the risk of moulds. The yield and quality of sprouts produced is influenced by many factors such as soaking time, grain quality, grain variety and treatments, temperature, humidity, nutrient supply, depth and density of grain in troughs and the incidence of mould (Sneath and Mclinton, 2003). To achieve maximum yield and nutritional benefits of sprouts, the grain should be clean, sound, free from broken or infested seeds and viable. Cereal seeds germinate equally well under dark or light conditions (Whyte, 1973; Bartlett, 1917 and Miller 1978). Regarding the growth process, Scott (2003) from the Nerang Hydroponic Centre (web site www.hydrocentre.com.au) comments that, “in 24 hours they sprout a root, green shoots day 2 and 3, by 5 days you can early harvest, 7 days is about max before they slow down and behave more like slow growing grasses. Hygiene is essential. In between crops, the trays must be cleaned, often with chlorine based cleaning solutions, to minimize the risk of mould.

2.17 Benefits of Sprouted Fodder

Green feed (http://t.co/www. 26ed5. 354 days ago. reply. retweet. favorite) reported that there are many benefits to be found from using fresh sorghum grass and spouted grains that have been organically and hydroponically grown. When sorghum is sprouted, it releases many vitamins and minerals as well as converting hard to digest starches in easily digestible proteins. Some of the benefits include:

- Water use reduction and conservation compared to field irrigation
- Reduction in overall daily feed costs.
- Significant reduction in feed waste - the entire root mass is consumed with the grass
- Increased nutritional value in the feed
- High yield in a very small area
- High digestibility
- Vitamins and mineral saturation

Source: (Sneath and McIntosh, 2003).

Hydroponic sprouts are highly nutritious. However, the challenge to their use is finding circumstances where their benefits outweigh their costs. Cuddeford (1989) describes some possible advantages of hydroponic sprouts for horses such as reduced starch and dust. Myers (1974) refers to subjectively observed health benefits in feedlot cattle receiving hydroponic barley grass but also states “it was recognized from the beginning that hydroponically grown grass was not the cheapest method of putting weight on cattle.

2.18 Things to consider before investing in sprout production

According to sneath and McIntosh (2003), the followings are the list of things that anyone thinking about investing in growing sprouts should consider:

- Cash outlay
- Opportunity cost of interest forgone
- Hours labour
- Number of head to feed

2.19 Labour Required

- Loading the grain into and filling the soak tank;
- Transferring the grain to the trays and loading the trays onto the shelves;
- Checking fodder growth daily;
- Washing, rinsing and sterilizing the trays and cleaning the growing chamber; and
- Feeding the green feed to the animals

Source: sneath *et al*. (2003)

2.20 Dry matter changes with sprouting

Sneath and McIntosh (2003) reported that during soaking and germination, seeds lose dry matter (DM) as they use their own energy reserves for growth. Sprouts can regain some DM weight with the uptake of minerals and effective photosynthesis.

However in the short growing cycle, there is most commonly a DM loss ranging from 7% to 47%. Within the literature reviewed for this report there were no substantiated examples of DM gains above the original grain DM input. An independent study by the Department of Horticulture, University College Dublin in 1986 Morgan *et al.* (1992) concluded that increased crop DM content over a short growing cycle is not possible.

Many factors affect the yield of sprouts in particular irrigation, water quality and pH, grain preparation, grain quality and variety, seeding density, temperature and growing duration. Hygiene is important to reduce the risk of mould. Soaking period, nutrients and light have some influence (sneath *et al*., 2003).

2.21 Seed soaking and germination

During soaking and germination seeds lose dry matter (DM). Chavan and Kadam (1989) stated that the original dry weight of the seed decreases during soaking and subsequent sprouting processes due to leaching of materials and oxidation of substances from the seed. When seeds are soaked, solutes leak out of them. Leakage is fastest at the start of imbibitions (water uptake) and comes to a half after about one day (Simon ,1984 as cited in Chung *et al*., 1989). Solutes that leak include proteins, amino acids, sugars, organic acids, and inorganic ions. During germination DM is lost due to the increased metabolic activity of sprouting seeds. The energy for this metabolic activity is derived by partial degradation and oxidation of starch (Chavan and Kadam, 1989).

2.22 Mineral uptake of sorghum

Morgan *et al.* (1992) found that the ash and protein content of sprouts increased from day 4 corresponding with the extension of the radicle (root), which allows mineral uptake. The absorption of nitrates facilitates the metabolism of nitrogenous compounds from carbohydrate reserves, thus increasing crude protein levels.

2.23 Photosynthesis

Light is not required to sprout cereal grains. In day one they sprout a root, in day 2 and 3 they sprout shoots. Some light in the second half of the sprouting period encourages some photosynthesis and greening of the sprouts. If the seedlings are grown without light or too low of light intensity, photosynthesis is non-existent or minimal (Hillier and Perry (1969) and Bidwell (1974) as cited in Peer and Leeson, (1985) and seedlings must rely on their starch and fat reserves to meet their energy demand. Where sprouts are stacked inside a shed, many sprouts may be heavily shaded.

In agreement with Morgan *et al*. (1992), lighting prior to day 3 was of little significance. However, Wagner (1984) as cited in Morgan *et al.* (1992), suggests that photosynthesis is not important for the metabolism of the seedlings until the end of day 5, when the chloroplasts are activated. Working with oats, Trubey *et al.* (1969) as cited in Morgan *et al.* (1992) found that light did not have a significant effect on DM content. Losses continued to increase from a value of 5.2% after 3 days to 12.3% after 6 days, probably reflecting the losses due to respiration and the negligible amount of photosynthesis by young seedlings at the low light intensity.

2.24 Nutrient quality of sorghum grain and sprouts

Processed grain and grain sprouts are both highly digestible, nutritious feeds. The energy in grain is largely starch and sprouting converts much of the starch to sugars. Sprouting also increases fibre levels. Chavan and Kadam (1989) stated that, "Sprouting grains causes increased activities of hydrolytic enzymes, improvements in the contents of total proteins, fat, certain essential amino acids, total sugars, B-group vitamins, and a decrease in dry matter, starch and anti-nutrients. The increased contents of protein, fat, fibre and total ash are only apparent and attributable to the disappearance of starch (Charles, 2003). However, improvements in amino acid composition, B-group vitamins, sugars, protein and starch digestibility, and decrease in phytates and protease inhibitors are the metabolic effects of sprouting process.

Soaking grain increases its moisture content and enzyme activity. These enzymes breakdown storage compounds into more simple and digestible fractions for example, starch to sugars, proteins to amino acids and lipids to free fatty acids. There is an overall reduction in dry matter (DM) and total energy. Total weight of protein stays similar, however due to DM loss, the protein percentage increases giving an apparent increase in protein. There is an increase in fibre and some vitamins and a reduction in antinutritional compounds (Carruthers, 2003).

The vitamin content is generally improved by sprouting. This may make little difference to the feed value though, Sneath and McIntosh (2003), reported that the increases in individual vitamins are so small that its practical significance in meeting the nutritional requirements of cereal-based diets is difficult to evaluate in feeding trials. Certain vitamins such as α-tocopherol (vitamin E) and β-carotene (vitamin A precursor) are produced during the growth process (Cuddeford, 1989).

2.25 Nutrient changes with sprouting grain

Soaking grain increases its moisture content and enzyme activity. These enzymes breakdown storage compounds into more simple and digestible fractions for example, starch to sugars, proteins to amino acids and lipids to free fatty acids (Shipard, 2005). There is an overall reduction in dry matter (DM) and total energy. Total weight of protein stays similar, however due to DM loss, the protein percentage increases giving an apparent increase in protein.

There is an increase in fibre and some vitamins and a reduction in antinutritional compounds. Chavan and Kadam (1989), stated that *"*the metabolic activity of resting seeds increases as soon as they are hydrated during soaking. Complex biochemical changes occur during hydration and subsequent sprouting in various parts of the seed. The reserve chemical constituents, such as protein, starch and lipids, are broken down by enzymes into simple compounds that are used to make new compounds or transported to other parts of the growing seedling Cuddeford, (1989), reported that dry barley grains contain up to 650 g starch/kg DM and that starch is the raw material that supports the growth of the plant.

According to Shipard (2005), sprouts are a tremendous source of (plant) digestive enzymes. Enzymes act as biological catalysts needed for the complete digestion of protein, carbohydrates and fats. The physiology of vitamins, minerals and trace elements is also dependent on enzyme activity." "Being eaten whilst extremely young, "alive" and rapidly developing, sprouts have been acclaimed as the "most enzyme-rich food on the planet". Estimates suggest there can be up to 100 times more enzymes in sprouts than in fruit and vegetables, depending on the particular type of enzyme and the variety of seed being sprouted. The period of greatest enzyme activity in sprouts is generally between germination and 7 days of age." (Shipard, 2005).

Grains and legume seeds of all plants contain abundant enzymes. However, while grains and seeds are dry, enzymes are largely inactive, due to enzyme inhibitors, until given moisture to activate germination. It is these inhibitors that enable many seeds to last for years in soil without deteriorating, whilst waiting for moisture. (Shipard, 2005). Heating, cooking and grinding processes can also inactivate certain digestive enzymes within grains and seeds. Fortunately, during germination and sprouting of grains and seeds, many enzyme inhibitors are effectively neutralized, whilst at the same time the activity of beneficial plant digestive enzymes is greatly enhanced, (Sneath and McIntosh, 2003).

Morgan *et al*. (1992) reported that among the carbohydrates, α-amylase is the main starch-hydrolyzing enzyme and barley develops higher α- and β- amylase activities than other cereal grains, which is why it is the preferred grain for malting. Amylase and maltase activity during sprouting of cereal grains results in a gradual decrease in starch with a concomitant increase in reducing and non –reducing sugars, which is available to the developing embryo. If no external nutrients are added, only water and oxygen are consumed by sprouting seeds (Chavan and Kadam,1989). Under optimum conditions of moisture, oxygen and warmth, the sugars will be used for cell wall synthesis and provide energy for growth. The grain fuels its own growth process with a subsequent respiratory loss of carbon. The accumulation of carbon through photosynthesis is very small because the light intensity in hydroponic units is usually too low and furthermore, in the immature plant, photosynthetic processes are not very efficient" (Cuddeford,1989). The desirable nutritional changes that occur during sprouting are mainly due to the breakdown of complex compounds into a more simple form, transformation into essential constituents and breakdown of nutritionally undesirable constituents (Chavan and Kadam,1989). "An increase in proteolytic activity during sprouting is desirable for nutritional improvement of cereals because it leads to hydrolysis of prolamins and the liberated amino acids such as glutamic and proline are converted to limiting amino acids such as lysine. Compared to carbohydrates and proteins, the lipids are present in relatively small amounts in cereal grains.

An increase in lipase activity has been reported in barley (MacLeod and White, 1962 as cited by Chavan and Kadam, 1989). Increased lipolytic activity during germination and sprouting causes hydrolysis of triacylglycerols to glycerol and constituent fatty acids. Lorenz (1980) stated that the sprouting of grains causes increased enzyme activity, a loss of total DM, an increase in total protein, a change in amino acid composition, a decrease in starch, increases in sugars, a slight increase in crude fat and crude fibre, and slightly higher amounts of certain vitamins and minerals (Sneat *et al.,* 2003). Most of the increases in nutrients are not true increases; they simply reflect the loss of DM, mainly in the form of carbohydrates, due to respiration during sprouting. As total carbohydrates decreases, the percentage of other nutrients increases.

2. 26 Nutritive Value of Sorghum Fodder

Feed contains many types of organic and inorganic materials such as carbohydrate, protein, fibre, minerals and also vitamins. These nutrients determine the nutritive values of the feed. Nutritive value is a role of the feed intake and the efficiency of nutrients extracted from the feed during digestion (NRC, 2006). Animals provided with feed of high nutritive produce values high levels of growth and productivity. Researchers have reported different result on the nutritive value of fodder.

Trubey *et al*. (1969) compared the nutrient composition of oat seedlings grown under light or dark conditions and the influence of culture solution at three and six days of sprouting. They found that six-day old seedlings had a higher fresh weight, CP, ash and soluble carbohydrate (CHO) content. However, the dry matter (DM) was higher in three-day old seedlings. There was no significant effect of light on the fresh weight, CP and water-soluble carbohydrate of the oats.

Hillier and Perry (1969) stated that the CP and CF contents of oat sprout based on DM basis was about 20.7 and 21.1 %, respectively as compared to the oat grain itself. However, the DM content was much lower. Peer and Leeson (1985) carried out two subsequent analyses on the composition and nutritive value of barley fodder. They also found that the younger the age of the sprout, the higher the DM content. CP did not significantly increase throughout the sprouting period. During growth, there was a linear increase in concentration of aspartic acid, alanine, lysine, threonine, glycine and gamma amino butyric acid, but proline and glutamic acid decreased.

2.27 Changes in anti-nutritional factors

Phytic acid occurs primarily in the seed coats and germ of plant seeds. It forms insoluble or nearly insoluble compounds with minerals including Ca, Fe, Mg and Zn. Diets high in phytic acid and poor in these minerals produces mineral deficiency symptoms in experimental animals (Gontzea and Sutzescu, 1958 as cited in Chavan and Kadam, 1989). The sprouting of cereals has been reported to decrease the levels of phytic acid.

Polyphenols and tannins usually present in the testa layer of seeds of certain cereals like sorghum, barley and millet, have been recognized as antinutritional factors. These are known to inhibit several hydrolytic enzymes, such as trypsin, chymotrypsin, amylases, cellulases and β-galactosidase (Salunkhe *et al.,* 1982 as cited in Chavan and Kadam, 1989). In addition, they bind with proteins and form tannin-protein complexes, thus making protein unavailable. Detrimental effects of polyphenols and tannins on the availability of minerals and vitamins have been reported (Salunkhe *et al.,* 1982 and Chavan *et al*., 1981 as cited in Chavan and Kadam, 1989). On reviewing the literature, Chavan and Kadam (1989) concluded that sprouting treatment does not decrease the tannin content of grain, but favours the formation of complexes between testa tannins and endosperm proteins. The problem of tannin however is not significant in low tannin types and other cereals that do not contain appreciable amounts of tannin.

2.28. Animal Performance on Hydroponic Fodder

A wide range of trials to assess livestock performance on sprouts have been conducted globally. These have included the performance of dairy cattle, beef cattle, pigs and poultry (Sneath and McIntosh, 2003). In their comprehensive review of hydroponic fodder in relation to beef cattle, Sneath and McIntosh (2003) reported that most of the trials on livestock performance from hydroponic sprouts showed no advantage to including them in the diet, especially when it replaces highly nutritious feeds such as grain. From a theoretical perspective, performance improvements occur if the supplement supplies the primary limiting nutrient(s) or improve feed use efficiency such as the situation Tudor *et al.* (2003) experienced with steers on protein deficient hay.

Early research showed an increase in animal performance on fodder, which they put down to a grass juice factor (Kohler Kohler., 1938). This is supported by Finney (1982), who showed that hydroponic sprouts are a good source of nutrients which contain a grass juice factor that leads to improved animal performance.

In contrast, some researchers have also shown that there is no improvement in animal performance with the feeding of hydroponic sprouts (Myers, 1974). In this case, when coupled with DM losses, there is in fact a significant cost to feeding fodder relative to un-sprouted grain. In a trial looking at the performance of feedlot calves fed on fodder, Fazaeli *et al*. (2011) found no significant difference in live weight gain or feed conversion efficiency between a fodder diet and a control diet, consisting of barley grain. They concluded, given the costs associated with sprouting the grain and DM losses, that feeding hydroponic barley fodder to feedlot calves is not recommended.

Tudor *et al*. (2003) have found that steers supplemented with hydroponic barley sprouts performed higher than expected for a period. They used barley sprouts to supplement steers on low protein hay. They found that steers fed on a restricted hay diet with 1.8 kg DM of barley sprouts over 48 days gained 1kg/head/day of live weight gain and a 5:1 feed conversion ratio. The same cattle fed for an additional 22 days given 1.5 kg DM of barley sprouts and ad lib hay gained 0.41 kg/head/day and a 22.8:1 feed conversion ratio. They concluded that further work was required to better evaluate the performance potential of sprouts and the reasons for the response.

Thomas and Reddy (1962) used a double reversal trial on 14 dairy cows over a 12-week period and compared four different types of hydroponic growth chambers for cost. They concluded that,“The different response of these two groups of cows indicates that feeding sprouted oats will not increase milk production in cows that are already receiving sufficient energy, but it may increase milk production in cows that are not receiving a high level of nutrients. This could explain some of the results observed on farms.” After noting that sprouted oats cost over four times as much as the original oats, they continued: “This high cost plus (1) loss in nutrients during sprouting, (2) the decreased digestibility of sprouted oats and (3) no observed increase in milk production when sprouted oats were added to an adequate ration indicated that this feed has no justification for being in any modern dairy ration.

Mincera *et al.* (2009) conducted a trial in which they fed lactating Comisana sheep on hydroponically germinated oats. They found that the integration of hydroponic oats into the sheep diet did not modify the biochemical and haematological parameters, but did seem to produce an improvement in animal welfare and milk production. Marisco *et al.* (2009) completed a parallel study with goats. They also found no change in biochemical and haematological profiles. Unlike the sheep trial, they did not find any change in milk yield between those fed on hydroponic sprouts and those fed on traditional diets. The findings of this review of animal performance are perplexing, with some showing positive results and others negative results or no results.

Hydroponic fodder may be best-suited to non-ruminants (horses, rabbits, pigs, and poultry) who would benefit more from the changes in the feed due to sprouting (e.g. less starch, more sugars) as compared to ruminants (sheep, goats, and cows) that are less efficient at digesting high quality feed (Iowa State Uni, 2013). Hydroponic fodder seems ideal for horses, though the research is lacking. A study with rabbits showed no detrimental effect to replacing up to 50 percent of the commercial diet with green fodder (Acta Agronomica, 2011).

Early workers found lower weight gain when pigs were fed 10-day sprouted maize relative to ground maize, but, when beef cattle were fed with hydroponics green fodder, an average of 200 g higher daily gain was obtained in comparison to those fed with a maize-control diet (Leitch, 1939).). Peer and Lesson (1985) found lower growth rate in pigs when fed sprouted barley than ground barley. Farlin *et al.* (1971) found no difference in performance of the cattle fed sprouted or non-sprouted grain.

Sneath and McIntosh (2003*)* reported that ruminant animals prefer diets that are leafy and non-stemmy and with leaves having a low to intermediate tensile strength. In one of the latest fodder studies, Dung *et al*. (2010) found crude protein; ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain. This illustrates an advantage to the fodder.

Abbas and Musharaf (2008) determined the effect of days of germination of sorghum grain on the growth performance of broiler birds. They reported that 3 days germinated grains had no effect on the growth performance of broiler birds but when days of germination increased it depressed the growth because tannin contents were increased. Hamid (2001) reported that 3days germinated grains improved growth performance.

Fafiolu *et al.* (2006) determined the effect of sprouted grains on the performance of layer during growing and laying phase. They reported that inclusion of sprouted sorghum in the diet of pullets at the level of 0, 150 and 300 g/kg of diet did not affect daily feed consumption, average weight gain and age at first egg during growing phase.

Similarly Musharaf and Latshow (1991) observed no significant effect on weight gain in layers by the addition of sprouted sorghum. In contrary to this, Adebule, (2002) observed decrease in weight gain when the level of sprouted grains increased in pullets diet. Fayed (2011) determined that addition of sprouted barley with rice straw and Tamarix mannifera decreased feed intake in lambs.

Cuddeford (1989) describes some possible advantages of hydroponic sprouts for horses such as reduced starch and dust.

2.29 Summary of Nutritional Benefits upon Sprouting

When seeds are sprouted, the hydrolytic enzymes breakdown grain storage compounds into more simple and digestible fractions -

Starch Simple Sugars and Soluble Carbohydrates

Protein Soluble Proteins and free Amino Acids

Fats Essential Fatty

Minerals chelate (i.e., merge with a protein molecule) in a way that increases their bioavailability

Sprouting grains results in -

Protein and Starch % Digestibility

Total Sugars

Crude Fibre

Protein % and Protein Quality

Lysine %

B-group Vitamins

Vitamin-E and Vitamin-A

Anti-Nutritional Compounds such as Phytates and Protease Inhibitors

All these actions greatly enhance the digestibility and nutrient value of sprouted grains, well above the original grain or seed (Shipard, 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site:

The experiments were conducted at the Teaching and Reasearch Farm of the Departmental of Animal Science, Ahmadu Bello University, Zaria, Kaduna state. The farm is located at an elevation of 676m, latitute 11.1623^0 North and longitude 007.6353 (Google, 2013). The zone is characterized by a rainy season that starts in April/May, stabilize in June and end in early October. The mean annual rainfall is 1100mm; maximum temperature varies between 27^0C and 35^0C, depending on the season. The relative humidity is about 72%. The dry season begins with a period of dry cool weather called harmattan that last from October to January. The harmattan is followed by a dry hot weather from February to April. The relative humidity at this period is about 37%. (Google, 2013).

3.2 Grains preparation

White kaura sorghum grains were sprouted in an ambient temperature throughout the 7 days sprouting period. Watering was done at 6hrs interval over 7 day's period of sprouting. The excess water was drained freely from the sprouting trays between watering.

Seeds of white kaura sorghum variety were steeped in warm water containing 0.1% sodium hypochlorite at 26^0C for 4hrs before they were transferred to the perforated tray for watering. The steeped seeds were placed in plastic containers at a rate of

6.6 kg m^{-2} (100g $tray^{-1}$). Thirty plastic containers measuring 10 by 15cm each (0.15m^2) were used. A daily random sampling of four containers was performed at approximately the same time over 7 day's period to determine DM and nutrient changes. At the time of daily sampling, the sprouts were removed from the containers and allowed to drain for at least 30 minutes and placed on an absorbent cloth in order to remove the surface water. The fresh sprouts were then weighed and transferred to storage after they were oven-dried. Samples of white kaura sorghum grains were also oven-dried to serve as control in order to determine the DM and nutrient changes in the sprouts over 7 days period. This was done by measuring the weights of both the hydroponic sorghum sprouts and dry grains.

3.3 Experimental design and management

The experimental animals consisted of ten (10) Red Sokoto goats allocated according to their body weights (ranging from approximately 11.30-11.31 kg) to two dietary treatments containing sorghum grains and sorghum sprouts, respectively with five goats per treatment in a complete randomized design (CRD). The animals were given prophylactic treatments consisting of intra-muscular injection of *Tetracycline* and *vitamin B complex*. They were dewormed with *Baminth* and bath with *Asuntol* powder solution (3g litres of water) to eliminate ectoparasites immediately after arrival.

The animals were pen-fed separately with hay and concentrate diets at 3% of their body weight for a period of 90 days. The diets consisted of *Digitaria smutsii* hay, cotton seed cake (CSC), maize bran, sorghum grain and sorghum sprouts. Daily records of feed offered and left over were recorded to determine the voluntary feed intake. Water and mineral salt lick were provided *ad libtum* to the animals. The goats were weighed fortnightly to determine live weight changes and to adjust the feed offered.

3.4 Digestibility and Nitrogen Balance Study

At the end of the feeding trial, three goats from each of the two treatment groups were randomly selected and housed in individual metabolic crates ideal for easy collection of urine and feces as described by Osuji *et al*. (1993). The goats were maintained on the same treatment diets used in the feeding trial. The residues of previous day's feed were collected and weighed each morning at 8:00am.

The daily total faecal output were collected for seven days, weighed, bulked, sub-sampled (40g) and oven-dried before they were stored in air tight containers until required for analysis. The daily urine output from each goat was collected into plastic containers containing 25ml of $0.1NH_2S0_4$ placed under the metabolic crates. Urine collection was also bulked and 10% of the total urine collected (aliquot) was kept in a deep-freezer (-4^0C) until required for analysis. The total faecal and urine collection also lasted for seven days.

3.5 Measurement of serum and rumen metabolites

Ten milliliters (10ml) of blood was collected in duplicate from three goats of every treatment by jugular vein puncture at the end of the feeding trial. These samples were taken prior to morning feeding at about 07.30 am, and were used for the assay of serum glucose, total protein, urea nitrogen and creatinine. Blood samples were centrifuged immediately and plasma was decanted into serum vials. The serum samples were stored in a deep freezer (-2^0C) until required for analysis.

Rumen liquor was sampled using stomach tube at 0, 6, 12, 24, and 30 hours before and after feeding for the determination of pH, total volatile fatty acid (TVFA) and rumen ammonia nitrogen (NH_3-N). The rumen fluids were immediately strained through cheese cloth and pH was determined using a digital pH meter. About 15ml liquor of the filter were taken and mixed with an equal volume of 1NH_2S04 saturated with MgS04 to acidify, deprotenize and reduced bacterial activities, as described by Briggs *et al.* (1957). This mixture was allowed to stand for 10 minutes before centrifuging at 6000rpm for five minutes. About 20mls of the supernatant were subsequently decanted into plastic bottles and stored in a deep freezer (-4^0C) until required for analysis of total volatile fatty acids (TVFA) and rumen ammonia-nitrogen (NH_3-N). These were analyzed according to the procedure described by Whitefield *et al.* (1976).

3.6 Determination of vitamin

Samples of sorghum grains and sprouts were taken to the laboratories of National Research Institute of Chemical Technology Basawa- Zaria for analysis. These samples were subjected to wet chemical digestion and the solution were used for analyses. Colour reactions were used to determined the presence of vitamins in the sorghum grains and sprouts. Ultraviolet Spectrophotometer (UV-S6405) was used for analyzing all the vitamins in the samples.

3.7 Laboratory analysis:

Samples of sorghum sprouts grains collected at day 7 were oven-dried, ground to pass through a 1mm mesh screen and stored in tightly sealed glass jars at room temperature and used for nutrient analysis. Daily samplings were done to determine dry matter loss over the 7 days period of sprouting. Three samples of dry white kaura sorghum seeds were also oven-dried along with the sprouts to serve as control. Nutrient analyses were done on dry ground samples.

Dry matter, crude protein, crude fibre, ash concentration of sprouts and non-sprouted white kaura sorghum were determined by AOAC (2000) methods. Organic matter was obtained as the difference between the dry matters and ash content. Urine was analyzed for nitrogen using Kjeldahl procedure (AOAC, 2000). Sample of experimental diets were ashed by charring Muffled funance at 500^{0} C for 6 hours. The rumen ammonia nitrogen (NH_3-N) was measured using the Steam Distillation Method (Barnett *et al.*, 1957). The rumen liquor samples were analyzed for pH using a digital pH meter. Total volatile fatty acids were measured according to the procedure described by Singh *et al*. (2010).

3.8 Statistical analysis

Analysis of variance was carried out on data collected on feed intake, nutrient digestibility, nitrogen balance and rumen pH were analyzed using the General linear Model Procedure (SPSS, 2009). Significant treatments means were separated using least significant differences (LSD) Test.

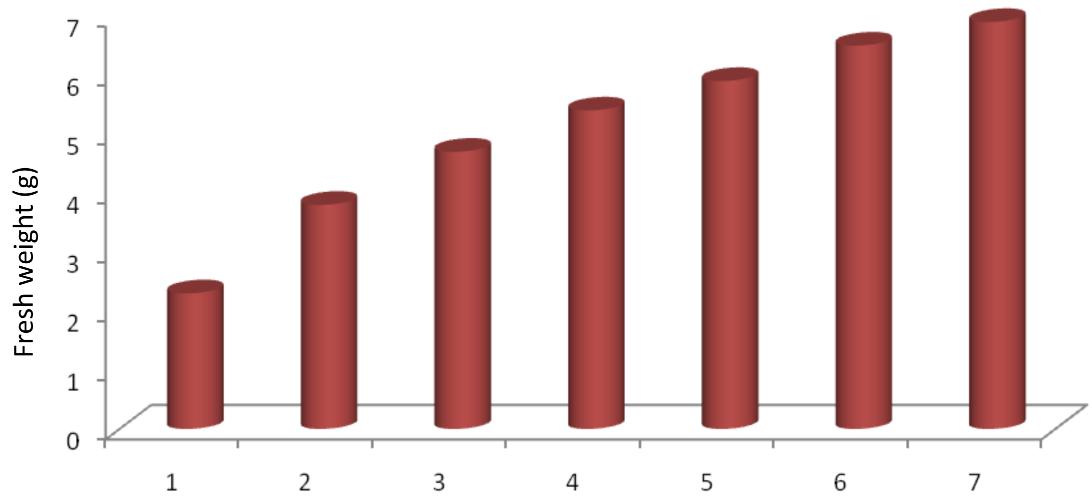
CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Fresh weight and dry matter changes in sprouts

Grains of white kaura sorghum gained weight over the 7 days sprouting period as a result of water imbibitions (water uptake). Fresh sprouts weighed about 2.23 Times their original pre-steeped weight after 1 day, 4.3 Times after 2 days, 5.2 Times after 3 days, 5.4 times after 4 days, 6.1 Times after 5 days, 6.5 Times after 6 days and 7.02 times after 7 days. (Figure4.1). The Dry matter concentration of the hydroponic white kaura sorghum sprouts was 79.24% after 1 day, 61.10% after 2 days, 59.11% after 3 days, 50.53% after 4 days, 45.46% after 5 days, 30.78% after 6 days, and 24.61% after 7 days of sprouting (Figure 4.2). The dry matter of oven-dried white kaura sorghum grain (control) was 95.08%. The 24.61% concentration of Dry matter in the 7 days sprouts clearly indicated the presences of water (about 75.39%). There was a gradual decline in dry matter content of the sprouts from day 1-7 of sprouting, peaking at an average dry matter loss of 24.61% on day 7.

The hydroponic white kaura sorghum was 9.5-10.1 cm in height at the end of the sprouting period of 7 days and had a substantial root mass at the base. Dung *et al.,* (2010) found that there was a gradual decline in DM content of the sprouts from day 1-7 of sprouting, peaking at an average dry matter (DM) loss of 21.90% on the day 7.



Days after pre-steeping

Figure 4. 1: fresh weight of white kaura sorghum after pre-steeping

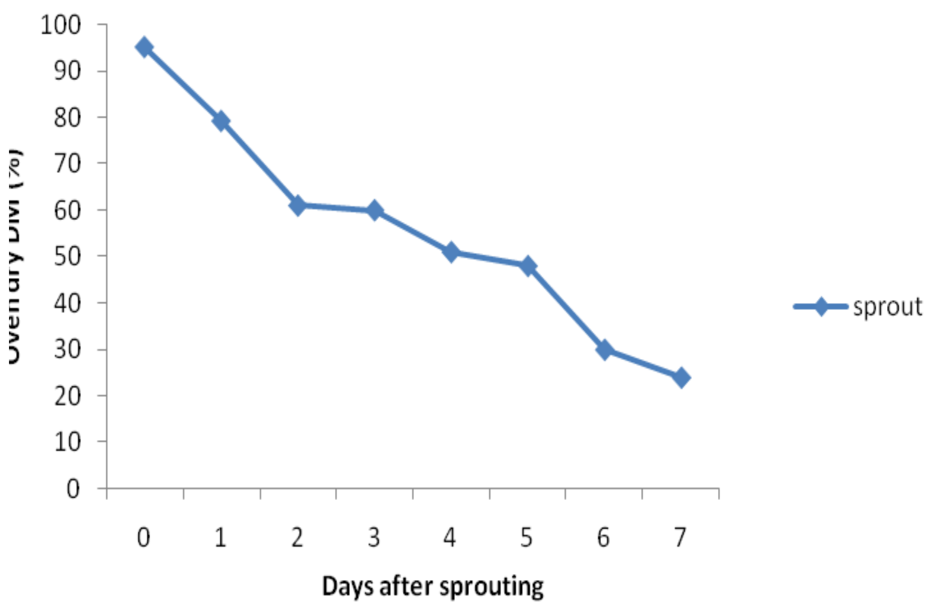


Figure.4 2: Dry matter content of white kaura sorghum over 7 day sprouting period

Seed soaking leads to the activation of enzymes, solubilisation and digestion of the starch stored in the endosperm to simple sugars. This provides substrate for the young developing plant for metabolic activities. These substrates are respired to produce energy, giving off carbon dioxide and water. This loss of carbon dioxide leads to a loss in DM. (Dung *et al*., 2010).

Report by Trubey *et al., (*1969) indicated an increase in fresh weight of barley sprouted for 3 and 6 days. The fresh weight of 6 days sprouts was higher than the 3 days sprouts due to the continuing uptake of water. The root development with time was also greater giving the older sprouts more absorptive capacity. Dung *et al*. (2010) also found an increase in fresh weight of barley seedlings in a 7 days growing period. This study also found an increase in fresh weight from day 1-7, these increases in weight attributed to continue irrigation and water uptake by growing plants.

Commercial sprouts growers have reported fresh weight increases of 6 and 10 fold (i e, 1kg of seed yielding about 6-10 kg of fresh sprouts), (Sneath and McIntosh, 2003). While trial yields from experiments indicated a 5-8 fold increase in fresh weight with sprouting of grains. Pre-steeping of the white kaura sorghum seed prior to the germination and sprouting enables the seed to imbibe water and swell (Sneath and McIntosh, 2003).

The swelling of the seed later allows for the splitting of the seed coat as well as part of endosperm, thereby allowing even more water to be absorbed by the seed as irrigation continues. There may also be absorption of minerals by the roots which could increase the ash content of the sprout and could add even more to the final weight. This study showed a gradual decrease in DM concentration of the original grain following pre-steeping and sprouting from day 1-7. Sneath and McIntosh (2003) reported a decrease from the original dry weight of seed during soaking and subsequent sprouting processes due to leaching of material and oxidation of substances from the seed. The leaking of the solutes from the seeds is fastest at the start of water imbibitions (uptake) and comes after about one day (Simon, 1984).

Solutes that leak include proteins, amino acids, sugars, organic acids and inorganic ions. Dung *et al*. (2010) reported that, seed soaking apart from causing the leaching of nutrients, also initiates a series of events that lead to oxidation of substrates stored in the grain causing a loss in DM. When water is imbibed into the embryo of the seed, it dissolves the plant hormone Giberrelic acid (GA) which is transported with water to the aleurone layer. In the aleurone layer, it activates DNA which translate amino acids present into the enzyme, amylase. The amylase is then released into the endosperm where it catalyzes the hydrolysis of the starch into its components glucose units. The glucose is then used for metabolic activities within the young growing plant, its oxidation generating ATP and releasing carbon dioxide.

The loss of DM through respiration in the young plant when compared to the gains of photosynthetic activities brings about net loss in DM when sprouting is completed. In a 7 day sprout, photosynthesis commences around day 5 when the chloroplasts are activated and this does provide enough time for any significance DM accumulation (Dung *et al.*, 2010).

4.2 **Nutrient profile of hydroponic White kaura Sorghum sprouts and grains:**

Proximate composition of sorghum grain and sorghum sprouts is show in Table 4.3

The DM content in day 7 sprouts showed a loss which reflected a lower value than the original sorghum grain. For all the reports summarized by Sneath and McIntosh (2003), a DM loss ranging from 7%- 47% was reported for short cycle sprouting. Most of the losses in DM in the sprouts were as a result of respiration, an energy requiring process which shows why there was lower energy on a DM basis in the sprouts. During germination, DM is loss due to the increased metabolic activities of sprouting seeds, the energy for these metabolic activities is derived by partial degradation and oxidation of starch (Sneath and McIntosh, 2003).

The original kaura sorghum grains had higher DM values than sprouted sorghum (95.08% and 24.61%.However, The crude protein content of sprout was higher than sorghum grains (5.56, 5.33%), respectively. The lipid content for the sprouts was significantly higher ($P<0.05$) in concentration on DM basis when compared to the sorghum grain. This was likely due to a change in weight of the carbohydrates used in providing energy for the young seedling through respiration as there was a 24.61% loss in DM after sprouting.

Some reports indicated an increase in crude protein; others decrease in CP, while a few indicated non- significant differences due to sprouting cereals. The increase in crude protein (CP) content has been attributed to loss in dry weight, particularly carbohydrates, through respiration during germination. Higher germination temperature and longer sprouting time means greater losses in dry weight and increases in CP content (Sneath and McIntosh, 2003).

Dung *et al*. (2010) found higher concentration in crude protein; ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain. This illustrates an advantage to the fodder. Sneath and McIntosh (2003) proposed that this is only an apparent increase in protein though and not a true increase. Their reasons for this are that the increase in protein is due to a decrease in dry weight through respiration during germination.

Table 4.1: Proximate composition of sprouted sorghum and grain at 7 days

Constituent (DM basis)	grains	sorghum sprouts	SEM
Dry matter	95.08[a]	24.61[b]	0.96
Crude protein %	4.1[b]	4.92[a]	0.17
Ether extract	1.45[b]	2.15[a]	0.15
Ash %	1.08[b]	1.12[a]	0.09
Crude Fibre%	1.06[b]	2.16[a]	0.24

[ab] Means with different superscripts within a row differed significantly ($P<0.05$), SEM= Standard Error of Mean.

Crude fibre was also significantly ($P<0.05$) higher in the sprouts (2.16%) than in the grains. However, Satya *et al*. (2012) reported lower crude fibre content of 17.0% for grains sprouts compared to the 19.4% for seeds.

Plate 4. l: Hydroponic sorghum sprouts at day 7 of growth.

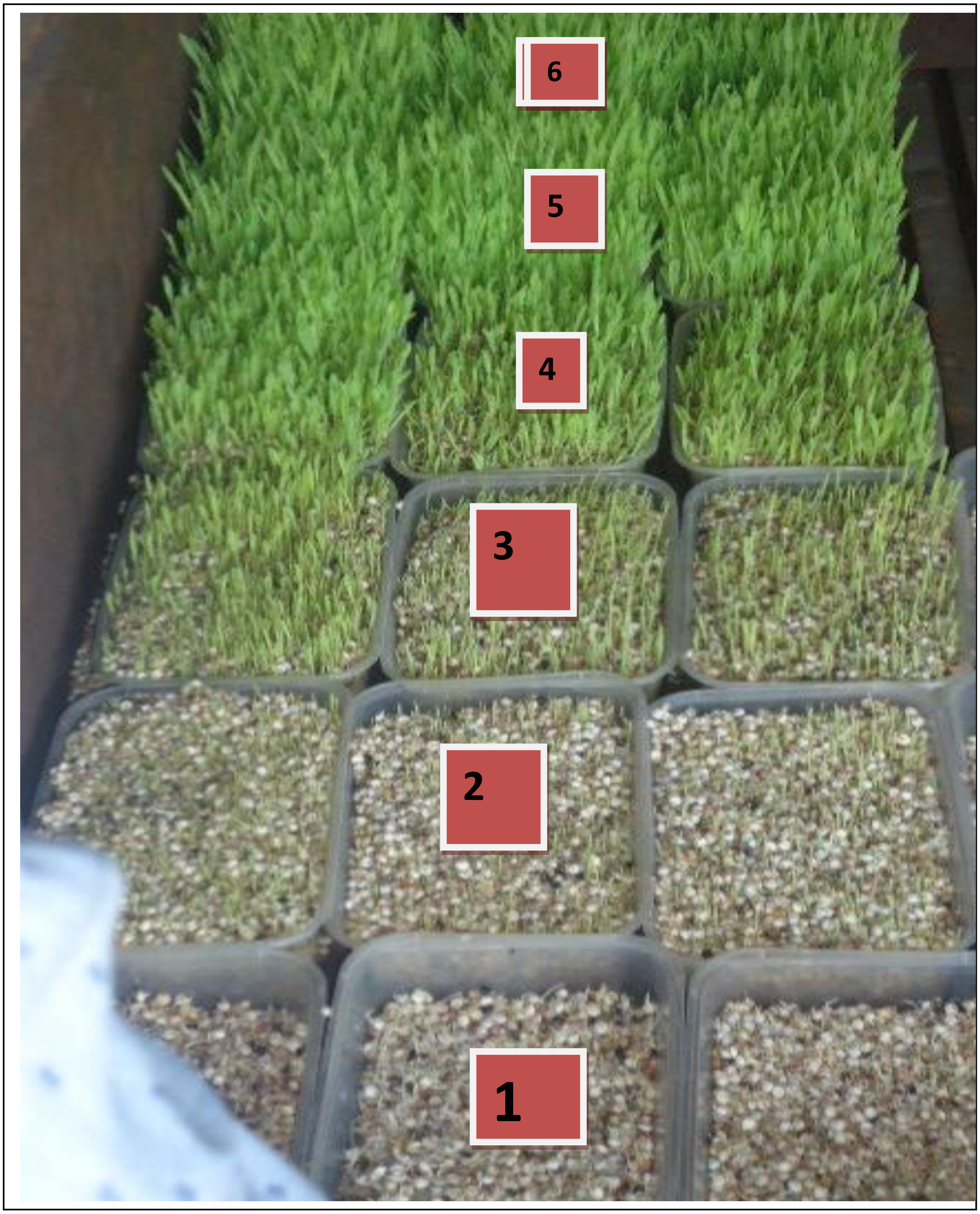


Plate 4. 2: Hydroponic sorghum sprouts showing stages of growth from day 1 to 6.

4.2: Vitamin profile of sorghum grains and sprouts

The vitamin profile of grains and sprouts of white kaura sorghum were shown in Table 4.2 Level of all vitamins studied in current study revealed significantly ($P<0.05$) higher values for the white kaura sorghum sprouts compare to the grains. According to Chavan and Kadam (1989) sprouting treatment of cereal grains generally improves their vitamin value, especially the B-group vitamins. Certain vitamins such as alpha tocopherol (Vitamin-E) and beta-carotene (Vitamin-A precursor) are produced during the growth process (Cuddeford, 1989).

The result of the current study showed higher values of 10.00,12.10,0.45, 1.15 and 1.05mg/L for the sorghum sprouts as against 8.20, 5.20, 0.26, 0.16, and 0.16mg/L(grains) respectively for vitamins A, C, E, biotin and beta carotene.

According to Shipard (2005), Sprouts provide a good supply of vitamin A, E C and B complex. Like enzymes, vitamins serve as bioactive catalysts to assist in the digestion and metabolism of feeds and the release of energy. They are also essential for the healing and repair of cells. However, vitamins are very perishable, and in general, the fresher the feeds eaten, the higher the vitamin content. The vitamin content of some seeds can increase by up to 20 times their original value within several days of sprouting, (Sneath and McIntosh, 2003).

Table 4. 2: Profile of vitamins of sprouted sorghum and grains at 7 days.

Vitamin (mg/L)	grains	Sprouts	SEM
vitamin A	8.20[b]	10.00 [a]	0.39
vitamin C	5.20[b]	12.10 [a]	0.54
vitamin E	0.26[b]	0.45 [a]	0.04
Biotin	0.16[b]	1.15 [a]	0.22
Beta-carotene	0.16 [b]	1.05 [a]	0.19

[ab] Means with different superscripts within a row differed significantly ($P<0.05$), SEM= Standard Error of Mean. Vitamin A- Retinol, C- Ascorbic Acid and E-Tocopherol, mg/l- milligramme per litre.

4. 3: Nutrient digestibility of Red Sokoto goats

Nutrient digestibility of Red Sokoto goats fed sorghum grains and sorghum sprouts in diets is presented in Table 4.3. All the values were significantly (P<0.05) different across the dietary treatments. Means for digestibility of dry matter (78.92 VS 77.04%), Crude protein (23.08 VS 22.18%) and ash (39.93 VS 32.31%) were higher for grains than for sprouts. However, organic matter (OM), Crude fibre (CF) and ether extract (EE) digestibility were higher for the sprouts than for the grains. The values were: 38.99 and 44.73% OM, 25.55 and 26.10%CF and 5.90 and 6.18% EE respectively for grains and sprouts.

Sneath and McIntosh (2003) reported that whether sprouting improves or reduces DM digestibility as compared to the raw grain, this comparison takes account of some basic processing of the grain. To optimize the utilization of grains, they need to be processed e.g. rolled or cracked, to improve its digestibility. When grains are not processed, it is estimated that only 60% of the starch is digested (Sneath and McIntosh, 2003).

The report of the current study is supported by Muhammad *et al*.(2013) which indicated that the digestility of nutrient has been increased by using sprouted grains in the diet of broiler and large animals. This is achieved by change in rate and extent of digestion and absorption. Also during germination enzymes are produced which reduces viscosity of the digesta and improved the digestion and absorption of nutrient. This is also due to the presence of highly soluble nutrient in the sprouted grains (Muhammad *et al*., 2013).

Table 4.3: Nutrient digestibility of sorghum grains and sorghum sprout fed to Red Sokoto goats

Parameter	sorghum grains	sorghum sprouts	SEM
Dry matter	78.92[a]	77.04 [b]	0.02
Organic matter	38.99[b]	44.73 [a]	1.32
Crude protein	23.08[a]	22.18[b]	0.03
Crude fiber	25.55[b]	26.10[a]	0.02
Ether-extract	5.90 [b]	6.18[a]	0.01
Ash	39.93[a]	32.31[b]	0.03

[ab] Means with different superscripts within a row differed significantly ($P<0.05$), SEM= Standard Error of Mean

4.4 Effect of feeding sorghum grains and sprouts on Performance of Red Sokoto goats

Result of Performance of Red Sokoto goats fed sorghum sprouts and grains are presented on Table 4.4. The final body weight was significantly differed between the sprouted and the control diets respectively, the sprouted has higher ($P<0.05$) values when compared with the sorghum grains (13.10 and 13.06) respectively. And the total body weight gain during the 90 day experimental period averaged 1.76 and 1.79kg for the control and treatment groups, respectively, these weights were significantly different for the two diets with lower ($P>0.05$) for the sorghum grains than the sprouted sorghum.

The observed trend can be explained by the fact that the sprouted sorghum in the diet might have helped to increase the efficiency of utilization of roughages by the rumen microbes which resulted in improved weigh gain due to the quality of the diet.

Live weight gain depends on several factors such as breed characteristics', age, initial live weight, nutrition, and management practice (Baker *et al.,* 2002).

Early research showed an increase in animal performance on fodder, which they put down to a grass juice factor, Finney (1982) showed that hydroponic sprouts are a good source of nutrients contains a grass juice factor that leads to improved animal performance.

4.4 Effect of feeding sorghum grains and sprouts on Performance of Red Sokoto goats

Parameters	sorghum grains	sorghum sprout	SEM
Final weight (kg)	13.06[b]	13.10[a]	0.17
Total weight gain (kg)	1.76[b]	1.79[a]	0.10
ADWG (g)	20.08[b]	20.12 [a]	0.63
DM intake (g/day)			
Concentrate	304.11[a]	295.71[b]	1.20
Digitaria hay	199.29[a]	197.56[b]	0.15
Total DM intake (g/day)	503.40[a]	493.27[b]	2.13
Total water intake (1/day)	1.86[a]	1.69[b]	0.01

[ab] Means with different superscripts within a row differed significantly (P<0.05),

SEM= Standard Error of Means.

4.6: Effect of sorghum sprouts and sorghum grains on rumen pH, Total volatile fatty acid (TVFA), Rumen Ammonia Nitrogen and serum metabolites.

The results of rumen pH, Total volatile fatty acid (TVFA), Rumen Ammonia Nitrogen of Red Sokoto goats are shown in Table 4.5. The Ruminal pH or hydrogen ion concentration is the result of a balance between production rate of short chain volatile fatty acids and hydrogen ion removal by absorption, neutralization, buffering and passage (Allen *et al*., 2006). The rumen pH differed significantly ($P>0.05$) between the grains and the sprout. The pH values obtained in this study are within the normal range of 6.4 and 6.43 respectively, for effective cellulolytic bacterial activity in the rumen (Ndlovu and Hove, 1995). The lowest average ruminal pH ever reported for a pasture diet was 5.6 (Williams *et al*., 2001).

Dehority, (2003) reported that the normal physiological range of total volatile fatty acids (TVFAS) in higher producing ruminant livestock has been reported to range between 31-73mg/L.

It was also observed that the level of ammonia nitrogen (NH_3-N) were significantly higher for the animals fed sprouted sorghum when compared for the grains. There was significant increase in ammonia compared to grains. The rumen ammonia N observed in this study was higher than the value (2-8 mg/100ml) reported for high producing ruminant.

Table.4.5: Effect of sorghum sprouts and sorghum grains on rumen pH, Total volatile fatty acid (TVFA), Rumen Ammonia Nitrogen and serum metabolites

Parameter	Grains	Sprouts	SEM
Rumen pH	6.43^{b}	6.5 ^{a}	0.06
NH_3-N (mg/100)	30.10^{b}	33.29^{a}	0.03
TVFA, mmol/ liter	13.06^{b}	20.91^{a}	0.13
Serum metabolites			
Total Protein (g/dl)	4.85^{b}	5.26^{a}	0.09
Blood Urea Nitrogen (Mmol/l)	5.2 ^{a}	5.16 ^{b}	0.02
Creatinine (µm/l)	76.53^{a}	71.50^{b}	1.12
Glucose (mmol/l)	4.44^{b}	4.95^{a}	0.11

^{ab} Mean with different superscripts within a row differ significantly ($P<0.05$),

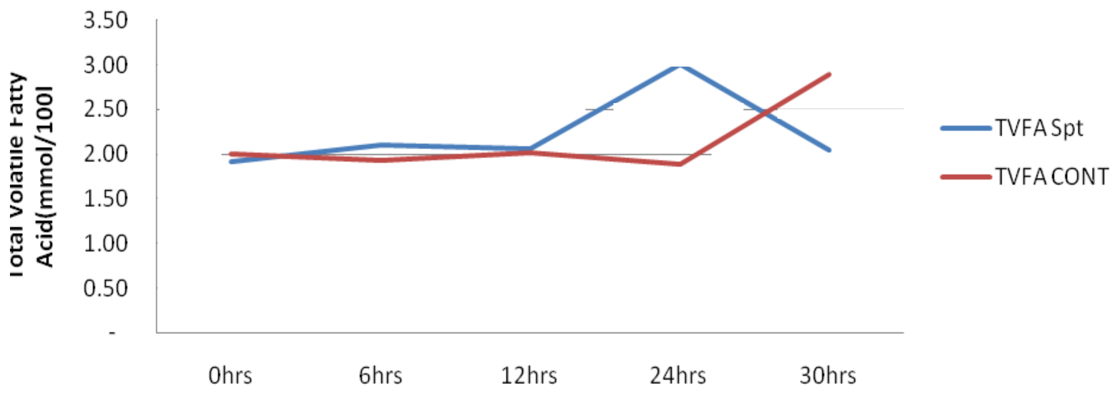
SEM= Standard Error of Mean.

`

However, blood urea nitrogen was similar for the sprouts and the control group respectively. Also, the creatinine was higher ($P< 0.05$) for the control diets compared to the fodder diet. However, the level of glucose was lower in concentration for control diet when compared to the fodder diet. The normal value for total protein in Red Sokoto goats has been reported to be 4.4±1.5g/100ml (Daraamola *et al*., 2005). The higher levels of total protein indicate that sprouted fodder has no negative effect on the health status of Red sokoto goats. However, the low value observed in control diet can be attributed to difference in efficiency of utilization of nutrients between the animals. Previous studies reported a similar result in West African Dwarf goats (fasae *et al*., 2011).

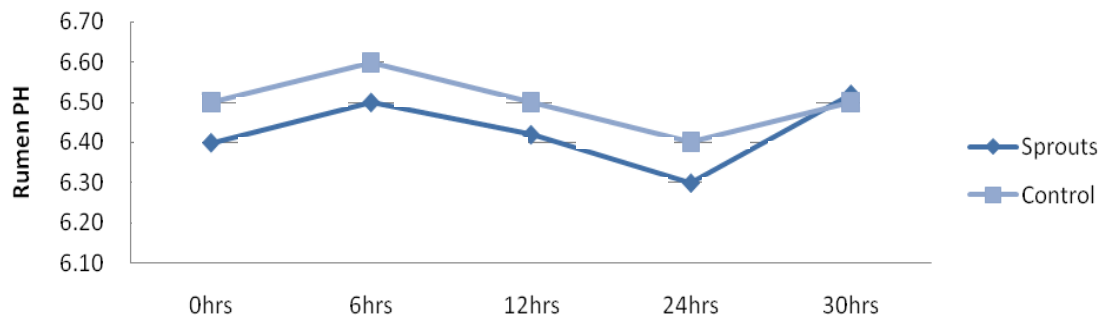
The normal blood urea nitrogen values reported for goats were 5.48± 0.4lmmol/L (lsmartoyo *et al*., 1993) and 3.57-7.14mmol/L (safari *et al*., 2011). The value observed in this study were all within the normal range expected for healthy goats. This indicated that the sprouted fodder can be included in the diet of Red Sokoto goats to supplement other low quality feed resources. The creatinine content of the Red Sokoto goats observed in this study fall within the normal range for goats (17.68-167.96 µmmol/L) (lsmartoyo *et al*., 1993). The significant higher creatinine concentration observed in the control diet in this study can be attributed to increase muscle mass and level of physical activity in the goats. Previous studies documented that creatinine levels may indicate proper physiological status of kidney in goats (lsmartoyo *et al*., 1993). The creatinine values observed in this study were similar to the report of Olafadehan (2011) but were higher than the values reported for other studies (Fasae *et al*., 2011).

The values obtained for blood glucose level varies ($P<0.05$) between the treatment with the higher value observed in fodder diet. The normal physiological range of the blood glucose in goats has been reported to be within a range of 2.78-3.89mmol/L and 64.2-78.4mmol/L (Sakha *et al.*, 2009). Therefore, the concentration of blood glucose observed in this study fall within the normal range. This therefore indicates that sorghum sprouts contains some glucose precursors which helped to prevent the occurrence of hypoglycaemia associated with excessive utilization of blood glucose in goats



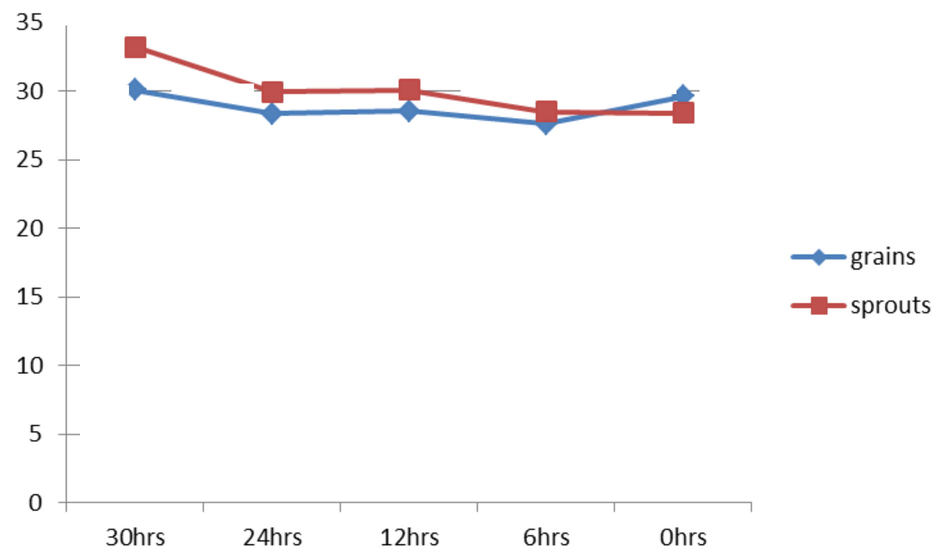
Sampling time (hrs.)

Figure.4.3: Total volatile fatty Acids mmol/100ml of Red Sokoto goats fed sorghum sprouts and sorghum grain. SPT= sprouts, CONT=control (grains)



Sampling time (hrs.

Figure. 4.4: Rumen pH of Red Sokoto goats fed Hydroponic white kaura sorghum sprouts and sorghum grains



Sampling time (hrs.)

Figure. 4.5: Rumen NH_3-N of Red Sokoto goats fed white kaura sorghum grains and sorghum sprouts.

4.7 Nitrogen balance of Red Sokoto goat fed sorghum grains and sprouts

The results of nitrogen balance and the percentage intake of nitrogen in the diets are presented in Table 4.6. The result showed that nitrogen intake for the animal fed sorghum sprouts were lower in value (24.24 g/day), than the animals fed sorghum grain, there was significant difference ($P<0.05$) between the treatment, (26.42 g/day) respectively. Nitrogen as percentage intake of animals fed sprouted sorghum was significantly lower ($P<0.05$) in value (80.52 g/day), than the grains (80.61 g/day) respectively. Nitrogen absorbed and nitrogen loss was higher ($P<0.05$) in diet containing grains compared to the sprouts (21.27 VS 5.12), respectively. Nitrogen retention is the major indicator used to assess the protein nutrition status of ruminant livestock (Abdu *et al.,* 2012).

Amodu *et al.* (2008) observed an increase in intake and digestibility coefficient in Yankasa rams when fed millet-lablab silage mixture 50:50 proportion compared to the control (0:100 millet-lablab silage mixture). Elseed *et al.* (2005) however, observed that supplementation of protein sources improved microbial N yield and N retention.

Table 4.6: Nitrogen balance of red sokoto goat fed sorghum grain and sprouts

Parameter	Sorghum Grain	Sorghum Sprouts	SEM
Nitrogen intake	26.24[b]	24.42 [a]	0.25
Total N loss	5.12 [b]	4.82[a]	0. 03
Nitrogen retention	21.42[a]	19.3[b]	0.13
N as % of intake	80.61 [b]	80.52[a]	0.05
Nitrogen absorbed	21.27[b]	19.43[a]	0.21

[ab] Means with different superscripts within a row differed significantly (P<0.05), SEM= Standard Error of Mean.

Table 4.7: Compositions of experimental diet (DM basis)

Parameter	Control	Sorghum sprouts
Hay (Digitaria)	30.00	28.00
Sorghum Grain	10.00	0.00
Maize bran	27.00	17.00
Cotton sSeed Cake	30.00	27.00
Bone meal/Salt	3.00	3.00
Sorghum sprouts	0.00	25.00
Total	100	100
Crude Protein (%)	12.00	11.82

[ab] Means with different superscripts within a row differed significantly (P<0.05), SEM= Standard Error of Mean.

Table 4.8: Proximate composition of experimental diets.

Parameter	sorghum grain	sorghum sprouts	SEM
Dry matter	94.98[a]	94.64 [b]	0.07
Crude protein	7.98 [b]	11.50[a]	0.78
Crude fibre	11.11[a]	11.02[b]	0.02
Ether extract	2.05 [b]	3.55[a]	0.33
Ash	3.22[b]	3.83[a]	0.13
Nitrogen free-extract	83.60 [a]	70.0[b]	3.02

[ab] Means with different superscripts within a row differed significantly (P<0.05), SEM= Standard Error of Mean.

4.8 Economic analysis of feeding sorghum sprouts and grains to Red Sokoto goats.

Table 4.9: shows the results of economic assessment of feeding sprouted sorghum and grains to Red Sokoto goats. The results indicated that feed cost per kilogram feed was higher ($P<0.05$) for the animals fed sprouted sorghum compared to the control diet. The total feed consumed by the goats during the three months period of the feeding trial was however lower ($P<0.05$) for the sprouts compared to control 44.39 and 44.46, respectively. It is clear from this study that feeding sorghum sprouts and grains to Red Sokoto goats resulted in positive Gross Margin and Income.

The positive gross margin observed in sprouts can be explained by the fact that additional amount of grains and other activities involved in day to day sprouting of the grain to meet the dry matter requirement of animals. Tudor *et al*. (2003) has used hydroponic fodder as a supplement to steers on low protein hay. Over a 48-day period steers on restricted hay intake given 1.8 kg DM of barley sprouts produced 1 kg/head/day live weight gains. In Australia in 1992, 1997 and 2003 journalists reported that ‘The Fodder Factory’ was the answer to drought for livestock producers.

Table.4.10: Economic analysis of the sprouts and grains sorghum fed to Red Sokoto goats

Parameter	sorghum grains	sorghum Sprouts	SEM
Feed Cost/kg	29.70[b]	34.39[a]	1.04
Total feed consumed (kg)	44.46[a]	44.39[b]	0.01
Live weight gain (kg)	1.75[b]	1.76a	0.03
Cost of feeding /goats/month	1418.51[b]	1965.60[a]	1.22
Value of life goats (/N)	21800.00[b]	32900.00[a]	22.36
Gross margin/goats	1583.86[b]	2453.27[a]	1.94

[ab] Mean with different superscripts within a row differ significantly ($p<0.05$),
SEM= Standard Error of Mean

CHAPTER FIVE

5.1 Summary and Conclusion

It was concluded that sprouted white sorghum had increased crude protein (4.92%), ether extract (2.15%) and crude fibre (2.16% content) compared to the grains which recorded lower values of 4.10, 1.45, and 1.06% respectively. The levels of vitamin studied were also higher in the sprouts than the grains. The values were: Vitamin A (10.00 and 8.20mg/L), Vitamin C (12.10 and 5.20mg/L), Vitamin E (0.45 and 0.26mg/L), Biotin (1.51 and 0.16mg/L), and Beta-carotene (1.05 and 0.16mg/L) for sprouts and grains, respectively

5.2 Recommendation

It is recommended to local farmers to use hydroponic sorghum sprouts as good source of feed supplement. It is also recommend that sprouts improved livestock performances, increase crude protein, vitamins. The 15% of sprouts in the diet of Red Sokoto goats also increases TVFA, rumen ammonia nitrogen, weight gain and lower Nitrogen retention.

REFERENCE

Abdul, S. B, Ehache. O. W., Adamu, A. M., Bawa, G. S., Hassan, M. R., Yashim, S. M. and Adamu, H. Y. (2012). Effect of varying Levels of Zizyphus (*zizyphus mauritiana*) Leaves Meal Inclusion in concentrate Diet on Performance of Growing Yankasa Ram lambs Fed Maize Stover Basal Diet. *Iranian Journal of Applied Animal Science 2(4): 253-256*

Aba, D.A, Idem, N.U.A., Marley, P. S., and Maigida, D. N (2004). Cereal crops of Nigeria: principles of production and utilization. Ade commercial press, Zaria. PP 38-78

Abbas, T. E. E, and Musharaf, N. A (2008). The effects of germination of low – tannin sorghum grains on its nutrient contents and broiler chicks performance. *Pakistan Journal of Nutrition*

Adebule, M. A. (2002). Utilization of malted sorghum sprouts by starting chicks. B. Agric Project report, Department of Animal Nutrition, University of Agriculture, Abeokuta, Nigeria 11-13.

Acta Agronomica, (2011), Productive response of rabbits fed with green hydroponic oats forage as partial replacement of commercial concentrate.

Agricultural Production,Worldwide, (2009). FAOSTAT, Food and Agriculture Organization of the United Nations. (2010).

Allen, M.S., Voelker, J.A. and Oba, M., (2006). Effective fibre and regulation of ruminal pH: it’s more than just chewing. Pp. 270-278 In: Production diseases in farm animals. Eds. Joshi, N.P., Herdt, T.H., Wageningen Academic Publishers, Wageningen, Netherlands.

Amodu, J. T., Kallah, M. S., Adeyinka, I. A., Alawa, J. P.and Lakpini, C. A. M. (2008). The nutritive value of silages made from mixtures of pear millet (*Pennisetum americanum*)and lablab *(Lablab purpurreus*) as feed for yankasa Rams. *Asian Journal of Animal and Veterinary Advance* 3(2):78-84.

Amsalu, A. and Endashaw B. (1998). Geographical patterns of morphological variations in sorghum (*Sorghum bicolour* (L.) Moench in Hereditas 129: 195-205.

A.O.A.C. (2000). Association of analytical chemist, 17th revisesd edition. Official method

Baker, J. F, Vann, R. C. and Neville, W. E.Jr. (2002). Evaluations of Genotype× Environment teractions Beef Bulls’ Performance Tested in Feedlot or Pasture. *Journal of Animal Science.,* 80(7): 1716-1724.

Balole, T.V. (2001). Strategies to improve yield and quality of sweet sorghum as a cash crop for small scale farmers in Botswana. PhD thesis, University of Pretoria, South Africa. 132 pp.

Barnett, A. J. G. and Reid, R. L. (1957). Studies on the production of VFAfrom grass by rumen liquor in an artificial rumen. The VFA production from grass *Journal of Agricultural Science*, cam. 48, pp:315-321.

Briggs, P. K. Hogon, J. P. and Reid. R. C. (1957). Effect of volatile fatty acid, lactic acid and ammonia on rumen pH in sheep. *Australian journal of Agricultural Research* 8:674

Burkill, H.M., (1994). The useful plants of West Tropical Africa. 2nd Edition. Volume 2, Families E–I. Royal Botanic Gardens, Kew, Richmond, United Kingdom. 636 pp.

Carruthers, S. (2003). Green Feed – Livestock Fodder Shed. Retrieved from http://owll.massey.ac.nz/referencing/apa-interactive.php

Chantereau, J., Trouche, G., Luce, C., Deu, M. and Hamon, P. (1997). Le sorgho. In: Charrier, A., Jacquot, M., Hamon, S. & Nicolas, D. (Editors). L'amélioration des plantes tropicales. Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) and Institut français de recherche scientifique pour ledéveloppement en coopération (ORSTOM), Montpellier, France. pp. 565–590.

Chavan, J. K. and Kadam, S.S. (1989). Nutritional improvement of cereals by sprouting. *Creatical Rev. Food Sci. Nutrition*., 28:401-437.

Chung. T. Nwokolo, E.N. and Sim. J. S. (1989). Compositional and digestibility changes in sprouted barley and canola seeds. *Plant Foods for Human Nutrition*. 39: 267-278.

Crop Production, Worldwide, (2010). data". FAOSTAT, Food and Agriculture Organization of the United Nations, (2011).

Cuddeford. D. (1989). Hydroponic grass In Practice 11(5): 211-214.

Curtis, D.L. (1967). Experimental Agriculture 3:275.

Daniel, Z. and Maria, H. (2000). *Domestication of plants in the Old World*, third edition (Oxford: University Press, Department of Agriculture Western Australia. Pp: 89

Daramola, J. O., Adeloye, A. A., Fatoba, T. A. and Soladoye, A. O. (2005). Haematological and biochedmical parameters of west African Dwarf goats. *Livestock research for Rural Development*, 17(8). Retrieved, from htt://www.lrrd.org/lrrd24/7/komw24108.htm on january 20th, 2013.

de Vries, J. T and Toenniessen, G. (2001). Securing the harvest: biotechnology, breeding and seed systems for African crops. CAB International, Wallingford, United Kingdom. 224 pp.

Dehority, B.A. (2003). Rumen microbiology. Nottingham University Press, Manor Farm, Main Street Thrumpton, Nottingham, NG11 0AX, UK. Pp. 1 - 365.

Dogget, H.D. (1988). Sorghum, second edition, New York, Longman scientific and tech, pp 441-448.

Duncan, D.G. (1955). Multiple ranges and multiple F-tests. 11:1-42.

Dung, D. D., Godwin, I. R., and Nolan, J. V. (2010). Nutrient Content and *in sacco* Digestibility of Barley Grain and Sprouted Barley. *Journal of Animal and Veterinary Advances,* 9 (19), 2485-2492.

Elseed, F. A. M. A. (2005). Effect of supplemental protein feeding frequency on ruminal characteristics and microbial N production in sheep fed treated rice straw. Small ruminant research. 57:11-17.

Elvehjem, C. A., Hart, E. Jackson H. C. and Weckel H. G, (1934). The nutritional values of Milk raw vs. Pasteurized and summer vs. winter .*Dairy Science*, 17:763-770

Etuk E. B., Ifeduba, A. V., Okata U. E., Chiaka I., Okoli, Ifeanyi C., Okeudo N. J., Esonu B. O., Udedibie A. B. I. and Moreki, J. C. (2012). Nutrient Composition and Feeding Value of orghum for Livestock and Poultry. *Journal of Anim Sci Adv* 2012, 2(6): 510-524

Fafiolu, A.O., Oduguwa, O., Ikeobi, C. N. and Onwuka C.F. I., (2006). Utilization of malted sorghum sprouts in the diet of rearing pullets and laying hens. *Archivos de Zootecnia.* 55: 361-371.

FAO, (1995), FAO. Food and nutrition series, No. 27.

FAO, (1995). Sorghum and Millet in Human Nutrition. Food and Nutrition Series. No. 27. Food and Agriculture Organisation, Rome/WHO p. 333 Retrieved on July 12, 2005 from http://www.fao.org/ DOCREP/TO818e/TOP18Eoo.html.

FAO, (2004). Compendium on post-harvest operation—Contains discussion on origin, processing and uses of sorghum.

FAO, http://www.feedipedia.org/node/379 *last updated on September* 4, 2012, 13:11

Farlin, S.D. Dahmen J. J. and Bell, T. D. (1971). Effect of sprouting on nutritional value of wheat in cattle diets. *Canadian. Journal of Animal science.,* 51:147-151.

Fasae, O. A., lbikunle, B. A., Oyenaiya, O. A. And Adu, l. F. (2011). Haematological carrcass characteristics and meat quality of intensively managed West African Dwarf goats slaugtered at different liveweights. *Bulletin of A nimal Health and production in Africa,* 59:208-215

Fayed, M.A. (2011). comparative study and feed evaluation of sprouted barley grains on rice straw versus Tamarix Mannifera on performance of growing Barki Lambs in Sinai. *Journal of. Animal. Science*. Pp: 7.

Fazaeli, H. Golmohammadi, H. A., Shoayee, A. A., Montajebi, N. and Mosharraf, S. h. (2011). Performance of Feedlot Calves Fed Hydroponics Fodder Barley. *Journal of Agricultural Science and Technology,* 13, 367-375.

Finney, P. L. (1982). Effect of germination on cereal and legume nutrient changes and food or feed value: A comprehensive review, *Phytochem*. 17:229-305.

ftp://ftp.fao.org/docrep/fao/009/a0540t/a0540t06.pdf, (2011).

General Sorghum"(2011). Agricultural Resource Marketing Center - partially funded by U.S. Department of Agriculture Rural Development Program.

Gontzea, I. and Sutzescu. P. (1958), Natural and Nutritive Substances in Foodstuffs and Forages.

Google maps (2013). Meet the new Google Maps: A maps of every person and place Retrieved 11 march, 2014 from *htt://www.trusedreviews.com*

Goonewardene, L. A., Spicer, H. M., Engstrom, D. F., ZoBell, D. R. and Yaremcio, B. J. (1998). A Study on Feeding Ammoniated and Processed Barley to Feedlot Steers. *Animal Feed Science and Technology.*, 74(2**)**: 135-142.

GreenfeedSA HTTP://t. Co/oww26ed5. 354days.ago.reply.retweet favorite, (2011)

Grigorev, N.G. Fistev, A. and lesnistskaya, l. (1986). Nutritive value of hydroponic feed and its use for feeding high-yielding cows. *Selskokhozyaistvennaya Biology*.7:47-50.

Gualtieri, M and, Rappaccini. S, (1990). Sorghum grain in poultry feeding. *World poultry Journal.* PP 46:246-254.

Hamid, F. H. (2001). The effects of germination and fermentation processes on chemical composition and nutritional value of low - tannin grain sorghum. M. Sc. Thesis, Faculty of Animal Production, University of Khartoum.

Harlan, J.R. and de Wet, J.M.J., (1972). A simplified classification of cultivated sorghum. *Crop Science* 12: 172–176.

Harris, D. A. (1973). Commercials hydroponic fodder growing in South Africa. Third International Congress on Soilless Culture.

Heuzé, V., Tran, G., Giger-Reverdin, S., Lebas, F., (2012). Sorghum forage. *Feedipedia*.org. A programme by INRA, CIRAD and AFZ and FAO. http://www.feedipedia.org/node/379 last updated on September 4, 2012, 11:11

Iowa State University, (2013). Hydroponic fodder systems for dairy cattle.

IAR (2009). Code and description of crop varieties released by Institute of Agricultural Research, Ahmadu Bello University, Samaru, Federal Ministry of Science and Technology, Abuja, pp. 14 – 15.

ICRISAT, (2000). *Sorghum bicolour* (L) Moench. Crop Gallery. International Crop Research Institute for the Semi-Arid Tropics. Retrieved on November 30, 2004 from http://www.icrisat.org/text/coolstuff/crops/gcrops2.html.

Ikediobi, O. (1989). Industrial malting of sorghum in Nigeria. Paper presented to the ICRISAT Workshop on industrial utilization of sorghum held in Kano, pp: 18.

Imasuen, J. A. And Otoikhhian, C. S. O. (2011). Assessment of serum biochemistry West African Dwarf does administered varying levels of Medroxyl-progesteron Acetate (MPA), An estrus synchronizing drug. *African journal of Biotechnology* 10(31):5887-5892

Impema, A.H., Goense, D., Hogewerf, P.H., Houwers, H.W.J. & Van Roest, H., (2008). Plot study to monitor body temperature of dairy cows with a rumen bolus. 64: 49 - 52.

Ismartoye, Dixon, R. M., Slocomba, R. F. And Holmes, J. H. G (1993). *Lablab purpureus* seed as a supplement for goats fed low quality roughage. *Asian-Australian Journal of Animal Sciences, 6(4):515-519*

Karen R. L, and Watson, (2001). Recovery of sorghum wax from selected processes" (January 1, 2001). ETD collection for University of Nebraska - Lincoln. Paper AAI3004616. http://digitalcommons.unl.edu/dissertations/AAI3004616.

Kohler,G.O., Elvehjem C.A. and Hart E.B., (1938). The relation of the grass juice factor to guinea pig nutrition. *Journal of Nutrition*. 15:445-459.

Kolan, S. P. K. and Ansah, T. (2012). Productive and blood indices of Dwarf Rams fed a mixture of rice straw and groundnut haulms alone or supplemented with concentrate containing different levels of shea nut cake. *Pakistan Journal of Nutrition*, 11(6):566-571

Magness, J. R., Markle, G. M and Compton, C. C. (1971). Food and feed crops of the United States – A descriptive list classified according to potential for pesticides and residues. International Research Project IR – 4, IR. Bull 1 (Bulletin 828) New Jersey Agric. Expt Station, Retrieved on June, 15th, 2007 from http://www.hort.pordune.edu/newcrop/crops/grain= sorghum.html.

Marisco, G. Miscera, E. Dimatteo, S., Minuti, F. Vicenti, A. and Zarrilli, A.(2009). Evaluation of animal welfare and milk production of goat fed on diet containing hydroponically germinating seeds. *Italian Journal of Animal Science, 8(2),pp: 625-627.*

Ma-under, B (2002). Sorghum - The global grain of the future. Retrieved November 30, 2004 from http://www.sorghumgrowers.com/maunder.htm.

Miscera, E., Ragni, M., Minuti, F., Rubino, G., Marisco, G. and Zarrilli, A. (2009). Improvement of sheep welfaee and milk production fed on diet containing hydroponically germinating seeds. *Italian Journal of Animal Science, 8 (2), pp :634-636.*

Morgan, J., Hunter. R.R.and Ohaire, R. (1992). Limiting factors in hydroponic barley grass production. 8th International congress on soilless culture, Hunter's Rest, South Africa. Pp.23-78

Muhammad, S., Hussain, A. and Subhani M., (2013). Use of sprouted grains in the diets of poultry and ruminants. *indian journal of research.* (2) 2250-1991**.**

Murty, D.S. and Renard, C., (2001). Sorghum. In: Raemaekers, R.H. (Editor). Crop production in tropical Africa. DGIC (Directorate General for International Co-operation), Ministry of Foreign Affairs, External Trade and International Co-operation, Brussels, Belgium. pp. 78–96.

Musharaf, A.G. and Latshow, R.T. (1991). The effect of high sorghum feed on broiler. *British Poultry Science*, 40: 44-49.

Myers, J. R. (1974). *Feeding Livestock from the Hydroponic Garden*. Agriculture Department. Phoenix, Arizona State University pp.23-30.

NCGRB, (2004). Crop varieties released and registered in Nigeria. National Centre for Genetic Resources and Biotechnology, Ibadan, pp. 24 – 25.

Ndlovu, L. R. and Hove. L. (1995). Intake, digestion and rumen parameters of goats fed mature veld hay ground with deep poultry manure and supplemented with graded levels of poorly managed groundnut hay. Retrieved, from http://www.lrrd.org/lrrd19/9/ngon19129.htm on 1st january,2013.

Norman, M. J.T, Pearson, C. J and Searle P. G., (1995). *Tropical Food Crops in their Environment*. 2nd ed. University Press, Cambridge. Pp21-34.

Nutrigrass, (2007). The jointing stage: When nutrients reach their peak. http://www.nutrigrass.com/jointingstage.htm.

Obilana, A.T. (2005).Lagos state polytechnic lecture series 2:1-27

Obilana, A. T., (1981) *Sorghum Grain Quility*. ICRISAT. Patancheru. Pp.45-54.

Ogbonna, A . C. Obi, S. K. C. and Okolo, B. N. (2003). *J. Inst. Brew*. 109:51-503

Ogbonna, A. C. (2000). Studies on malting parameters purification and characterization of proteolytic enzymes from sorghum malt varieties .University of Nigeria. Ph.D. Thesis.

Ogwumike, O.O. (2002). Hemopoietic effect of aqueous extract of the leaf sheath of Sorghum bicolor in albino rats. *African Journal of Biomedical Research* 5(1–2): 69–71.

Olafadehan, O. A. (2011). Change in haematological and biochemical diagnostic parameters of Red Sokoto goats fed tannin-rich *Pterocarpus erinaceus* forage diets. *Veterinary Archive*, 81(4):471-483

Osuji, P.O. Nsahlai, T. V. and Khalili, H. (1993). Feed evaluation. ILCA MANUAL 5. ILCA (International Livestock Center for Africa), Addis Ababa, Ethiopia. Pp. 40.

Peer, D. J. And Leeson S., (1985). Nutrient content of hydroponically sprouted barley. *Animal Feed Science Technology*. 13:191-202.

Plaza, L., B.de Ancos and M.P. Cano,(2003). Nutrition and health-related compound in sprouts and seeds of soybean (*Glycin max*), wheat, (*Triticum aestivum L*.) and alfalfa (*Medicago sativa*) treated by a new drying method. *Eur. Food Resource. Technology.*, 216:138-144.

Price, M. L., Scoyoc, S. V. and Buttler, L. G. A. (1978). Critical evaluation of vanilli reaction as an assay for tannin in sorghum grain. *Journal of Agric food chem*., 26:121-1218

Reddy, B.V.S., Ramesh, S. and Reddy, P.S. (2004). Sorghum breeding research at ICRISAT - goals, strategies, methods and accomplishments. *International sorghum and millets.* 45: 5–12.

Robert S. Charles, (2003).The Charles Feed Shed,

Roger, S. and Felicity M. Ms, (2003). Review of hydroponic fodder production for Beef cattle.

Rooney, L.W. and Serna-Saldivar, S.O., (2000). Sorghum. In: Kulp, K. and Ponte, J.G. (Editors). *Handbook of cereal science and technology. 2nd Edition. Marcel Dekker, New York, United States*. pp. 149–175.

Safari, J., Mushi, D. E., Kifaro, G. C., Mtenga, L. A. And Eik, L. O. (2011).Seasonal variation in chemical composition of native forages grasing behavior and some blood metabolize of small East African goats in Semi-Arid area of Tanzania. *Animal Feed Science and Technology, 164: 62-70.*

Sakha, M., shamesdini, M. And Mohamad-Zadeh, F. (2009). Serum Biochemistry Value in Raini Goat of lran. *The internet Journal of Vetesrinary Medicine 6(1). DOI:10.5580/l acf*

Salunkhe, D.K., Chavan., J. K and S.J. Jadhav, (1984). *Nutritional and processing quality of sorghum*. Oxfords and IBH Publishers, NewDelhi ,India.

Sanders, J.H., Ahmed, M.M.and Nell, W.T., (2000). New sorghum and millet cultivar introduction in sub- Saharan Africa: impacts and research agenda. *Agricultural Systems* 64(1): 55–65.

SAS institute, Inc. (2002).SAS User guide: statistical. Version 9.SAS institute, Carry, NC.27513,USA

Satya. S. N. Anwar. A. Hamama and Harbans, L. Bhardwaj, (2012). Nutritional and mineral composition of Flax sprouts.

Scott, (2003): Nerang Hydroponic center.

Seshu, R. K. V., (1991). Insect pests of sorghum in Africa.12(5–6): 653–657.

Shipard, I. (2005). *How Can I Grow and Use Sprouts as Living Food*, Stewart Publishing.

Pp.34-67

Shuma"ila, K., Arif, M. B., Bakhtyawar, A. K., Sobia, D., Muhammad, A., Muhammad, A.and Furhan, l. (2012). Effect of Age and gender on some blood biochemical parameters of apparently healthy small ruminants from Southern Punjab in Pakistan. *Asian Pacific Journal of Tropical Biomedicine, 304-306pp*

Showemimo, F. A.,Echekwu, C. A and Yeye, M.Y. (2000). *The Plant Scientist*. 1:24-31.

Singh. S. P. And Gupta, B. N. (1986). Effect of feeding ammoniated straw impregnated with urea digestibility and VFA production rates in buffaloes. *Indian journal of animal science, 56:1210-1214*

Simon. E. W. (1984). Early events in germination. Seed Physiology.

Simons. E. B. (1976). Samaru Miscell. Paper 5.

Smith, C.W. and Frederiksen, R. A.(2000). *Sorghum: origin, history, technology, and production.* John Wiley & Sons, New York, United States. 8

Smith, W. C. (1995). Crop Production: Evolution, History and Technology. John Wiley and Sons Inc. Toronto, Canada.

Sneath, R. and McIntosh, (2003). Review of hydroponic fodder production for beef cattle. Queens land Government, Department of primary Industries, Dolby, Queensland. Pp. 12-67.

Taylor, J.R.N. (2003). Overview: importance of sorghum in Africa. In: Belton, P.S. and Taylor, J.R.N. (Editors). *Enhancing nutritional and functional properties for Africa* Pretoria, South Africa, 2–4 April 2003. Afripro. (Internet). http://www.afripro.org.uk/. Accessed April 2005.

Thomas. J. W. and Reddy. B. S. (1962). Sprouted oats as a feed for dairy cows. *Quarterly Bulletin of the Michigan Agricultural Experiment Station.* 44: 654-655.

Trinder. D. W. (1998). A survey of aflatoxins in industrially brewed South African sorghum beer and beer straining. *Journal of INST. BREW*. 95 (5) 307–309.

Trubey,C.R.,Rhyckerd, C.H. Noller, D.R. Ford and J.R. George (1969). Effect of light, culture solution and growth period on and chemical composition of hydroponically produced oat seedlings *Agron. Journal*. 61:663-665.

Tudor, G., T. Darcy,P.Smith and Shallcross F. (2003). The intake and live weight change of drougtmaster steers fed hydroponically grown, young sprouted barley fodder (Autograss), Department of Agriculture Western Australia.

U.S. Grains Council. (2005). "*Sorghum Handbook*"pp.36.

United States Grain Council. (2010). Sorghum. Pp. 23-56.

USDA, 2004. USDA. national nutrient database for standard reference, release 17. [Internet] U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory, Beltsville Md, United States. http://www.nal.usda.gov/fnic/foodcomp. Accessed June 2005.

Van der Walt. H. P. (1956). Kafficorn matling and brewingss studies II-Studies on the microbiology of Kaffir Beer. *Journal of Science Food Agric*. 7(2); 105–113.

Van soest, P.J. Mascarenhas-ferreira, A and Harley, R.D. (1991). Chemical properties of fiber in relation to nutritive quality of ammonia treated forages. *Animal Feed Science and Technology. 10:pp.155.*

Van Wyk, B-E. and Greicke, N. (2000). *People's Plants*. Pp67-87

Wang, Y. Y. D. and sorghum in the home to improve nutritive value. *Journal of Food Science. 43. 1113*

Watson, (1970). *Sorghum production and Utilization*. A.V. I Publishing C. Westport. Connecticut. Pp.23-78.

Whye, K. C. (1973). The complete sprouting Cookbook. San Francisco, Troubator press.pp23-56

Williams, Y.J., Walker, G.P., Wales, W.J. and Doyle, P.T. (2001). Effect of pasture type and intake on the rumen pH of grazing cows in spring. *Austiralian. Journal of Dairy Tech. 56:163.*

www. Worldsorghumproduction.com