NUTRIENT COMPOSITION OF COOKED LABLAB BEAN VARIETIES FOR IMPROVING NUTRITION AND FOOD SECURITY IN TANZANIA

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ABSTRACT

Legumes are important crops for improving food and nutrition security in Africa. However, there are few nutrition researches on lablab beans in Africa, except for programs focusing on improving soil properties. This study was conducted to evaluate the nutritional composition of seven varieties of cooked lablab beans grown in Tanzania. The lablab bean varieties both green and dried were cooked then analyzed for chemical composition, cooker-ability and sensory qualities. The parameters studied in chemical composition were proximate composition (protein, carbohydrates, fat, fiber, ash, moisture and carbohydrate) and mineral content (Calcium, Copper, Iron, Manganese and Zinc). Anti-nutritional factors investigated were phytic acid and tannin. Sensory quality parameters assessed were appearance, colour, mouth feel, taste and overall acceptability. Results showed that, both green and dried beans had chemical composition that could meet the recommended amounts of nutrients. Based on proximate composition ILRI6536 had highest content of protein (29.75 g/100 g) and Eldoret Black had highest fibre content (12.5 g/100 g). Based on mineral composition, DL 1002 had the highest Iron (3.35 g/100 g) and Calcium contents (3.93 g/100 g) while ILRI 6536 had the highest Zinc content (8.7 g/100 g). Lower levels of anti-nutrients were observed in ILRI 6536 (2.88 g/100 g) for tannin and Echo Cream (1.10 mg/100 g) for phytic acid and higher content of both phytic and tannin were in Echo Cream. Based on sensory evaluation, Karamoja Red was ranked best on appearance, smell and taste. In quantitative descriptive analysis, Elodert black was ranked best in market demand. It was concluded, based on the study that, lablab beans can be a good food source for improving food and nutrition security as most of the varieties had high nutrients and low anti-nutrients. Therefore there is a need to promote and improve this orphan crop by researching on protein profile and vitamins recommended.

DECLARATION

I, MONICA MICHAEL MORRISON, declare to the Senate of Sokoine University of Agriculture, that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution for a degree award.

……..…… ……

MONICA MICHAEL MORRISON **Date**

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The above declaration is confirmed by

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Prof. MOSHA, T. C. E **Date**

Supervisor

…… ……..……

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This work is dedicated to my beloved Father Mr. Michael Morrison and mother Scholastica Michael Morrison who have always believed in me and laid down the foundation of my education and shaped me to who I am today.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percent
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CA	Conservation agriculture
CA	SARD
CF	crude fat
CFGB	Canadian Food grains Bank
CF_I	Crude Fiber
CHO	Carbohydrate
Cu	Copper
DFNC	Department of Food Technology, Nutrition and Consumer Sciences
DHS MIS	Demographic and Health Survey and Malaria Indicator Survey
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
$Fe(NO_3)_3$	Iron(III) nitrate
ILO	International Labor Organization
Kg	Kilogram
Mg	Magnesium
Mg	Milligram
Mg/100	Milligram per 100
Min	Minutes
NaOH	Sodium Hydroxide
NAS	National Academy of Science
NH_4OH	Ammonium hydroxide

NH_4OH	Ammonium Hydroxideg
NM-AIST	Nelson Mandela Africa Institute of Science and Technology
P	Phosphorous
PA	Phytic acid
QDA	Qualitative Descriptive Analysis
RDI	Recommended daily intake
SD	Standard Deviation
SUA	Sokoine University of Agriculture
TARI-S	Tanzania Agricultural Research Institute – Seliani
TCA	Trichloroacetic Acid
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WHO	World Health Organization
Zn	Zinc
µg	Microgram

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

"Food and nutrition security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (McGuire, 2013). Insufficient food production has become a major problem in most developing countries, and being the core reason for food shortage in Sub-Sahara region (FAO 2003). In a region where 70% of the population relies on their own food production, the main vehicle for addressing food and nutrition security is agriculture (Haddad *et al.*, 2015). According to the United Nations Development Programme (UNDP) (2012), nearly 218 million people are food insecure and undernourished, and food security is a core component of the human development and capability paradigm.

In Africa, about two-thirds of the working population are still making their living from agriculture (ILO, 2007). It has been reported that, approximately 88% of countries are currently facing a serious burden of malnutrition (Hawkes and Fanzo, 2017), where the most common recognized cause is inadequate food consumption. To overcome this burgeoning food and nutritional challenge, use of potential crop plants appears to be a better choice (Chang *et al*., 2018). In the literature, there is much focus on the effects of climate change on food security in the developing world (WHO, 2010). In these developing areas, there is good evidence that climate change will compound existing and predicted food insecurity and under nutrition (Cohen and Thompson, 2008). If agricultural production in the low-income developing countries is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and their vulnerability to food insecurity, malnutrition and hunger will increase. Hence there is a

need to re-introduce the use of orphan crops among the society that will help lessen the burden towards increasing risk of food insecurity.

Legumes have often been associated with poverty throughout history. In cultures where a portion of the population can obtain protein from animal sources, beans are seen as food only fit for peasants; the "poor man's meat" (Albala, 2017), but play a particularly important role in the diet of the underprivileged. Food and Agriculture Organization (FAO) recommends that, beans (Pulses) need to be eaten daily as part of a healthy diet to prevent and manage chronic diseases, and to address the growing global obesity issues (FAO, 2016). This was emphasized during the International Year of Pulses in 2016, where the focus was on the contribution of pulses to production and dietary diversity to eradicate hunger and malnutrition (Considine *et al.*, 2017).

Lablab bean, *Lablab purpureus* L. Sweet is known to belong to the family *Fabaceae* and is one of the most ancient crops among cultivated plants (Engle and Altoveros, 2000). It is a legume species that grows in the tropic and the sub-tropic regions of the world. It is presently grown throughout the tropical regions of Asia and Africa and it remains a minor crop in these regions. As an indigenous leguminous cover crop in Africa that once fed much of the continent, largely through household garden production by women (Maass *et al.*, 2010). However, the crop was lost to most of Africa during the colonial era when farmers were encouraged, or forced, to grow maize and common beans intended for export markets (Robertson, 1997).

Hossain *et al.* (2016) found that, lablab seed contains high nutrients with potentials to meet the nutritional requirements of human being. Despite the nutritional supports behind lablab beans, they have a very poor image around the world as a food source. They are

usually grown by smallholder farmers, either for consumption or local sale, and are a major food source for 600 million rural Africans (Foyer *et al*., 2016).

The extent of production of Lablab in East Africa (Kenya and Tanzania) has not been well documented, despite relatively long existence of the bean in the counties. In several small communities of northern Tanzania, for example in Mang'ola and Kondoa, lablab beans continued to be grown and consumed throughout the colonial era.

Despite this expansion and farmer interests, genetic improvement of lablab beans was completely ignored by the scientific research community in Tanzania until recently. In 2017, Seliani - Tanzania Agriculture Research Institute (TARI, Seliani) maintained and distributed to farmer three landraces, but selection or improvement was not attempted until 2015. Nelson Mandela African Institution for Science and Technology (NM-AIST), in collaboration with the Canadian Food Grains Bank (CFGB), obtained a set of core accessions from the ILRI gene bank in Addis Ababa, and began screening them alongside six Kenyan released varieties and farmer landraces collected throughout East Africa. The NM-AIST collection now includes nearly 400 accessions from around the world, and 30-35 of these accessions have been tested for yield, farmer preference, and agronomic properties on research stations in three agro-ecological zones for the past two years (Miller *et al.*, 2018). Results of these trials have been used to select seven best-bet accessions, which are now being tested on 36 farmer-managed trials in major lablab producing areas of Northern Tanzania during the 2018 season.

1.2 Problem Statement and Justification of the Study

It was reported in a study done in Kenya that anti-nutritional factor content in legume grains may differ as a result of species, cultivars, climatic conditions, soils, locations,

seasons and seed germination (Sridhar and Seena, 2006). Based on the different physical and nutritional characteristics, there is potential to select lablab varieties with good cooking and nutritional characteristics among the varieties grown.

Despite its importance in the food and farming systems, particularly among communities in arid and semi-arid lands, lablab bean has remained neglected and underutilized in many African countries (National Research Council, 2006). In Bangladesh it has been highly neglected recently, except by some street vendors who sell the fried seeds as a traditional afternoon snack. Though lablab has been reported to be of high nutritional value, it is still of limited economic importance in the global market, consequently attracting minimal attention from researchers and the food industry generally (Hossain *et al*., 2016; Foyer *et al*., 2016).

There are few nutrition researches on lablab beans in Africa, except for programs focusing on improving soil properties by using green-manure/forage crops, such as in maize based systems of Kenya (Mureithi *et al*., 2003; Cheruiyot *et al*., 2007; Lelei *et al*., 2009) and in Tanzania (Tefera, 2006).

The production of lablab beans in Tanzania has mainly been as cover crop used in areas like Mbuyuni farm along the Mkata plains (Kimango), Mang'ola and Kondoa. Other areas such as in Hedaru have made use of lablab bean for export mainly to Kenya and as a cover crop. In order to bring lablab back on farmers' fields, there is a need to identify short-season varieties that are well-adapted to the environmental conditions in semi-arid areas and well-accepted by farmers in terms of yield, sensory and nutritional quality (Whitbread *et al*., 2011).

Most studies done have based on the assessment of nutritional quality of dried lablab beans and the green leaves that have been used as food for human consumption. This study focused on assessing the nutrient composition of cooked green and dry lablab beans so as to recommend the best variety for human consumption based on cooking qualities, sensory and consumer acceptability, anti-nutritional factor and nutrient composition.

1.3 OBJECTIVES

1.3.1 General objective

The general objective of the study was to determine nutrient composition, ant-nutritional factors, cooking time, sensory attributes and consumer acceptance of cooked lablab beans.

1.3.2 Specific objectives

The specific objectives of the study were to:-

i. Determine the nutrient composition of cooked lablab beans varieties. (Proximate composition, mineral content)
ii. Determine the anti-nutritional factors (tanning and phytic acid)in lablab beans
iii. Determine the cooking time of the lablab beans accessions
iv. Assess sensory attributes and consumer acceptability of the cooked lablab bean accessions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Beans Nutrition Profile

Beans are often the main source of protein, and a significant source of minerals for low-income populations (Laparra *et al.*, 2009). Green beans have been reported to have a good source of protein (12.67 to 17.19 %), dietary fiber (37.31 to 26.46%) and minerals specially calcium (51.03 to 135.81 mg/100 g), iron (4.30 to 6.81 mg/100 g), zinc (3.18 to 6.02 mg/100 g) and potassium (919.41 to 953.79 mg/100 g) (Rani and Punia, 2017).

Dry common beans (fully matured and dried) are a rich source of proteins which ranges between 15 and 35% which meets the minimal need of human requirements endorsed by the World Health Organization and Food and Agriculture Organization. They also supply starch, unsaturated fatty acids (linoleic acid), dietary fibre, vitamins and minerals, which are considered as important food resources (Ganesan and Xu, 2017). Beans are among the only plant foods that provide significant amounts of the indispensable amino acid lysine. Commonly consumed dried beans are also rich in total and soluble fiber as well as in resistant starch, all of which contribute to the low glycemic index of these foods (Messina, 2014).

Due to their high concentration of health-promoting nutrients, consuming more beans in diet could improve overall health and also decrease the risk of developing certain diseases, including heart disease, obesity and many types of cancers (Kotue *et al.*, 2018).

2.2 Agriculture Production and Nutrition

There is an accelerating progress in nutrition situation in Tanzania, whereas in the period of 1992–2010, prevalence of stunting was 42%, underweight of children was 16%, while those suffering from acute malnutrition were 5%. This situation improved according to DHS-MIS (2015–16), 34% of children less than 5 years are stunted, 14% of under five children where underweight while 5% of under five children suffer from acute malnutrition (wasting or low weight-for-height).

From January 2018, various USAID programs with a focus on nutrition have been active in Tanzania making emphasis on agriculture as a driver of economic growth through a strategy that encompasses five core investment areas: agriculture, nutrition, policy, infrastructure, and institutional capacity with an integration in nutrition-sensitive efforts through agricultural activities with the aim of improving families' access to and consumption of nutritious foods (USAID, 2018).

Investing in nutrition is essential for Tanzania to progress. It is estimated that the country will lose US$20 billion by 2025 if the nutrition situation does not improve. In contrast, by investing in nutrition and improving the population's nutritional status, the country could gain up to US$4.7 billion by 2025 (UNICEF, 2017).

2.3 Origin and Spread of Lablab Beans

The wild forms of lablab are believed to have originated in India or South-East Asia, and it was introduced into Africa from South-East Asia during the eighth century. It was widely distributed to many tropical and subtropical countries (Murphy and Colucci, 1999). There is little evidence, to prove the presumption that, lablab has been trans-domesticated in India. Figure 1 shows African origin and global dispersal of *Lablab purpureus* derived

from diverse sources (Carney and Rosomoff, 2011; Fuller and Boivin, 2009; Giblin and Fuller, 2011; Maass and Usongo, 2007; Maass *et al*., 2005).

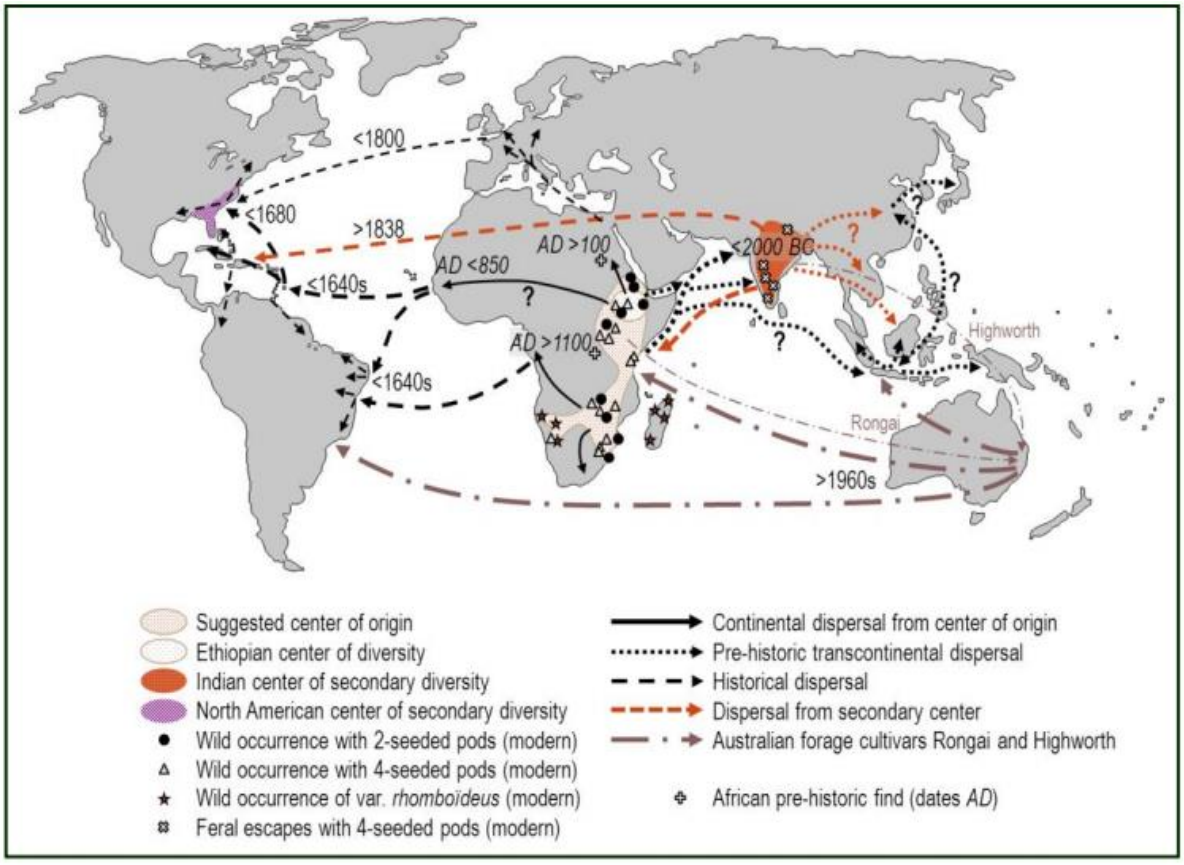

Figure 1: African origin and global dispersal of *Lablab purpureus* derived from diverse sources (unpublished data); basic world map from 2009 (www.outlineworld-map.com).

Lablab bean is one of the lesser known legume crops of arid and semi-arid regions and is classified by National Academy of Sciences (NAS) as a potential source of protein that has not been explored yet (Osman, 2007).

In the late 1990s, the FAO-sponsored Conservation Agriculture for Sustainable Agriculture and Rural Development project (CA-SARD) used farmer-cooperatives to select lablab as their primary cover crop for Conservation Agriculture (CA) (Mbaga and

Friesen, 2003). Lablab production has ever since continued to expand, largely through farmer-to-farmer dissemination and driven by a ready export market to the Kikuyu population in Kenya. Although there are no official statistics on production due to its status as a "minor crop" we estimate some 8,000 tonnes are produced annually, with a retail value $6-10M. (W. Mariki, personal communication).

2.4 Lablab as an Orphan Crop

There is almost no ongoing lablab research in Africa, except for programs focusing on improving soil properties by using green-manure/forage crops, such as in maize-based systems of Kenya (Mureithi *et al.,* 2003; Cheruiyot *et al.*,2007; *Lelei et al.,* 2009). A small number of studies (Mureithi *et al.,* 2003; Nyende and Delve, 2004; Tefera, 2006) have attempted to address with farmers the issue of acceptability of lablab beans, its varieties and potential uses. With the exception of the study by Tefera (2006) in Tanzania recent inception of a plant improvement program at Moi University, Kenya, there are no reports of ongoing research on improving lablab as a food for Africa. According to Maass *et al.* (2010) the conventional differences of lablab in Africa is without a doubt beneath danger of hereditary disintegration. Given its one of a kind and critical hereditary asset for any potential advancement program, be it in Asia or Africa, a considerable preservation program needs critically to be embraced. Therefore, the promise of orphan legume crops remains largely unexplored, even though they may represent a treasure trove of undiscovered and potentially unique traits due to their great genetic diversity (Foyer *et al*., 2016).

2.5 Outstanding Adaptation to Drought and Improving Soil Fertility

Lablab is ranked first among legumes because it is highly drought tolerant and grows well as an intercrop, and is known to be adaptive to drought (Maundu *et al*., 1999) and more

tolerant than common beans (*Phaseolus vulgaris*) or cowpea (*Vigna unguiculata*) (Piper and Morse, 1915). Keller *et al*. (2006) surveyed diversity of indigenous vegetables in eastern Tanzania, and lablab was recorded from the dryer regions. It was cultivated in 9 out of 10 villages surveyed in the Kongwa district (Keller, 2004). Cook *et al.* (2005) maintained that lablab is able to extract soil water from at least 2 m depth, even in heavy-textured soils. Lablab is known to be a more drought-tolerant crops, when comparing its grain yield with those of soybean (*Glycine max*) and different *Vigna* species. That was confirmed by Singh and Matsui (2002) on relative shoot drought tolerance of major crops grown in the semi-arid tropics, where only seedlings of some cowpea accessions and lablab survived in reasonable percentages.

Lablab is known to have a higher symbiotic relationship with rhizobia which fixes nitrogen in the soil, reducing the need for fertilizer and therefore promoting cheap efficient agricultural practices (National Research Council, 2006).

2.6 Economic/ Uses / Importance of Lablab

Traditionally, lablab was used in various ways whereby the seeds were used to stimulate stomach, as antidote for poisoning, menopause spasms, and for the treatment of cholera, diarrhoea, colic, rheumatism and sunstroke (Al-Snafi, 2017). *Lablab* is also used as a medicine to cure various illnesses, and by pregnant and lactating women to produce more milk (lactogogous food) (Sustainet, 2006).

Dried seeds are used to make protein concentrates, eaten directly as wholesome cooked or processed to form bean cake (*tofu*) or fermented to *tempeh* (Subagio, 2006). Lablab beans can be processed into *loshoro* (mixed with pounded maize plus milk) or *makande* (mixed

with pounded maize only). The flowers were used to treat inflammation of uterus and to increase menstrual flow in women of reproductive age (Kante and Reddy, 2013).

In Africa, Asia, and Caribbean lablab green leaves were also consumed as green vegetable (Sheahan, 2012). Additionally, the young leaves can be eaten as a green vegetable, the leaves are occasionally used as a potherb, although they are said to be less palatable and less popular than cowpea leaves (Sustainet, 2006).

Lablab is a readily available fodder that women can harvest daily in fields to feed animals, saving time for other activities, also used for ornamental purposes (Anderson *et al*., 1996). Based on chemical constituents, uses and pharmacological effects of *Dolichos lablab* is a promising medicinal plant with wide range of pharmacological activities which could be utilized in several medical and nutritional applications.

2.7 Anti-nutritional Factors in Beans

Anti-nutritional factors are compounds in legume which are deleterious to humans or in some ways that can reduce the bioavailability of nutrients (Hamid and Kumar, 2017). Much interest has been generated in examining some of these compounds with respect to chronic disease prevention (Bennink and Rondini, 2008). These compounds incorporate saponins, phytic acid, plant sterols, phenolic compounds, enzyme inhibitors and lectins. The anti-nutritional factors mainly occur in pulses and grain legumes and foods and feed materials prepared from grain legumes and pulses (Friedman, 2001). They can cause detrimental effects to both humans and animal in their growth and performance by impairing intake, uptake or utilization of other nutrients and feed components or by causing discomfort and stress to humans and animals (Bora, 2014).

Dietary phytate is reported to confer several beneficial health-promoting properties (Greiner *et al*., 2006). These include prevention of diabetes, heart disease and kidney stones due to its anticancer activity and anti-oxidant effect (Greiner et al., 2006). Phytates bind proteins causing reduced protein solubility (Pusztai, 1991). It forms insoluble complexes with metals reducing absorption of minerals and causing severe mineral ions deficiency in human (Nikmaram *et al.*, 2017).

Tannins interfere with digestion as it binds to dietary proteins and digestive enzymes, which results to complexes not readily digestible (Raes *et al.*, 2014). Tannins are involved in healing of wounds and inflamed mucus membrane and they also exhibit astringent and antimicrobial potentials.

2.8 Cooking of Lablab Beans

It has been reported that, cooking is necessary for bean preparation and consumption, as it tends to increase digestibility, inactivating anti-nutritional factors, increasing nutrient biological value and providing sensory quality and color characteristics requisite with consumer demands (Tharanathan and Mahadevamma, 2003; Costa *et al*., 2006). Similarly cooking is known to alter sensory attributes and nutritional quality while the consumption of vegetables depends largely on their sensory appeal rather than their nutritional quality (Kala and Prakash, 2006). Common bean cooking time is affected by many factors including; seed size, storage time, humidity and temperature of storage environment (Arruda *et al*., 2012). However, some processing methods such as- soaking, cooking, dehulling influence the nutritional quality of beans. Soaking and cooking reduce the amount of crude protein, crude fat, crude fiber and total ash (Emiola, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Tanzania Agriculture Research Institute (TARI)-Selian station in Arusha, Tanzania. TARI is located at Latitude 03º22' S and Longitude: 36º37' E above the sea level. The study was conducted from September 2018 to August 2019; analytical work was conducted at TARI Seliani laboratory.

Lablab beans were collected from various agricultural centers including Arusha: mid-altitude 1300-1500 m above sea level (villages north of Arusha town), Kondoa district : mid altitude 1400-1500 m above sea level (known for growing white lablab beans for many years), Hedaru in Same disrtict: low altitude 600-800 m above sea level (one of the top producers of black lablab, Mang'ola in Karatu district: low-mid altitude 1100-1200 m above sea level (one of the oldest lablab growing areas in the country), in Karatu district: high altitude 1500-1800 m above sea level (producers of black lablab).

3.2 Study Design

This was a cross sectional study design involving laboratory tests on nutrients and anti-nutrients content, cook-ability and consumer acceptability of new lablab bean varieties.

3.3 Sample Size

A total of seven lablab beans varieties were involved in the study including seven dried grains and seven green grains making a total of 14 samples as summarized in Table 1.

Table 1: Characteristics of collected lablab accessions in Northern Tanzania[1]

Variety of beans	Characteristics
Q6880B	Very early maturing, high yielding, drought tolerant, does well as an intercrop, and semi-indeterminate.
DL 1002	Registered in Kenya, early maturing, high yielding, determinate
Eldoret B2	Registered in Kenya, selected for fast cooking, medium maturity, and variable yield record.
ECHO Cream	Plump, white seed, consistently high yielding, drought resilient once established, mid-late maturity, very good forage potential
Karamoja Red	Plump, red-brown seed, high yielding, medium maturity, indeterminate.
ILRI 6536	Light brown seed, medium maturity, strongly indeterminate and drought resilient with very high forage potential.
Dodoma White	White seed, very high yielding especially in cooler moist conditions, late maturity, indeterminate.

Table [1] showing various characteristics of the seven selected lablab bean varieties sources (published data); lablab beans survey 2017

3.4 Sampling and Sample Collection

A total of one kilogram (kg) of both green and dried lablab beans from each of the seven accessions were collected with pods based on availability from various research sites namely Kondoa (kambi ya simba) and Hedaru (where both seven green and dried beans were collected) Mang'ola (three dried samples were collected) Karatu (Kambi ya Simba) (four dried beans samples were collected) and TARI-Seliani (where seven varieties of green beans were obtained). Samples were weighed and stored in brown paper bags for transport to the laboratory.

Collected samples were weighed with pods before being peeled. After peeling, they were then weighed as fresh weight for both green and dried beans. The selected samples for green lablab beans were soaked for four hours at room temperature (25^0 C) then water was discarded. The oaked green beans were thereafter boiled for 60 minute. Dried lablab beans were soaked overnight at room temperature (25^0C) and then water was discarded thereafter they were boiled for 65 minutes with no addition of ingredients. Cooked samples were then cooled before drying in an oven set at temperature of 60-70^0 C for 48 h. About 100 grams of each sample was ground into powder using a grinder (Retsch-sk100 cross beater miller), sieved at comparable particle size (100 µm) and packed in airtight bags for further analysis.

3.5 Laboratory Analysis

3.5.1 Proximate composition of dried Lablab beans

Proximate composition was determined according to AOAC (2005) and values were recorded in dry matter basis.

3.5.1.1 Moisture content

Moisture content cooked green and dried lablab beans was determined according to AOAC (2005) method 925.09.

Moisture content was recorded using the following equation:

$$\text{Moisture (\%)} = \frac{(W_1 - W_2) \times 100}{W1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: W_1 = weight (g) of sample before drying

W_2 = weight (g) of sample after drying

3.5.1.2 Crude protein

This was determined by the semi-Kjedahl method, (AOAC, 2005) method 920.152.A conversion factor of 6.25 was used to convert % nitrogen to % protein.

Protein content was calculated using the following equation:

$$\text{Protein (\%)} = \frac{(A-B) * N * 1.4007 * 6.25}{W} \quad \text{..... (2)}$$

Where

A = volume (ml) of 0.2 N HC1 used in sample titration

B = volume (ml) of 0.2 N HC1 used in blank titration

N = normality of HC1

W = weight (g) of sample

14.007= atomic weight of' nitrogen

6.25 =the factor for conversion of % nitrogen to % protein

3.5.1.3 Crude lipid

Crude lipid/fat was determined by using Soxhlet apparatus as described in the AOAC (2005) method number 945.87 (AOAC, 2005). The dry sample (3 g) was placed into the extraction thimble and assembled to the soxhtec apparatus. The petroleum ether 60 mL of was used for continuous reflux for 55min in three phases, the boiling phase for 15min, the fat extraction phase for 30 min and petroleum ether recovery phase for 10 min. Petroleum ether was then recovered by evaporation. Pre-weighed cups containing fat were dried in an oven at 105^0C for 30 min to evaporate any remaining petroleum ether, cooled in a desiccator for 20 min and weighed.

Percentage fat was calculated by using the formula:

$$\text{\% Crude fat} = \frac{\text{Weight of crude fat (g)}}{\text{(Weight of dry sample (g))}} \times 100 \quad \text{..... (3)}$$

3.5.1.4 Total ash

Total ash was predetermined by the AOAC (2005) method number 923.3, five g of the ample were weighed into pre-weighed crucibles. Crucibles with sample were combusted in a muffle furnace set at 600°C for 6 hours.

Ash content was then calculated as:

$$\% \text{ Ash} = \frac{\text{Weight (g) of ash}}{\text{Weight (g) of dry sample}} \times 100 \quad \ldots\ldots (4)$$

3.5.1.5 Crude fiber

Crude fiber was determined by using AOAC (2005) official method 920.86. Ankom Fibre Analyzer (Model ANKOM 220, USA) was used for the determination of crude fibre. Exactly 1.0 g of sample was first digested by dilute sulphuric acid (0.125M H2SO4) for 30 minutes and washed three times with hot distilled water. The residues were then digested by dilute alkali (0.125M KOH) for another 30 minutes and washed three times by hot distilled water. Digested residues were dried in an oven set at 100^0C for 12 hours, then cooled in a desicator and weighed. The residues were then placed in a muffle furnace and ashed at 550^0C for 2 hours, then cooled and weighed. Total fibre content was taken as the difference between the weight of residues before and after ashing.

$$\% \text{ crude fiber} = \frac{W1 - W_2}{W} * 100 \quad \ldots\ldots (5)$$

Where:

W_1 = Weight of sample residues before ashing (g)

W_2 = Weight of sample residues after ashing (g)

W = Weight of dry sample taken for determination (g)

3.5.1.6 Total Carbohydrate

Total carbohydrate was calculated as a difference of the sum of protein, fat, moisture, fiber and ash subtracted from the total weight of the food. This is referred to as *total carbohydrate by difference* and is calculated by the following formula:

100 - (Weight in grams of [protein + fat + moisture + fiber + ash] in 100 g of food)

3.5.2 Mineral Content

The content of mineral elements was determined using digestion with nitric-perchloric acid. The samples were analyzed using an atomic absorption spectrophotometer at TARI Seliani. The following wavelengths were used: 422.7 nm for calcium, 248.3 nm for iron, 285.2 nm for manganese, and 213.9 nm for zinc (AOAC, 2005).

3.5.3 Determination of Anti-nutrients

3.5.3.1 Phytic acid

Phytic acid was determined by spectrophotometric determination of phytic acid base in precipitation of phytate (Makkar *et al*., 2007).

TCA (3 g) was weighed and dissolved in 100 mL distilled water, 3 g sodium sulphate were dissolved in the 100 mL of 3% TCA. Then 6 g sodium hydroxide were dissolved in 100 mL distilled water. Nitric acid (20.5mL) were used and volume made to 100 mL with distilled water, followed by interaction of phytic acid, hexadi-hydrogenphosphate with metal ions and Phytic Acid. Furthermore, 583 mg $FeCl_3$ were dissolved in 100 mL of 3% TCA (1.5M) and 29.15 g of potassium thiocyanate in 200 mL distilled water. Then 433 mg $Fe(NO_3)_3$were dissolved in 100 mL of distilled water in a volumetric flask.

3.5.3.1 Tannin

Tannin was determined by Follin Dennis titration method as described by Pearson (1976) was used, where 20 g of the processed sample in a cornical flask was added to 100ml of petroleum ether and covered for 24 h. The sample was then filtered and the filtrate was allowed to stand for 15 min allowing petroleum ether to evaporate. It was then re-extracted by soaking in 100 ml of 10% acetic acid in ethanol for 4 hrs. The sample was then filtered and the filtrate was collected. Then, 25 ml of NH_4OH were added to the filtrate to precipitate the alkaloid. The alkaloid was heated with hot plate to remove some of the NH_4OH still in solution. The remaining volume was measured (3 ml). Five milliliters of this solution were taken and 20 ml of ethanol. It was titrated with 0.1M NaOH using phenolphthalein as indicator until pink end point was reached. Tannin content was then calculated in %.

3.5.4 Cook-ability of the Lablab bean grains

Cook ability of the lablab bean varieties (7 dried beans and 7 fresh beans) was recorded using Matson cooker (Fig. 3).

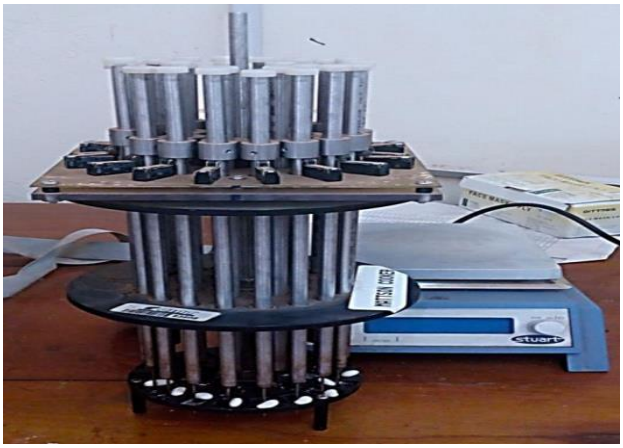

Figure 2: Automated Matson cooker

Prior to cooking, the seeds were soaked for 12 hours in distilled water. Matson cooker utilize 25 stainless steel cylindrical holes, with 82 g piercing tip rods in contact with the

surface of the bean. The cooker was then placed into a 2000 mL beaker containing 400 ml of distilled water at 90°C and was left to cook. The bean grains were judged as 'cooked' when the 2 mm diameter piercing tip of the brass rods passed through in 80% of the beans (Nin, 2004), as indicated by the plungers dropping and penetrating individual beans, with time being recorded at dropping time. This was repeated for each of the 14 samples.

3.5.5 Acceptability of Lablab bean

3.5.5.1 Preparation of beans for sensory evaluation

Grains were sorted and 200 g were soaked in 1 liter of water over night, then washed and cooked in 1 liter of distilled water with one teaspoon of salt until the grains were soft (Grotelüschen, 2014). Cooking time for each variety was recorded, as well as perceived uniformity of cooking. Cooking water was discarded and each bean variety was placed in a serving container with moderate heat and 100 ml water (just enough water to keep them from scorching).

Accessions were completely randomized, assigned a letter for identification. Test panelist received instructions and a rating sheet, and were instructed not to discuss or indicate their preferences with each other until after the rating session. During rating of each parameter, each participant began with a different accession and after tasting they were required to rinse their mouth with clean water.

3.5.5.2 Consumer preference test

The test was conducted at six villages (Karatu-Kambi ya Simba, Ilkushini, Mungushi, Karatu- Mangola, Kondoa and Hedaru) which were project sites. A total of 68 untrained consumers were involved in the test and a 5 point hedonic scale (where 1= dislike extremely and 5= like extremely) as described by (Heyman and Lawless, 2013) was used.

3.5.5.2.1 Appearance

Panelists first viewed each accession, then returned to their starting place and rated successive accessions on a five-point hedonic scale indicating their intensity of preference or non-preference (Shivachi *et al.,* 2012; Grotelüschen, 2014).

3.5.5.2.2 Smell

Panelists rated smell using a similar procedure (smelling all accessions first, and then returning to their starting place for rating).

3.5.5.2.3 Taste and texture

Panelists took sample of about one teaspoon of cooked grain for evaluation of taste and texture of each accession.

After every testing, they rated the accession, and then rinsed their mouth with water and cleaned the teaspoon. Panelists were allowed to return to re-teste any accession for confirmation of their initial rating.

3.5.5.3 Quantitative Descriptive Analysis (QDA)

A descriptive sensory profiling was conducted at TARI – Seliani by a trained sensory panel of 12 assessors. The panelists were selected and trained according to ISO Standard (1993). Panelist came to an agreement on the selected parameters (color, smell, appearance, taste, mouth feel).

3.6 Statistical Analysis

Data were analyzed by GenStat software, means were separated by Turkey's Honest Significant difference was determined at $p \leq 0.05$. Systematic variations between variables were analyzed using t-test and ANOVA for the inter-variation between varieties. Bio-plot was done to indicate the relationship between sensory and consumer liking. Results were be expressed as means and presented in tabular and graphical forms.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Proximate Chemical Composition

Table 2 shows proximate chemical composition of the selected lablab bean varieties.

4.1.1 Protein content

Table 2 shows the protein content in the lablab bean varieties. A significant difference ($p < 0.05$) was observed in the concentration of protein between dry and green lablab bean varieties, with an average of 24.83 g/100 g and 16.08 g/100 g for dry and green lablab bean respectively. In dry lablab beans highest concentration of protein was in ILRI (29.75 g/100 g) and lowest concentration was found in Echo Cream (20.4 g/100 g).For green lablab beans, highest concentration of protein was in Karamoja Red (19.25 g/100 g) and lowest concentration was found in Echo Cream (11.80 g/100 g).

Research done by Davari *et al*. (2018) on lablab beans reported that protein content ranged from 18.02 to 28.7 g/100 g. Another research on lablab by Sonali and Ashwin (2015) reported that, the highest protein concentration of 27.5 g/100 g and lowest concentration of 17.7 g/100 g. Sulaiman and Lawal (2018) reported lablab beans to contain protein concentration of 20.46 g/100 g. Similarly Kalpanadevi and Mohan (2013), reported protein content of 20 g/100 g in brown lablab beans grown in India. With these findings, there is a wide selection of high protein lablab varieties across the globe that can be used to provide food and nutrition security. Despite legume being considered as richest food sources of proteins and amino acids, they have incomplete proteins due to relatively low quantities of the essential sulphur containing amino acids cystine, methionine and cysteine and relatively low quantities of lysine (Curran, 2012). Therefore beans should be combined with other nutrients rich in complete protein

4.1.2 Carbohydrate content

Table 2 shows the carbohydrate content in the lablab bean for the seven selected varieties. A significant difference ($p < 0.05$) was observed in the concentration of carbohydrate between dry and green lablab bean varieties. It was observed that dried beans contained more carbohydrate compared to the green beans with average of 41.76 and 21.1 g/100 g respectively. In dry lablab beans highest levels of carbohydrate were found in Echo Cream (48.69 g/100 g) and lowest levels were in ILRI 6536 (36.84 g/100 g). For green lablab beans, highest concentration of carbohydrate were in Echo Cream (52.04 g/100 g) and lowest concentration was in Karamoja Red (3.96 g/100 g).

The carbohydrate content observed in this study were lower than levels reported by Davari *et al*., (2018) which ranged from 54.16 to 61.32 g/100 g. Similar carbohydrate levels were reported in other bean varieties such as Black Jamapa (37.72 g/100 g) and Pinto Americano (50.53 g/100 g) (Hawkesand Fanzo, 2017). Carbohydrate containing food is important vehicle for protein, vitamins, minerals and other food components such as phytochemicals and antioxidants (Bowman and Russel, 2001).

4.1.3 Crude fiber

Table 2 shows the amount of crude fiber found in the selected varieties of lablab beans. There was no significant difference ($p > 0.05$) observed in the concentration of fiber between dry and green lablab beans. It was observed that, green beans had more crude fiber compared to dried beans with mean of 12.27 g/100 g and 11.46 g/100 g; respectively. In dry lablab beans highest levels of fiber were found in Q6880B (12.4 g/100 g) while lowest levels were found in Karamoja Red (10.5 g/100 g). For the green lablab beans highest levels of fiber were in Dodoma White (13.10 g/100 g) and lowest levels were in Karamoja Red (11.80 g/100 g). Sonali *et al*. (2015) reported that, lablab and field beans

contain fibre content ranging from 13.8 to 33.1 g/100 g while fibre concentration in lablab beans ranged from 3.48 g/100 g to 4.73 g/100 g according to Davari *et al*. (2018). Other beans such as faba beans were reported to contain fibre content of 8.06 to 8.47 g/100 g (Ali *et al*., 2014).

The consumption of fibre has been associated with decreasing total and low-density lipoprotein (LDL) cholesterol, thus decreasing the risk for developing coronary heart disease, metabolic syndrome, stroke, hypertension, diabetes, obesity and some gastrointestinal diseases (Anderson *et al*., 2009).

4.1.4 Crude fat

Table 2 shows the amount of crude fat found in the selected varieties of lablab beans. A significant difference ($p < 0.05$) was observed in the concentration of fat between dry and green lablab bean varieties. It was observed that the green beans had more crude fat compared to the dried beans with mean of 4.03 and 3.04 g/100 g respectively. In dry lablab beans highest levels of fat were in Q6880B (5.84 g/100 g) and lowest levels were in Echo Cream (2.64 g/100 g). For green lablab beans highest levels of fat were in Eldoret Black (3.59 g/100 g) and lowest levels were in Dodoma White (2.42 g/100 g). Fat content in lablab has been observed to be 0.87 g/100 g (Omondi, 2011), with a range of 0.91 to 2.07 g/100 g (Shruthi, 2008). Mosisa and Tura (2017) reported fat content ranging from 1 to 2 g/100 g.

These results were in agreement with Audu and Aremu (2011) and Mubarak (2005) who reported that reduction of crude fat could be due to the leaching of the fat into the cooking water.

4.1.5 Moisture content

Table 2 shows moisture content in the selected varieties of lablab beans. A significant difference ($p < 0.05$) was observed in the concentration of moisture between dry and green lablab bean varieties. It was observed that the green beans had more moisture content compared to the dried beans with an average of 43.23 and 13.34 g/100 g for green and dried beans respectively. In dry lablab beans highest moisture levels were found in Q6880B (16.20 g/100 g) and lowest levels were in DL 1002 (10.51 g/100 g). For green lablab beans highest levels of moisture were in Karamoja Red (58.51 g/100 g) while lowest levels were in Echo Cream (17.68 g/100 g). Lower moisture content in lablab varieties was reported by Soetan and Fafunso (2010) ranging from 10.13 to 9.96 g/100 g. Kamatchi *et al*. (2010) reported moisture content in lablab beans ranging from 12 to 14 g/100 g. Moisture content in common bean reported by Barros and Prudencio (2016) ranged from 14.47 to 12.09 g/100 g. High moisture content could be due to water absorption by the carbohydrate and fibers and other natural chemical components during heat treatment (Mittal *et al*., 2012).

4.1.6 Ash content

Table 2 shows the amount of ash found in the selected varieties of lablab beans. A significant difference ($p < 0.05$) was observed in the concentration of ash between dry and green lablab bean varieties. It was observed that the green beans had more ash compared to dried beans with an average of 4.65 and 3.91 g/100 g for green and dried beans respectively. In dry lablab beans highest ash levels were observed in Karamoja Red (4.38 g/100 g) and lowest levels were found in Q6880B (3.48 g/100 g). For the green lablab beans highest levels of ash were in ILRI 6536 (5.24 g/100 g) and lowest levels were in Echo Cream (4.40 g/100 g). Ash concentration from three varieties of lablab beans namely High worth (4.77 g/100 g), Rongai Brown (6.85 g/100 g) and Rongai White (8.82 g/100 g)

was reported by Shaahu *et al*. (2015). Audu and Aremu (2011) reported ash content in Red Kidney beans ranging from 3.0-5.8 g/100 g. Ash concentration observed in this study were comparable to ash content (4.2 g/100 g) reported in soybeans. Soybeans occupy a unique position (rich in minerals especially calcium, potassium, magnesium, iron, zinc and copper) among leguminous crops (Temple *et al* ., 1991).

High ash content indicates that the legume could provide essential and useful minerals needed for good health. Conventional cooking decreased ash content of kidney beans and Mung beans (Mittal *et al*., 2011: Mubarak, 2005). As ash content is directly proportional to inorganic elements, reduction in ash might be due to leaching out of both macro- and micro- elements into the cooking water which is normally discarded (Mosisa and Tura, 2017). Thus may lead to macro and micro nutrient deficiency resulting to food and nutrition insecurity.

4.2 Mineral Composition

4.2.1 Calcium content

Table 3 shows the amount of calcium content found in the selected varieties of lablab beans. A significant difference ($p < 0.05$) was observed in the concentration of calcium between dry and green lablab bean varieties, with green beans having more calcium compared to the dried beans with average of 3.0 and 2.0 g/100 g for green and dried beans respectively. In green lablab beans highest Ca levels were found in DL 1002 (3.9 g/100 g) while lowest levels were found in Echo Cream (2.31 g/100 g). For the dry lablab beans, highest levels of calcium were in Q6880B (2.52 g/100 g) and lowest levels were found in ILRI 6536 (1.55 g/100 g). Low calcium contents was observed in raw lablab seeds between High Black and Rongai Brown varieties were calcium concentration ranged from 0.66 g/100 g to 0.70 g/100 g with means of 0.16 g/100 g (Soetan and Fafunso, 2010).

Table 2: Proximate chemical composition (g/100) of green and dried *lablab purpureus* seeds[1]

Sample		Ash		Moisture		Crude Fibre		Protein		Crude Fat		Carbohydrates	
		Green	Dry	Green	Dry	Green	Dry	Green	Dry	Green	Dry	Green	Dry
1	DL 1002	4.42^{e}	3.86^{d}	31.02^{d}	10.51^{e}	12.30^{a}	11.20^{a}	16.92^{bcd}	25.67^{b}	3.40^{ab}	3.39^{c}	32.61^{b}	44.10^{bc}
2	ILRI 6536	5.24^{a}	4.10^{b}	57.02^{b}	13.01^{c}	12.10^{a}	10.80^{a}	17.50^{b}	29.75^{a}	3.10^{b}	4.24^{bc}	5.34^{f}	36.84^{cd}
3	KARAMOJA RED	4.48^{d}	4.38^{a}	58.51^{a}	10.80^{d}	11.00^{a}	10.50^{a}	19.25^{a}	23.92^{cd}	2.90^{bc}	5.45^{a}	3.96^{g}	45.30^{ab}
4	Q6880B	4.56^{c}	3.48^{f}	47.79^{bc}	16.20^{a}	13.00^{a}	12.40^{a}	15.75^{cd}	24.50^{c}	3.00^{b}	5.84^{a}	16.50^{d}	36.98^{cd}
5	ELDORETBLACK	4.66^{b}	4.02^{c}	49.43^{bc}	13.90^{b}	12.50^{a}	12.10^{a}	17.50^{b}	24.50^{c}	3.59^{a}	4.81^{ab}	12.32^{e}	40.68^{cd}
6	DODOMA WHITE	4.80^{ab}	3.92^{c}	41.18^{c}	15.48^{a}	13.10^{a}	12.10^{a}	14.58^{cd}	25.08^{bc}	2.42^{c}	2.69^{cd}	24.93^{c}	39.72^{cd}
7	ECHO CREAM	4.40^{f}	3.64^{e}	17.68^{e}	13.51^{bc}	11.90^{a}	11.10^{a}	11.08^{d}	20.42^{d}	2.90^{bc}	2.64^{cd}	52.04^{a}	48.69^{a}

[1] Means within a column with different superscripts are significantly different at $p \leq 0.05$).

Calcium requirements are greatest during growth and development such as childhood, early pregnancy and lactation with recommendations of 350 - 550 mg/day for infants while teenage girls and boys 800 – 1000 mg/day, adult men and women require 700mg of calcium per (National Research Council, 2017). The calcium concentration in the study meet the recommended amounts for all age groups. Calcium is fundamental in muscle contraction, building strong bones and teeth, blood clotting, nerve drive, transmission, regulating heart beat and fluid balance within the cells (Rolfes *et al.,* 2014).

4.2.2 Copper content

Table 3 shows the amount of copper in the selected varieties of lablab beans. It was observed that there was no significant difference ($p > 0.05$) in copper concentration between dried and green lablab bean varieties except in Dodoma White dry beans (3.31 mg/100 g).

According to a report by the International Beans Standards, Cu concentration in beans range from 1.40 to 0.50 mg/100 g (Oomah *et al.,* 2008). Cu concentration of 0.88 mg/100 g was reported in Canadian beans. Similar ranges were observed by Gouveia *et al*. (2014) on various bean varieties (0.50 - 1.40 mg/100 g; 0.90 - 1.20 mg/100 g). Copper is necessary for the absorption and use of iron, in the formation of haemoglobin, and is an important compound of enzymes. The recommended daily allowance for copper is 0.9 mg with upper level of 10 mg/day. Intake of Cu above the recommended limit has been associated with liver damage (Turnlund *et al*., 2005).

4.2.3 Iron content

Table 3 shows the concentration of iron found in the seven selected varieties of lablab beans it was observed that there was a significant difference ($p < 0.05$) in the

concentration of iron between green beans and dried beans. The highest concentration of iron was found in green DL 6536 (3.350 mg/100 g) and dried Q6880B (1.640 mg/100 g) while the lowest concentration of iron were observed in green Q6880B (1.520 mg/100 g) and dried ILRI (0.140 mg/100 g).

The observed concentration of iron were lower than those reported by Olaleye *et al. (2017)* in lablab (6.30 mg/100 g), this could be due to leaching of iron during soaking and boiling water. Research on various bean varieties showed that, iron concentration ranged from 2 to 3 mg/100 g (Kotue *et al*., 2018; US Department of Agriculture's Nutrient Database for Standard Reference, 2006). According to Shimelis and Rakshit (2005) and Oomah *et al*. (2008), Fe concentration in bean seeds varies from 2.83 mg/100 g and 8.40 mg/100 g. Levels of iron obtained in this study were lower than the ranges reported by Gouveia *et al*. (2014) (4.10 to 10.00 mg/100 g and 4.50 to 8.00 mg/100 g).

According to the Food and Nutrition Information Center of the USDA, the Recommended Dietary Allowance (RDA) for iron is 8 mg per day for males ages 19 and older, 18 mg per day for women between the ages of 19 to 50, and 8 mg per day for women ages 51 and older. However, the RDA for iron in pregnant women is increased to 27 mg per day. Iron has several vital functions in the body including serving as an oxygen carrier from lungs to the tissues and as a transport medium for electrons within cells (Kühn, 1996).

4.2.4 Manganese content

Table 3 shows the concentration of Mn in the selected varieties of lablab beans. It was observed that, there was a significant difference ($p < 0.05$) in the concentration of Mn between the green and dried beans with average of 0.6 mg/100 g and 0.4 mg/100 g for green and dried beans, respectively. Karamoja Red green had the highest concentration of

Mn (0.6800 mg/100 g) while Echo Cream dry beans had the lowest concentration of Mn (0.3800 mg/100 g). According to Gopalan *et al.* (1989), high levels of Mn were observed in whole Green Gram (2.47 mg/100 g), black soya (2.35 mg/100 g), cowpeas (1.34 mg/100 g), while low levels were observed in dried peas (0.58 mg/100 g) and lentil (0.81 mg/100 g).

Manganese intake has been associated with formation of bones and in amino acid, lipid, and carbohydrate metabolism (Rude *et al*., 2003). The daily Adequate Intake (AI) levels for manganese are: infants 3 μg to 600 μg; children aged 1 to 8 1.2 mg to 1.5 mg; adults including pregnant and lactating women is 9 mg. The manganese content observed in this study were too low to meet the recommended daily intake for all age groups.

4.2.5 Zinc content

Table 3 shows the concentration of Zn in the selected varieties of lablab beans. There was a significance difference ($p < 0.05$) in Zn concentration among the green and dried bean varieties. Dried ILRI 6536 beans had the highest Zn concentration (8.785 mg/100 g) while green Echo Cream, green Q6880B and dry Echo Cream dry (5.2, 5.1, 5.1 mg/100 g) respectively had the lowest concentration.

Comparable levels of zinc (6.01 mg/100 g) in lablab beans were reported by Olaleye *et al. (2017).* Lower levels were also reported in a study by Gouveia *et al*. (2014) where Zn concentration in beans ranged from 2.20 to 5.00 mg/100 g, and 2.90 to 4.00 mg/100 g. Recommended Daily Intake of Zn for women is 11 mg and 8 mg for males. Zinc deficiency has been associated with impaired growth and reproduction, immune disorders and a variety of other health problems (Adeyeye *et al*., 2014). Zinc is an important mineral for growth and development and improves immune function in elderly people who are often deficient in several micronutrients (Chandra, 2002).

Table 3: Mineral content in the green and dried *lablab purpureus* seeds[1]

Sample		Ca (g)		Cu(mg)		Fe(mg)		Mn(mg)		Zn(mg)	
		Green beans	Dried beans	Green beans	Dried beans	Green beans	Dried beans	Green beans	Dried beans	Green beans	Dried beans
1	DL 1002	3.93^{a}	1.70^{c}	0.07^{b}	0.16^{a}	3.35^{a}	1.57^{b}	0.64^{bc}	0.41^{bcd}	6.9^{abc}	7.3^{b}
2	ILRI 6536	3.28^{ab}	1.55^{c}	0.10^{b}	0.12^{a}	1.81^{abc}	0.14^{d}	0.57^{c}	0.44^{abc}	6.5^{bc}	8.7^{a}
3	KARAMOJA	3.11^{b}	1.90^{b}	0.07^{b}	0.14^{a}	1.73^{abc}	1.50^{c}	0.68^{a}	0.39^{cd}	7.2^{ab}	6.1^{c}
4	Q6880B	2.64^{b}	2.52^{a}	0.14^{b}	0.12^{a}	1.52^{d}	1.64^{a}	0.43^{c}	0.47^{ab}	5.1^{de}	7.1^{bc}
5	ELDORET BLACK	2.67^{b}	2.67^{a}	0.11^{b}	0.15^{a}	1.88^{ab}	1.31^{cd}	0.65^{ab}	0.52^{ab}	5.6^{d}	7.3^{b}
6	DODOMA WHITE	3.13^{b}	1.88^{b}	3.31^{a}	0.14^{a}	1.64^{bc}	1.59^{b}	0.58^{bc}	0.53^{a}	7.7^{a}	7.1^{bc}
7	ECHO CREAM	2.31^{b}	1.96^{b}	0.10^{b}	0.07^{a}	1.59^{c}	1.26^{cd}	0.49^{c}	0.38^{d}	5.2^{f}	5.1^{d}

[1] Means within a column with different superscripts are significantly different at $p \leq 0.05$).

4.3 Anti-nutrient Content

Table 4 indicates the levels of ant-nutrients found in the selected varieties of lablab beans.

Table 4: Anti-nutritional factor content in the selected varieties of green and dried *lablab purpureus* seeds[1]

	Tannic acid (g/100 g)		Phytic acid (mg/100 g)	
Sample	**Green**	**Dried**	**Green**	**Dried**
DL	3.32^{c}	3.29^{c}	1.42^{c}	1.81^{a}
ILRI	2.88^{e}	3.07^{e}	2.05^{ab}	1.37^{cd}
KARAMOJA RED	3.37^{cd}	3.58^{a}	1.46^{c}	1.68^{ab}
Q6880B	3.15^{d}	2.89^{e}	1.91^{bc}	1.79^{a}
ELDORET BLACK	3.41^{c}	3.51^{b}	1.96^{ab}	1.44^{bc}
DODOMA WHITE	3.59^{b}	3.28^{d}	1.27^{c}	1.84^{a}
ECHO CREAM	3.84^{a}	3.19^{d}	2.16^{a}	1.10^{d}

[1] Means within a column with different superscripts are significantly different at $p \leq 0.05$).

4.3.1 Tannic Acid

Echo Cream green had the highest tanning content (3.840 g/100 g) while ILRI dry contained the lowest levels (2.880 g/100 g), that is below the permissible limit of 20 mg/g. Tannin levels observed were higher compared to those reported by Shaahu *et al*. (2015) (1.74 g/100 g) in raw lablab seeds. Tannin levels reported were higher than the concentration 1.41 g/100 g found in mucuna (Tuleun and Patrick, 2007) and in some varieties 0.34 g/100 g found in African oil bean seeds (Enujiugha and Agbede, 2000). The concentration of tannins in dry bean seeds vary from 0.00 to 0.93 g/100 g (Deshpande *et al*., 1986).

These anti-nutritional factors have antioxidant and probiotic activities, and protect DNA damage that may cause various cancers (Phillippy, 2003). The levels of tannins may be reduced through various traditional processing methods, such as fermentation, cooking and malting (Gibson *et al.*, 2007).

4.3.2 Phytic acid

Green Echo Cream had the highest concentration of Phytic acid (2.16 mg/100 g) while dried Echo Cream had the lowest phytic acid concentration (1.100 mg/100 g), this levels were lower than the levels of 10 to 60 mg/g that could pose health problem in humans (Thompson, 1993). Sandberg (2002) reported that, low bioavailability of mineral content in beans is linked to the presence of anti-nutrients (phytic acid). Soaking, cooking, germination and fermentation processes have been reported to reduce phytate levels in dry beans to as much as 50 to 80% (Deshpande and Cheryan, 1983).

4.4 Cook-ability

Table 5 shows the cooking time (minutes) for the selected varieties of lablab beans. It was observed that, the green beans took shorter time to cook compared to the dried beans, with an average time of 62.1 and 69.1 minutes for green and dried beans respectively. Echo Cream took shorter time to cook for both green and dried beans. Of the green accessions dried Dodoma White took the longest time (72 minutes) to cook while green Karamoja Red beans took 70 minutes to cook. Mughi (2017) reported cooking time among 152 genotypes ranging from 35 to 100 minutes and 43 to 122 minutes depending on the season.

Prolonged cooking time has been reported to cause structural changes in the cellular level of the grain, resulting in loss of micronutrients (Ribeiro *et al* ., 2013) such as Fe and Zn. Long cooking time of beans has been associated with loss of more micronutrients during the cooking process (Cichy *et al*., 2012) than shorter cooking time types. According to Jones (1999) and Zamindar *et al*. (2013) cooking time of dry beans affects market price, processing costs, shelf life and consumption patterns. Long cooking time has been reported with limit utilization and adaptation of beans in daily meals (Mishili *et al*., 2011).

Table 5: Cook-ability (minutes) of selected varieties of green and dried *lablab purpureus* seeds[1]

	Sample	Time(minutes) Green beans	Dried beans
1	DL 1002	68.00^{b}	70.2^{c}
2	ILRI 6536	59.06^{cde}	74.2^{ab}
3	KARAMOJA RED	70.00^{a}	62^{cd}
4	Q6880B	63.07^{cd}	68.3^{c}
5	ELDORET BLACK	65.00^{bc}	72^{bc}
6	DODOMA WHITE	57.01^{de}	79^{a}
7	ECHO CREAM	51.02^{e}	58^{d}

[1] Means within a column with different superscripts are significantly different at $p \leq 0.05$).

4.5 Sensory Evaluation and Acceptability

4.5.1 Consumer preference test

Sensory evaluation of food products is important for determining consumer acceptability (Samuel *et al*., 2006). Preference test determine if consumers prefer one product when compared to another product

4.5.1.1 Appearance of lablab beans after cooking

Figure 4 shows the results for sensory evaluation scores for the selected lablab bean varieties based on appearance after cooking. Consumers who ranked the cooked beans as "like extremely" were, 29.4% for Eldoret Black, 30.9% for Karamoja Red, 22.1% for Echo Cream, 16.2% for DL 1002, 13.2% for ILRI 6536, 26.5% for Dodoma White and 16.2% for Q6880B. Karamoja Red was therefore preferred most based on appearance (30.9%). Consumers who ranked appearance as "dislike extremely" were 19.1% for Q6880B and 16.2% for Eldoret Black this was due to the unappealing appearance of the beans. Researchers have established that food appearance determines how fulfilling a food is before its consumption since consumers use visual cues to judge the quality of food they are meant to eat (Maina, 2018).

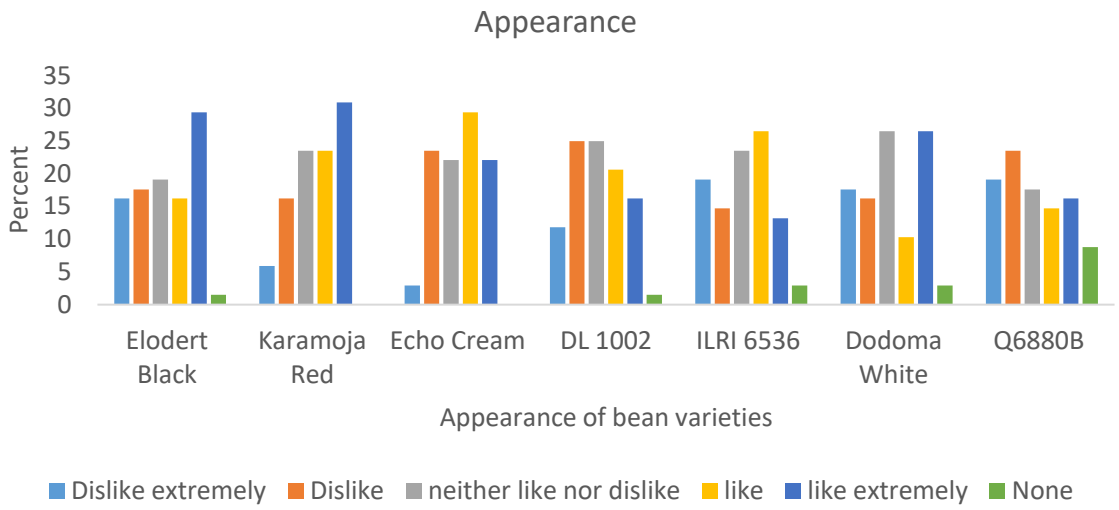

Figure 3: Sensory scores of cooked lablab beans based on appearance

4.5.1.2 Smell of lablab beans after cooking

Figure 5 shows sensory scores for the selected lablab bean varieties based on smell after cooking. Consumers who ranked the cooked beans as "like extremely" were, 23.5% for Eldoret Black, 25.0% for Karamoja Red, 16.2% for Echo Cream, 14.7% for DL 1002, 20.6% for ILRI 6536, 10.3% for Dodoma White and 13.2% for Q6880B. Karamoja Red variety was therefore the most preferred bean variety based on smell (25.0 %). Consumers who ranked cooked beans as "dislike extremely" were 35.3% for Q6880B and20.6% for Eldoret Black. The reason was the strong smell that the beans produced after cooking making the beans not preferred by consumers.

In food products, smell acts as a signal for edible or inedible food even before the consumer sees the food itself (Maina, 2018). Ambient odor is critical in determining the level of food acceptability among consumers (Tauferova *et al*. 2015).

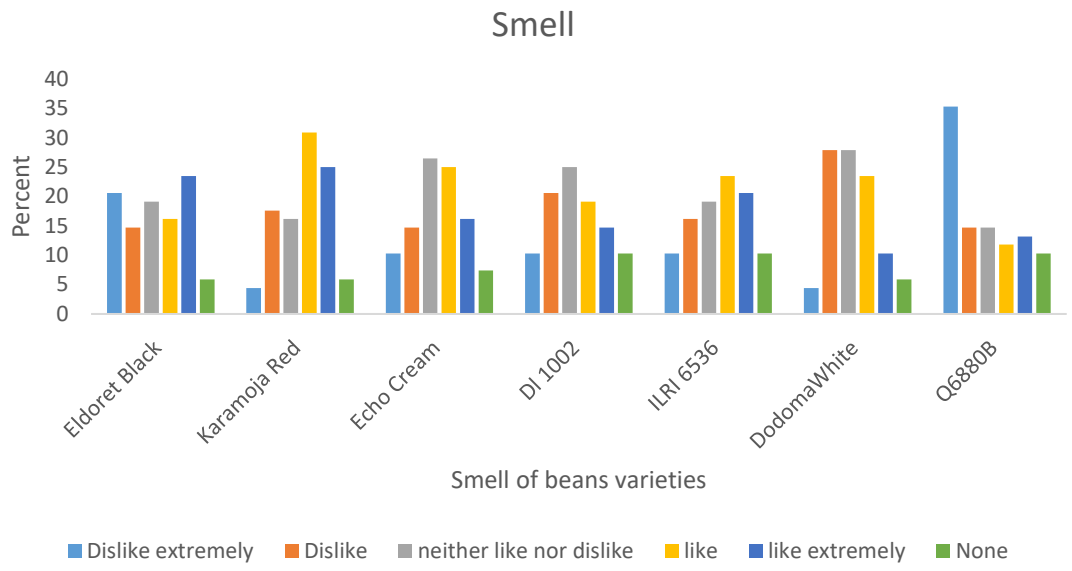

Figure 4: Sensory scores of cooked lablab beans based on smell evaluation

4.5.1.3 Taste of lablab beans after cooking

Figure 6 shows the sensory scores for the selected lablab bean varieties based on taste after cooking. Consumers who ranked the cooked beans as “like extremely” were, 30.9% for Eldoret Black, 32.4% for Karamoja Red, 30.9% for Echo Cream, 4.4% for DL 1002, 20.6% for ILRI 6536, 22.1% for Dodoma White and 13.2% for Q6880B, hence Karamoja Red variety therefore has been preferred most based on test (30.9%). Consumers who ranked the cooked beans as “Dislike extremely” were 35.3% for Q6880B and 13.2% for Eldoret Black. The reason for taste dislike was the strong unappealing smell and the sharp taste of the beans.

Taste is referred to as the proximal sense that requires direct contact of food with stimuli on the tongue to determine the quality of the ingested food, as it provides the consumer with crucial information about its quality and thus its acceptability (Li *et al*., 2015).

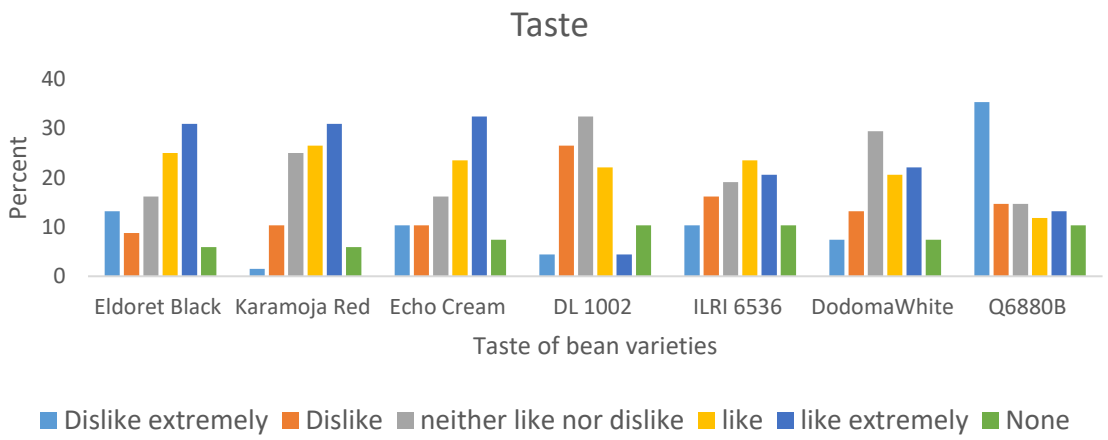

Figure 5: Sensory scores of cooked lablab beans based on taste

4.5.1.4 Mouth feel of lablab beans after cooking

Figure 7 shows the sensory scores for the selected lablab bean varieties based on mouth feel after cooking. Consumers who ranked the mouth feel as “like extremely” were, 22.1% for Eldoret Black, 27.9% for Karamoja Red, 29.4% for Echo Cream, 16.2% for DL 1002, 22.1% for ILRI 6536, 13.2% for Dodoma White and 7.5% for Q6880B. Echo Cream was therefore the most preferred bean based on mouth feel (29.4%). Consumers who ranked the mouth feel as “dislike extremely” were 22.4% for Q6880B and 14.7% for Eldoret black. This could be due to the unpleasant smell and appearance of the cooked beans. Mouth feel has been related to physical properties of food which is of great importance in sensory impression of many foods and thus it is associated with consumer acceptability (Kiumarsi *et al*., 2019).

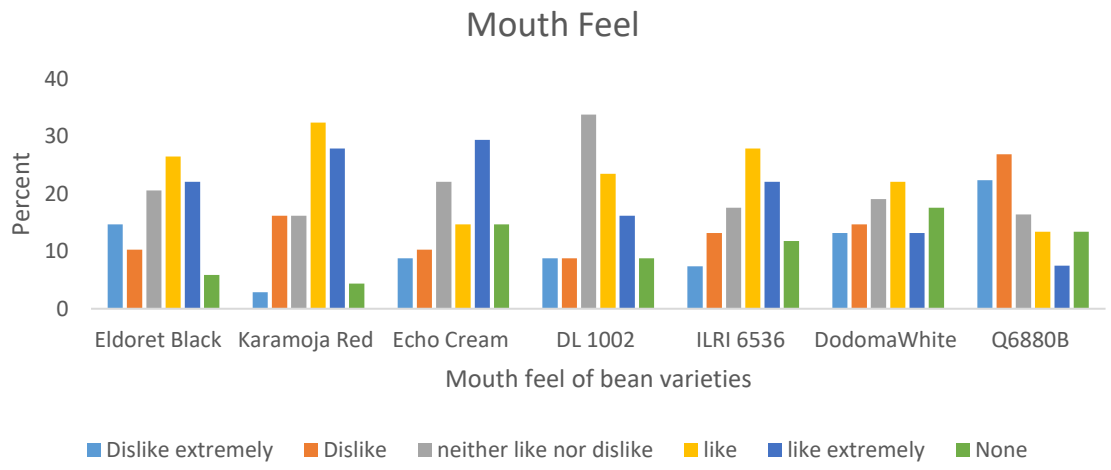

Figure 6: Sensory score of lablab beans based on mouth feel

4.5.1.5 Market value of lablab

Figure 8 shows the sensory evaluation scores for the selected lablab bean varieties based on market value scores. Consumers who ranked market value of lablab beans as "liked extremely" were, 36.8% for Eldoret Black, 23.5% for Karamoja Red, 19.1% for Echo Cream, 22.1% for DL 1002, 14.7% for ILRI 6536, 8.8% for Dodoma White and 13.2% for Q6880B. Eldoret Black variety was therefore the most preferred beans based on market value (36.8 %). Consumers who ranked market value of lablab beans as "dislike extremely" were 16.2% for Dodoma White and 11.8% for Q6880B and Eldoret Black. Dodoma white was not preferred based on market value due to easy infestation by insects and low market price.

Market value affects selection of food as consumers prefer what is cheaper at the market regardless of the nutrient content. Farmers usually go for what is more valuable in the market for income generation, thus selection of bean variety is influenced by market value.

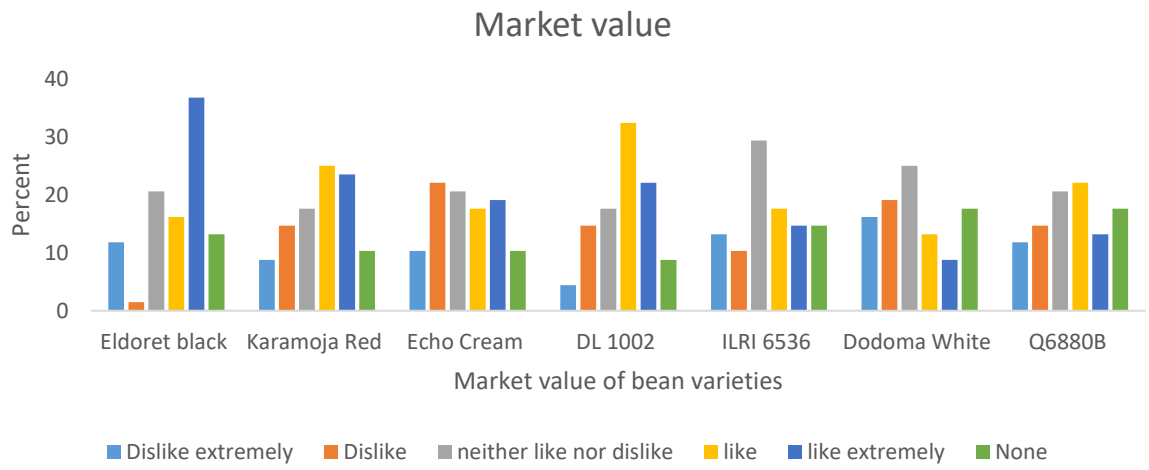

Figure 7: Market value score of lablab beans acceptability

4.5.2 Quantitative Descriptive Analysis (QDA)

Figure 9 shows bi-plot with the two first significant principal components from principal component analysis (PCA) on average sensory attributes. PC 1 accounted for 53.48% of the systematic variation in the data and is contrast between three samples Karamoja Red, Echo Cream and Dodoma White associated with appearance and smell attributes on one side and four samples Eldoret Black, DL 1002, Q6880B, and ILRI 6536 associated with color, taste and mouth feel. PC 2 accounted for 44.80% of variation, it was a contrast between samples Eldoret Black, DL 1002, Q6880B, and ILRI 6536. Eldoret Black and DL 1002 had higher association in taste and mouth feel attributes whereas sample ILRI 6536 and Q6880Bhad higher association in color. Most consumers fall to the right of the vertical Y-axis implying that, consumers had highest preference for Karamoja Red associated with overall liking. Very few consumers preferred Eldoret Black bean variety.

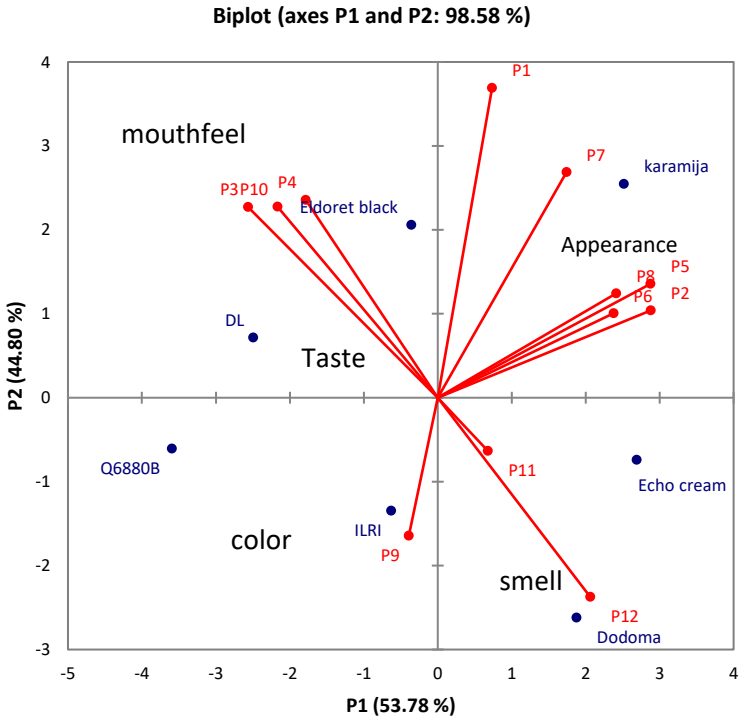

Figure 8: Bi-plot of PCA showing systematic variation of samples and their associated attributes in intensity values

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusion

The study has shown that, lablab beans varieties were rich in nutrient. Based on proximate composition, Dodoma White had the highest protein content while Q6880B had the highest fibre content. This implied that Dodoma White can be of more benefit for weight loss and lowering cholesterol. For mineral composition, the best varieties were Q6880B for iron (Fe), DL 1002 for calcium (Ca), and ILRI for zinc (Zn). Higher content of both phytic and tannin were in Echo Cream, lower levels of tannins were observed in Q6880b and ILRI while for phytic acid low content was observed in Echo Cream and Dodoma White beans. Based on sensory evaluation Elodert black had the best score and in terms of overall acceptance and market value which implied that it can be used to improve nutrition and food insecurity in terms of income and nutrition. Most of the lablab bean accessions therefore have the potential to bring about a better solution to food and nutrition security.

5.2 Recommendations

i. It is recommended based on the findings of this study that lablab beans are good source of nutrients, although neglected. Thus, there is a need to promote use of lablab for food and nutrition security and income generation.

ii. Further research is needed to determine vitamins, protein profile or Amino Acid score of the selected bean varieties.

iii. Breeding should be done based on varieties with high content so as to come up with the best variety in terms of yield and nutrient content.

REFERENCES

Adeyeye, E.I., Oyarekua, M.A., Adesina, A.J., (2014). Proximate, mineral, amino acid composition and mineral safety index of *Callinectes* latimanus.*International Journal of Development Research*; 4 (12). 2641-2649.

Albala, K. (2017). *Beans: A History*. Bloomsbury Publishing New York.

Ali, E. A. A. M. O., Awadelkareem, A. M., Gasim, S., and Yousif, N. E. (2014). Nutritional composition and anti-nutrients of two faba bean (*Vicia faba L*.) LINES. *International Journal of Advanced Research*, *2*(12):538-544.

Al-Snafi, A. E. (2017). The pharmacology and medical importance of Dolichos lablab (Lablab purpureus)-A review. *IOSR Journal of Pharmacy*, *7*(2), 22-30.

Anderson, J.W., Baird, P, Davis R.H., Ferreri S, Knudtson M, Koraym A, (2009). Health benefits of dietary fiber. *Nutr Rev.* ;67(4):188-205.

Anderson, R.G., Bale, S. and Jia, W (1996). Hyacinth Bean: Stems for the Cut Flower arket. In: Janick, J. and Simon, J.E., Eds., *Progress in New Crops*, ASHS Press, Arlington, 540-542.

AOAC (2005). Official Methods of Analysis of Association of Official Agriculture Chemist. Association of Analyti-cal Chemist, Washington. D.C.

Arruda, B., Altamir, F. G., Jefferson, L. M., and Jaqueline, B. (2012). Environment is crucial to the cooking time of beans. *Ciência e Tecnologia de Alimentos*, 110, 573-578.

Audu, S. S., and Aremu, M. O. (2011). Nutritional composition of raw and processed pinto bean (Phaseolus vulgaris L.) grown in Plateau State, Nigeria. *J. Food Agric. Environ*. 9 (3&4): 72-80.

Barros, M. De, and Prudencio, S. H. (2016). Physical and chemical characteristics of common bean varieties. Semina: Ciências Agrárias, 37(2): 751. https://doi.org/10.5433/1679-0359. 2016v37n2p751.

Bennink, M and Rondini, E. (2008). Beans and health: A comprehensive review. http://www.beaninstitute.com/health-benefits/dry-beans-and-humanhealth.

Bora, P. (2014). Anti-nutritional factors in foods and their effects. *Journal of Academia and Industrial Research*, *3*(6), 285-290.

Bowman, A. B. and Russell, M. R. (2001). Present knowledge in Nutrition. International life science institute, Washington DC. 805pp.

Carney, J., and Rosomoff, R. N. (2011). *In the shadow of slavery: Africa's botanical legacy in the Atlantic world*. Univ of California Press.

Chandra, R. K. (2002). Nutrition and the immune system from birth to old age. *European journal of clinical nutrition*, *56*(S3): S73.

Chang, Y., Liu, H., Liu, M., Liao, X., Sahu, S. K., Fu, Y., and Hendre, P. S. (2018). The draft genomes of five agriculturally important African orphan crops. *GigaScience*, *8*(3): 152.

Cheruiyot, E. K., Mwonga, S. M., Mumera, L. M., Macharia, J. K., Tabu, I. M., and Ngugi, J. G. (2007). Rapid decay of dolichos [*Lablab purpureus* (L.) *Sweet*] residue leads to loss of nitrogen benefit to succeeding maize (*Zea mays* L.). *Australian Journal of Experimental Agriculture*, *47*(8):1000-1007.

Cichy, K., Wiesinger, J., Porch, T., and Miklas, P. (2012). Diversity for cooking time in Andean dry beans. *Bean Improvement Cooperative*, 54, 50-51.

Cohen, M. J. and Thompson, B. (2008). *Impact of Climate Change and Bioenergy on Nutrition.* Food and Agriculture Organization, Rome. 126pp.

Considine, M. J., Siddique, K. H., and Foyer, C. H. (2017). Nature's pulse power: legumes, food security and climate change. *Journal of Experimental Botany*, *68*(8): 1815-1818.

Cook, B. G., Pengelly, B. C., Brown, S. D., Donnelly, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M and Schultze-Kraft, R. (2005). *Tropical Forages:* an interactive selection tool.Web Tool. CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia.

Costa, A., Queiroz.-Monici, K,S, and Oliveira, S. (2006). Chemical composition,dietary fiber and resistant starch contents of raw and cooked pea,common bean, chickpea and lentil legumes. *Food Chemistry*, 94: 327-330.

Davari, S. A., Gokhale, N. B., Palsande, V. N., and Kasture, M. C. (2018). Wal (Lablab purpureus L.): An unexploited potential food legumes. *IJCS, 6*(2), 946-949.

Deshpande S. S. and Cheryan, S. S. (1983). Changes on phytic, tannins and trypsin inhibitor activity on soaking of dry beans (Phaseolus vulgaris L.). *Nutr. Rep. Intl*: 27: 317-327.

Deshpande, S. S., Cheryan M., and Salunkhe, D.K. (1986). Tannin analysis of food products. CRC Crit. *Rev. Food Sci. Nutr*., 24, 401–449.

Emiola, I. A., Ologhobo, A. D., Akinlade, J., Adedeji, O. S., and Bamigbade, O. M. (2003). Effect of inclusion of differently processed mucuna seed meal on performance characteristics of broilers. *Trop. Anim. Prod. Invest*, *6*, 13-21.

Engle, L. M., and Altoveros, N. C. (2000). Collection, conservation and utilisation of indigenous vegetables: Asian Vegetable Research and Development Center. *Shanhua, Taiwan*, p142.

Enujiugha, V.N. and Agbede, J.O. (2000). Nutritional and anti-nutritional characteristics of African oil bean (*Pentaclethra Macrophylla* Benth) Seeds. Appl. *Trop. Agric*,5(1): 11-14.

FAO (2003). FAOSTAT Agriculture Data; FAO: Rome, Italy, Available online: http://apps.fao/cgi-binnph-db.pl?suset=agriculture (accessed on 05 January 2019).

FAO (2013). FAOSTAT online statistical service. FAO.

Foyer, C. H., Lam, H., Nguyen, H. T., Siddique, K. H. M., Varshney, R. K., Colmer, T. D. and Shi, K. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants*, 2: 16112.

Friedman, M. (2001). Nutritional and health benefits of soyproteins. *J. Agri. Food Chem*. 49: 1069-1086.

Fuller, D. Q., and Boivin, N. (2009). Crops, cattle and commensals across the Indian Ocean. Current and potential archaeobiological evidence. *Etudes Ocean Indien*, (42-43): 13-46.

Ganesan, K., and Xu, B. (2017). Polyphenol-rich dry common beans (*Phaseolus vulgaris* L.) and their health benefits. *International Journal of Molecular Sciences*, *18*(11):2331.

Giblin, J. D., and Fuller, D. Q. (2011). First and second millennium a. d. agriculture in Rwanda: archaeobotanical finds and radiocarbon dates from seven sites. *Vegetation History and Archaeobotany*, *20*(4):253-265.

Gibson, R.S., Hotz, C. and Kelvin, M. (2007). Traditional Food – Processing and Preparation Practices to Enhance the Bioavailability of Micronutrients in Palnt – *Based Diets. J. Nutr* 137(4):1097 – 1100.

Gouveia, C. S., Freitas, G., de Brito, J. H., Slaski, J. J., and de Carvalho, M. Â. P. (2014). Nutritional and mineral variability in 52 accessions of common bean varieties (Phaseolus vulgaris L.) from Madeira Island. *Agricultural Sciences*, *5* (04): 317.

Greiner, R., Konietzny, U., and Jany, K. D. (2006). Phytate-an undesirable constituent of plant-based foods. *Journal für Ernährungsmedizin*, *8*(3): 18-28.

Grotelüschen, K. (2014). *Lablab purpureus (L.) Sweet: A promising multipurpose legume for enhanced drought resistance and improved household nutritional status in smallholder farming systems of Eastern Kenya* (Doctoral dissertation, MSc. Thesis submitted to Georg-August-University Göttingen, Germany).

Haddad, L., Achadi, E., Bendech, M. A., Ahuja, A., Bhatia, K., Bhutta, Z., and Eriksen, K. (2015). The Global Nutrition Report 2014: actions and accountability to accelerate the world's progress on nutrition. *The Journal of Nutrition*, 145(4): 663-671.

Hamid, N. T., and Kumar, P. (2017). Anti-nutritional factors, their adverse effects and need for adequate processing to reduce them in food.

Hawkes, C., and Fanzo, J. (2017). Nourishing the SDGs: *Global nutrition report 2017 Bristol Development Initiatives Poverty Research Ltd.*

Heymann, H., and Lawless, H. T. (2013). *Sensory Evaluation of Food: Principles and Ppractices*. Springer Science & Business Media.

Hossain, S., Ahmed, R., Bhowmick, S., Mamun, A. A. L and Hashimoto, M. (2016). Proximate composition and fatty acid analysis of *Lablab purpureus* (L.) legume seed: implicates to both protein and essential fatty acid supplementation. Springer Plus, 5(1899): 1–10. https://doi.org/ 10.1186/s40064-016-3587-1.

ILO (2007). Employment by sector. In *Key indicators of the Labour Market (KILM), 5th edition* Available at: www.ilo.org/public/ english/employment/ strat/kilm/download/ kilm04.pdf.

ISO (1993). Sensory analysis-Methodology-General guidance for the selection, training and monitoring of assessors- Part 1: Selected assessors, *In International IDF Standard.* Pp. 1-11.

Kala, A. and Prakash, J. (2006). The comparative evaluation of the nutrient composition and sensory attributes of four vegetables cooked by different methods. *Intr. J. Food Sci. Technol*. 41: 163-171.

Kalpanadevi, V. and Mohan, V. R. (2013). Nutritional and anti-nutritional assessment of under- utilized legume D. lablab var. vulgaris L. *Bangladesh Journal of Scientific and Industrial Research*, *48*(2): 119-130.

Kamatchi, K. B., Tresina, S. P., Mohan, V. R., and Vadivel, V. (2010). Nutrient and Chemical Evaluation of Raw Seeds of Five Varieties of *Lablab purpureus*(L .) Sweet. *Advances in Bio research,* 1: 44–53.

Kante, K., and Reddy, C. S. (2013). Anti diabetic activity of Dolichos lablab (seeds) in Streptozotocin-Nicotinamide induced diabetic rats. *Hygeia Journal for Drugs and Medicines*, 5 (1): 32-40.

Keller, G. (2004). African nightshade, eggplant, spiderflower et al. – production and consumption of traditional vegetables in Tanzania from the farmers point of view. MSc thesis, Georg-August-Univ., Göttingen, Germany, 251 pp.

Keller, G. D., Mndiga, H and Maass, B. L. (2006). Diversity and genetic erosion of traditional vegetables in Tanzania from the farmer's point of view. *Plant Genet Resoure* 3:400–413.

Kiumarsi, M., Shahbazi, M., Yeganehzad, S., Majchrzak, D., Lieleg, O., and Winkeljann, B. (2019). Relation between structural, mechanical and sensory properties of gluten-free bread as affected by modified dietary fibers. *Food chemistry*, *277*: 664-673.

Kotue, T. C., Marlyne Josephine, M., Wirba, L. Y., Amalene, S. R. H., Nkenmeni, D. C., Fokou, E., and Fokam, D. P. (2018). Nutritional properties and nutrients chemical analysis of common beans seed. *MOJ Biol Med.*3(3): 41–47.

Kühn, L. C. (1996). *Control of cellular iron transport and storage at the molecular level* (No. CONF, pp. 17-29). John Libbey & Company.

Laparra, J. M., Glahn, R. P. and Miller, D. D. (2009). Assessing potential effect of inulin and probiotic bacteria on Fe availability from common beans (*Phaseolus vulgaris* L.) to caco-2 cells. *J. Food Sci*. 74 : 40-46.

Lelei, J. J., Onwonga, R. N.and Freyer, B. (2009). Organic based nutrient management strategies: effect on soil nutrient availability and maize (*Zea mays L*.) performance in Njoro, Kenya. *Afr J. Agric Res* 2:92–99.

Li, X., Jervis, S. M.and Drake, M. A. (2015). Examining extrinsic factors that influence product acceptance: a review. *Journal of Food Science*. 80(5): 901-909.

Maass, B. L., and Tolera, T. (2008). Relative molecular similarity in wild *Lablab purpureus* from India underlines the crop's African center of origin. In *Poster presented at Harlan II International Symposium–Biodiversity in Agriculture: Domestication, Evolution, and Sustainability* pp. 14-18.

Maass, B. L., and Usongo, M. F. (2007). Changes in seed characteristics during the domestication of the lablab bean (*Lablab purpureus* (L.) Sweet: Papilionoideae). *Australian journal of agricultural research*, *58*(1): 9-19.

Maass, B. L., Jamnadass, R. H., Hanson, J., and Pengelly, B. C. (2005). Determining sources of diversity in cultivated and wild *Lablab purpureus* related to provenance of germplasm by using amplified fragment length polymorphism. *Genetic Resources and Crop Evolution*, *52*(6): 683-695.

Maass, B. L., Knox, M. R., Venkatesha, S. C., Angessa, T. T., Ramme, S., and Pengelly, B. C. (2010). *Lablab purpureus*—A crop lost for Africa?. *Tropical Plant Biology*, *3*(3): 123-135.

Maina, J. W. (2018). Analysis of the factors that determine food acceptability. *The Pharma Innovation*, 7(5D): 253.

Makkar, H. P. S., Siddhuraju, P., and Becker, K. (2007). Methods in molecular biology: plant secondary metabolites. *Humana Press Inc*, *393:* 93-100.

Maundu, P. M., Ngugi, G. W, and Kabuye, C. H. S. (1999). Traditional food plants of Kenya. National Museums of Kenya, *English Press, Nairobi*, Pp. 270.

Mbaga, E. T., and Friesen, D. (2003). Adoptable maize/legume systems for improved maize production in northern Tanzania. In *African Crop Science Conference Proceedings*. 6: 649-654.

McGuire, S. (2013). WHO, World Food Programme, and International Fund for Agricultural Development. 2012. The State of Food Insecurity in the World 2012. *Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition*. Rome, FAO.*Advances in Nutrition*, 4(1): 126–127.

Messina, V. (2014). Nutritional and health benefits of dried beans. *The American Journal of Clinical Nutrition*, *100*(suppl-1), 437S-442S.

Miller, N. R., Mariki, W., Nord, A., and Snapp, S. (2018). Cultivar Selection and Management Strategies for *Lablab purpureus* (L.) Sweet in Africa. *Handbook of Climate Change Resilience*, 1-14.

Mittal, R., Nagi, H. P. S., Sharma, P., and Sharma, S. (2012). Effect of processing on chemical composition and antinutritional factors in chickpea flour. *Journal of Food Science and Engineering*, *2*(3), 180.

Mosisa, M. T. and Tura, D. C. (2017). Effect of processing on proximate and mineral composition of hepho, a black climbing bean (*Lablab purpureus* L.) flour. *J. Food Nutr Sci*, *5:* 16-22.

Mubarak, A. E. (2005). Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolusaureus*) as affected by some home traditional processes. *Food Chem*. 89:489-495.

Mukai, M. I. (2017). Inheritance and characterization of cooking time, seed iron and zinc content in selected African common bean germplasm. Thesis (Master of Science in Plant Breeding and seed systems). Makerere University. Kampala. UG. 74 p.

Mureithi, J. G., Gachene, C. K. K and Ojiem, J. (2003). The role of green manure legumes in smallholder farming systems in Kenya: the legume research network project. *Tropical and Subtropical Agroecosystems* 1:57–70.

Murphy, A. M. and Colucci, P. E. (1999). A tropical forage solution to poor quality ruminant diets: A review of *Lablab purpureus*. *Livestock Research for Rural Development*, *11*(2): 1999.

National Research Council, Recommended Dietary Allowances (2017): 10th edition. Washington, DC: National Academy Press.

National Research Council. (2006). *Lost Crops of Africa: Vegetables* (Vol. 2). National Academies Press. https://doi.org/10.17226/11763.

Nikmaram, N., Leong, S. Y., Koubaa, M., Zhu, Z., Barba, F. J., Greiner, R., and Roohinejad, S. (2017). Effect of extrusion on the anti-nutritional factors of food products: An overview. *Food control*, *79*: 62-73.

Nin, W. (2004). Determination of cooking time using automated Mattson cooker apparatus. *J. Sci. Foods and Agric.* 85 (10): 1631-1635.

Nyende, P.and Delve, R. J. (2004). Farmer participatory evaluation of legume cover crop and biomass transfer technologies for soil fertility improvement using farmer criteria, preference ranking and logit regression analysis. *Exp Agric* 40:77–88.

Olaleye, A. A, Adeyeye, E. I, and Adesina, A. J. (2013). Chemical composition of bambara groundnut (*V. subterranea* L. Verdc) seed parts. *Bangladesh J. Sci. Ind. Res.* 48 (3):167-178.

Omondi, O. S. (2011). *The potential for njahi (Lablab purpureus* L.*) in improving consumption adequacy for protein, iron and zinc in households: a case for Nandi South District, Kenya* (Doctoral Dissertation, University of Nairobi.

Oomah, B.D., Blanchard, C. and Balasubramanian, P. (2008). Phytic acid, phytase, minerals, and ntioxidant activity in Canadian dry bean (*Phaseolus vulgaris* L.) cultivars. *Journal of Agricultural and Food Chemistry*, 56: 11312- 11319.

Osman, M. A. (2007). Effect of different processing methods, on nutrient composition, antinutrional factors, and in vitro protein digestibility of *Dolichos lablab* bean [*Lablab purpuresus* (L) Sweet]. *Pakistan Journal of Nutrition*, *6*(4): 299-303.

Ovando-Martinez, M., Luis, A., Bello-Pereza, L. A., Whitney, K., Osorio-Diaz, P. and Senay, S. (2011). Starch characteristics of bean (*Phaseolus vulgaris* L.) grown in different localities. *Carboh. Polym.* 85**:**54–64.

Pearson, D. (1976). Chemical Analysis of Foods. (7th Edition), *Churchill Livingstone*, Edinburgh, UK.

Phillippy, B.Q. (2003). Inositol phosphates in food. *Adv. Food Nutr*. Res. 45:1–60.

Piper, C. V. and Morse, W. J. (1915). The bonavist, lablab or hyacinth bean. USDA, Washington DC, USA. *USDA Bull* 318:1–15.

Pusztai, A. (1991). *Plant Lectins*. Cambridge University Press UK.

Raes, K., Knockaert, D., Struijs, K., and Van Camp, J. (2014). Role of processing on bioaccessibility of minerals: Influence of localization of minerals and anti-nutritional factors in the plant. *Trends in Food Science and Technology*, *37*(1): 32-41.

Rani, M., and Punia, D. (2017). Nutritional evaluation of products prepared from fresh beans. *Journal of Applied and Natural Science*, 9(4): 2033-2035.

Ribeiro, N. D., Ritiela B. M., Lindolfo, S., Marina, P., and Cristina Wayne N., (2013). Combined selection for grain yield, cooking quality and minerals in the common bean. *Revista Cie`ncia Agronomica*, 44:869-877.

Robertson, C. C. (1997). Black, white, and red all over: beans, women, and agricultural imperialism in twentieth-century Kenya. *Agricultural History*, *71*(3): 259.

Rolfes, S. R., Pinna, K., and Whitney, E. N. (2014). *Understanding normal and clinical nutrition*. Cengage Learning Wadsworth: 1192pp.

Rude, R. K., Gruber, H. E., Wei, L. Y., Frausto, A., and Mills, B. G. (2003). Magnesium deficiency: effect on bone and mineral metabolism in the mouse. *Calcified tissue international*, *72*(1), 32-41.

Sandberg, A. S. (2002). Bioavailability of minerals in legumes. *British Journal of Nutrition*, 88 (3): 281-285.

Shaahu, D. T., Kaankuka, F. G., and Okpanachi, U. (2015). Proximate, amino acid, anti-nutritional factor and mineral composition of different varieties of raw *lablab purpureus* seeds. *Intl. J. Sci. Technol Res.*, 4: 157-161.

Sheahan, C. M. (2012). Plant guide for Lablab (*Lablab purpureus*), USDA-Natural Resources Conservation Service, Cape May Plant Materials Center. *Cape May, NJ, 8210*.

Shimelis, E. A., and Rakshit, S. K. (2005). Proximate composition and physico-chemical properties of improved dry bean (Phaseolus vulgaris L.) varieties grown in Ethiopia. *LWT-Food Science and Technology*, *38*(4): 331-338.

Shivachi, A., Kinyua, M. G., Kiplagat, K. O., Kimurto, P. K., and Towett, B. K. (2012). Cooking time and sensory evaluation of selected Dolichos (Lablab purpureus) genotypes. *African Journal of Food Science and Technology*, *3*(7): 155-159.

Shruthi, B. S. (2008). *Nutrient Composition, Product Development and Sensory Evaluation of Dolichos Bean (Lablab purpureus)* (Doctoral Dissertation, University Of Agricultural Sciences at GKVK, Bengaluru.

Singh, B. B., and Matsui, T. (2002). Cowpea varieties for drought tolerance. *Challenges and Opportunities for Enhancing Sustainable Cowpea Production*, pp 287-300.

Soetan, K. O., and Fafunso, M. A. (2010). Studies on the proximate and mineral composition of three varieties of lablab beans (*Lablab purpureus*). *International Journal of Applied Agricultural Research*, *5:* 291-300.

Sonali, A., Manju, V., and Ashwin, K. (2015). Comparative Study of Indian Varieties of Lablab and Field Bean for Phenotypic and Nutritional Traits. *Legume Genomics and Genetics*, Vol.*6*, No.3, 1-7.

Sridhar, K. R. and Seena, S. (2006). Nutritional and anti-nutritional significance of four unconventional legumes of the genus *Canavalia*–A comparative study. *Food Chemistry*, 99(2): 267-288.

Subagio, A. (2006). Characterization of hyacinth bean (*Lablab purpureus* (L.) Sweet) seeds from Indonesia and their protein isolate. *Food chemistry*, 95(1): 65-70.

Sulaiman, A. and Lawal, M. A. (2018). A proximate, mineral composition and anti-nutritional factors of the aerial parts of *Lablab purpureus* (L.) Sweet. *Bayero Journal of Pure and Applied Sciences*, *11*(1): 37-40.

Sustainet, G. T. Z. (2006). Sustainable agriculture: A pathway out of poverty for East Africa's rural poor: Examples from Kenya and Tanzania. *Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn*.

Tauferova A, Tremlova B, Bednar J, Golian J, Zidek R, and Vietoris V. (2015). Determination of Ketchup Sensory Texture Acceptability and Examination of Determining Factors as a Basis for Product Optimization. *International journal of food properties*. 18(3):660-669.

Tefera, T. A. (2006). Towards improved vegetable use and conservation of cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*): agronomic and participatory evaluation in northeastern Tanzania and genetic diversity study. *CuvillierVerlag, Goettingen*.

Temple, V. J., Odewumi, L., and Joseph, K. (1991). Soybeans and soybeans based diets. *Proceedings of the 3rd Regional Workshop on Rural Development*, pp. 45-50.

Tharanathan, R. N., and Mahadevamma, S. (2003). A Review: Grain legumes, a boom to human nutrition. *Food Science and Technology*, 14: 507-518.

Thompson, L. U. (1993). Potential health benefits and problems associated with anti-nutrients in foods. *Food Research International*, 26: 131-149.

Tuleun, C. D. and Patrick, J. P. (2007). Effect of duration of cooking *Mucuna utilis* seed on proximate analysis, levels of antinutritional factors and performance of broiler chickens. *Nig. J. Anim. Prod*, *34*(1): 45-53.

Turnlund, J. R., Keyes, W. R., Kim, S. K., and Domek, J. M. (2005). Long-term high copper intake: effects on copper absorption, retention, and homeostasis in men. *The American journal of clinical nutrition*, *81*(4): 822-828.

United Nations Development Programme (UNDP) (2012). Africa Human Development Report 2012: Towards a Food Secure Future; United Nations Development Programme (UNDP): New York, NY, USA.

USAID(2018) Tanzania Nutrition profile https://www .usaid.gov /sites/default/ files/documents/1864/.

UNICEF (2017). Tanzania nutritional fact sheet https:// www .unicef. org/ tanzania/ nutrition.html.

Vargas-Torres, A., Osorio-Dıaz, P., Islas-Hern!andez, J. J, Tovar, J., Paredes- Lopez, O. and Bello-Perez, L. A. (2004). Starch digestibility of five cooked black bean (Phaseolus vulgaris L.) varieties. *J. Food Comp. Anal*. 17:605–612.

Whitbread, A. M., Ayisi, K., Mabapa, P., Odhiambo, J. J., Maluleke, N., and Pengelly, B. C. (2011). Evaluating *Lablab purpureus* (L.) Sweet germplasm to identify short-season accessions suitable for crop and livestock farming systems in southern Africa. *African Journal of Range & Forage Science*, *28*(1): 21-28.

WHO (2010). Trade, foreign policy, diplomacy and health. food security. [http://www.who.int/trade/en] site visited on 14/8/2018.

APPENDICES

Appendix 1: Questionnaire for Preference Test

Location:_____ Name of Panelist:_____

Farm-ID:_____ Date: _____

Have you ever eaten a lablab grain before? Yes:_____ No:_____

If yes, how frequently do you eat lablab? Once a week: _____Once a month:_____Rarely: _____

Are you a farmer? _____Cook? _____What is your ethnic group?_____

1. How does each variety Appear after cooking ?

Variety	Dislike extremely	Dislike	Neither like or dislike	Like	Like extremely	Comments
A						
B						
C						
D						
E						
F						
G						

2. How does each variety smell after cooking?

Variety	Dislike extremely	Dislike	Neither like or dislike	Like	Like extremely	Comments
A						
B						
C						
D						
E						
F						
G						

3. How each variety taste after cooking ?

Variety	Dislike extremely	Dislike	Neither like or dislike	Like	Like extremely	Comments
A						
B						
C						
D						
E						
F						
G						

4. **How is the texture of each variety? How does it feel in your mouth after cooking?**

Variety	Dislike extremely	Dislike	Neither like or dislike	Like	Like extremely	Comments
A						
B						
C						
D						
E						
F						
G						

5. **How do you rate the acceptability of the dry grain in the marketplace?**

Variety	Dislike extremely	Dislike	Neither like or dislike	Like	Like extremely	Comments
A						
B						
C						
D						
E						
F						
G						

Appendix 2: Quantitative Descriptive Sensory Evaluation Form

Sensory Evaluation Form

Quantitative descriptive Analysis (QDA) of *lablab* beans varieties

Sex……..……Age……Time……

Please evaluate each coded sample in the order they are listed. Choose appropriate number in a scale from 1 to 5, where 1 is low intensity and 5 is high intensity. How do you find the following characteristics for different *lablab* beans. Put the appropriate number against each characteristic.

Sample number

Colour

Faint 1 2 3 4 5 Very concentrated

Taste

Not viscous 1 2 3 4 5 Very viscous

Mouth feel

Not viscous 1 2 3 4 5 Very viscous

Appearance

Not appealing 1 2 3 4 5 Very appealing

Aroma /smell

Not aromatic 1 2 3 4 5 Very aromatic