

**NUTRITIONAL, TECHNOLOGICAL AND SENSORY CHARACTERISTICS OF
IMPROVED COWPEA (*Vigna unguiculata* L.) LINES AND VARIETIES
CULTIVATED IN ARID AND SEMI-ARID LANDS OF EASTERN KENYA**

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**A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements
for the Master of Science Degree in Food Science of Egerton University**


EGERTON UNIVERSITY

JANUARY, 2021

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not, wholly or in any part, been presented for the award of a degree in any other university.

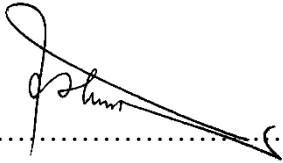
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Recommendation

This thesis has been submitted for examination with our approval as the official University supervisors.

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DEDICATION

I dedicate this work to my father Joseph, mother Elizabeth Ng'eny, my wife Dr. Rebecca Jerop and my children Faith Cheptoo, Precious Chepkoech and Brian Kiprotich.

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ABSTRACT

Food and nutrition insecurity is a big challenge for people living in the arid and semi-arid lands (ASALs) of Kenya. They rely mostly on food aid and cereals, which are poor in key nutrients supply, especially proteins. Most crops are unable to grow well in this region due to harsh climatic conditions and poor soils. Cowpea (*Vigna unguiculata* L.) is a drought-tolerant highly nutritious legume which matures within a short period. Therefore, it is an excellent crop to boost protein-deficient diets and solve food and nutrition insecurity in the arid and semi-arid regions. This study analyzed ten newly bred cowpea lines IT97K-499-35, IT82D- 889, IT82D-889-1, TEXAN PINKEYE, TX123, IT98K-205-8, IT98K-1111-1, IT97K-1042- 3, IT85F-867-5, and IT98K-589-2 and five varieties (checks) KVU27-1, M66, K80, KUNDE MBOGA and KENYA KUNDE for the nutritional and techno-functional quality. Samples were obtained from Kenya Agriculture and Livestock Research Organization (KALRO), Katumani, Kenya. The proximate composition of the new cowpeas lines and varieties varied where protein contents ranged from 23.37-29.70%; total carbohydrates 49.37-55.74%; crude ash 2.99-3.34%; crude lipids 0.13-0.81% and crude fibre 1.40-4.34%. Minerals contents ranged from 1.97-2.69 mg/100 g for calcium, 3.23-3.90 mg/100 g for magnesium, 205.53-223.30 mg/100 g for sodium, 0.80-1.23 mg/100 g for zinc, 1071.15-1152.62 mg/100 g for potassium and 0.62-1.06 mg/100 g for phosphorus. For technological properties, improved cowpea lines absorbed water equivalent to their weights, and they were comparable to varieties grown in the region, such as K80 and KVU27-1. The results showed that cowpea lines IT97K-1042-3, TEXAN PINKIYE, IT85F-867-5, and IT82D-889 had desirable attributes such as high crude protein content, high water absorption capacities above 100%, and high volumetric expansion of 64.14%. Cooking decreased protein contents by 3.59% in TEXAN PINKIYE line and the levels of potassium, phosphorus calcium, magnesium, and zinc in cowpea grains also decreased at different levels. IT82D-889, IT85F-867-5, and IT97K-1042-3 lines recorded high retention of proteins and minerals after cooking with high consumer preference in taste, colour, aroma, flavour and general acceptability. The taste of cowpeas was the main determinant affecting the general acceptability of new cowpea lines and was well comparable with existing K80 variety. The results suggest that these cowpea lines are acceptable for home consumption and can be used to enrich foods of low protein like complementary foods. Cowpea lines IT82D-889, and IT85F-867-5 can be approved as new varieties based on nutritive content sensory, and technological characteristics results of this study.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION	ii
COPYRIGHT	iii
DEDICATION.....	iv
ACKNOWLEDGMENTS	v
ABSTRACT.....	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF ABBREVIATIONS AND ACRONYMS	xii
CHAPTER ONE	1
INTRODUCTION.....	1
1.1 Background Information.....	1
1.2 Statement of the Problem.....	4
1.3 Objectives	4
1.3.1 General Objective	4
1.3.2 Specific Objectives	4
1.4 Hypotheses.....	5
1.5 Justification.....	5
1.6 Scope and Limitations.....	5
1.7 Operational Definition of Terms.....	7
CHAPTER TWO	8
LITERATURE REVIEW	8
2.1 Overview of Cowpea	8
2.2 Utilization of Cowpeas	9
2.2.2 Agronomical benefits.....	12
2.4 Nutritional Profile of Cowpeas	13
2.4.2 Challenges hindering optimum utilization of cowpeas.....	18
2.4.3 Hard to cook phenomenon.....	19
2.5 Cooking and Retention of Nutrients in Cowpeas after Cooking.....	20
2.6 Technological Properties	21

2.7 Sensory Evaluation	23
2.8 Conclusion	24
CHAPTER THREE	25
MATERIALS AND METHODS	25
3.1 Study Location and Materials	25
3.2 Sample Preparation	27
3.3 Sampling Plan and Sample Preparation	28
3.3.1 Sample size	28
3.3.2 Preparation of cooked cowpea flour for effects on protein and minerals analyses ..	28
3.3.3 Preparation of cowpea grains for technological analyses	28
3.3.4 Preparation of cowpea samples for sensory analysis	28
3.4 Nutritional Analyses	28
3.4.1 Determination of moisture content	28
3.4.2 Determination of ash content	29
3.4.3 Determination of crude protein content	29
3.4.4 Determination of fat content	30
3.4.5 Determination of crude fibre.....	30
3.4.6 Carbohydrate content determination.....	31
3.4.7 Determination of mineral contents.....	31
3.4.8 Amino acid analysis	31
3.5 Technological Properties	31
3.5.1 Water absorption capacity before cooking	32
3.5.2 Water absorption capacity after cooking	32
3.5.3 Volumetric expansion and density of cowpea grains	32
3.6 Sensory Evaluation	33
3.6.1 Determination of Consumer Acceptability of the Cooked Cowpeas.....	33
3.7 Experimental Design and Statistical Analysis	33

CHAPTER 4	34
RESULTS AND DISCUSSION	34
4.1: Determination of proximate composition and minerals composition of cowpea lines in comparison with existing cowpea varieties (checks) cultivated in Eastern Kenya of Machakos Kitui and Makueni Counties.	34
4.1.1 Proximate composition of new breeding lines and existing varieties (checks).	34
4.1.3: Pearson correlation of minerals in cowpeas	39
4.2: Technological properties of new cowpea breeding lines and varieties grown in Eastern Kenya.....	39
4.3: Effects of cooking on protein and mineral contents of newly improved cowpeas lines and varieties cultivated in Eastern Kenya.	42
4.4: Consumer acceptability of the newly improved cowpea lines and varieties from Eastern Kenya.....	45
4.4.1: Pearson correlation coefficients between different sensory attributes of lines and varieties from Eastern Kenya.	46
CHAPTER 5	48
CONCLUSIONS AND RECOMMENDATIONS	48
5.1: Conclusions.....	48
5.2: Recommendations.....	48
5.3: Further research	49
REFERENCES	50
APPENDICES	62
Appendix A: Some selected statistical outputs from the work.	62
Appendix B: Amino acids results for one cowpea flour sample representative.	65
Appendix C: Paired T- test comparison of uncooked and cooked cowpeas lines and varieties minerals protein contents.....	66
Appendix D: Consumer/ Sensory evaluation form.....	67
Appendix E: Research output.	68
Appendix F: NACOSTI Research authorization	69

LIST OF TABLES

Table 1: Food uses of cowpea grains and major opportunities.....	10
Table 2: Comparison of proximate composition of cowpea and other legumes.....	13
Table 3: Amino acid profile of Bechuana white cowpea flour, values expressed as g/100g protein.	14
Table 4: Methionine and tryptophan contents in cowpea meal and protein	15
Table 5: Nutrient composition and amino acid profile of selected legumes.....	16
Table 6: Cowpea lines/varieties and description used in research- from KALRO Katumani Kenya.	27
Table 7: Proximate composition of different lines and varieties grown in Eastern Kenya.	36
Table 8: Different mineral contents (mg/100g) of different cowpea lines/varieties grown in Eastern Kenya.	38
Table 9: Correlation coefficients (r^2) between the different mineral dependent variables of different lines and varieties obtained from Eastern Kenya.	39
Table 10: Technological properties of different lines/varieties grown in Eastern Kenya.	41
Table 11: Proteins and selected minerals contents of cowpea lines and varieties before and after cooking from Eastern Kenya.	44
Table 12: Consumer acceptability of newly bred cowpeas lines and varieties grown in Eastern Kenya.	46
Table 13: Showing correlation analysis (r^2) between the different sensory attributes of different lines and variety obtained from Eastern Kenya.....	47

LIST OF FIGURES

Figure 1: Cowpea varieties (checks) from Eastern Kenya used in this research.....	25
Figure 2: Cowpea lines used in this research.....	26

LIST OF ABBREVIATIONS AND ACRONYMS

AACC	-	Association of American Cereal Chemists
ANOVA	-	Analysis of Variance
AOAC	-	Association of Official Analytical Chemists.
ASALs	-	Arid and Semi-Arid Lands.
CP	-	Crude Protein.
ECOWAS	-	Economic Community of West African States.
FAO	-	Food and Agriculture Organization of the United Nations.
GC	-	Gas Chromatography.
HPLC	-	High-Pressure Liquid Chromatography.
HTC	-	Hard-to-Cook Defect.
IITA	-	International Institute of Tropical Agriculture.
KALRO	-	Kenya Agricultural and Livestock Research Organization.
KEPHIS	-	Kenya Plant Health Inspectorate Service,
Kt	-	Kilo tonnes- thousand tonnes
NDMA	-	National Drought Management Authority.
SAS	-	Statistical Analysis Systems.
TAGDev	-	Transforming African Agricultural Universities to Meaningfully Contribute to African Growth and Development.
TIA	-	Trypsin Inhibitor Activity.
USAID	-	United States Agency for International Development
WHO	-	World Health Organization.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Food and nutrition security is a development challenge for Kenya whereby approximately 25% of the country's population suffers chronic food insecurity and poor nutrition leading to high levels of malnutrition. Africa spends an estimated US\$35 billion per year on importing food with the figure projected to shoot up to US\$110 billion by 2025 (Hazel, 2017; Adesina, 2019). It is estimated that 5% of the country's population depends on food aid from government and humanitarian agencies (Mutungi & Affognon, 2013), and this population comes majorly from the arid and semi-arid lands (ASALs). In Kenya, ASALs cover approximately 83% of the country's total area, and agriculture in this region depends on seasonal rainfall (Shisanya *et al.*, 2011). Kenya's changes in rainfall patterns have been observed for the last 50 years (USAID, 2010). Key observations have been that rainfall has become irregular and very hard to predict its patterns, more intense and less downpours in some parts of the country (Nzau, 2003). In these regions, actual observed temperature trends indicate significant warming (USAID, 2010). It is seen with the crop failure especially during drought periods, which is an indication of serious challenges, and measures are required within the agricultural sector that will be able to protect livelihoods by ensuring local/national food and nutrition security.

Reports have shown that there is low levels of human development in Kenya's ASALs hence high levels of poverty, increased vulnerability and climate stresses especially drought (Mbaya *et al.*, 2015). These factors have caused greater consequences in these regions, such as acute food shortages leading to severe acute malnutrition widely prevalent among developing countries especially Kenya and a major cause of morbidity and mortality (Mbaya *et al.*, 2015). Kenya's drought conditions are expected to persist leaving 3.4 million people severely food insecure and an estimated 500,000 people without access to food and water (NDMA, 2017). An estimated 482,882 children require treatment for acute malnutrition, including 104,614 who are suffering from severe acute malnutrition (SAM), 83,691 are from 23 arid and semi-arid counties (NDMA, 2017).

Cowpea (*Vigna unguiculata* L.) is a nutritious crop, which does well in ASALs because of its tolerance to drought, making it an environmental and climate-change friendly crop. It is an important source of good quality dietary protein to millions of people living in ASALs of

Eastern Kenya and is the most widely produced pulse grain after common dry beans (*Phaseolus vulgaris*), and chickpea (*Cicer arietinum*) (Awika & Duodu, 2017). Cowpea has agronomical and social benefits and takes a relatively short time to mature (Langyintuo *et al.*, 2003; Timko & Singh, 2008; Goncalves *et al.*, 2016). The crop has a high protein content 19- 31%, better carbohydrate contents of above 50%, relatively low fat 1-2% and complementary amino acid pattern compared to cereal grains. The legume is also an important source of vitamins and key minerals such as zinc and iron (El-Jasser, 2011). It is a rich source of bioactive compounds such as peptides, phytochemicals, antioxidants and vitamins possessing specific properties that benefit human health in various ways (Jayathilake *et al.*, 2018).

However, some cowpeas varieties also contain high levels of polyphenols, which play an important role in the reduction of protein and starch digestibility (Punia & Darshan, 2000). Phytic acid which is widely distributed in food grains also lowers the bioavailability of minerals and inhibits proteases and amylases (Punia & Darshan, 2000). For this reason, there is need to breed varieties with low levels of these phenolic compounds. High antinutrient components of cowpea (trypsin inhibitors, oxalates, tannins, and phytates), oligosaccharides (stachyose, raffinose, and verbascose) that cause flatulence (Sreerama *et al.*, 2012), have also contributed to low utilisation of cowpeas. Pre-processing techniques such as dehulling, boiling and soaking, have been evaluated to determine their potential in reducing the fermentation of these indigestible oligosaccharides and antinutrients in cowpea and thus reducing the associated problems (Onyenekwe *et al.*, 2000; Sreerama *et al.*, 2012).

Efforts aimed at breeding and improving cowpea varieties for specific characteristics such as high yield, early maturity, desired seed quality and resistance to insects and diseases have been reported (Singh & Mare, 1985). The efforts put in by plant breeders in developing a high-yielding variety may be of little significance unless the cowpea lines and varieties nutritive value, its retention after cooking, technological properties and consumer acceptability are evaluated. There are numerous significant health problems due to poor nutrition. Many research has shown that the reasons for these health problems are caused by economic weakness and a lack of knowledge about good nutrition (Sert & Ceyhan, 2012). Eastern Kenya grows cowpeas but there are reports of high malnutrition among children despite these varieties being available; hence there is need to check on nutrients contents on new lines and also on existing varieties and their acceptability by consumers.

FAO of the United Nations ranks cowpea as one of the best options in increasing protein supply due to its low production cost (Silva *et al.*, 2017). Therefore, the selection of new cowpeas lines with high proteins and mineral contents which can be retained after cooking is important for human health mainly for the low-income population in the ASALs regions of Eastern Kenya. Prolonged cooking time should also be avoided since this causes structural changes at the cellular level hence reducing the availability of some nutrients (Pujola *et al.*, 2007). Presence of antinutrients has been a problem, but different processing methods, including soaking and cooking in water have been reported to reduce them (Sreerama *et al.*, 2012).

According to Gilani *et al.* (2012), cowpea is still considered a neglected and underutilized crop species based on socio-economic issues. Therefore, there is still limited research related to its development as a local food security crop, especially in East Africa. Hitherto, some research has been done to improve cowpea yield and early maturity time. However, there is limited research on cowpeas in terms of nutritional quality, technological/processing characteristics, consumer acceptability, and retention of proteins and mineral after cooking in Kenya. This raises concern in terms of food insecurity and malnutrition which is still endemic in ASALs despite efforts by the crop breeders. Reports have also shown high antinutrient components of cowpea such as (trypsin inhibitors, oxalates, tannins, and phytates), and oligosaccharides (stachyose, raffinose, and verbascose) that cause flatulence (Sreerama *et al.*, 2012). However, attempts have been made using food processing techniques such as dehulling, boiling and soaking, in order to reduce the fermentation of these indigestible oligosaccharides and antinutrients in cowpea and thereby reducing the associated problems (Onyenekwe *et al.*, 2000; Sreerama *et al.*, 2012).

This study was aimed at determining nutritional quality, technological characteristics, effects of cooking on proteins, minerals and hence consumer acceptability of new cowpea lines as compared to the existing varieties in Machakos, Kitui and Makeni counties of Kenya. This was geared towards contributing to mitigations aimed at reducing food insecurity, malnutrition and also to recommend best cowpeas lines to be used by farmers and consumers in ASALs of Kenya.

1.2 Statement of the Problem

Despite cowpeas good adaptation to ASALs, food and nutrition insecurity is still a problem. In recent years, there have been further efforts to breed varieties with better traits, such as increased drought tolerance, early maturity, and increased yield. Farmers in the coastal part of Kenya rejected new varieties because of colour, grain size, and poor palatability (taste) as compared to their traditional ones (Ndiso *et al.*, 2015). However, nutritional, technological characteristics and consumer acceptability of new cowpea lines and existing varieties have not been evaluated or documented especially in East Africa. This calls for pragmatic approaches to understand and document on the properties of these lines and varieties in order to improve food and nutrition security of the ASALs populations. Findings from the study can be used to approve the recommended new cowpea lines based on their nutritional, technological and consumer acceptability.

1.3 Objectives

1.3.1 General Objective

To contribute to food security by identifying and recommending best cowpea varieties from new cowpea lines developed for use by farmers in Eastern Kenya of Machakos, Kitui and Makueni counties, based on nutritional and processing qualities.

1.3.2 Specific Objectives

- i. To determine the proximate composition and minerals contents of improved cowpeas lines and varieties cultivated in Eastern Kenya.
- ii. To assess the technological qualities of new improved cowpea lines and varieties grown in Eastern Kenya.
- iii. To assess effects of cooking on proteins and minerals contents of newly improved cowpeas lines and varieties cultivated in Eastern Kenya.
- iv. To determine sensory consumer acceptability of the newly improved cowpea lines and varieties from Eastern Kenya.

1.4 Hypotheses

- i. Proximate composition and mineral contents of improved cowpeas lines and traditional varieties cultivated in Eastern Kenya do not differ significantly.
- ii. There is no significant difference in technological quality of newly improved cowpeas lines and varieties cultivated in Eastern Kenya.
- iii. Cooking does not significantly affect the proteins and minerals content of newly improved cowpeas lines and varieties cultivated in Eastern Kenya.
- iv. There is no significant difference in consumer acceptability of newly improved cowpea lines and varieties cultivated in Eastern Kenya.

1.5 Justification

Food insecurity and malnutrition in ASALs is still high despite the introduction of high yielding and drought tolerant varieties of cowpeas. Therefore, determining nutrients in cowpea samples, technological/processing properties, consumer acceptability and nutritional value retention will help to identify best-suited cowpeas varieties for use by households and industries in ASALs. Therefore, the selection of new cowpeas lines of high nutritional content (especially proteins and minerals) is important for human health mainly for the low-income population in the ASALs regions. This should have fast cooking time and high nutrient retention after cooking being an important requirement since people living in the ASALs are suffering from shortages of fuel and other resources. Knowledge on the nutrient quality, processing characteristics will also inform the researchers on what they are producing and how to improve on their breeding of new lines and also consumers will be informed on what they are consuming. There is limited knowledge on the technological characteristics of cowpeas grown in East Africa. Providing relevant data should inform on the characteristics that shape consumer acceptance in new lines or varieties hence guide the release of the new varieties for production to address food and nutrition security in Machakos, Kitui and Makueni counties and entire ASALs.

1.6 Scope and Limitations

The focus on this study was only ten new cowpea lines selected by breeders from KALRO Katumani and five cowpea varieties selected from those grown by farmers in Machakos, Kitui, and Makueni counties, Kenya. This research was only on selected variables of nutritional and technological (processing) properties. Sensory analysis for consumer acceptability was limited to cowpeas lines which were superior in nutritive qualities and panellist used were only for

those who understood the product. Cooking effects on proteins and selected minerals was also done but for other constituents like phytochemicals retention (phenolics) were not done. Possibility of using these lines as ingredient in complementary foods also storability infestation by pests were not done. The study was on samples planted in September 2018 - December 2019 season.

1.7 Operational Definition of Terms

Technological characteristics – Defined as physiochemical characteristics related to processing of cowpeas examples are hydration properties (Water Absorption Capacity Before Cooking, Water Absorption Capacity After Cooking), volumetric expansion before cooking and after cooking as done in this research.

Hard to cook (HTC) – This is phenomenon used in describing cowpeas seeds when it remains hard even after soaking and cooking by boiling for more than one hour. It can be caused by interaction of proteins and polyphenols and polymerization of polyphenolic compounds.

Variety- Individual crop with same characteristics. For this research cowpea varieties are those ones been accepted by KEPHIS (Kenya Plant Health Inspectorate) and released to be planted by farmers and consumed.

Line- This is individual crop with same characteristics. It's still undergoing breeding process and has not been approved by KEPHIS (Kenya Plant health inspectorate Service, Kenya Plant health inspectorate Service) hence not released to be planted by farmers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Cowpea

Cowpea belongs to *Leguminosae* or *Fabaceae* family and it is an ancient crop which it was domesticated near Southern Africa, before it was widely spread to East and West Africa, Asia, Europe and the Americas (International Institute of Tropical Agriculture [IITA], 2015). The crop is widely grown in sub-Saharan Africa (Anyango, 2009). The exact origin of cowpea (*Vigna unguiculata* L.) is not known, even though, a lot of evidence points that the legume may have originated from Southern Africa (Singh & Ntare, 1985). Primitive wild forms of this crop which was strongly suggested by Padulosi (1987) and Padulosi *et al.* (1990) to be found in the areas currently occupied by Botswana, Namibia, Zambia, Mozambique, Zimbabwe, Swaziland and South Africa. Cowpea was first domesticated in Africa between 1700 to 1500.

Before the Current era (Singh, 2014) and all cultivated varieties grown in the world today originated from East and West Africa (Xiong, 2016). The relatively small size of cowpeas seeds is reported to have favoured its dispersal by birds throughout West and East Africa (Timko & Singh, 2008). Cowpea grain is mainly a dicotyledonous seed which can be oval, kidney or globular shaped seed (Anyango *et al.*, 2011a). It is an important food as well as forage legume that is well suited to arid and semi-arid regions of Africa, Asia, Southern part of United States, Central and South America as well as Southern regions of Europe (Singh, 2005). Cowpea is also a heat tolerant crop that can survive in semi-arid soil conditions experienced in sub-Saharan-Africa. Cowpea grains vary according to their size, colour, skin texture, eye colour, and insect (*Callosobruchus maculatus*) damage tolerance. The colour of the cowpeas (often referred to as skin colour or testa colour) varies and can be white, black, brown or red. Cowpea skin can be uniform in colour or speckled. The skin or outer coating of the cowpeas may be rough or smooth. The colour of the eye of the cowpeas can also be black, grey or brown (Murdock *et al.*, 2003).

Africa is reported to as the highest producer of cowpeas in the world and in the year 2017, over 87% of the crop was produced in Africa (FAOSTAT, 2019). The leading ten producers of dry seeds grains cowpeas in the year 2017 were Nigeria (3410 thousand tonnes (kt)), Niger (1959 kt), Brazil (749 kt), Burkina Faso (604 kt), the United Republic of Tanzania (201 kt), Cameroon (198 kt), Myanmar (179 kt), Kenya (146 kt), Mali (145 kt) and Sudan (130 kt) (FAOSTAT, 2019). In Kenya, where there are many poor socio-economic subsistence farmers, cowpea could be a suitable alternative to expensive sources of protein such as meat and fish, because of its

unique attributes and low agronomical requirement in terms of fertilizer (Ojwang, 2012). In Africa, it is regarded as an economically important traditional legume crop (Langyintuo *et al.*, 2003). It is able to improve human health and also prevent various diseases (Ojwang, 2012). Subsistence farmers are mainly more prone to malnutrition because quality proteins from animal sources are rather expensive for them to get. Therefore, to improve their nutritional status, less costly, nutritious plant sources such as cowpeas can be a source of cheap protein to them.

Cowpea is an economically important indigenous African legume crop compared to others (Langyintuo *et al.*, 2003). In Kenya it is an important crop in traditional intercropping systems in the semi-arid regions. It accounts for about 16% of Kenya's pulse production, and 90% of the production takes place in the semi-arid lands of Eastern Kenya, mainly in Kitui, Machakos, Makueni, Embu, and Tharaka-Nithi counties. Minor volumes are produced in the Coast (3.70%), Rift Valley (1.6%), North Eastern (0.8%), Central (0.6%) and Western (0.3%) regions (USAID, 2010). There are several cowpeas that are grown in Kenya such as Katumani 80 (K80), Kunde mboga, MTW 63, MTW 610, Machakos 66 (M66), KVVU 27-1, KVVU 419 (M'Ragwa & Mutua, 2008; Greenlife, 2018). M'Ragwa and Mutua (2008) suggested that M66, K80 and KVVU27-1 were the most suited varieties in the ASALs regions of Kenya.

2.2 Utilization of Cowpeas

Cowpea is a good multifunctional crop; it is able to provide food to man and livestock, given its good nutritional profile; has agronomical benefits; serves as a dependable and valuable commodity for generating revenue not only to farmers but also to traders (Timko & Singh, 2008). The crop is reported to be an underutilized legume crop with a high potential for food and nutritional security in South Africa and produced for grain, immature green pods and fresh leaves due to its nutritional composition (Gerrano *et al.*, 2015a; 2015b).

Primarily, cowpea is grown in Africa for human consumption. It is used in over 50 different varieties of dishes (Dovlo *et al.*, 1976; Langyintuo *et al.*, 2003). Cowpea can be used to produce a large range of dishes and snacks (Uzogara & Ofuya, 1992; Asif *et al.*, 2013). This is shown in Table 1 below.

Table 1: Food uses of cowpea grains and major opportunities

Cowpea food	Description	Uses
<i>Akara</i>	Fried cowpea balls	Breakfast foods and snacks
<i>Moin-moin</i>	Steamed cowpea paste	Lunch and also dinner foods
<i>Ewa-ibji</i>	Boiled whole cowpea	Lunch and dinner foods
<i>Danwake</i>	Boiled dehulled cowpea	Lunch and dinner foods
<i>Gbegiri</i>	Cowpea soup	Appetizers
<i>Adayi</i>	Cowpea purée	Pureed baby foods
Cowpea spread	Boiled mashed cowpeas with fat and seasoning	Spread on bread and yams
Roasted cowpea	Flavoured roasted cowpea	Snack food
Cowpea bread	Local bread made with cereal flour and cowpea flour	Breakfast, lunch and snack food
Cowpea cake	Cowpea used as an ingredient in cakes and pies	Breakfast and snack food
<i>Akidi-na-oka</i>	Dish of maize, cowpea	Food for adults
Cowpea sorghum dish	Boiled sorghum and cowpea	Food for adults
Cowpea plantain potage	Boiled cowpea and plantain	Food for adults
Cowpea yam potage	Boiled cowpea and yam	Food for adults
Cowpea weaning food	Dehulled and then boiled cowpea supplemented to cereal-based infant foods	Infants, children food

Source: Asif et al. (2013)

Cowpeas may be harvested and consumed as tender leaves, immature pods but they are commonly used as mature dry seeds. The young green leaves of the growing plant, green peas and green pea pods can be consumed as vegetables. Leaves intended for eating should be harvested while still young and tender (Greenlife, 2018) which can be done as early as 2-3 weeks after planting. Cowpea leaves are consumed as a fried vegetable, boiled, fermented or steamed. In West Africa for example, traditional recipes, which employ cowpea paste and soup are *akara* (deep-fried de-hulled cowpea paste), *moin-moin* (steamed cakes), *gbegiri* (cowpea soup) and *kpejigaou* (a griddled cowpea-paste) (Anyango, 2009). In East Africa, young shoots of the cowpea (*kunde*), are often consumed (Ojwang, 2012). Immature pods can be harvested 12-16 days after the crop flowers. Depending on the variety as well as the climatic conditions, dry pods can be harvested after 60-120 days of planting (Langyintuo *et al.*, 2003; Greenlife, 2018). Dry seeds are often consumed with other cereals such as rice. The flour obtained from cowpea has been incorporated into a variety of processed foods such as baked food products and baby foods (Okwu & Orji, 2007). It has been suggested that innovations in the product development of cowpea can meet the protein and fiber daily needs as well as increase the consumption of legumes (Kirse & Karklina, 2015).

High protein varieties (protein content ranges from 20-40%) are especially valued as a cheap source of protein for low-income populations who cannot afford animal protein. In Ghana, for instance cowpea-based weaning foods were shown to reduce malnutrition (Phillips *et al.*, 2003). The protein is of high quality and compares well with proteins of soybean when substituted in diets at equivalent protein proportions (Aguirre *et al.*, 2003; Obatolu *et al.*, 2003). Limited studies have also shown that cowpeas have the antioxidant capacity (Nzaramba *et al.*, 2005; Siddhuraju & Becker, 2007) and that the anti-nutrient properties can be improved by heat processing or fermentation methods (Doblado *et al.*, 2005). It is reported that about 60% of the world population is an iron deficit (White & Broadley, 2009). However, a 200 g of cooked cowpea in serving has the potential of supplying 100%, 68.5% and 56.4% of the RDA of iron, magnesium and phosphorus respectively (Granito *et al.*, 2005). The legume is also an important source of carbohydrates (50-60%), as well as vitamins (El-Jasser, 2011).

Evidence suggests that cowpea seeds are effective in binding and lowering blood cholesterol (Frota *et al.*, 2008). Other than phenolic compounds, cowpea proteins, peptides and protease inhibitors in cowpea have also been reported in improving lipid profile, blood glucose level, and

blood pressure and aids in cancer prevention through suppression of cancer cells growth along the cell lines. Furthermore, it is reported to exert its positive effects on disease prevention hence indicating a likelihood of synergistic interactions between the compounds present in cowpea seeds (Jayathilake *et al.*, 2018). Socially, the contribution of cowpea to food, nutrition and income security of rural ASALs communities that domesticate it cannot be understated. On the other hand, cowpea is regarded as a women's crop, which enables them to provide food and supplement family incomes. It helps to bridge the hunger gap that often plagues households during periods before the next harvest because the green leaves and green seeds are consumed as the crop awaits full maturity (Langyintuo *et al.*, 2003).

The soft cooked texture of cowpea grains as used in traditional dishes makes it an ideal source of nutrition for vulnerable groups including young children, the sick and the elderly (Timko & Singh, 2008; Goncalves *et al.*, 2016). Thus, this crop can be used to meet the nutritional requirements for most people living in the ASALs. Indeed, greater use of pulses is recommended to pregnant mothers, and advocated for prevention and treatment of malnutrition among young children in low-income settings (Welthungerhilfe and Concern Worldwide, 2014). From the agronomic point of view, the main benefit of growing cowpea is the short maturation period of 2-3 months.

2.2.2 Agronomical benefits

Unlike other legumes, cowpea has high tolerance to stresses of drought and has a good adaptation to high temperatures (Timko & Singh, 2008). The fact that the legume can grow even in harsh climatic conditions, is the reason why it suits well in the ASALs. The crop has a low input requirement which makes it ideal for resource-poor farmers. Cowpea cultivation also has a low ecologic foot print in terms of water because the crop is tolerant to drought and is thus a good candidate for resilient climate agriculture (Modi & Mabhaudhi, 2013). Therefore, farmers in the ASALs can cultivate the crop successfully. In addition, the plant improves soil by fixing nitrogen, it also acts as a cover crop, and is therefore traditionally suitable for intercropping systems.

Cowpea, like all other legume crops, has a symbiotic relationship with a specific soil bacterium (*Rhizobium* spp.). *Rhizobium* makes atmospheric nitrogen to be available to the plant through a process called nitrogen fixation. This nitrogen Fixation occurs in root nodules of the plant and the bacteria is able to utilize sugars produced by the plant because of its high rate of nitrogen

fixation (Elowad & Hall, 1987) and this makes cowpea a valuable crop in farming systems where intercropping is practiced. In the ASALs, persistent drought contributes to soils becoming infertile and hence limits crop yields. Cowpea also has some better adaptation capabilities to ASALs, soil infertility does not affect its yield (Kwapata & Hall, 1985). Additionally, Ghanbari *et al.* (2010), have shown that cowpea has the potential of increasing water retention of soil either when grown alone in the field. According to Fery (1990) cowpea is capable of tolerating soils with pH ranges of 5.5 to 6.5. It has also been used for green manure in South Eastern America and parts of Australia (Ehlers & Hall, 1997).

2.4 Nutritional Profile of Cowpeas

Cowpea is a good source of macronutrients, micronutrients and some phytochemicals. Its proximate composition compares well with most legumes (Table 2) even though it is mostly grown in the ASALs region. Its seed supply mankind with protein ranging from 20.3 – 39.4% (Goncalves *et al.*, 2016). Thus, cowpea is an undisputed source of dietary protein in countries where animal protein consumption is limited either due to non-availability or because of cultural and religious reasons (Kirse & Karklina, 2015). Nutritional properties and chemical composition of cowpea grains vary depending on environmental conditions, genotype, season, agronomic practices and soil fertility. Varietal differences also affect the nutritional balance of cowpea. The major cowpea seed proteins are the globulins which contain significant amount of lysine but relatively low amounts of sulphur-containing amino acids (Ojwang, 2012).

Table 2: Comparison of proximate composition of cowpea and other legumes

Legume Type	Protein (%)	Carbohydrates (%)	Dietary Fibre (%)	Fat (%)	Energy (kCal/100g)
Cowpea	20.3 – 39.4	35.5 – 51.0	25.1 – 35.6	0.91 – 1.5	198
Chickpea	15.5 – 28.2	62.3	12.5	4.25 – 6.48	269
Lupin	34.8 – 62.5	40.4 – 44.4	11.3 – 16.1	9.4 – 19.12	225
Bean (<i>Vicia, Phaseolus</i>)	19.4 – 24.8	50.5 – 61.6	15.0	1.27 – 3.02	227
Lentils	24.7 – 26.1	39.86	15.6	0.95 – 1.6	230

Source: Carvalho *et al.* (2012), Rebello *et al.* (2014) and Goncalves *et al.* (2016).

Biological value of protein is normally measured in terms of its amino acids composition. Cowpea has been reported to provide adequate quantities of amino acids such as glutamine,

asparagine, tyrosine and phenylalanine, leucine, proline, lysine, valine, arginine (Abu *et al.*, 2005; Carvalho *et al.*, 2012) as shown in Table 3 below.

Table 3: Amino acid profile of Bechuana white cowpea flour, values expressed as g/100g protein.

Amino Acids	Total protein in grain ^a	WHO Standard
Aspartic acid	2.76	-
Glutamic	4.29	-
Histidine	0.73	1.8
Arginine	1.69	-
Lysine	1.66	5.2
Tryptophan	0.008	0.7
Serine	1.41	-
Tyrosine	0.68	-
Cysteine	0.23	-
Alanine	1.10	-
Proline	1.03	-
Valine	1.12	4.2
Methionine	0.35	2.6 ^b
Isoleucine	0.93	3.1
Leucine	1.84	6.3
Phenylalanine	1.38	4.6 ^c
Glycine	0.93	-

Sourced from (Abu *et al.*, 2005). WHO requirements are based on the essential amino acid composition of a 1 to 2-year-old child (WHO/FAO/UNU, 2007).

^bMethionine + cysteine

^cPhenylalanine + tyrosine. Tyrosine and cysteine not essential amino acids.

Cowpea contains high amounts of carbohydrates, and by extension a good source of dietary fibre. Various researchers have shown that cowpea contains between 2.0 – 4.0% of dietary fiber (Granito *et al.*, 2005; Carvalho *et al.*, 2012; Goncalves *et al.*, 2016). This is a positive fact given that dietary fibre aids in the prevention of digestive tract diseases, diabetes and cardiovascular diseases (Brownlee, 2011). Unlike legumes such as chickpea and lupin, cowpea is a low-fat grain

(Schuster-Gajzago, 2004) and this implies that it is a good nutrient choice for people that are on strict diets due to weight gain cases. Cowpea provides a good source of protein (Boukar *et al.*, 2011) whole cowpea grain contains protein levels ranging from 16% to 31%. Cowpea seed coat contains 12% protein (Aremu, 1990). Most of the cowpea grain proteins consist of globulins with lower levels of albumins, glutelins, and prolamins (Goncalves *et al.*, 2016; Vasconcelos, 2010). The major proteins in cowpea cotyledon are albumins and globulins accounting for 45% and 51% of its crude protein composition, respectively (Freitas *et al.*, 2004). Globulins found in cowpeas are approximately 70% of the total crude protein in the cowpea seed (Anyango, 2009). These globulins are further grouped into two classes, the 11S (legumins) and 7S (vicilin), basing on their sedimentation coefficients (Freitas *et al.*, 2004).

The amino acid composition in cowpea is highly rich in lysine, leucine, arginine and other essential amino acids and this can fulfil the essential amino acid requirements of a human diet. However, cowpeas are low in the sulphur containing amino acids (methionine and cysteine) as compared to cereals and animal products. For a balanced diet then cowpeas need to be supplemented with cereals or vegetables, meat or dairy products (FAO, 2004; Iqbal *et al.*, 2006). Methionine contents of cowpeas range from 0.12-0.26% and (0.46-1.4 g/16 g N) while the tryptophan ranged from 0.11 to 0.22% and (0.45-1.03 g/ 16 g N) in various cultivars as shown in Table 4. Methionine and tryptophan are reported to be the first and second limiting amino acids in cowpea proteins and its reported that some white seeded varieties have relatively higher methionine and tryptophan than other varieties.

Table 4: Methionine and tryptophan contents in cowpea meal and protein

Cultivar	Methionine		Tryptophan	
	g/100g	g/ 16 g N	g/100g	g/ 16 g N
V-385	0.16	0.65	0.11	0.45
V-134	0.24	1.29	0.16	0.86
V-118	0.17	0.76	0.15	0.67
V-701	0.26	1.13	0.11	0.48
V-105	0.21	0.66	0.20	0.90
S-488	0.14	0.66	0.20	0.95
CG-104	0.14	0.76	0.19	1.03

Source: Kachare *et al.* (1988)

Cowpeas contains high amounts of proteins as compared to other legumes, therefore it is superior to others as shown in the Table 5 below.

Table 5: Nutrient composition and amino acid profile of selected legumes

Nutrients (g/100g)	Legume			
	Cowpea	Chickpea	Lentil	Green pea
Crude protein	29.9	21.9	25.4	24.9
Crude fat	2.9	5.4	2.1	1.5
Ash	4.2	3.6	2.8	3.6
Amino acids				
Arginine	7.5	8.3	7.8	7.2
Leucine	7.7	8.7	7.8	7.4
Lysine	7.5	7.2	7.0	8.1
Methionine	2.2	1.1	0.8	1.1
Phenylalanine	7.5	5.5	5.0	5.2
Tryptophan	0.7	0.9	0.7	0.8
Valine	5.0	4.6	5.0	5.0
Histidine	3.1	3.0	2.2	2.4
Isoleucine	4.5	4.8	4.1	4.5
Leucine	7.7	8.7	7.8	7.4
Alanine	4.2	4.97	4.2	5.2
Aspartic acid	10.8	11.0	11.8	11.0
Glutamic acid	17.2	17.3	21.5	17.5
Proline	4.0	3.8	3.5	3.8

Source: Ojwang (2012)

The crude fat content of cowpea whole grain ranges from 0.5% to 3.9%. The lipid profile of cowpea has high of triglycerides (41.2% of total fat), followed by phospholipids (25.1% of total fat), monoglycerides (10.6% of total fat), free fatty acids (7.9% of total fat), diglycerides (7.8% of total fat), sterols (5.5% of total fat) and hydrocarbons and sterol esters (2.6% of total fat) (Goncalves *et al.*, 2016).

Apart from being a good source of macronutrients, cowpea contains considerable amounts of micronutrients. This legume fulfils the recommended daily intakes of a number of minerals

including calcium, potassium, iron, zinc and magnesium (Granito *et al.*, 2005; Ayogu *et al.*, 2016; Goncalves *et al.*, 2016). Twenty-one inorganic elements, made up of six major minerals (Na, K, Mg, Ca, P, and Cl), and 15 trace elements (As, Co, Cu, F, Fe, I, Mn, Mo, Ni, Se, Si, Sn, V and Zn), are now considered as being essential to human life (Linder, 1991). Thus, consumption of cowpea can be used to curb the iron deficit experienced in 60% of the world population (White & Broadley, 2009).

Phytochemicals are also found in cowpea in considerably good amounts. The most commonly found phytochemicals in cowpea include flavonoids, saponins and alkaloids. Flavonoids are known to limit free radicals and to improve aggregation of platelets (Vita, 2005; Bouchenak & Lamri-Senhadjji, 2013). Saponins have also been shown to reduce cholesterol levels by forming an insoluble complex with cholesterol, thus inhibiting its absorption (Campos-Vega *et al.*, 2010). In addition, saponins increase the excretion of bile acids and thus indirectly decreases cholesterol levels. It is also believed that saponins have anti-cancer activity through its ability to suppress the metastatic potential of tumors (Sidhu & Oakenfull, 1986). Therefore, cowpea is a wonderful legume, because the phytochemicals it contains helps in the prevention and management of cardiovascular diseases, obesity and diabetes (Rebello *et al.*, 2014).

Cowpea contains some anti-nutrients phytic acid, phenolic compounds and trypsin inhibitor and flatulence-causing oligosaccharides (Ogun *et al.*, 1989; Sreerama *et al.*, 2012; Goncalves *et al.*, 2016). Phytic acid has been known to inhibit the bioavailability of minerals such as zinc, calcium, magnesium and iron as well as limiting the digestibility of starch and protein through inhibition of amylases and proteases (Urbano *et al.*, 2000; Goncalves *et al.*, 2016).

Phytic acid has also been shown to act as hypocholesterolemic agent, an antioxidant and to suppress oxidation that depends on iron (Zhou & Erdman, 1995). Phenolic compounds pose a threat of impairing proper absorption of macro and micronutrients (Goncalves *et al.*, 2016). For example, when they interact with proteins, they form complexes that inhibit attack by proteolytic enzymes thereby reducing the solubility of proteins (Sreerama *et al.*, 2012). Presence of trypsin inhibitor limits the intake of amino acids by inhibiting degradability of proteins by digestive enzymes (Sreerama *et al.*, 2012).

2.4.2 Challenges hindering optimum utilization of cowpeas.

The main challenges facing the utilization of cowpea is the hard to cook defect, the longer time used in its preparation (Kirse & Karklina, 2015). The hard-to-cook (HTC) defect in cowpea is associated with phytic acid contents (Nyakuni *et al.*, 2008). A survey conducted in Nigeria found that cooking difficulty was main leading constraint to cowpea consumption (Uwaegbute Nnanyelugo, 1987). Anti-nutrients such as flatulence factors (α -galactosides) and other substances that affect nutrient digestibility and bioavailability (trypsin inhibitors, hemagglutinins/lectins, polyphenols, phytic acid, tannins) are a major constraint to the utilization of cowpeas (Sreerama *et al.*, 2012). These factors may be minimized by processing methods such as de-hulling, pressure cooking, extrusion, dry roasting, fermentation, germination, and enzyme processing (Onayemi *et al.*, 1986; Granito *et al.*, 2005; Goncalves *et al.*, 2016).

Trade-related issues on the other hand are also challenges hindering full utilization of cowpea. On the other hand, investigations in Central and West African markets also determined that cowpeas infestation by weavils *Callosobruchus maculatus* lowers market value by 0.2 - 1.2% for each damaged grain in 100 grains (Golob, 1999; Langyintuo *et al.*, 2003). Whereas the nutritional quality losses are largely unknown, the study by Oke & Akintunde, (2013) reported that highly infested cowpeas were of inferior nutritional value, while another study by Modgil (2003) showed that highly infested legumes might contain substances that impair good health. Sreerama *et al.* (2012) hinted that brown coloured cowpea contained averagely 14.0 mg/g phytic acid, while other cultivars had a phytate content of 8.4–9.92 mg/g. Phytic acid contributed 54–59% of the phosphorous in cowpea. Boiling has been found as a more effective method of phytic acid reduction compared to steaming according to Giami (2005). The author reported that phytic acid reduced by about 41% when boiled as compared to 13.5% reduction in steamed cowpea, this is because more assayable phytates could leach into the cooking liquor. Phytic acid is the major storage form of phosphorus in cowpea grains accounting approximately 75% of the total grain phosphorous (Schlemmer *et al.*, 2009). Metallic cations (K^+ , Mg^{2+} , Mn^{2+} , Fe^{2+} , Ca^{2+} , and Zn^{2+}) and proteins are able to bind strongly with highly charged six phosphate groups in phytic acid structure resulting in mixed phytate or phytin. Phytate-to-cation molar ratio, presence of other compounds in the solution, pH, proteins, and individual cation influences the solubility and stability of the protein-phytate or the cation-phytate complexes (Greiner & Konietzny, 2006). This contributes to minerals stability.

2.4.3 Hard to cook phenomenon

Cowpeas do not soften easily and remain hard even after cooking by boiling for more hours. This textural defects can be classified as: hard-shell, when this cowpeas seeds do not absorb sufficient water during cooking and therefore not able to soften when cooked. Hard-to-cook (HTC), when cowpea seeds absorb enough water but it fails to soften upon cooking (Perina *et al.*, 2014). Several mechanisms are proposed for the HTC defect in cowpea seeds, including; lipid oxidation and polymerization; autolysis of cytoplasmic organelles, poor plasmalemma integrity, and lignification of the middle lamella; phytin catabolism and pectin demethylation with subsequent formation of insoluble pectate; interaction of proteins and polyphenols and polymerization of polyphenolic compounds; inadequate postharvest handling and storage techniques (Segura-Campos *et al.*, 2013; Sanchez-Arteaga *et al.*, 2014). The above information has shown that variety, storage conditions and age of the crop can have negative impacts on the cooking process, hence affecting the product's nutritional quality. The cooking process softens cowpea seeds, improves texture and palatability hence its consumer acceptability, and helps to increase the access of digestive enzymes to starch and protein in the cell (Sanchez-Arteaga *et al.*, 2014).

Physical testing is important in evaluating textural properties (elasticity, chewiness, and hardness), because they play a primary role in how a product is perceived by the targeted consumers. From these textural properties, the final hardness of common cowpeas is commonly associated with the degree of cooking and this becomes the initial cause for rejection by consumers. From a scientific perspective, the physicochemical changes experienced by seed beans during the cooking process are interrelated with configurational and conformational changes of the (chemical composition) biomolecules, principally to starch (gelatinization) and protein (denaturalization). Both this phenomenon makes up the legumes food matrix. Thus, the irreversible changes to legumes caused by the cooking process can be done by texture analysis (Dos-santos *et al.*, 2013), chromatographic techniques (Dos-santos *et al.*, 2013), or by differential scanning calorimetry (DSC). The degree of Cooking could be associated to the endothermic transitions in the cooked grains produced during the cooking processes. These endothermic transitions are related to the chemical composition of cowpea seeds (protein and starch concentration, types of protein, amylose content, and minerals), (Sanchez-Arteaga *et al.*, 2014). It was also found out that certain elements of the cooking process of legumes (cooking degree and hardness) are associated with their proximal composition, principally the relationship

of amylase/amylopectin and type of proteins present in the seeds especially the heat resistant proteins.

2.5 Cooking and Retention of Nutrients in Cowpeas after Cooking.

Cooking is one of the most common processing techniques used for cowpeas seeds. It has been found to greatly reduce the content of flatus-forming oligosaccharides in cowpea seeds. Soaking of cowpea seeds in tap water or sodium bicarbonate solution for 12 h, followed by cooking, caused losses of sucrose, raffinose, stachyose and verbascose to the extent of 45.6-64.2, 78.8-100, 43.3-62.8 and 41.9-60 %, respectively (Abdel-Gawad, 1993). Legume grains require a relatively long cooking time. This time of cooking depends primarily on the softness of the cooked seeds. We have both subjective and objective methods used in determining the cooking time of cowpea seeds. Subjective method measures softness of the cooked seeds by squeezing the seed between the fingers (Singh *et al.*, 1991). Objective methods for determination of the optimum cooking time is categorized into methods measuring either the time required to penetrate the cooked seed by a plunger of defined weight, or measurement of the force required to compress or extrude cooked seeds through an extrusion grid or measurement of the force required to shear cooked seeds using a multiblade shear press (Sefa-Dedeh *et al.*, 1978). However, none of the above methods used in checking the cooked cowpeas give results on the changes in the main nutritive components of the during cooking process.

Retention of nutrients in cooked cowpeas is important for the consumer especially in ASALs areas because it's one of the crop people living in this region rely on. It has been a good option for the diet of several populations. Therefore, retention and accumulation of some minerals are influenced by the interaction of different factors, such as varieties, environmental conditions, part of the grain where the mineral is concentrated and minerals solubility during immersion and cooking (Pereira *et al.*, 2014). High concentration of tannins and phytates present in the cowpea grains would also affect the availability of some minerals after cooking (Carvalho *et al.*, 2012). This would affect also presence of zinc and iron in cooked cowpeas. Cooking time also was reported to be affected by presence of phytates and tannins in cowpeas (Lazarte *et al.*, 2015). Cooking time, protein and mineral contents are affected by variety of cooked cowpeas whereas cooking may reduce the calcium, iron and zinc contents in cowpeas (Silva *et al.*, 2017).

2.6 Technological Properties

Determination of the technological quality of the legumes (cowpeas included) grains involves testing of water absorption before and after cooking, cooking time, percentage of marceration and soluble solids in the broth, and colour volumetric expansion after soaking and cooking and grain density differences. Nutritional quality testing includes assessments of crude protein, dietary fibre, crude fat, mineral and vitamin contents (Bassinello *et al.*, 2003). Common bean (*Phaseolus vulgaricus*) genetic breeding programs have provided farmers with cultivars of high grain yield, along with tolerance to drought, pests and diseases, as well as production of grains of a size, shape, colour and sheen acceptable in the market. Legume grains should have desirable cooking features, such as reduced cooking time, good palatability, soft texture of the seed coat and the ability to produce a clear, dense broth after cooking (Mesquita *et al.*, 2007). In Brazil testing of technological quality came to be required at the time of registration of a new variety with the National Cultivar Registry, Ministry of Agriculture as from 1999 for the variety to become a commercial seed product in Brazil (Brazil, 2001). The concerned body directed on the parameters to be followed in relation to seed grains quality. These are determination of cooking time and the protein content of the varieties that are included in the experiments called “Value of Cultivation and Use” (VCU) and hence its acceptance of the new varieties (Brazil, 2001). The technological characteristics of grains are normally affected by the genotype, environment and genotype/environment interaction (Perina *et al.*, 2014).

Water absorption during seed soaking determines the optimum time of the process. Soaking of leguminous plant seeds is the initial stage of most technological processes in this group of raw materials seeds. Proper selection of soaking conditions is important, as it affects the behavior of seeds during further processing, as well as the nutritive and sensory quality of the final product. The amount of water absorbed by seeds during soaking decides about protein denaturation and the degree of starch granule gelatinization during heat treatment. That is why it is one of the most important factors determining good seed texture (Reyes-Moreno *et al.*, 1993; Sadowska *et al.*, 1994; Giczewska & Borowska, 2003) found out that small-seed varieties show better water-holding capacity, confirmed by changes in the mechanical resistance of seeds. These varieties require shorter soaking than large seed ones, and hot soaking may be an alternative for them, as it allows reducing the time of this process to two hours.

Cooking of cowpeas is a form of hydrothermal processing which involves hydration and heating and may take place separately or same time (Sefa-Dedeh *et al.*, 1978). Hydration properties of the cowpea seeds at ambient/room temperature hydration rate and hydration capacity are usually used to show cooking properties of grains. Hydration rate of leguminous seeds has mainly been linked to structural characteristics of the seed coat and cotyledon, while protein content and other macromolecules such as cell wall material and pectins affect hydration capacity (Sefa-Dedeh *et al.*, 1979a). Hydration capacity (water absorption) is a reflection of the water holding capacity of the seeds which includes water of hydration as well as capillary water Sefa-Dedeh & Stanley (1979b) proposed that water uptake in cowpeas could be a sequential process involving seed coat structure and thickness during the initial soaking stage of less than 3 hours seed size /volume and hilum size in the intermediate stage (3-6 h) and protein content (more than 12h) in the final stages of soaking.

Cowpea seed coat is part in direct contact with water during soaking and is one of the conduits for water to the cotyledon. Variations in cowpea seed coat structural characteristics and mode of attachment to the cotyledon have been documented (Sefa-Dedeh & Stanley, 1979a; Sefa-Dedeh & Stanley, 1979b; Lush & Evans, 1980). Thin and amorphous cowpea seed coats have been shown to promote higher rate of seed hydration during soaking as compared to the more organised palisade cells found in thicker seed coats (Sefa-Dedeh *et al.*, 1978; Sefa-Dedeh & Stanley, 1979b; Lush & Evans, 1980). The same time, some cowpea seed coats have a waxy layer on the top side which was reported to contribute towards delayed hydration in those cowpea varieties (Sefa-Dedeh & Stanley, 1979a). Apart from the seed coat structural differences, Olapade *et al.* (2002) reported that cowpeas with a tightly attached seed coat absorbed less water than cowpeas with moderately attached seed coats. In addition to the seed coat characteristics, the seed cotyledon structure has been reported to affect hydration rate. Sefa-Dedeh & Stanley (1979b) reported that cowpea varieties with porous cotyledons had higher rates of hydration than seeds with compact cotyledons. Water imbibition by the cotyledon involves the physical process. The high water solubility of cowpea protein has been associated with good foaming and water absorption properties of cowpea flour. Cowpea protein is relatively heat stable compared to soy protein with denaturation temperature ranging from 78 °C to 88 °C (Horax *et al.*, 2004; Abu *et al.*, 2006). There is movement of water to fill in the inter-cellular spaces (Phlak *et al.*, 1989). Hence loosely packed cotyledon parenchyma cells would provide easier access for water as compared to compactly packed cells. With increasing soaking time, the cotyledon properties

have been reported to play major role in the hydration process. Cowpea seed protein content was reported to be the main factor affecting water absorption during extended soaking (more than 12 h) (Sefa-Dedeh & Stanley, 1979b). Cowpea protein has been reported to be relatively hydrophilic (Horax *et al.*, 2004) and thus plays a major role in hydration of the seed (Sefa-Dedeh & Stanley, 1979b).

Water is held by proteins through the formation of hydrogen bonds with the hydrophilic polar side chains. The hydration capacity of cowpea seeds has been reported to range from 1.14 to 1.60 g g⁻¹ (Olapade *et al.*, 2002) and it is positively related to protein content. Sefa-Dedeh *et al.* (1978) did their studies and reported a correlation between water absorption during soaking and cooked cowpea texture, which could be used to predict cooked grain texture. Although there is wide variation in hydration rate and capacity of cowpeas during soaking, a concrete relationship with cooking time and texture has not been fully known and established.

2.7 Sensory Evaluation

Sensory evaluation comprises of techniques that involve psychology, statistics, food science, physics, engineering, ergonomics, sociology, mathematics, humanities and various other biological sciences. It is categorized into objective and subjective testing. Objective method hedonic response of a product is determined by skilled evaluators whereas in subjective testing method, consumers are involved in the evaluation process (IFT, 2007). For successful sensory evaluation in food industries it is achieved by linking sensory properties to physical, chemical, formulation and process variables which enables manufacturing food products with maximum consumer acceptance (Sharif *et al.*, 2017). According to the Institute of Food Technologists (IFT), its explained that sensory evaluation is a scientific method used to evoke, measure, analyse and interpret those responses to products as perceived through the senses of sight, hearing, touch, smell and taste (Stone & Sidel 1993; IFT, 2007). In consumer acceptance studies large number of semi or untrained individuals are used. Therefore, the use of sensory evaluation in evaluating consumer acceptance is applicable in this case of new cowpea lines and varieties.

A soft cooked texture is an important quality characteristic in cooked cowpeas. The overall texture of cooked cowpeas is a composite of the characteristics of the seed coat and the cotyledon. Cowpea varieties that have high amylopectin content (Akinyele *et al.*, 1986) would possibly have a mushy texture as compared to that of varieties with high amylose content, since

the high amylose would retrograde during cooling to form a firm gel which would not be the case in high amylopectin seeds. Another contributing factor to a grainy mouthfeel in cooked cowpea could be due to differences in protein content. Akinyele *et al.* (1986) observed that the cooking time of 18 cowpea varieties increased with increase in protein content. This may imply that high protein content could increase the competition for water between starch gelatinization and gelation and in the process limit hydration of starch. The poor hydration of the starch would result in a grainy feel in the mouth.

2.8 Conclusion

Cowpea (*Vigna unguiculata* L.) is drought tolerant crop, and can grow in poor nutrient soils (fixes nitrogen). It is highly nutritious crop which can be used to reduce food insecurity and malnutrition in Eastern Kenya. However new cowpeas lines have not been evaluated for its nutritional, processing qualities, consumer acceptability and its capability to retain minerals and proteins after cooking. The selection of new cowpea lines with high protein and mineral contents in the grains is crucial for human health, especially in the diet of the low-income population in the semi-arid regions of Eastern Kenya is important at this time.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Location and Materials

This study was conducted at Guildford Dairy Institute, Department of Dairy and Food Science and Technology, Egerton University. The permit for research was no. 19/877034/2608 NACOSTI research permit. Laboratory experiment was arranged in Completely Randomized Design (CRD) with three replications where treatments were assigned to the experimental units completely at random. Randomization was done without any restrictions. Improved cowpea lines IT97K-499-35, IT82D-889. IT82D-889-1, TEXAN PINKEYE, TX123, IT98K-205-8, IT98K-1111-1, IT97K-1042-3, IT85F-867-5, and IT98K-589-2. and varieties (checks) KVVU27-1, M66, K80, KUNDE MBOGA and KENYA KUNDE were sourced from Kenya Agricultural Livestock Research Organisation (KALRO) Katumani Research Centre Machakos County (1° 35'S and 37° 14'E), 80 km southeast of Nairobi, and 9 km south of Machakos town. Cowpeas seeds samples that were used are shown in Figures 1 and 2 and their description given in Table 6.

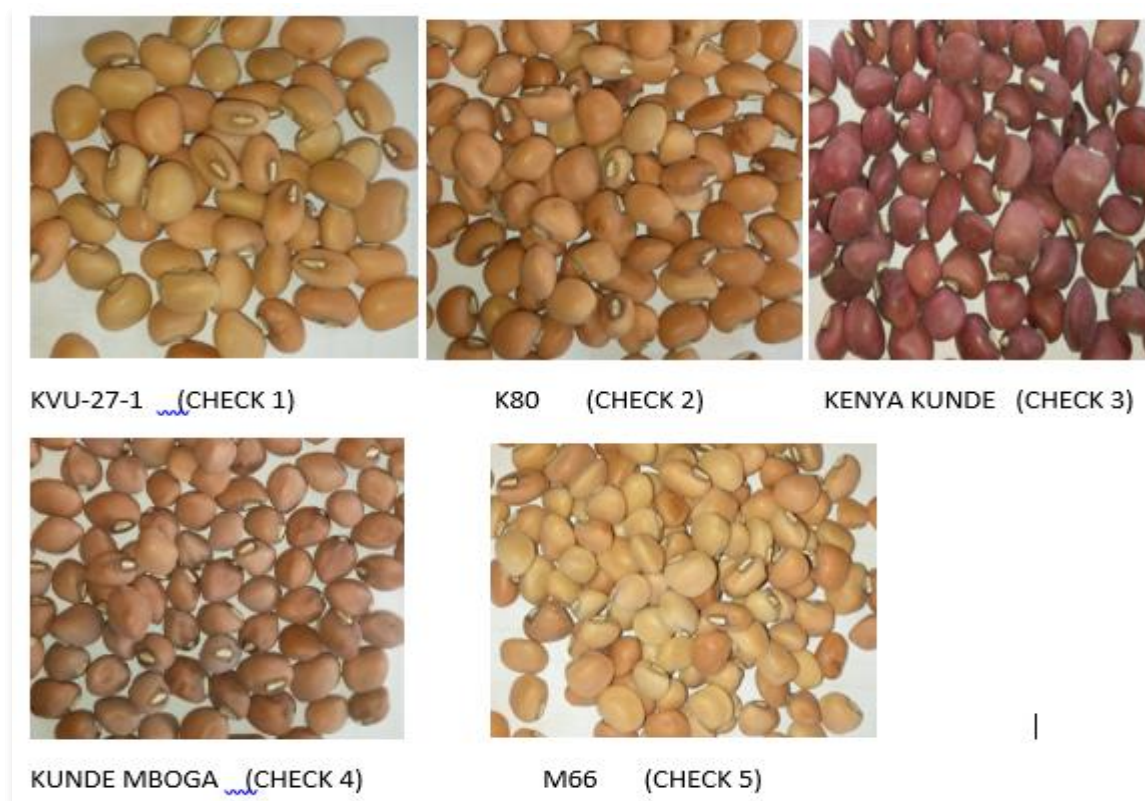


Figure 1: Cowpea varieties (checks) from Eastern Kenya used in this research

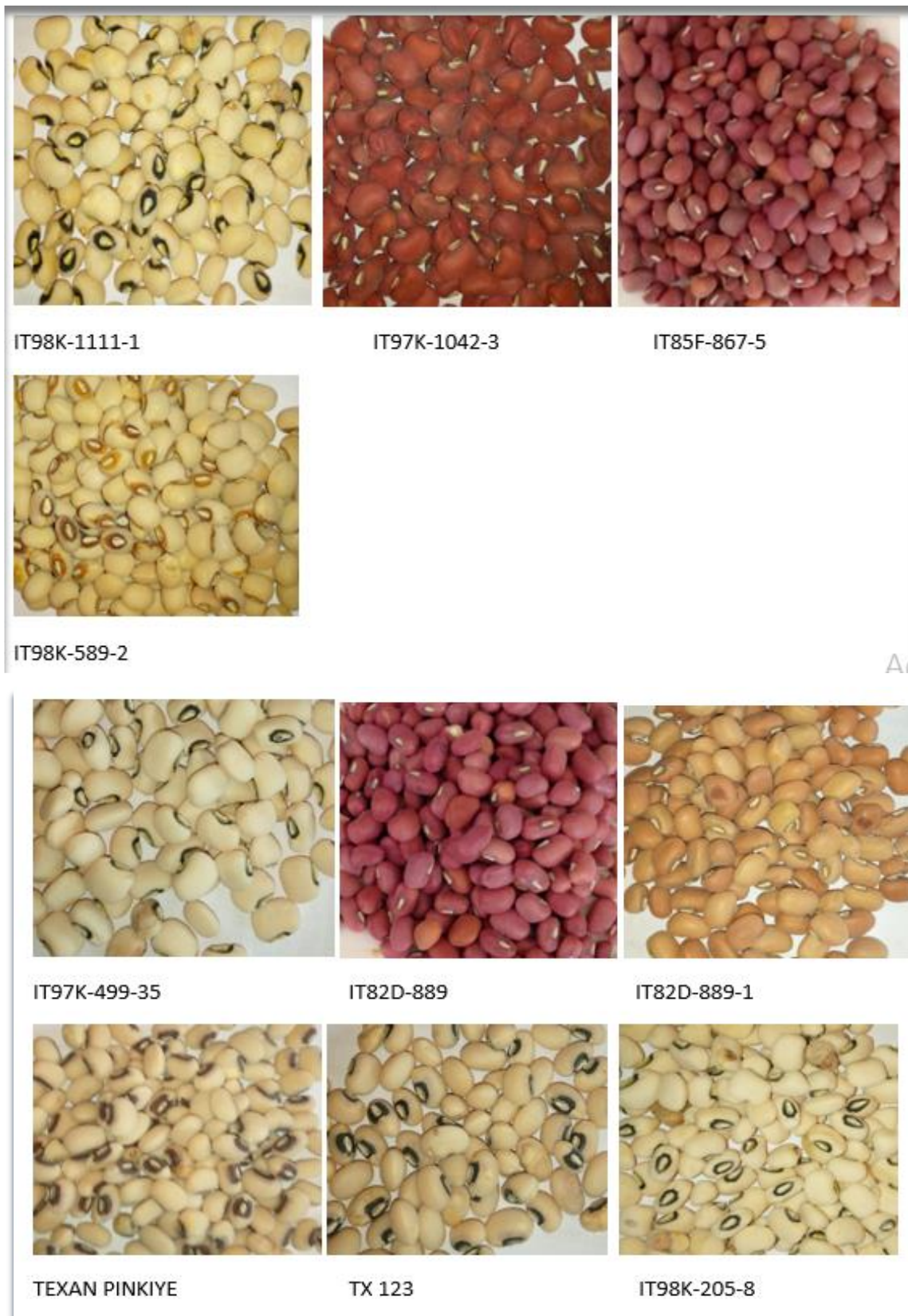


Figure 2: Cowpea lines used in this research.

Table 6: Cowpea lines/varieties and description used in research- from KALRO Katumani Kenya.

Line/Variety	Description
KVU-27-1	A dual-purpose variety for both grain and leaf production, pointed leaves, dark red grains in colour, tolerant to aphids, pod borers, and also moderately resistant to foliar fungal disease and mosaic virus.
K-80	Dual purpose variety, resistant to aphids, thrips, pod borers, foliar fungal disease, mosaic virus and leafhopper.
KENYA KUNDE	Early maturing and drought tolerant.
KUNDE MBOGA	Early maturing and drought tolerant.
M66	Dual variety, and high yielding. This variety is resistant to yellow mottle virus and scab, aphids and thrips damages.
IT97K-499-35	Early maturing, resistant to fungal and bacterial diseases.
IT82D-889	Early maturing, resistant to cowpea yellow mosaic, aphids, smooth texture coat, kidney shaped seed, black colour hilum and maroon coloured seed coat.
IT82D-889-1	Drought tolerant
TEXAN PINKIYE	Texture wrinkled seed, ovoid seed shaped, dark red hilum colour, bright pink eye insect/disease resistance, and cream coloured seed coat
TX 123	Early maturing, high seed weight
IT98K-205-8	Early maturing, Resistant to cowpea yellow mosaic and aphids.
IT97K-1111-1	Drought tolerant.
IT97K-1042-3	Resistant to multiple viruses and Heat and drought tolerant.
IT85F-867-5	Resistant to cowpea yellow mosaic and aphids
IT98K-589-2	Susceptible to drought

3.2 Sample Preparation

Matured, dry grains (250 g) were cleaned, involving removal of foreign matter, broken seeds and immature seeds. Grains were then milled using a Microphyte lab disintegrator model Fz102 (Tianjin, China), fitted with 500- μ m sieve to give whole grain flour, and then stored at $8\pm 2^\circ\text{C}$ until other analyses were done.

3.3 Sampling Plan and Sample Preparation

3.3.1 Sample size

Samples were collected from KALRO Katumani Kenya where ten cowpea lines and five traditional varieties (checks) each 250gms each, was used. It was then mixed to get a homogenous sample from each line and variety.

3.3.2 Preparation of cooked cowpea flour for effects on protein and minerals analyses

Dry sorted cowpeas grains (150 g) was soaked in 1 L distilled water for 16 h at 20°C. The soaking water was removed, and the soaked cowpeas placed and cooked in an open aluminum pot in water at 93.5°C (the boiling temperature of water in Njoro) until tender soft. The evaporated water was replenished with hot water. After cooking, samples were dried in an oven set at 45°C to a moisture content of 10-12%. Dried grains were milled using a Microphyte lab disintegrator model Fz102 (Tianjin, China). The cooked cowpeas flours were then stored at 8±2°C until mineral and proteins analyses were done.

3.3.3 Preparation of cowpea grains for technological analyses

Cowpea grain samples were first mixed and sieved in sieves with holes of (5.16×19.05 mm) and visibly damaged grains from insects or from mechanical processes were removed before analysis. After selection, the grains were stored in refrigerator with a stable temperature of below 10°C before technological analyses were done.

3.3.4 Preparation of cowpea samples for sensory analysis

Dry sorted cowpeas grains (250 g) were soaked in 1 L of distilled water for 10 h at 20°C. The soaking water was removed, and the soaked cowpeas placed in an aluminium pot and cooked in an open pot at 93.5°C (the boiling temperature of water in Njoro) until tender soft. A pinch of salt was added to taste then kept in clean place before sensory analysis was done.

3.4 Nutritional Analyses

3.4.1 Determination of moisture content

Moisture content of the samples was determined using oven-drying method according to AACC International (2000), Method 44 - 15 A. This involved exposing samples to air oven drying at 107°C for 3 h. Moisture content was then calculated as the loss in weight expressed as a percentage of the original weight of a sample.

%Moisture Content

$$= \frac{(\text{weight of pan} + \text{wet sample}) - (\text{weight of pan} + \text{dry sample})}{\text{weight of sample}} \times 100$$

..... (Equation 1)

3.4.2 Determination of ash content

The AOAC (2000) Method 942.05 was used. Ground cowpea grains sample (2 g) was weighed (W_1) into a crucible that was previously calcined and weighed (W_2), and then heated in a muffle furnace (Model: MR170; S/N: 6800616; Hereaus GMBH, Hanau, Germany) at 550°C for 12 h. The crucible with the ashed sample was then cooled in a desiccator and reweighed (W_3). Ash content was calculated using the expression:

$$\text{Ash (\%)} = 100 \times (W_3 - W_1) / W_2 \dots\dots\dots (\text{Equation 2}).$$

3.4.3 Determination of crude protein content

Determination of crude protein was done according to AOAC (2000) Method 984.13. Ground cowpeas sample (2 g) were mixed with 20 mL of concentrated sulphuric acid in a clean well-labelled digestion tube. Kjeldahl tablets (catalyst) were added to the mixture (selenium powder and concentrated sulphuric acid (2.8 g/800-mL), in the tube and the sample digested in a Gerhardt Kjeldatherm digester (Model: KB40; Gerhardt GMBH and CO. Kg; Germany) for 1 h at 420°C. Distilled water was added to the digest to make 80 mL volume. Exactly 50 mL of Sodium hydroxide solution was added to the mixture and this was followed by distillation of the ammonia into concentrated boric acid using a 2200 Kjeltect™ auto distillation unit (Foss Analytical, Höganäs, Sweden). Titration was done using hydrochloric acid (0.1 mol/L) after adding a few droplets of indicator solution. Nitrogen content (g/100g) was obtained using the formula;

$$N(\text{g}/100\text{g}) = (V_s - V_b) \times M_{(HCl)} \times 1 \times 14.007 / W \times 10 \dots\dots\dots (\text{Equation 3})$$

Where: V_s is volume of HCl (mL) needed to titrate sample; V_b is volume of HCl (mL) needed to titrate the blank test; $M_{(HCl)}$ is the molarity of hydrochloric acid; the numeral one (1) is the acid factor; 14.007 is the molecular weight of nitrogen; W is the weight of the sample (g) and 10 is the conversion factor from mg/g to g/100g. Crude protein content was obtained by multiplying the nitrogen content by 6.25.

3.4.4 Determination of fat content

Crude fat extraction was done according to AOAC (2000) Method 920.39. Sample (5 g) was weighed (W_1) into the extraction thimble and covered with a fat-free clean wad of cotton wool. The thimble was then fitted to a clean dry round bottom flask that had been cleaned, dried and weighed (W_2). Exactly 25 mL of petroleum ether was added into the extraction flask. The Electro-thermal Soxhlet-Apparatus (Model: EME 6250/CF; Cole Parmer; England) was set to extract the sample for 6 h, after which the solvent was evaporated, flask dried in a desiccator and reweighed (W_3).

Crude fat content (%) was calculated as:

$$100 (W_3 - W_2) / W_1 \dots\dots\dots \text{(Equation 4)}$$

Where:

W_1 is the initial sample weight in grams, W_2 is the tare weight of flask in grams, and W_3 is the weight of flask and fat residue in grams.

3.4.5 Determination of crude fibre

Crude fibre was determined according to AOAC (2000) Method 6865. Two (2) g of the grounded sample was extracted with ether to remove fat. After extraction 2g of the sample was boiled with 200 mL of sulphuric acid for 30 Minutes, then filtered through muslin cloth and washed with boiling water until no longer acidic. Then boiled with 200 mL Sodium hydroxide for 30 minutes, filtered through muslin cloth and washed with 25 mL of boiling 1.25% Sulphuric acid, 3-50 mL Portions of water and 25 mL alcohol all this was done in a Fibertec digester (FOSS, Sweden). The residue was removed and transferred to ashing dish (pre-weighed dish – W_1). The residue was then dried for 2 hrs. at $130 \pm 2^\circ\text{C}$. then cooled in a desiccator and weighed (W_2). Then ignited for 30mins @ 600°C in muffle furnace (Model: MR170; S/N: 6800616; Hereaus GMBH, Hanau, Germany) then cooled in the desiccator and reweighed (W_3).

The formula used

$$\text{Crude Fibre} = [(W_2 - W_1) - (W_3 - W_1)] / \text{Weight of Sample} \times 100 \dots\dots\dots \text{(Equation 5)}.$$

3.4.6 Carbohydrate content determination

Carbohydrate content was calculated by difference method using the following equation.

% Carbohydrate = 100% - (Moisture + Crude fat + Ash + crude protein) % (Equation 6).

3.4.7 Determination of mineral contents

Minerals determination was done using method described by AOAC (2000). Amount of 5 ml conc. HNO₃ and 1ml Conc. HClO₄ were used to digest 1 g of sample. Allowed to stand closed overnight at room temperature to predigest the sample and there after placed in oven at 100°C for 8 hours and cooled to room temperature in fume hood. Atomic absorption spectrophotometer (Thermo Jarrell Ash Corporation model 6) was used for analysis of Calcium, Magnesium, Zinc, Sodium, Phosphorus. Flame spectrophotometer (Flame photometer model 410, United Kingdom) was used for potassium and UV/visible spectrophotometer (JENWAY 7315) for phosphorus.

3.4.8 Amino acid analysis

Pico-Tag method, described by Bidlingmeyer *et al.* (1984), was used in determining amino acid composition of cowpea flour samples. The three main steps procedure is: hydrolysis of proteins and peptides yielding free amino acids (Performic acid was used in oxidising sulphur-containing amino acids cysteine and methionine into cysteic acid and methionine sulphone), Sodium metabisulphite was added to decompose excess performic acid, Amino acids were liberated from proteins using 6 N HCl.

Then pre-column derivatization of sample was done with O-phthalaldehyde (OPA) and analysis by reverse phase Ultra Performance Liquid Chromatography (UPLC) in fluorescence detection. The Pico-Tag column part (3.9 mm x15 cm) employed and the wavelength detector was operated at 254 nm hence get the peak area and read with respective calibration curves.

3.5 Technological Properties

Grain samples was first mixed and sieved in sieves with holes of (5.16×19.05 mm) and visibly damaged from insects or from mechanical processes were removed before analysis. After selection, the grains were stored in domestic use refrigerators with a stable temperature of below 10°C before analysis were done.

3.5.1 Water absorption capacity before cooking

This was determined in accordance with the modified methods described and used by Perina *et al.* (2014). Whereby 30 g sample of cowpea grains was placed in a 250 mL beaker with 100 mL of distilled water for 16 hrs at ambient temperature. After the soaking period, the water was drained, the grains reweighed and the water absorption capacity before cooking (WACBC) was calculated by the formula:

$$\text{WACBC} = [(sw-dw)/dw] \times 100 \dots\dots\dots \text{(Equation 7)}$$

in which dw = beginning weight of dry grains; sw = grain weight after maceration.

3.5.2 Water absorption capacity after cooking

The drained cowpea grains were once more placed in the beaker, with 100 mL of distilled water, and heated for an hour by an electric hot plate, beginning time count when the water began to boil. The broth was drained and water absorption capacity after cooking (WACAC) calculated by the formula:

$$\text{WACAC} = [(cw-dw)/dw] \times 100, \dots\dots\dots \text{(Equation 8)}$$

Where dw = beginning weight of dry grains; cw = weight of grains after cooking.

3.5.3 Volumetric expansion and density of cowpea grains

Determinations of the characteristics related to volumetric expansion and density of the cowpea grains was done according to method used by Perina *et al.* (2014). Ten (10) g of raw grains were weighed, which were then soaked in distilled water for 16 hours at environmental temperature (room temperature). After this period, the water was drained and the grains were weighed. The grains were then placed in glass jars with 100 mL of boiling water added and the grains were cooked in a small aluminium cooking pan (sufuria) for 1 hour. The volume of the raw, macerated and cooked grains was determined using the water displacement principle to a graduated cylinder with a 100 mL capacity containing 50 mL of water, and the volume of displaced water was noted.

The technological characteristics, volumetric expansion of grains before cooking (**VEXPBC**), volumetric expansion after cooking (**VEXPAC**), dry/raw grain density (**R/SD**), grain density after soaking (**SD**) and grain density after cooking (**CD**) were calculated using the formulas:

$$\text{VEXPBC} = [(vs - vr)/vs] \times 100; \text{VEXPAC} = [(vc - vr)/vc] \times 100; \text{R/SD} = dw/vr; \text{SD} = sw/ vs; \text{CD} = cw/vc; \text{ in which } vr = \text{volume of water displaced by raw grains; } vs = \text{volume of water}$$

displaced by grains after soaking; v_c = volume of water displaced by the grains after cooking; d_w = weight of the dry/raw grains; s_w = weight of the grains after soaking.

3.6 Sensory Evaluation

3.6.1 Determination of Consumer Acceptability of the Cooked Cowpeas

Sensory analysis of the cowpeas was done by panelists consisting of 30 semi trained people familiar with the cowpea cooked product. The panelist consisted of 17 females and 13 males aged between 18 - 55 years. All the panelist was picked from the department of Dairy, Food Science and Technology staff including students. The coded cowpea samples were presented in white plastic plates, and panelists were given instructions to rinse their mouth with water between each sample tasting. The assessors were asked to appreciate how much they liked the taste, appearance, flavor, texture, and the overall acceptability of the cooked cowpeas. Rating scale was as follows: 7 (like extremely), 6 (like moderately), 5 (like slightly), 4 (neither like nor dislike), 3 (dislike slightly), 2 (dislike moderately) and 1 (dislike extremely).

3.7 Experimental Design and Statistical Analysis

A Completely Randomized Design (CRD) was used in this experiment with the following statistical model being employed:

$$Y_{ij} = \mu + \bar{u}_i + R_j + \epsilon_{ij}$$

Where, Y_{ij} = the observation of the dependent variable of raw and cooked cowpea grains/flour nutrients, technological properties, proteins and minerals after cooking, and sensory scores.

μ = Overall mean responses

\bar{u}_i = The effect of i^{th} line/variety.

R_j = The effect due to Replication

ϵ_{ij} = Random error component.

Analysis was done using PROC GLM procedures of the statistical analysis systems of version 9.1.3 (SAS, 2006) in performing analysis of variance(ANOVA) test at 95% confidence level. Significant differences between means were determined using Tukey's honestly significant difference (HSD). Then calculations were performed using Statistical Analysis System (SAS Institute Inc, 2006) version 9.2 based on 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

The research determined proximate, minerals, processing or technological properties of new breeding lines and varieties grown in Eastern Kenya of Makueni, Machakos and Kitui counties. Effect of cooking on protein and minerals losses were also determined on selected lines (IT82D-889, IT85F-867-5, IT97K-1042-3, IT978K-205-8, IT98K-589-2 and TEXAN PINKIYE) and K80 variety. Consumer acceptability was also done on cooked cowpea grains. Various studies have shown that nutritional quality of cowpea was more influenced by the genetic component of the lines/varieties and not the environmental conditions (Okonya & Maass, 2014).

4.1: Determination of proximate composition and minerals composition of cowpea lines in comparison with existing cowpea varieties (checks) cultivated in Eastern Kenya of Machakos, Kitui and Makueni Counties.

Proximate and mineral composition were determined for the ten cowpea lines and five varieties grown in Eastern Kenya.

4.1.1 Proximate composition of new breeding lines and existing varieties (checks).

Proximate analysis results (Table 7) indicated that ash contents among cowpea lines ranged from 2.99% to 3.37%. This shows that they are superior in minerals contents. Line IT98K589-2 had high amounts of ash contents of 3.37% followed by IT82D-889-1, IT97-1042-3, and IT97-499-35 at 3.34% but not significantly different at $p > 0.05$. Line IT98K-111 recorded lowest of 2.99%. The values recorded slightly agreed with what of Gondwe *et al.* (2019) got by analysing five improved varieties in Swaziland. However, it was lower from the report of Ajeigbe *et al.* (2008) on analysis of cowpea varieties grown in Nigeria. This differences could be attributed to varietal genetic differences.

Total carbohydrates were the highest nutritional components on studied cowpeas and there was no statistical difference at $p > 0.05$. Line TEXAN PINKIYE recorded the lowest amounts of carbohydrates of 50.09% and line IT97K-499-35 had high of 56.45%, as shown in Table 7. The results compared well with those of Otitoju *et al.* (2015) who reported cowpeas carbohydrates ranging from 49.37 to 55.74 % in a study conducted on four cowpeas varieties from four different states in Nigeria.

Crude Protein contents of cowpeas lines ranged from 23.37% to 29.70%. TEXAN PINKIYE line recorded highest amounts of protein at 29.70% followed by IT97K-1042-3 at 28.37% although they were statistically not different at $p>0.05$ between lines and varieties (checks). Line IT97K-499-35 recorded the lowest of 23.37%. These values corresponded to those obtained by other scientists, which ranged from 17.4% to 31.7% (Frota *et al.*, 2008; Onwuliri & Obu, 2002; Thangadurai, 2005; Carvalho *et al.*, 2012) and confirmed the high nutritional value of this cowpea lines. High proteins contents among these lines could be a good ingredient in solving problems of malnutrition in Eastern Kenya and entire country Kenya. There were variations in proteins contents across lines and varieties. This revealed that protein content of lines and varieties differ because of genetic differences as shown in Table 7 below.

Fat content means ranged from 0.13% to 0.81% which is within the fat content range of cowpea seeds reported by Chavan *et al.* (1989) and Otitoju *et al.* (2015). Cowpea variety KUNDE MBOGA recorded the highest amount of 0.81% followed by IT82D-889 at 0.60% and most of the cowpea lines had fat contents as low as 0.13% in IT98K-1111-1. This means that fat content for cowpea lines and varieties were on the lower side overall. However, there were no significant difference ($p>0.05$) between varieties and cowpea lines in the study.

Crude fibres are the plant materials that remain after solvent extraction then followed by digestion with dilute alkali and acid. Crude fibres of cowpeas varieties and lines tested in this study were not statistically different at ($p>0.05$) between lines and varieties. Crude fibres ranged from 1.40-4.34%. Line IT82D-889 recorded highest amounts of crude fibre at 4.34% while variety KVU27-1 had lowest crude fibre of 1.40%.

Generally, from the results of proximate analysis, cowpea breeding lines exhibited good proximate properties and compares well with varieties existing varieties. This cowpeas lines can be used in reduction of high malnutrition among people living in ASALs region. Differences in cowpea proximate composition could be attributed to soil type, cultural practices, environmental conditions, and mainly the genetic make-up of cowpeas samples (Chinma *et al.*, 2008)

Table 7: Proximate composition of different lines and varieties grown in Eastern Kenya.

Lines/Variety	Ash(%)	Fat(%)	Protein(%)	Crude Fibre(%)	Carbohydrates (%)
IT82D-889	3.23 ^{ab} ±0.05	0.60 ^{ab} ±0.05	25.73 ^{abc} ±0.88	4.34 ^a ±1.01	53.40 ^{ab} ±1.78
IT82D-889-1	3.34 ^{ab} ±0.04	0.47 ^{abc} ±0.14	26.69 ^{abc} ±1.23	3.98 ^{ab} ±0.29	52.55 ^{ab} ±1.08
IT85F-867-5	3.25 ^{ab} ±0.04	0.47 ^{abc} ±0.07	25.68 ^{abc} ±1.00	2.90 ^{ab} ±0.29	54.74 ^{ab} ±1.23
IT97K-1042-3	3.34 ^{ab} ±0.06	0.21 ^{bc} ±0.11	28.37 ^{ab} ±0.49	3.28 ^{ab} ±0.70	56.45 ^a ±0.66
IT98K-205-8	3.08 ^{ab} ±0.11	0.22 ^{bc} ±0.08	26.80 ^{abc} ±1.00	4.12 ^a ±0.28	53.52 ^{ab} ±1.29
IT98K-589-2	3.37 ^a ±0.07	0.48 ^{abc} ±0.06	24.76 ^{±bc} 0.60	3.58 ^{ab} ±0.24	55.13 ^{ab} ±0.69
K80	3.14 ^{ab} ±0.05	0.44 ^{abc} ±0.13	28.22 ^{ab} ±1.00	4.18 ^a ±0.43	51.56 ^{ab} ±1.23
KENYA KUNDE	3.27 ^{ab} ±0.06	0.53 ^{abc} ±0.15	26.77 ^{abc} ±0.54	4.61 ^a ±0.69	51.98 ^{ab} ±0.81
KUNDE MBOGA	3.31 ^{ab} ±0.05	0.81 ^a ±0.10	26.51 ^{abc} ±0.61	3.25 ^{ab} ±0.72	53.40 ^{ab} ±1.08
KVU27-1	3.27 ^{ab} ±0.04	0.51 ^{abc} ±0.08	26.10 ^{abc} ±0.55	1.40 ^b ±0.18	55.81 ^{ab} ±0.59
M66	3.22 ^{ab} ±0.07	0.50 ^{abc} ±0.12	25.74 ^{abc} ±0.54	3.42 ^{ab} ±0.66	54.07 ^{ab} ±1.03
TEXAN PINKIYE	3.28 ^{ab} ±0.05	0.53 ^{abc} ±0.07	29.70 ^a ±0.49	3.93 ^{ab} ±0.71	50.09 ^b ±0.73
TX123	3.21 ^{ab} ±0.05	0.50 ^{abc} ±0.01	26.53 ^{abc} ±1.66	3.25 ^{ab} ±0.52	53.92 ^{ab} ±2.36
IT97K-499-35	3.34 ^{ab} ±0.06	0.21 ^{bc} ±0.11	23.37 ^c ±0.49	3.28 ^{ab} ±0.70	56.45 ^a ±0.66
IT98K-1111-1	2.99 ^b ±0.11	0.13 ^c ±0.02	25.62 ^{abc} ±1.25	3.00 ^{ab} ±0.26	55.08 ^{ab} ±1.45

Key: Values of a parameter in a column, followed by different superscript letters are significantly different at $p \leq 0.05$, The Values are means \pm standard deviations.

4.1.2: Determination of minerals contents in cowpeas breeding lines and varieties grown in Eastern Kenya.

Minerals are mainly inorganic nutrients which are required by human body in small amounts. They are required by human body in quantities ranging from 1 to 2500mg/100 g per day (Soetan *et al.*, 2010). As seen in Table 8, all the lines and varieties was not statistically significant different at $p>0.05$, for zinc, sodium, magnesium, calcium, phosphorous and potassium contents. Line IT97K-499-35 had the lowest amounts of calcium (1.93mg/100g) and variety KVU27-1 had the highest calcium amounts (2.69mg/100g). KENYA KUNDE variety of cowpea had highest amounts of magnesium (4.90mg/100g) and line IT97K-1042-3 had lowest amounts of 3.23mg/100g. Zinc ranges from 1.23 mg/100g to 0.80 mg/100g, line TX123 recording 1.23 mg/100g and KUNDE MBOGA variety recording low at 0.80 mg/100g zinc. Sodium levels were moderately high with minimal difference between lines and varieties line IT98K-1111-1 recorded highest amounts of sodium at 223.30 mg/100g and variety KUNDE MBOGA lowest of 181.28 mg/100g. Phosphorus contents were low compared to other minerals across all the cowpea lines and varieties, line IT98K-1111-1 had highest of 1.06mg/100g of phosphorus while KENYA KUNDE variety had lowest of 0.62 mg/100g. Potassium levels of all the cowpea lines and varieties were high with line TX 123 recording high of 1152.62 mg/100g and KENYA KUNDE variety having low as 1071 mg/100g. Overall, line TX 123 had highest amounts of minerals and IT97K-1042-3 had the lowest amounts of minerals compared to other cowpeas in this study. This means that line IT97K-1042-3, probably absorbed less of this minerals from the soils and TX 123 may had absorbed more. From the results potassium was highly concentrated across all the varieties and lines. Generally, cowpea samples may be regarded as good sources of essential minerals.

Sodium and potassium are normally required to maintain the body fluids osmotic balance and pH, this regulate muscle and nerve irritability and it is able to control glucose absorption in the body. The ratio of sodium to potassium in the body is of great concern for prevention of high blood pressure (hypertension). Therefore, sodium to potassium ratio for the samples were less than 1:1 which is highly recommended (Soetan *et al.*, 2010). This means that the cowpea lines samples would not promote high blood pressure hence they are good for maintaining good health. However, results of Calcium to Phosphorus ratio in the cowpea samples were above two indicating that this would help increase the absorption of calcium in the small intestines (Soetan *et al.*, 2010).

Table 8: Different mineral contents (mg/100g) of different cowpea lines/varieties grown in Eastern Kenya.

Line/variety	Calcium	Magnesium	Zinc	Sodium	Phosphorus	Potassium
KVU27-1	2.69 ^a ±0.63	3.90 ^{ab} ±0.18	1.03 ^a ±0.24	218.84 ^a ±7.48	0.92 ^{ab} ±0.06	1122.89 ^a ±35.36
TX123	2.07 ^{bcd} ±0.37	3.44 ^b ±0.22	1.23 ^a ±0.30	219.19 ^a ±3.36	1.03 ^a ±0.06	1152.62 ^a ±28.52
IT98K-205-8	2.25 ^{abcd} ±0.42	3.55 ^{ab} ±0.02	1.17 ^a ±0.19	220.50 ^a ±7.06	0.85 ^{ab} ±0.05	1146.36 ^a ±33.96
IT98K-1111-1	2.07 ^{bcd} ±0.43	3.43 ^b ±0.05	1.18 ^a ±0.19	223.30 ^a ±0.65	1.06 ^a ±0.08	1145.89 ^a ±28.52
IT97K-1042-3	1.93 ^d ±0.44	3.23 ^b ±0.07	1.21 ^a ±0.16	216.22 ^a ±10.62	0.91 ^{ab} ±0.05	1101.55 ^a ±18.93
IT85F-867-5	2.11 ^{bcd} ±0.43	3.68 ^{ab} ±0.24	1.03 ^a ±0.12	221.45 ^a ±6.84	0.99 ^{ab} ±0.07	1131.58 ^a ±11.15
IT98K-589-2	1.97 ^{cd} ±0.30	3.64 ^{ab} ±0.29	0.89 ^a ±0.11	208.83 ^a ±8.03	0.71 ^{ab} ±0.12	1097.19 ^a ±29.57
M66	2.62 ^{ab} ±0.55	3.72 ^{ab} ±0.20	0.87 ^a ±0.18	222.31 ^a ±0.36	0.77 ^{ab} ±0.04	1078.94 ^a ±21.35
K80	2.53 ^{abc} ±0.59	3.70 ^{ab} ±0.27	0.81 ^a ±0.04	216.99 ^a ±4.20	0.89 ^{ab} ±0.01	1141.13 ^a ±31.53
KUNDE MBOGA	2.20 ^{abcd} ±0.38	4.90 ^a ±0.76	0.80 ^a ±0.07	219.22 ^a ±4.20	0.83 ^{ab} ±0.04	1109.30 ^a ±33.60
KENYA KUNDE	2.17 ^{abcd} ±0.42	3.71 ^{ab} ±0.20	0.93 ^a ±0.08	181.28 ^a ±32.88	0.62 ^b ±0.08	1071.15 ^a ±24.08
IT97-K-499-35	2.27 ^{abcd} ±0.39	3.77 ^{ab} ±0.24	0.97 ^a ±0.20	212.95 ^a ±5.17	0.83 ^{ab} ±0.03	1142.26 ^a ±33.81
IT82D-889	2.27 ^{abcd} ±0.43	3.74 ^{ab} ±0.16	0.94 ^a ±0.10	212.19 ^a ±6.07	0.87 ^{ab} ±0.18	1105.73 ^a ±34.22
IT82D-889-1	2.22 ^{abcd} ±0.32	3.59 ^{ab} ±0.20	1.22 ^a ±0.19	205.53 ^a ±5.47	0.80 ^{ab} ±0.10	1120.81 ^a ±16.40
TEXAN PINKIYE	2.24 ^{±abcd} 0.50	3.51 ^b ±0.27	1.01 ^a ±0.20	212.07 ^a ±2.02	0.90 ^{ab} ±0.08	1120.97 ^a ±11.86

Key: Values of a parameter in a column, followed by different superscript letters are significantly different at $p \leq 0.05$, The Values are means \pm standard deviations

4.1.3: Pearson correlation of minerals in cowpeas

The correlation analysis revealed significant degree of association between and among mineral elements in the studied cowpea varieties and lines from Eastern Kenya. From Table 9, The Pearson correlation coefficient showed that there was significant ($P \leq 0.001$; $P \leq 0.01$; $P \leq 0.05$) correlation among some of the minerals evaluated in table below Calcium was significantly and positively correlated with magnesium ($r = 0.35$), Sodium ($r = 0.08$), and Potassium ($r = 0.29$). Calcium also significantly and negatively correlated with Zinc ($r = 0.56$) and Phosphorus ($r = 0.39$). Magnesium was also significant and positively correlated with Sodium ($r = 0.40$), Phosphorus ($r = 0.21$) and Potassium ($r = 0.26$) but there no significant correlation with Zinc. Sodium was also significantly and positively correlated with Phosphorus ($r = 0.29$) and Potassium ($r = 0.60$). Zinc was significantly and positively correlated with Sodium ($r = 0.27$), Phosphorus ($r = 0.41$) and potassium ($r = 0.64$). Phosphorus was only significantly and positively correlated with potassium ($r = 0.45$). These positive correlations among minerals suggested a close genetic and inherent association among them which implies that both pair of the minerals amounts can be improved simultaneously through breeding. The result of this study therefore, implies that Potassium levels is associated with high content of Calcium, Magnesium, Zinc, Sodium and Phosphorus can be improved simultaneously.

Table 9: Correlation coefficients (r^2) between the different mineral dependent variables of different lines and varieties obtained from Eastern Kenya.

	Calcium	Magnesium	Zinc	Sodium	Phosphorus
Zinc	-0.56***	0.14 ^{ns}			
Sodium	0.08***	0.40***	0.27**		
Phosphorus	-0.39***	0.21*	0.41**	0.29**	
Potassium	0.29**	0.26*	0.64***	0.60***	0.45***

Key: NS: Not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

4.2: Technological properties of new cowpea breeding lines and varieties grown in Eastern Kenya.

Technological properties (hydration properties, volumetric expansion and grain density differences) of different cowpea lines and varieties are given in Table 10. Grains from studied cowpea lines and varieties were able to absorb water before cooking equivalent to their weights. This is seen with variations of 104.43 to 114.17%. The overall mean of water absorption before cooking was 109.3%. Various studies have reported an inverse association between cooking

time and water absorption (Dalla Corte *et al.*, 2003; Rodrigues *et al.*, 2004). Therefore, cowpea lines or varieties with the highest water absorption capacity will not automatically have the shortest cooking time and vice versa (Carbonell *et al.*, 2003). Cowpea grains having differential characteristics in water absorption before cooking and after cooking which is associated with the rigidity of the seed coat, cotyledon adherence, elasticity, porosity and colloidal properties in water absorption (Perina *et al.*, 2014). Water absorption of legumes has been shown to be influenced by seed coat thickness and seed size (Giami, 2001). Cowpea grains with high values of water absorption capacity before cooking (WACBC) and water absorption capacity after cooking (WACAC) are highly recommended for commercial food industries and kitchens because they yield or increase more after cooking (Perina *et al.*, 2014). Generally, from results in Table 10, all the varieties and lines had good water absorption capacities having water equivalent to their weights (Perina *et al.*, 2014). Line IT82D-889-1 had highest water absorption capacity after cooking of 144.42% while TEXAN PINKIYE recorded 132.34%. Line IT98K-589-2 recorded lowest water absorption after cooking of 107.05%.

Volumetric expansion is a desirable characteristic which has an influence on acceptability of new cowpeas lines. It should have high grain expansion after cooking. Volumetric expansion rate expresses water diffusion within the grains. Cowpea line IT85F-867-5 recorded the highest volumetric expansion of 64.42 % and therefore it is highly recommended new cowpea line. This shows that it has low lignin level in the grain. Water diffusion is affected by lignin levels (degree of lignification) in the grain (Teixeira *et al.*, 2005). Grain densities of raw cowpeas as high as 1.24 g.mL⁻¹ dropped after soaking and further reduced after cooking as low as 1.05 g.mL⁻¹. This drop in densities of the soaked and cooked grains is due to the increase in volume in relation to the weight when water is absorbed by the grain.

Analysis of variance was done for the completely randomized design for variety as a factor. Variety/lines significantly affected all the technological properties at $p > 0.01$ except cowpeas density after soaking (SD) where it was not significant $p < 0.05$. Genetic content of cowpeas grains affects its technological characteristics. Water uptake in cowpeas samples is a process involving seed coat structure and thickness during soaking. This is because seed coat is in direct contact with water during soaking and is conduit to the cotyledon. From this experiment seed coats of the cowpea samples seems to be thin, amorphous, porous and loosely attached and this allowed more water to be imbibed (Perina *et al.*, 2014). Cowpea proteins are also a factor in determining hydration properties. This is due to their hydrophilic nature and water is held by proteins by formation of hydrogen bonds. Water absorption would also affect the cooked texture of cowpea samples.

Table 10: Technological properties of different lines/varieties grown in Eastern Kenya.

Lines/variety	WACBC	WACAC	VEXPBC	VEXPAC	R/SD	SD	CD
KVU27-1	105.95 ^{bcd} ±0.63	122.97 ^c ±0.40	57.02 ^{bc} ±0.34	59.52 ^{efd} ±0.73	1.24 ^a ±0.01	1.07 ^a ±0.01	1.10±0.01
TX 123	111.29 ^{abc} ±3.03	131.47 ^b ±1.66	58.65 ^{ab} ±0.03	59.20 ^{defg} ±1.33	1.17 ^{bc} ±0.02	1.07 ^a ±0.01	1.05±0.02
IT98K-205-8	104.43 ^{cd} ±0.88	127.79 ^{bc} ±0.43	57.03 ^{bc} ±0.78	63.95 ^{ab} ±1.27	1.25 ^a ±0.01	1.18 ^a ±0.01	1.08±0.03
IT98K-1111-1	114.17 ^a ±1.43	128.14 ^{bc} ±0.55	61.18 ^a ±0.67	62.09 ^{bcd} ±0.82	1.22 ^{ab} ±0.04	1.09 ^a ±0.01	1.06 ^{de} ±0.02
IT97K-1042-3	113.45 ^a ±1.07	125.97 ^{bc} ±1.72	55.99 ^{bcd} ±0.36	63.49 ^{abc} ±0.95	1.25 ^a ±0.01	1.10 ^a ±0.05	1.08 ^a ±0.02
IT85F-867-5	108.85 ^{abcd} ±1.67	132.01 ^b ±0.73	57.05 ^{bc} ±0.77	64.42 ^a ±0.84	1.18 ^{abc} ±0.01	1.08 ^a ±0.01	1.05 ^{bc} ±0.01
IT98K-589-2	101.94 ^d ±0.41	107.05 ^d ±1.20	56.35 ^{bcd} ±1.00	57.14 ^{efg} ±0.73	1.18 ^{abc} ±0.01	1.10 ^a ±0.01	1.05 ^e ±0.01
M66	102.49 ^d ±1.03	122.85 ^c ±1.53	54.70 ^{cd} ±0.55	58.09 ^{defg} ±0.77	1.18 ^{abc} ±0.01	1.09 ^a ±0.01	1.07 ^{bc} ±0.01
K80	106.97 ^{abcd} ±1.28	126.88±2.01	57.10 ^{bc} ±0.43	59.94 ^{def} ±1.27	1.17 ^{bc} ±0.02	1.07 ^a ±0.01	1.05 ^{bc} ±0.01
KUNDE MBOGA	105.32 ^{bcd} ±1.00	125.88 ^{bc} ±1.48	55.94 ^{bcd} ±0.69	57.91 ^{efg} ±1.34	1.14 ^d ±0.02	1.08 ^a ±0.01	1.05 ^{bc} ±0.01
KENYA KUNDE	107.39 ^{abcd} ±1.13	127.80 ^{bc} ±1.55	58.73 ^{ab} ±0.52	60.47 ^{cde} ±1.11	1.18 ^{abc} ±0.01	1.08 ^a ±0.01	1.05 ^{cde} ±0.01
IT97K-499-35	103.81 ^d ±0.82	127.70 ^{bc} ±1.12	55.47 ^{bcd} ±0.21	60.81 ^{bcd} ±0.55	1.18 ^{abc} ±0.01	1.13 ^a ±0.02	1.08 ^{bc} ±0.01
IT82D-889	107.20 ^{abcd} ±0.32	131.82 ^b ±1.95	53.83 ^{cd} ±1.19	58.17 ^{defg} ±0.92	1.12 ^{cd} ±0.01	1.12 ^a ±0.01	1.08 ^{bc} ±0.01
IT82D-889-1	107.46 ^{abcd} ±0.92	144.42 ^a ±2.06	52.94 ^d ±0.31	58.20 ^{defg} ±0.05	1.12 ^{cd} ±0.01	1.11 ^a ±0.01	1.08 ^{bcd} ±0.02
TEXAN PINKIYE	112.10 ^{ab} ±0.31	132.34 ^b ±0.95	53.33 ^{cd} ±0.81	55.20 ^g ±0.62	1.14 ^d ±0.01	1.09 ^a ±0.01	1.06 ^{cde} ±0.01

Key: Values of a parameter in a column, followed by different superscript letters are significantly different at $p \leq 0.05$, The Values are means \pm standard deviations. WACBC-Water Absorption Capacity Before Cooking, WACAC-Water Absorption Capacity After Cooking, VEXPBC-Volumetric Expansion Before Cooking, VEXPAC-Volumetric Expansion After Cooking, R/SD-Dry/Raw Grain Cowpeas Density, SD- Grain Density After Soaking, CD- Grain Density After Cooking of the cowpea varieties and lines.

4.3: Effects of cooking on protein and mineral contents of newly improved cowpeas lines and varieties cultivated in Eastern Kenya.

Cooked cowpea lines and K80 variety (control) were highly significantly different for total protein, potassium, magnesium, and zinc contents ($p \leq 0.0001$) between lines and cowpeas varieties. Calcium was significantly different at $p \leq 0.05$ across all studied cooked lines and varieties as shown in Table 11. Cowpea line and varieties showed differences for proteins contents at $p \leq 0.0001$. The highest differences were seen in cowpea line TEXAN PINKIYE at 3.59% decrease in proteins before and after cooking and IT82D-889 recorded the lowest of 1.28% decrease. This loss was also reported by Silva *et al.* (2017) of up to 26% cowpea on proteins during cooking. Potassium levels across all the lines and variety had a significant loss of maximum of 92mg/100g cowpea samples in variety K 80 and lowest of 51mg/100g in IT82D-889 cowpea line. Zinc, magnesium, and calcium levels also decreased at different percentages across all lines and variety. Cowpea lines TEXAN PINKIYE had higher protein content both in the cooked products and the uncooked and IT98K-205-8 had higher potassium content in the uncooked product. After cooking IT85F-867-5 had highest percentage of retained proteins in cooked sample. Proteins and minerals availability may be compromised due to high contents of antinutritional factors, such as phytates, tannins and fibers, which negatively influenced the protein and minerals content, apart from processing methods such as cooking. From this study there was difference between the percentage averages of total proteins and minerals before and after cooking.

Cooking is the most common processing techniques used for cowpea seeds. During this process, two simultaneous changes occur inside and outside the cotyledon cells. These are gelatinization of intracellular starch and denaturation of proteins accompanied by softening of the seeds as a result of plasticization or partial solubilization of the middle lamella, which leads to separation of individual cotyledon cells. Cooking process depends on water imbibition and rate of heat transfer. The size, composition and structure of cowpea seeds have a large influence on the cooking time and nutrient retention after cooking. Changes in quality during the processing of cowpeas could be positive or negative, depending on the final use to which the products are put into. We have nutrient losses (vitamins, minerals, and proteins), reduction in anti-nutritional (tannins, phytates) toxic factors, and flavour and colour changes. For this the main one is nutrient loss hence curbing problems of food malnutrition among the arid and semi-arid persons.

Heat treatment, especially heating in water (hydrothermal heating), affects the vitamin content of most legumes during processing. This could also lead to loss of other nutrients like proteins and minerals in cowpeas. Cooking has been shown by various studies to have effect on the proteins of cowpeas legumes (Anyango *et al.*, 2011a). Decortication of cowpeas during processing could lead to loss of nutrients especially minerals, (Akinjayeju & Enude, 2002). They also reported that removal of seed coat reduced the crude fibre and flatulence causing oligosaccharides. Leaching of proteins into processing water during cooking has also been reported in legumes (Khalil & Mansour, 1995).

Selection of highly productive cowpea lines with low cooking time, high protein and mineral contents before and after cooking available to farmers and consumers is highly needed. The line IT85F-867-5 showed high potassium, calcium, and zinc contents above the overall average before and after cooking. Thus, this cowpea line was the most promising line for cultivation and the one that had better availability of nutrients after cooking.

Table 11: Proteins and selected minerals contents of cowpea lines and varieties before and after cooking from Eastern Kenya.

	Proteins %		Potassium mg/100g		Zinc mg/100g		Mg. mg/100g		Calcium mg/100g	
	Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking
IT82D-889	25.73 ^e ±0.01	24.45 ^{bc} ±0.06	1105.73 ^e ±0.01	1054.92 ^b ±0.88	0.94 ^a ±0.01	0.80 ^{bcd} ±0.03	3.74 ^a ±0.01	3.49 ^{ab} ±0.08	2.27 ^b ±0.01	2.07 ^{bc} ±0.02
IT85F-867-5	25.68 ^f ±0.01	23.89 ^{cd} ±0.18	1131.58 ^c ±0.01	1079.20 ^a ±1.38	1.04 ^c ±0.01	0.84 ^{abc} ±0.04	3.68 ^c ±0.01	3.50 ^{ab} ±0.01	2.11 ^d ±0.01	2.02 ^b ±0.02
IT97K-1042-3	28.42 ^b ±0.01	26.48 ^a ±0.16	1101.55 ^f ±0.01	1031.79 ^d ±1.87	1.21 ^a ±0.01	0.96 ^a ±0.01	3.24 ^g ±0.01	3.05 ^d ±0.02	1.93 ^f ±0.01	1.55 ^b ±0.05
IT978K-205-8	26.78 ^d ±0.01	24.48 ^{bc} ±0.47	1146.36 ^a ±0.01	1054.94 ^b ±1.47	1.17 ^b ±0.01	0.92 ^{ab} ±0.03	3.56 ^e ±0.01	3.27 ^c ±0.03	2.27 ^b ±0.01	2.06 ^b ±0.01
IT98K-589-2	24.76 ^g ±0.01	22.75 ^d ±0.28	1097.19 ^g ±0.01	1031.01 ^d ±5.18	0.89 ^f ±0.01	0.72 ^{cd} ±0.03	3.63 ^f ±0.01	3.53 ^a ±0.01	1.97 ^e ±0.01	1.57 ^b ±0.05
K80	28.22 ^b ±0.01	25.40 ^{ab} ±0.29	1141.13 ^{bc} ±0.01	1049.32 ^{bd} ±0.98	0.82 ^g ±0.01	0.68 ^d ±0.04	3.70 ^b ±0.01	3.35 ^{bc} ±0.01	2.53 ^a ±0.01	2.90 ^a ±0.32
TEXAN	29.75 ^a ±0.01	26.16 ^a ±0.43	1120.77 ^d ±0.01	1042.05 ^{cd} ±0.68	1.03 ^d ±0.01	0.84 ^{abc} ±0.02	3.51 ^f ±0.01	3.23 ^{cd} ±0.04	2.24 ^c ±0.01	2.07 ^b ±0.03
PINKIYE										

Key: Values of a parameter in a column, followed by different superscript letters are significantly different at $p \leq 0.05$, The Values are means \pm standard deviations.

From the above results proteins and minerals were lost mainly because of leaching, most minerals losses were through soaking water. Proteins mean loss was 2.246 mg/100g, potassium 71.584 mg/100g, zinc 0.192mg/100g, magnesium 0.232mg/100g, and calcium 0.155mg/100g, loss. IT82D-889 line was overall better in terms of nutrients retention compared to all others and also in comparison with the control K 80 variety.

4.4: Consumer acceptability of the newly improved cowpea lines and varieties from Eastern Kenya.

Sensory parameters analysed by the panellist where colour, aroma, texture, taste and general acceptability of the cooked cowpea samples. K80 (control) variety was most liked by the panelist followed by IT82D-889 line. Aroma, texture, and taste of the TEXAN PINKIYE line were ranked highly by the panelists despite its colour being ranked poorly. Generally, K80 variety was liked/scored higher in all the attributes. Line IT82D-889 was generally accepted due to its colour, taste and aroma while IT98K-205-3 was accepted due to its texture and taste. Line IT98K-589-2 and TEXAN PINKIYE were generally accepted due to their aroma and texture as seen in Table 12 below. Lines IT85F-867-5 and IT97K-1042-3 were poorly ranked on taste and texture. There was no significant difference ($p < 0.05$.) in the general acceptability of cowpea lines IT82D-889, IT98K-205-8, IT98K-589-2, TEXAN PINKIYE and K80 variety. All of them had positive acceptance and were rated within the hedonic terms “liked moderately” and “Just like.” This indicated high acceptance. However, lines IT85F-867-5 and IT97K-1042-3 showed significant difference at $p < 0.05$ it was rated slightly lower but moderately accepted.

Understanding consumer requirements regarding cowpea variety preference is important in the breeding of cowpea improvement for acceptance and eventual adoption in the targeted community.

Table 12: Consumer acceptability of newly bred cowpeas lines and varieties grown in Eastern Kenya.

Lines/variety	Colour	Aroma	Texture	Taste	General acceptability
IT82D-889	5.53 ^{ab} ±0.24	5.20 ^{abc} ±0.20	4.97 ^{bc} ±0.27	5.03 ^{dc} ±0.16	5.47 ^a ±0.20
IT85F-867-5	5.50 ^{ab} ±0.27	4.87 ^{bc} ±0.29	4.83 ^c ±0.30	4.50 ^d ±0.32	4.70 ^b ±0.26
IT97K-1042-3	5.17 ^{bc} ±0.28	4.70 ^c ±0.26	4.83 ^c ±0.31	4.87 ^{dc} ±0.30	4.83 ^b ±0.28
IT98K-205-8	5.23 ^{bc} ±0.31	5.37 ^{abc} ±0.24	6.13 ^a ±0.24	5.87 ^{ab} ±0.20	5.73 ^a ±0.23
IT98K-589-2	4.90 ^{bc} ±0.30	5.77 ^a ±0.27	5.60 ^{abc} ±0.29	5.57 ^{bc} ±0.27	5.47 ^{ab} ±0.27
K80	6.27 ^a ±0.14	5.60 ^{ab} ±0.18	5.93 ^{ab} ±0.23	6.17 ^{ab} ±0.15	6.27 ^a ±0.15
TEXAN	4.37 ^c ±0.32	5.93 ^a ±0.23	6.17 ^a ±0.15	6.40 ^a ±0.16	5.97 ^a ±0.22
PINKIYE					

Key: Values are means± standard deviations. Values in a column followed by different letter notations are significantly different at $p \leq 0.05$, $n=21$, 7-point hedonic scale.

4.4.1: Pearson correlation coefficients between different sensory attributes of lines and varieties from Eastern Kenya.

The correlation analysis were done on sensory attributes as shown in Table 13, The Pearson correlation coefficient showed that there was significant ($P \leq 0.001$; $P \leq 0.01$; $P \leq 0.05$) correlation among sensory attributes. Colour was significantly and positively correlated with aroma ($r = 0.25$), Texture ($r = 0.21$), Taste ($r = 0.19$) and general acceptability ($r = 0.34$). Aroma also significantly and positively correlated with texture ($r = 0.34$), taste ($r = 0.34$) and general acceptability ($r = 0.50$). Texture significantly correlated with taste ($r = 0.47$), and general acceptability ($r = 0.58$). The result of this study therefore shows that all the sensory attribute at $p < 0.001$, had a positive correlation to one another tasting having a strong correlation with the general acceptability of the product ($r = 58$).

Table 13: Showing correlation analysis (r^2) between the different sensory attributes of different lines and variety obtained from Eastern Kenya.

	Colour	Aroma	Texture	Taste
Aroma	0.25***			
Texture	0.21***	0.34***		
Taste	0.19***	0.34***	0.47***	
General acceptability	0.34***	0.50***	0.49***	0.58***

Key: ***= $p < 0.001$; **= $p < 0.01$ and * = $p < 0.05$.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1: Conclusions

- i. Proximate composition, and minerals composition results of cowpea lines compared well with cowpea checks.
- ii. Cowpea grains absorbed water almost equivalent to their weights after soaking, most of them having high volumetric expansion after soaking and cooking. Density dropped after soaking and cooking due to increase in volume.
- iii. Cooking effected the proteins and minerals contents of cowpeas; there were losses after cooking at varied levels.
- iv. Taste of cowpeas samples analyzed affected the general acceptability of the cowpeas lines. Variety K80 highly accepted and TEXAN PINKIYE aroma preferred by consumer panelist.

5.2: Recommendations

From the results of the study the following recommendation are made.

- I. Nutritional qualities of new cowpea lines are important parameters which should be considered in activities involving the development of new varieties in order to ensure that what consumer gets is known and has the potential to reduce malnutrition levels.
- II. Technological properties and nutrient retention assessment should be considered in acceptance of new cowpea varieties because they determine the end use of the released product.
- III. There is need for production of cowpea with consumer preferred sensory attributes which would enhance acceptance by consumers and hence increase utilization in the region and other parts of Kenya to address food and nutrition problems.
- IV. The cowpeas lines IT82D-889, IT85F-867-5, and IT97K-1042-3 can be accepted on special case based on this study and confirmed as new varieties. This is because from the study they have shown better nutritive contents, retention of good amounts of nutrients, good technological properties as compared to others and they were accepted by the consumer panelist.

5.3: Further research

- I. Results on proteins and minerals retention before and after cooking is not enough there is need to find out cooking effects on phytochemicals (retention of phenolic), flavonoids and overall antioxidant activity of boiled cowpea lines samples from Eastern Kenya.
- II. It is recommended to explore on possibilities of using the new cowpea lines as ingredient in processing cereal-based complementary food as the major weaning food among children in Eastern Kenya hence reducing protein malnutrition.
- III. There is need to determine the possible storage ways putting in mind the use of the chemical-free methods such as hermetic storage and checking its effects on pest infestation, mold infection, aflatoxin contamination, and other quality parameters of the cowpea grains.

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APPENDICES

Appendix A: Some selected statistical outputs from the work.

Mean square table for the completely randomized design for lines/varieties as the dependent variables of the different mineral contents.

SOV	DoF	Calcium	Magnesium	Zinc	Sodium	Phosphorus	Pottasium
Lines	14	0.292 ^{***}	0.823 ^{ns}	0.136 ^{ns}	652.10 ^{ns}	0.081 ^{**}	3753.22 ^{ns}
Reps	5	17.12 ^{***}	0.241 ^{ns}	1.263 ^{***}	440.56 ^{ns}	0.136 ^{**}	24605.46 ^{***}
Error	70	0.077 ^{***}	0.461 ^{ns}	0.099 ^{***}	684.44 ^{ns}	0.034 ^{***}	3418.24 ^{***}
R ²	-	94.31	78.29	64.29	69.22	73.66	79.32
CV	-	7.41	7.34	8.80	9.22	8.20	5.22

Key: DoF = Degrees of Freedom; Reps = Replicates CV = Coefficient of variation, R² = Coefficient of determination * = significant at p<0.05, ** = Significant at p<0.01 and *** = Significant at p<0.001 and ns = not significant at p<0.05

Mean square table for the completely randomized design for lines/varieties as the dependent variables of the different technological properties.

SOV	DoF	WACBC	WACAC	VEXPBC	VEXPAC	ADD	SD	CD
Lines	14	29.11 ^{***}	118.59 ^{***}	11.10 ^{***}	13.99 ^{***}	0.01 ^{***}	0.001 ^{ns}	0.01 ^{***}
Reps	1	0.00 ^{ns}	7.46 ^{ns}	0.02 ^{ns}	18.35 ^{***}	0.00 ^{ns}	0.00 ^{ns}	0.00 ^{ns}
Error	14	3.33 ^{***}	3.69 ^{***}	0.91 ^{***}	0.62 ^{***}	0.00 ^{***}	0.00 ^{ns}	0.00 ^{***}
R ²	-	89.74	97.00	92.46	96.13	95.86	70.54	94.54
CV	-	1.70	1.50	1.69	1.31	1.50	1.93	1.74

Key: SOV = Source of Variation; DoF = Degrees of Freedom; Reps = Replicates CV = Coefficient of variation, R² = Coefficient of determination * = significant at p<0.05, ** = Significant at p<0.01 and *** = Significant at p<0.001 and ns = not significant at p<0.05

Analysis of variance was done for the completely randomized design for different varieties. Variety/lines significantly affected all the minerals and the protein composition at $p < 0.001$. The model was significant at $p < 0.01$ for all the variables. Mean square table for the completely randomized design for lines/varieties as the independent variables for the different minerals and the protein content.

SOV	DoF	Proteins		Potassium		Zinc		Magnesium		Calcium	
		Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking	Before Cooking	After Cooking
Lines	6	9.74 ^{***}	5.15 ^{***}	1168.85 ^{***}	4962.09 ^{***}	0.061 ^{***}	0.03 ^{***}	0.09 ^{***}	0.09 ^{***}	0.13 ^{***}	0.60 ^{***}
Reps	2	0.00 ^{ns}	0.39 ^{ns}	0.000 ^{ns}	9.72 ^{ns}	0.00 ^{***}	0.00 ^{ns}	0.00 ^{ns}	0.01 ^{ns}	0.00 ^{ns}	0.02 ^{***}
Error	12	0.00 ^{***}	0.25 ^{***}	0.00 ^{***}	17.49 ^{***}	0.00 ^{***}	0.00 ^{**}	0.00 ^{***}	0.00 ^{***}	0.00 ^{***}	0.05 ^{**}
R²	-	100.0	91.34	1.00	95.94	100	85.89	100.0	92.04	100.0	85.44
CV	-	0.00	2.02	0.00	0.39	0.00	6.20	0.00	1.91	0.00	11.19

Key: DoF = Degrees of Freedom; Reps = Replicates R²=Coefficient of determination, CV = Coefficient of variation; Key: Significance

for ***= $p < 0.001$; **= $p < 0.01$ and * = $p < 0.05$.

Amino acids of different lines grown (g/100 g sample) of cowpea flour.

Lines/Varieties	Met	Cys	Lys	Thr	Arg	Lue	Ile	Val	Hist	Phe	Gly	Ser	Pr	Al	Asp	Glu
TX 123	0.34	0.23	1.56	0.87	1.70	1.82	1.01	1.19	0.75	1.33	0.89	1.16	0.94	0.97	2.71	4.07
IT98K-205-8	0.33	0.23	1.59	0.89	1.68	1.82	1.00	1.18	0.78	1.33	0.89	1.17	0.97	0.98	2.76	4.12
IT98K-1111-1	0.33	0.24	1.54	0.88	1.67	1.77	0.98	1.15	0.74	1.30	0.88	1.15	0.92	0.97	2.70	3.92
IT97K-1042-3	0.38	0.26	1.04	1.01	2.35	2.02	1.14	1.34	0.86	1.46	1.06	1.35	1.12	1.11	3.29	4.66
IT85F-867-5	0.34	0.23	1.62	0.89	1.95	1.83	1.02	1.19	0.75	1.34	0.98	1.23	0.98	0.99	2.92	4.08
IT98K-589-2	0.31	0.23	1.42	0.80	1.50	1.66	0.89	1.06	0.68	1.28	0.80	1.04	0.86	0.89	2.02	3.57
IT97K-499-35	0.32	0.25	1.51	0.83	1.59	1.69	0.93	1.10	0.71	1.27	0.84	1.09	0.93	0.92	2.58	3.82
IT82D-889	0.32	0.23	1.51	0.81	1.80	1.69	0.94	1.13	0.73	1.28	0.92	0.97	0.93	0.93	2.61	3.83
IT82D-889-1	0.32	0.22	1.56	0.87	1.76	1.81	1.02	1.18	0.73	1.34	0.94	1.15	0.92	0.97	2.69	3.95
TEXAN PINKIYE	0.37	0.26	1.74	0.97	1.99	1.09	1.95	1.29	0.84	1.43	0.99	1.27	1.01	1.08	3.04	4.46

Appendix B: Amino acids results for one cowpea flour sample representative.

AMINONIR®

Analytical Report

Jomo Kenyatta University Of Agriculture and Technology (74686), Nairobi, Kenya

Lab Customer: JKUAT, Nairobi, 61166

Lab code: DE19-0000690-032

Description: 15Kiboo

Material: Peas

Results of amino acid analysis

Parameter	Content (% as is)	Content (%)*	Content (% in CP)
Dry matter	90.76		
CP **	21.31	20.66	
Methionine	0.205	0.199	0.963
Cystine	0.321	0.312	1.508
Methionine + Cystine **	0.552	0.535	2.59
Lysine	1.563	1.516	7.334
Lysine	1.563	1.516	7.334
Threonine	0.787	0.763	3.691
Tryptophan	0.2	0.194	0.939
Arginine	1.483	1.438	6.956
Isoleucine	0.918	0.89	4.309
Leucine	1.647	1.597	7.728
Valine	0.988	0.958	4.635
Histidine	0.504	0.489	2.366
Phenylalanine	1.119	1.085	5.249
Glycine	0.924	0.896	4.336
Serine	1.008	0.977	4.729
Proline	0.845	0.819	3.963
Alanine	0.907	0.879	4.255
Aspartic acid	2.456	2.381	11.524
Glutamic acid	3.576	3.467	16.778
NH3	0.368	0.356	1.725
Total including NH3 **	19.534	18.941	91.658
Total without NH3 **	19.059	18.48	89.425

* DMS: Figures standardized to a dry matter content of 88%, CP = Crude protein, calibration based on Dumas combustion method (CP factor 6.25)

** estimated with separate calibration equation

NIRS calibration equation: agPEAS00_39259_v7



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Appendix C: Paired T- test comparison of uncooked and cooked cowpeas lines and varieties minerals protein contents

T-test was done for paired comparison to see whether there was difference between the uncooked cowpeas and the cooked cowpeas in terms of proteins and the mineral contents and results tabulated in the Table 14 All the paired means were significantly different at $p < 0.001$ except for Calcium that was significant at $p < 0.05$.

Paired comparison	LL	Mean	UL	Stddev	t-value	P-value
ProBC-ProAC	1.864	2.246	2.638	0.8392	12.26	<0.0001
KBC-KAC	64.188	71.584	78.979	16.247	20.19	<0.0001
ZnBC-ZnAC	0.164	0.192	0.22	0.062	14.24	<0.0001
MgBC-MgAC	0.188	0.232	0.277	0.097	10.94	<0.0001
CaBC-CaAC	0.017	0.155	0.294	0.304	2.34	<0.0305

Key: LL = Lower limit; UL = Upper limit; Stddev = Standard Deviation; ProBC= protein before cooking, ProAC= protein after cooking, KBC= Potassium before cooking; KAC= potassium after cooking, ZnBC = Zinc before cooking; ZnAC = Zinc after cooking; MgBC = Magnesium before cooking; MgAC= Magnesium after cooking; CaBC = Calcium before cooking and; CaAC = Calcium after cooking

Appendix D: Consumer/ Sensory evaluation form

Sensory Evaluation for cooked Cowpeas (*Vigna unguiculata*) for general consumer acceptability.

Score sheet for a 7 Hedonic point Scale Ranking (1=Extremely Dislike to 7= Extremely Like)

Where 7= Extremely like, 6= Like moderately, 5= Just like, 4= Neither like nor Dislike, 3= Dislike, 2= Dislike Moderately and 1= extremely dislike.

No. Panellist..... Name of Panellist.....

Date.....

Instruction: - You are provided with coded samples, Kindly score and record each sample per your judgement of the attributes listed on the left side of the table in the appropriate box.

Attribute	Hedonic Scale	Sample Codes						
Colour	(1=Extremely dislike to 7= Extremely Like)							
Flavour	(1=Extremely dislike to 7=Extremely like)							
Aroma	(1=Extremely dislike to 7=Extremely like)							
Texture	(1=Extremely dislike to 7=Extremely like)							
Taste	(1=Extremely dislike to 7=Extremely like)							
General Acceptability	(1=Extremely dislike to 7=Extremely like)							
General Comment								

Appendix E: Research output.



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Nutritional and Technological Characteristics of New Cowpea (*Vigna unguiculata*) Lines and Varieties Grown in Eastern Kenya

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Abstract

Protein sources in the diet of people living in semi-arid land of Kenya are lacking and if available it is costly to them. In terms of safe food and a healthy food supply, cowpeas (*Vigna unguiculata*) are a significant source of protein, carbohydrates, and minerals especially for poor populations in the Kenya, it is said to be poor man's meat. The aim of this study was to determine nutritional composition of newly bred ten cowpea lines and five varieties commonly grown in Eastern Kenya of Kitui, Machakos and Makueni counties to understand their potential utilization in curbing rising food and nutrition insecurity in arid and semi-arid lands ASALs and in any other food applications in Kenya. The experiment was arranged in Completely Randomized Design (CRD) whereby proximate composition and minerals were determined using standard AOAC and AACC methods and technological characteristics checked using modified methods used by other researchers. Collected data were subjected to Analysis of Variance (ANOVA) using SAS (2006) version 9.1, mean separation was done using Tukey's Honestly Significant Difference (HSD) method at 5% level of significance. Cowpeas composition ranged from 12.28% - 13.35% for moisture content, 49.37% - 55.74% for total carbohydrates, 2.99% - 3.34% for crude ash, 0.13% - 0.81% for crude lipids, 23.37% -

