CASSAVA UTILIZATION IN KILIFI AND TAITA TAVETA COUNTIES AND EFFECTS OF INCLUSION OF PROCESSED CASSAVA PEELS IN BROILER DIETS ON PERFORMANCE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR MASTERS OF SCIENCE DEGREE OF THE UNIVERSITY OF NAIROBI,

(ANIMAL NUTRITION AND FEED SCIENCE)

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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DEDICATION

To my son and daughter

ACKNOWLEDGMENT

To the Almighty Father from whom all the knowledge comes!

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BW	Body Weight
CF	Crude Fibre
CP	Crude Protein
DM	Dry Matter
EE	Ether Extract
FCPM	Fermented Cassava Peel Meal
FCR	Feed Conversion Ratio
KeBS	Kenya Bureau of Statistics
M.S. S	Mean Sum of Square
SCPM	Sun- Dried Cassava Peel Meal
SBM	Soya Bean Meal
SS	Sum of Square
VPMP	Veterinary Pathology, Microbiology and Parasitology

ABSTRACT

The unprecedented increase in demand for conventional feedstuffs like wheat, sorghum and maize, for human consumption and production of animal feeds has led to the increase in their prices resulting in higher cost of foods of animal origin. This has necessitated the need for research on alternative and non-competitive feed resources to either partially or totally replace the grains that are main energy sources in broiler diets. The potential of cassava peels in Kenya has not been fully exploited partly due to fear of cyanide poisoning and the knowledge gap on various processing methods to reduce toxicity. The objective of this study was to document the use of cassava and cassava byproducts as livestock feed in 2 counties in Kenya and to assess the effect of inclusion of treated cassava peel meal in broiler chicken diets on performance.

In the first study, data was collected on the availability of cassava and its by-products and their usage as animal feed in Kilifi and Taita Taveta counties through a semi-structured questionnaire. Results indicated that 69.6% of the respondents in both Counties grew cassava majorly for household consumption of the tubers with the rest being sold to generate income. Cassava leaves (68%) were the major cassava plant part fed to cattle. The majority of the respondents (86.6%) fed the peels to the livestock immediately after the peeling without any processing.

In the second study, the effect of the inclusion of sun-dried cassava peel meal (SCPM) and *Aspergillus Oryzae* fermented (FCPM) cassava peel meal in broiler diets on performance, diet digestibility, carcass characteristics and cost-benefit were determined. The diets were formulated to contain 0% CPM, 5% (SC5), 10% (SC10) and 15% (SC15) sun dried Cassava Peel Meal (CPM) and 5% (FC5), 10% (FC10) and 15% (FC15) fermented CPM respectively. Two hundred and ten (210) Cobb 500 day old broiler chicks were purchased from a commercial hatchery, acclimatized for five days and then randomly housed in 21 metallic cages (10 birds in each cage) and put into

the seven dietary treatments (30 birds per treatment) for 42 days. The birds were fed on both starter and finisher rations formulated to be iso-caloric and iso-nitrogenous. On day 42 of the feeding trial, three birds were randomly selected from each replicate, fasted overnight and sacrificed for the determination carcass characteristics. At the conclusion of the feeding period (42 days), four birds were randomly selected for each of the seven diets and placed in metabolic cages for determination of apparent digestibility of the diets using the total collection method.

The daily feed intake (DFI) decreased with increasing FCPM in the diet from 126.8g/d in FC5 to 114.8g/d in FC15 but increasing with increased SCPM in the diet (from 121g/d in SC5 to 125g/d in SC15) compared with the control (125.2g/d). The daily body weight gain (BWG) increased with the increased inclusion of fermented cassava peel meal (FCPM) with birds on 15% FCPM having a significantly higher BWG (64.72g/d) compared to other treatments. The feed conversion ratio (FCR) decreased with increase inclusion of the fermented peels with birds on 15% FCPM having the lowest ($P<0.05$) FCR (1.77). The carcass characteristics; dressing weight, meat colour and pH of thighs, breast and drumstick were not affected by treatment. The apparent digestibility of DM was not affected by treatment while that of CF decreased with increased inclusion of SCPM in the diets from 36.74% for control to 33.02% for SC15 but increased with the increase of the FCPM in the diets from 36.83% for FC5 to 39.98% for FC15 treatment. The gross profit margin varied from 277.3 in SC15 to 326.6 Ksh/bird in FC15 treatment while the return on investment (RoI) varied from 95.2 in SC15 to 115.2Ksh/bird in FC10 treatment and was significantly affected by the treatments with the control having the lowest RoI (91.8).

In conclusion, the study demonstrated that *A. Oryzae* fermented cassava peels resulted in reduction in CF and HCN, higher CP and could be included up to 15% in broiler rations resulting in better BWG, DFI and FCR and reduced cost of BWG.

Keywords: Cassava peels, performance, digestibility, broiler chicken

CHAPTER ONE: INTRODUCTION

1.1 Background information

By the year 2030, it is estimated that meat consumption is bound to increase to 45.3 kg per capita worldwide with poultry meat singly contributing 38% (Wahyono & Utami, 2018). This will partly be driven by the rapidly growing global population, conscious consumers and increased income levels (Coffey et al., 2016). In Kenya, there were 57162 thousand heads of poultry that produced 334,717 MT of meat in 2020 (FAOSTAT, 2021). The expected increase in demand of animal protein in the country will mostly be met from the broiler chicken industry from its popularity in the upcoming urban and peri-urban areas with limited space, low capita and less time required to maturity in comparison with other livestock species (Kingori et al., 2010). This rise in demand will inadvertently increase the requirements for conventional animal feeds ingredients such as maize, soya bean meal (SBM), wheat and sorghum.

Kenya faces a huge challenge of producing enough maize, which is the main energy source for human consumption, starch industry and animal feeds. To cope with year-round demand, maize is imported from neighboring countries from time to time leading to high costs in feed production thereby increasing the cost of poultry production (Morgan et al., 2015). Alternative energy sources including cassava and their by-products could go a long way to fill this gap.

Cassava production has been promoted globally by Food and Agriculture Organization of the United Nations (UNFAO), International Fund on Agriculture and Development (IFAD) and MASTERCARD foundation among other development partners due to its importance as human food and as industrial raw material for livestock feed manufacturing, starch, alcohol and pharmaceutical industries (Ajaelu et al., 2008). In Kenya, the Agriculture Ministry, nongovernmental organizations and research institutes like Kenya Agricultural and Livestock Research Organization (KALRO) have put in a lot of effort in research to improve the production potential and promoting cassava as a food crop with special emphasis on its commercialization and marketing strategies to improve income for the farmers and other actors across the market chain.

The main objectives of the study were to determine the cassava production and utilization as livestock feeds in the selected counties and the effects of inclusion of processed cassava peels in broiler diets on performance.

1.2 Problem Statement

Feed is the major input in poultry production constituting 70-75% of all production costs consisting largely of cereal grains and their by-products (65-70%) that provide energy to the birds (Raza et al., 2019). In Kenya most of the raw materials ranging from cereals, cotton seed cake, cowpeas and soy beans in poultry feeds production are imported from neighboring countries. For example, the over 95% deficit on demand for soy bean is covered by importation from Uganda, Zambia, Malawi, Brazil and other countries (Murage et al., 2019).

Cassava is the second most valued root crop in Kenya after Irish potato majorly grown in Eastern, Western and Coastal regions mainly for human consumption and is intercropped with other crops (Githunguri & Gatheru, 2017). Manual peeling and minimal processing is common practice in Western and Coastal regions and farmers mostly trade their produce through middlemen in form of composite flour, tubers or chips (Githunguri & Gatheru, 2017) . The cassava peel, that ensues during processing to reduce the cyanide content of the tuber, constitutes a huge waste around cassava processing plants (Salami et al., 2017). According to Burns et al., (2012) more than 50%

of the total cyanide content in the cassava tuber is located on the peels. Inadequately processed peels causes neurologic symptoms in livestock related to cyanide poisoning including tropical ataxic neuropathy, spastic paraparesis, endemic goiter and konzo diseases in animals (Adewusi et al., 1999).

The major constraint for the use of cassava peels in chicken feeds is its low protein, high phytate, presence of high hydrogen cyanide (HCN) in bitter varieties of cassava, high fibre content (9-12%) in comparison to maize (Babatunde, 2013). The phytate in the peel is determined through acid extraction of phytic acid then reacted with phytase and phosphatase to release phosphorous that is quantified with a color reaction of Ammonium molybdate (Darambazar, 2018) while in crude fibre determination, sulfuric acid and sodium hydroxide are used to digest the sample and the residue is calcined with the weight difference indicating the amount of fibre in the cassava peel sample (AOAC, 2005). The peels also tend to spoil very fast due to high moisture content warranting immediate processing (Babatunde, 2013).

For optimal utilization as livestock feed, reduction of the cyanide and fibre contents and enrichment of protein content in the cassava peels are paramount (Oboh, 2006). Sun-drying could be used to effectively reduce the HCN content of the cassava and its by-products to below toxic levels as the cyanide is highly heat labile (Ekwe et al., 2011). This method has no noticeable effect on the nutritional content of the peels and also saves costs of energy, chemicals and equipment that may be limiting in small scale farming systems common in Africa.

1.3 Objectives

1.3.1 General Objective

Determine cassava utilization in Taita Taveta and Kilifi Counties and the effect of inclusion of fermented and sun-dried cassava peel meal in broiler chicken diets on performance and economics of production.

1.3.2 Specific Objectives

a) To determine cassava peels utilization by livestock keepers in Taita Taveta and Kilifi Counties.

b) To determine the effects of inclusion of fermented and sun-dried cassava peel meal on growth performance, carcass traits and cost of production in broiler chickens

1.4 Hypotheses

H1: Cassava peels are not utilized as feed by livestock keepers in Taita Taveta and Kilifi Counties.

H2: Inclusion of CPM in broiler diet does not influence economics of production, feed intake, live weight gain, feed efficiency, carcass quality and cost of production.

1.5 Justification

Cassava is widely grown in Kenya in the western regions (Busia and Homabay) and coastal areas (Kilifi, Taita Taveta and Malindi) where though the production potential remains untapped, the cultivation is favored by the prevailing climatic conditions (Nyasimi et al., 2014). The introduction of high producing and improved varieties of cassava together with intensive extension services, construction of drying facilities for the farmers and marketing techniques (value addition by making chips, fortified flour and cakes) conducted by research institutions like KARLO, UoN, Egerton and MALF (Mulu-Mutuku et al., 2013) seeks to tap into the production shortfall and increase the availability of cassava peels for livestock feeding.

Improved varieties of cassava mature faster and have less HCN and higher nutrition composition (energy and crude protein) compared to the bitter traditional varieties (ILRI, 2014). Traditional methods of reducing the HCN in cassava including soaking/retting and drying have been applied in other parts of Africa with variable success depending on the crop variety, age at harvest and the target animal to be fed (Fayemi & Ojokoh, 2014).

When cassava is consumed either whole or processed, it is peeled and 7-13% of the tuber (depending on the peeling method) is mostly wasted yet it has potential to be used in livestock feeding (Uguru et al., 2022). The recent efforts by research institutions such UON, KARLO and others to supply the farmers with clean cassava cuttings to boost production, value addition services, supply of processing equipment and extension services will further increase the availability of cassava peels for livestock feeding (Adhiambo, 2021).

The use of cassava and its byproducts has the potential to partly replace maize as the main source of energy for poultry feed. Cassava tuber has been included in chicken diets at 50% without negative effects on production and quality of products; eggs, meat and reproduction (Uguru et al., 2022; Etchu et al., 2017 and Aro et al., 2012). Coupled by the fact that cassava is a cheaper energy source, this could substantially reduce the broiler production costs (Uguru et al., 2022). Cassava is more reliable in drought situations, better pest and disease resistance and could do well with minimal inputs (labor or fertilizers) compared to maize (FAOSTAT, 2021).

Cassava peels are high in carbohydrate and low in protein, amount varies depending on the variety and age at harvest (Obadina et al., 2006). The use of cassava peel meal in poultry diets could also help to resolve environmental problem associated with the disposal of cassava peels (Adeleke et al., 2017). This will create a safe and ecofriendly environment especially in cassava processing regions of Kilifi, Taveta and Busia in Kenya.

Processing through fermentation in addition to sun drying reduces the toxic hydrocyanide acid that is detrimental to health and productivity of livestock from as high as 180 ppm to 4ppm (Etchu et al., 2015). An 88% reduction of cynogenic glycosides (linamarin and litaustralin) on fermentation with *Aspergillus Oryzae* have been reported (Zvauya R. et al., 1995). The process had pre-fermentation processing including crushing, sundrying and milling that considerably reduced the HCN by 40%. During fermentation, the *Aspergillus Oryzae* produces linamarase enzyme that degrades the glycosides in the cassava. The enzyme linamarase is produced by lactic acid bacteria present during fermentation (Giraud et al., 1992). Though sun-drying of cassava peels alone results in reduction of HCN, fermentation has been reported to have superior effects. The crude protein of the peels that were fermented was also high (9.25%) compared to sundried (4.86%).

Cassava tuber and the by-products utilization as poultry feed in Kenya is not well documented as most research data is from West Africa and elsewhere globally where cassava is a staple food (FAO, 2013). The lack of data on the use of cassava peels from locally grown cultivars to replace maize as the main source of energy in poultry diets in Kenya, informed the proposed study to determine the effects on the inclusion of processed cassava peel meal on performance of broiler chicken. Fermentation of cassava tuber with *A. Oryzae* has been reported elsewhere but data on the feeding of broiler chicken fed on the peels fermented by the microorganisms and economic comparison with sun dried peels is lacking.

CHAPTER TWO: LITERATURE REVIEW

2.1 Broiler production in Kenya

In Kenya, the production of broilers and layers rose steadily during the period 2010 to 2015 (MoALF Kenya, 2015). This was mostly attributed to the increasing population, urban settlements and rising incomes for the middle class (MoALF Kenya, 2015). The State Department of Livestock Production (SDP) in Kenya reported that there were over 4 million broiler chicken distributed across the country by 2018 up from 3 million in 2016 (MoALF, 2018). A range of bird species kept by Kenyan farmers includes ostrich, ducks, quails Guinea fowl, geese, doves, indigenous chicken and pigeons under varied production systems from back yard/free range to intensive systems mostly in the large urban centers and cities (MoALF, 2018).

The Kenyan indigenous chicken has the highest population at 41,450,829 heads of the total poultry sub-sector according to MoALF (2019) in comparison to layers (4.04 million heads) and broilers (3.8 million heads). The indigenous chicken plays a major role in economic and social life of often resource-poor households in rural Kenya, contributing immensely as a readily available source of animal protein and income (Magothe et al., 2012). The poultry subsector was the most flexible and fastest growing of all livestock sectors in Kenya according to FAO (2013) and this applies almost elsewhere in the world. According to the report, the growth is driven by a strong demand for affordable white meat and conscientious consumers that is the middle class with disposable income. From business and economic point of view, broiler production is the most preferable investment in poultry subsector due to their fast body weight gain to reach market weight and feed conversion efficiency (Mallick et al., 2020).

Poultry keeping is commonly seen as a supplementary livelihood activity though it is also an insurance, saving and the venture also contributes to income diversification for the rural populace in Kenya (Kabuage, 2019). The sale of the birds brings cash and serve as a buffer against shocks such as bad harvests. As poultry numbers increases, the excess birds could be exchanged for goats or sheep thereby further improving poor household's food security and livelihoods (Kabuage, 2019).

2.2 Constraints of poultry production in Kenya

The 21st century poultry farmer is faced by a myriad of concerns including consumer confidence on product quality and safety, emergence of diseases and erratic price hikes of vital feed ingredients worldwide (Hafez & Attia, 2020). Poultry production in Kenya faces several challenges including high feeds costs, infectious diseases, poor nutrition and market constraints due to competition from poultry products from other East African countries including Uganda and Tanzania that are able to sell at lower prices due to their lower production costs (Kanui *et al*., 2016).

Poultry sector productivity in Kenya has been reduced by the scarcity and subsequently high and erratic costs of the conventional energy and protein sources (Murage *et al.*, 2019). The high price of poultry feeds is the major disincentive to producers (Murage *et al*., 2019) .

A study in Bureti District, Kenya on poultry production, feed cost was identified as a major constraint and a key determinant of the profitability of the enterprise and a venue that requires improvement (Vincent *et al.*, 2010). Utilization of locally available non-conventional ingredients minimizes expenditure for the venture and savings can be re-invested to generate more profit for the farmer. Kabuage *et al.* (2019) reported that the major constraints to the indigenous poultry subsector included low genetic potential, poor feeding, lack of organized market, low productivity with little supplementation, high prevalence of diseases and poor management. Considerable amount of effort is essential to address the shortfalls and spur production through appropriate measures including capacity building and sensitization at all levels of production. The interventions that are required at the producer level includes the use of use of locally available feedstuffs, supplements and on-farm feed formulation (Kabuage *et al*., 2019).

In a balanced poultry ration, the combined costs of energy and protein portions has been reported to reach 95% or more in the total feed costs (Ravindran, 2013). As such, the use of locally accessible energy and protein feed ingredients could go a long way in reducing the costs of the broiler rations. In contrast to Asia and Americas that grow maize primarily for livestock feed, Kenya produces it as the staple food for human consumption and is synonymous with food security (Ravindran, 2013). Kenya is a net importer of major feed ingredients including maize, soy bean and wheat from the East and South African countries, and as far as Brazil and Mexico occasioned by shortfalls in production.(Adhiambo *et al*., 2021).

There lacks a confluence between Kenyan pricing movements and global price fluctuations in wheat and maize that are the major energy source for poultry feeds (Adolwa *et al.*, 2021). This leaves the poultry feed industry at the mercies of feed mill owners and brokers who dictate the pricing of the final products thereby affecting profitability of the poultry rearing enterprises (Njuguna *et al.*, 2017). Inadequate and inaccessibility of quality poultry feed at affordable price is considered by the small holder farmers as one of the major constraints they face in their day to day operations (Macharia *et al.*, 2020). Due to the price fluctuations of the poultry feed ingredients, most small holder farmers affected are forced to abandon the enterprises as a result of increased production costs (Njuguna *et al*., 2017).

Cereals and oils constitute major energy sources in poultry feeds. The cereals includes maize, sorghum and wheat while the fats are from either tallow or poultry fat (Mallick *et al*., 2020). In the near future, the competition for cereals between feed, food and agrofuels is expected to aggravate the already precarious situation in the pricing of poultry feeds hence forcing producers to look for alternative energy ingredients (Gura *et al*., 2008). With the energy in the feeds constituting 60-70% of total feed costs, it's the single major component in the feed that can be manipulated (lowered feed costs) to lower the production costs and subsequently better marketing of poultry and poultry products (Mallick *et al.*, 2020). Feed intake in poultry is dependent on energy concentration whose requirement may depend on age environmental condition of the surroundings (Mallick *et al.*, 2020) .

Table 1 below shows the energy content and other nutrients of common sources of energy ingredients in broiler diets.

Table 1: Nutrient content of common energy feedstuffs in broiler diets

Ingredients Nutrients (%)	Maize (x1)	Wheat (x2)	Sorghum (x3)	Broken rice (x4)	Rice Bran (x5)	Wheat Bran (x6)
ME (kcal/kg)	3350	3100	3263	2345	2937	1069
Protein	13.6	13	9	7.9	12.7	14.7
Fat	2.1	2.3	4.6	1.7	13.9	3.8
Calcium	0.22	0.5	0.02	0.11	0.27	0.19
Phosphorous	0.35	0.2	0.15	0.8	1.37	1.12
Lysine	1.01	0.5	0.3	0.06	0.4	0.5
Methionine	0.2	-	0.1	-	0.44	0.16
Sodium (g/kg)	0.1	0.6	0.1	-	0.7	0.6
Chloride (g/kg)	0.7	0.8	0.8	0.3	0.7	0.9

Adapted from Banerjee, 2010

Tuber crops such as potatoes and cassava have also been used to provide energy in broiler diets with results showing no adverse effect on growth (Sultana *et al.*, 2012; Babatunde, 2013). However, their use has been limited by the presence of antinutritive factors and protein quantities when compared with maize based rations (Babatunde 2013). Cassava tuber and by-products of cassava processing have variable energy content that depends on climate, variety and stage o maturity (Morgan et al.,, 2016). Enzymes such as phytase, xylanase and amylase have been added to diets containing cassava tuber and peels to breakdown the complex carbohydrate elements and increase their availability for improved performance in broiler chicken (Morgan et al.,, 2016). In comparison to maize, cassava based diets have more readily digestible starch (and in larger quantities) as it contains higher levels of amylopectin (Gomes et al., 2005).

2.3.1 Cassava production and agronomy

In 2018, Africa's cassava production stood at 61% of the world's 278 million MT of cassava with 62% of global production expected from sub-Saharan Africa by 2025 (FAOSTAT, 2020). Cassava production could be one of the strategies to tackle climate change due to its low inputs requirements, ability to tolerate drought, acidity and low soil fertility (Chitiyo & Kasele, 2005). In terms of energy yield per unit area in tropical climatic conditions, cassava tuber is the most productive crop with a production of 25-60t/ha (Garcia & Dale, 1999) compared to wheat at 4t/ha (Osundwa *et al.,* 2013) and maize at 8t/ha (Tefera *et al.*, 2011).

In Kenya, cassava was introduced by the Portuguese traders in the 16th century on the coast region from where cultivation spread up to Vihiga and Luo Nyanza by 1930s (Githunguri *et al*., 2017). Currently cassava production has spread throughout the country but is concentrated mostly in Western, Coastal and Eastern regions (Githunguri *et al*., 2017). The commercialization of the venture into cassava production owing to its gluten free properties, tolerance to cassava pests and diseases, value addition potential and emergence of the high yielding varieties as is the case with Tajirika has encouraged more farmers from the coast region to embrace cassava farming (Mwang'ombe et al., 2013). Implementation of respective policies for example the Seed and Plant

Varieties Act (cap 326) and support offered by the local governments of Kilifi and Taita Taveta Counties will spur production further and motivate farmers to invest more in cassava production (Kidasi et al., 2021)

The annual cassava production in the country stood at 1.1 million tons grown in approximately 90 thousand hectares of land (1.2t/ha) in the year 2016 (FAOSTAT, 2017). Due to the fact that cassava grows well in marginal lands requiring low production inputs and is tolerant to pests and diseases its production potential in above regions is still underexploited (Githunguri et al., 2017).

Cassava is mainly grown for its tubers that are boiled or fried for human consumption and to a lesser extent, animal feeding (FAO, 2004). Most of the Kenyan produce goes to human consumption as boiled and roasted tuber or processed into chips, crisp and composite flour especially in western region (Githunguri et al., 2017). In order to promote production that has been declining, the government has developed a National Root & Tuber Crops Development Strategy (Kidasi et al., 2021) . The aim of the strategy is to transform the subsector into a viable commercial venture and vibrant industry contributing to food security and feed for livestock rearing (Kidasi et al., 2021) .

During cassava growing, interspecific hybridization between cassava and other related crops like *Manihot Oligantha* produced a high protein variety of cassava with high lysine and methionine content in comparison to the conventional cassava (Morgan et al., 2016).

The major problems faced by cassava farmers includes lack of clean planting materials and market for their produce (Kidasi et al., 2021). A wide variety of cassava cultivars are planted by farmers including Kibadameno, Tajirika (KME-08-02), Kaleso, Agriculture, Nzalauka in descending order of preference by farmers in Kilifi and Taita Taveta counties (Kidasi et al., 2021). The popularity of Kibadameno due to its preferred taste and higher yields per plant compared to other varieties in the study areas partly influenced its choice for use in this study.

Due to this low cost, cassava has the potential to completely replace maize as the energy source in poultry feeds (Morgan et al., 2016).

2.4 Cassava processing and by products

Table 2 shows the mean proximate composition of cassava peels, starch and tubers from different research studies (at least 10 citations from each mean) as adapted from Morgan (2016).

Table 2: Proximate composition (g/kg DM) of cassava tuber and by-products

Product	DM, g/kg	SEM	CP, g/kg	SEM	CF, g/kg	SEM	EE, g/kg	SEM	NFE, g/kg	SEM	Ash, g/kg	SEM
*Peels	287.6	7.99	53.57	3.18	158.26	15.06	15.97	2.26	681.21	18.14	60.49	4.9
**Peel meal	875.9	11.58	53.3	2.52	142.3	9.85	18.1	3.3	703.8	10.94	55.1	4.3
***Root meal	894.24	6.90	31.0	3.67	37.26	3.87	9.85	1.67	827.73	18.67	38.84	4.86
****Starch	794.4	82.6	11.6	2.1	69.2	31.1	1.4	0.05	725.0	6.1	10.8	2.89

**Peels- Raw cassava peels; **Peels- Dried cassava peels, ***Root meal- Cassava tuber ground with its peels into a meal; ***Starch- Cassava starch*

Cassava root chips and pellets have been widely used in animal feed industry in Indonesia, Malaysia, Thailand and Nigeria (Chauynarong et al., 2009). The chips are from dried root that is shredded and sun dried then mashed or pelleted to reduce transportation costs (Morgan et al., 2016) Inclusion of cassava products in broiler rations showed improved health status requiring less antibiotics use in the birds compared to maize-based diets (Ojewola et al., 2006; Tathawan et al., 2002) probably because of the reduced gut colonization by *E. coli* as observed by Promthong et al., (2005).

Abu et al (2015) conducted a 49-day feeding trial to determine the growth performance of broilers fed on cassava peel meal (CPM) and cassava leaf meal to replace soya bean meal (SBM) and maize at 20% correspondingly. Feed intake, body weight gain (BWG) and feed conversion ratio (FCR) of birds on control diet were significantly higher ($p<0.05$) in comparison other treatment with 20% cassava peels and leaves.

2.5 Cassava peels

The use of cassava peels as animal feeds ingredients has not been fully exploited due to its high cyanogenic glycoside compounds (linamarin and lotaustralin), low crude protein content (5.2-7.1%DM) and essential vitamins and minerals (Oladunjoye et al., 2014). The cyanogenic glycosides are hyrolysed to hydro-cyanide that is detrimental to animal health, productive performance and could cause death if fed in large quantities (Garcia *et al*., 1999). After ingestion, the hydrogen cyanide is converted in the liver to thiocyanate by rhodanase enzyme that is later excreted in urine (Garcia *et al*., 1999). This process requires sulphur donated from methionine, hence increasing the requirement of this amino acid in the broiler diets. Studies by Ngiki *et al*. (2014) and Tewe *et al.* (1992) found cyanide levels of 650 and 200 mg/kg in bitter and sweet varieties respectively and protein content is between 46 to 55 g/kg

In a study by Ofuya and Obilor (1993) where young chicks fed on a starter diet containing unfermented cassava peel meal had poor feathering, caecal disease and retarded growth. This could be explained by the lower total amino acid in the unprocessed peels (32.6g/100g) when compared to the fermented peels. Amino acids Leucine, Phenylalanine, Tyrosine/Alanine were not detected in the unfermented peels (Ofuya *et al.,* 1993)

For the reasons above, unprocessed cassava peels are rarely used in poultry feeding hence the need for processing to improve the nutritional value and reduce the hydrogen cyanide to safe levels for normal growth and performance.

2.6 Use of cassava peels in poultry feeding

2.6.1 Dried cassava peels

Oven and sun-drying are the most common methods used in reducing the amount of hydro-cyanide in cassava tuber, leaves and peels, with sun-drying reported to be more effective (Ngiki *et al.,* 2014). The presence of sun almost throughout the year in the tropics where cassava is grown makes this an inexpensive but labor-intensive process where the peels are spread thinly on plastic sheets, metal or concrete slab with frequent turning at hourly intervals until the moisture level of 10-12% is acquired for better storage (Ngiki *et al.,* 2014).

The calculated Metabolizable Energy (ME) in sun-dried cassava peel meal from a sweet cassava variety (TMS30572) fed to day old broiler chicks ranged from 2.66 to 2.86 Kcal/g with Anak strain (Oladunjoye *et al.*, 2014). Phuc et al., (1996) observed sun drying to be more effective than fermentation in terms of reducing the hydro-cyanide levels from to 22.5 mg/kg and 147 mg/kg for sun drying and ensiling respectively. Reports from various studies have varied in the degree of reduction. Free HCN was reduced by 36% (Gomez *et al.,* 1988), by 96% (Tewe *et al.*, 1992), by 83% reported by Tweyongyere *et al.* (2002) and by 85% by Gomez *et al*. (1984) through sun-drying. During cooler months, slower rate of sun-drying eliminates the bound HCN on the peels more effectively as apart from the slow heat buildup a "dry fermentation" occurs that further reduces the cyanide concentration from increased hydrolysis of the cyanogenic glucosides by linamarase enzyme due the slow heating of the peels during sun-drying (Famurewa and Emuekele, 2014; Lukuyu *et al*., 2014).

A study by Osei (1989) showed lowered feed costs and intake by broilers fed on oven dried cassava peels meal as compared to control diets with maize and fish meal. There was no substantial effect on the broilers carcass characteristics, water intake and blood parameters. However, the inclusion of oven dried cassava peels significantly reduced overall weight gain, feed conversion efficiency and feed consumption (Osei *et al*.,1989).

Studies on broilers fed with sun-dried cassava peels have shown varied performance depending on the cassava variety, maturity, peeling method (machine or manual with knives) and the source of the peels. A study by Babatunde *et al.* (2013) with the inclusion of sun-dried cassava peel meal at 10% in broiler diets reduced the feed cost with no adverse effect on their growth and carcass characteristics. Another study by Elanchezhian *et al.* (1999) found that the inclusion of 5% sun-dried cassava peel meal resulted in higher body weight gain and improved feed consumption coupled with no adverse effect on blood composition and dressing percent in layers. Etchu (2017) study on broiler fed sun dried cassava peels and rice bran to replace maize at 7.2% and 9% respectively had higher feed intake but lower final weights when compared to the control. Similar results were recorded (adverse effect on egg production and egg weight, terminal body weights) when layers were fed on sun dried cassava peels beyond 50% inclusion levels (Salami *et al*.,2003). A dietary replacement of maize with 30% SCPM reduced daily feed intake and growth in starter and finisher broiler chicken (Tewe *et al*., 1983 and Odunsi *et al.,* 2001). This could be attributed to physical capacity of the gut and the limit to accommodate enough feed to meet energy and growth requirement and the high crude fibre and residual hydrocyanide content in the cassava peels based diets (Oladunjoye *et al*., 2014). Ehebha 2018 reported depressed final live weights of broiler chicken fed on graded levels of sun-dried cassava peel meal that decreased with the increased inclusion of the peels. The feed intake seemed to increase with increase in the level of inclusion of cassava peel meal (CPM) in the diet that was attributed to the lower nutrient density in the diets. Salami *et al.* (2003) found that unprocessed CPM at 10 to 40% inclusion rates in layer diets significantly lowered their productive performance, averagely with 15% less egg-lay on 20%

inclusion of the CPM in the diet. These results suggest that SCPM should be included in low levels in broiler or layer chicken diets or other feed ingredients incorporated to maintain production and growth.

2.6.2 Fermented cassava peels

Two methods, solid state and wet fermentation, have been applied to improve the protein content and reduce the hydro-cyanide levels in the peels for better performance of broiler birds. Iyayi et al., (2001) reported a protein increase of peels from 5.6% to 14.14% after 20 days fermentation of CP using *Aspergillus niger.* Fermentation using *Saccharomyces cerevisiae* resulted in a protein content increase to 15.22% after 7 days incubation (Antai and Mbongo, 2014). Pure cultures of *Saccharomyces cerevisiae* improved protein content of cassava tuber from 4.4% to 10.9% (Boonnop *et al.*, 2009).

From a study conducted by Okpako *et al*. (2008), a mixture of *Aspergillus Niger* and *Lactobacillus rhamnosus* fermented cassava peels for two days had significant increase in the ash, moisture and protein content (24.4±0.46%). This is thought to be through biosynthesis of vitamins, essential amino acids, proteins and enhanced fibre digestibility. Fermentation also improves the bioavailability of micronutrients and consequent degradation of the antinutritive factors in the peels (Okpako *et al*., 2008). These results are similar with findings by Khempaka *et al*. (2014) that showed high crude protein and improved starch digestibility with CPM fermented with *Aspergillus Oryzae*.

Cassava pulp fermented with *Aspergillus Oryzae* fed to laying hens had no adverse effects on enzyme activities of cholesterol, alanine aminotransferase, aspartate aminotransferase or total immunoglobulin (Okrathok S. *et al.,* 2017). From a number of studies, fermentation of CPM with rumen filtrate was the most effective and cheapest method of improving the protein content in cassava peels (Olaifa *et al*, 2015; Ubalua and Ezeronye 2008); up to 237.8% levels increase in crude protein reported by Olaifa (2015).

Fermentation by retting is also another method that is widely used to transform and preserve cassava tuber and the by-products because it requires low technology and energy and results in favorable organoleptic qualities of the final product (Daeschel et al., 1987). This entails steeping roots or peels in water for about 4 days. This process not only softens the roots but also leads to the disintegration of the tissue structure in contact of linamarin with linamarase enzyme located in the cell walls that is subsequently hydrolysed to glucose and cyanohydrins, which easily break down to ketone and HCN (Mkpong *et al*., 1990).

2.6.3 Ensiled cassava peels

In this method, cassava peels are left to wilt for a few days under a shade and then packed in silos that are pressed to remove air and left to ferment for three weeks (Niayale *et al*., 2020). Ensiling cassava peel meal is not only better in reduction of HCN when compared to sun drying as this process reduced the HCN by 96% compared to sun drying's 86% reduction (Tewe, 1992) but also has improved the in-situ DM degradability of the peels from 70% to 73% (Asalou, 1988). The effectiveness of the ensiling is generally attributed to the extent of reduction of pH and the heat generated during the process (Lukuyu *et al*., 2014). In a study with sheep fed on ensiled peels there was significant increase in CP content and hence growth performance when compared to control diets sun dried peels (Niayale *et al.*, 2020) that was accounted to the increase in the population of the microbial cells of the mould used.

A study carried out by Amadi et al., (2016) with ensiled cassava peels and dried caged layer manure to partially replace maize in cockerel starter diet showed enhanced weight gain, adequate energy and appreciable cost per kilogram gain

2.6.4 Fat (tallow) enriched cassava peels

Addition of fat improves the texture, boosts the energy levels, palatability and reduces dustiness of the cassava based ration whilst simultaneously enriching them with essential fatty acids (Muller et al., 1974). This allows pelleting of the diets and improved performance has been reported by Ogbonna (1976) and Olaifa (2015). A high SCPM diet (40%) on broilers showed depressed weight gain, poor feed intake and poor feed conversion efficiency that was reversed with supplementation of animal fat (tallow) and challenzymes (Avinesh et al., 2018). Reduced feed intake is known to be caused by longer retention of the ingested structural materials in broilers and this could help explain the lower feed intake in the high un-supplemented SCPM (Svihus 2011; Meremikwu et al 2013). The weight gain from the addition of fat was prominent at the finisher period than the starter periods as observed by Avinesh (2018). This was explained by the inability of young birds to effectively and efficiently utilize dietary fat as they are unable to recycle bile salts effectively (Diarra et al., 2018).

2.6.5 Knowledge Gap

The potential of cassava peels use as feed ingredient is largely untapped due its high perishability nature, presence of cyanide and antinutritive factors (Okike *et al.,* 2022). The information on the use of *Aspergillus Oryzae* fermented cassava peels and their effects on inclusion in broiler diets is lacking.

CHAPTER THREE: UTILIZATION OF CASSAVA PRODUCTS AS LIVESTOCK FEED IN KILIFI AND TAITA TAVETA COUNTIES

Abstract

Cassava is the second most important root crop in Kenya after Irish potato and is mostly grown as an intercrop by smallholder farmers. The objective of the study was to survey the production and utilization of cassava and its byproducts as animal feed in 2 Counties in Kenya.

The two counties (Taita Taveta and Kilifi) and their sub-counties (Kaloleni, Kilifi North, Mawatate, Wundanyi and Taveta) were purposively selected for the purpose of the field survey on use of cassava products in livestock feeding as cassava was widely grown. A semi-structured questionnaire was administered to collect information on socio-demographics, production and utilization of cassava and by-products as livestock feed from 247 respondents randomly selected in the 2 counties. The pool of respondents was purposely selected from those who grew cassava and kept livestock.

Majority of the farmers in Kilifi and Taita Taveta (67.7 and 67.5% respectively) preferred planting Kibadameno cassava variety due to its taste and superior production performance. The roots were mostly (69.6%) consumed within the household in both counties and only 30.4% were sold to neighbors and in the local markets. The byproducts of cassava plant and roots available for livestock feeding included small inedible tubers, peels, leaves and stems. Majority of the farmers (68%) fed cassava leaves to sheep and goats in Kilifi while in Taita Taveta only 6% fed the leaves to sheep and goats. Most of the respondents in Taita Taveta (97%) composted the peels into manure with only a few (3%) feeding them to livestock. In Kilifi County (43%) of the respondents discarded the cassava peels. Low usage of peels by the respondents in Taita Taveta was attributed to lack of knowledge of processing methods to reduce the cyanide levels in the peels (86.6%), reluctance by animal to feed on the peels (23.3%) and cyanide poisoning in animals as a result of

feeding on the peels (20.4 %). The difference in utilization of cassava peels as livestock feed in the two counties was attributable to the fact that traditional unimproved cassava varieties with peels having higher cyanide content (Nzarauka, Shibe and Karembo) were more predominant in Taita Taveta than Kilifi County.

The potential of the cassava plant and root byproducts as livestock feed was not fully exploited by the farmers for various reasons. There is need for sustainable interventions to address the constraints identified in the usage of cassava plant and root byproducts to develop a viable cassava value chain in the study areas.

3.1 Introduction

More than 70% of Kenyan landmass is classified as arid and semi-arid and is synonymous with low and unreliable rainfall patterns coupled with high ambient temperatures most of the year (FAO, 2009). This scenario, combined with the adverse effects of climate change, has rendered some important crops including maize and beans to be unproductive as they dry before maturity or perform poorly (FAO, 2009).

These arid and low agriculture potential areas are suitable for such drought-tolerant crops as millet, sorghum and cassava and livestock keeping; mostly sheep, goats, donkey and cattle (MoALF, 2016). A large number of animals are reared in these areas either in communal grazing or within ranches where water is provided through seasonal water pans (Matere *et al.*, 2019). These agroecological conditions supports cassava production which requires moderate rainfall conditions and temperatures (Tirra *et al.*, 2019).

The livestock keepers in crop-livestock production systems supplement their animals with crop residues. In cassava growing areas such as Kaloleni sub-county of Kilifi County, in Kenya farmers supplement livestock with crop left overs, cassava tubers, peels from tubers, wild tree tubers and commercial feed supplements during the drought periods that are characterized by feed and water scarcity (Omolo *et al.*, 2020).

A study by Opondo et al. (2020) on commercialization of cassava production in Kilifi County reported that 69% of the farmers grew the commodity to earn income while the rest were for subsistence. The majority of those in commercial production marketed low-value-added products and had a higher income than those who did not engage in cassava production. Marketing of cassava and its byproducts is constrained by being very perishable commodities owing to their high moisture content of 60-70% thus a short shelf life of 3 days (Saravanan *et al*., 2016). During cassava tuber processing into other value-added products, peels amounting to about 10% of the tuber weight are left as waste (Okike *et al.*, 2022).

Cassava peels have moderate to high energy content (Okoli, 2020) thus, could be used as alternative and affordable energy source for livestock. The cassava peels have been documented as having 10-15% starch, 3.1-5% crude protein and 9-12% crude fibre depending on stage maturity, variety, soil quality and whether sweet or bitter (Kobawila et al., 2005).

The dustiness of the dried cassava based products, moldiness during storage and the high fibre content limits their use in livestock feeding and storage beyond certain periods (Diarra & Devi, 2015). The utilization of cassava peels has been hampered by presence of antinutrients such as high phytin and tannin and low digestible energy content and poison (hydrocyanic acid) which limits their use (Dayal et al., 2018). Toxicity of cassava byproducts can be lowered through processing to reduce the risk of poisoning through consumption and several methods have been suggested. These include fermentation, drying, boiling, pounding and soaking (Umuhozariho *et al.*, 2011). Other traditional processing methods have many effects on the anti-nutrients reduction and improved nutrients retention (Wafula et al, 2016). Fermentation is one of the oldest method that is widely used for the purposes of increasing sensory, shelf-life and nutritional properties (Ochieng, et al, 2018).

The inclusion of cassava-based feed ingredients during commercial feed production, in cassava producing regions could reduce the pressure and demand on the available cereal grains thus lessen the human-animal competition currently witnessed in the areas. In addition, this would also guarantee the supply of energy for livestock feeds, in these areas that are perennially in acute shortage of animal feed ingredients. The results of this study would also guide further studies on processing of cassava peels and improve its utilization in livestock feeding.

3.2 Materials and methods

3.2.1 Study Site

The field study was conducted to evaluate production and use of cassava and its byproducts by livestock keepers in Kilifi and Taita Taveta counties of the Kenyan coastal region using the questionnaire on Figure 1. Taita Taveta County lies at an altitude of 500 – 2,228 m above sea level with diverse terrain patterns and an annual rainfall of 440 mm/annum in low lying areas and 1900 mm/annum in the highland areas (KNBS and SID, 2013). Kilifi county lies at an altitude of 60-340m above sea level mostly a plateau (Nyika) and has two rainy seasons; long rains; between the months April and June and short rains experienced from October to December having an annual rainfall of 900–1000 mm that are normally erratic with intervals of droughts and poor pastures for livestock (Omolo et al., 2020).

A cross sectional study was conducted in the two coastal Counties of Kilifi and Taita Taveta using questionnaires to gather data on social economics, farming and livestock keeping activities of the respondents. The two counties and the sub counties were purposively selected being within the region where cassava was widely grown and having highest cassava production in the area. Semi-structured questionnaire (Appendix 1) was administered to the randomly selected respondents who kept livestock and cultivated cassava using digital Open Data Kit (ODK) application. The sample size was (Kilifi n=121 and Taita Taveta n=127).

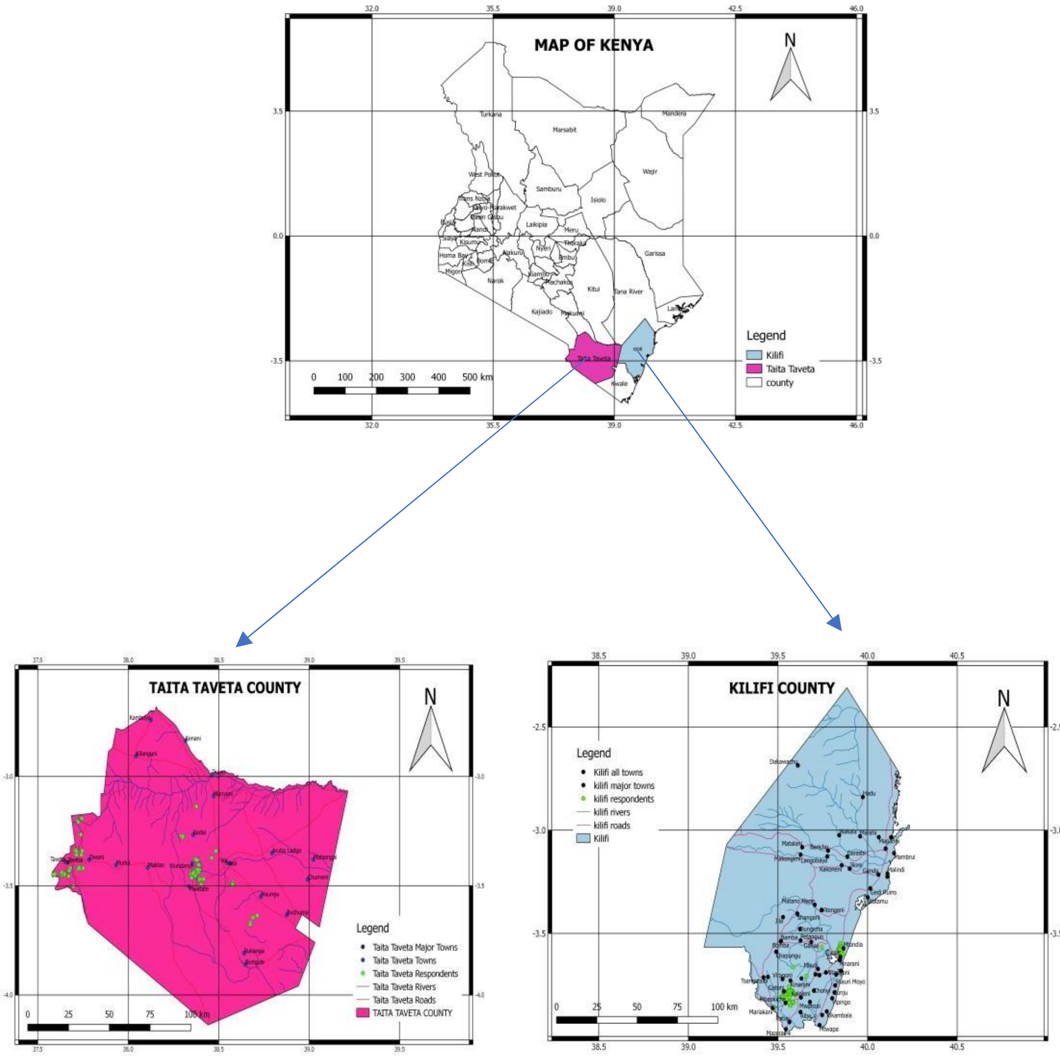

Figure 1: Kilifi and Taita Taveta counties map

3.2.2 Sample size determination, sampling and survey

According to Sign and Masaku *et al.* (2014) sample size could be determined by conducting a census for finite or mall populations, using tested and published tables, using determined formulae to calculate the sample size or imitating sample size used in similar or related studies. In this study the sample size was determined using cassava production data in the region, similar studies conducted earlier as deployed by Tirra (2019); Florence *et al.* (2017) and Ogunleye *et al* (2021) using the formulae below by Anderson (2016).

$$n = \frac{p\,(1 - p)\,Z^2}{E^2}$$

where n is the sample size, p is the sample population having the major interest (in this case cassava cultivation), Z is the confidence interval and E is the margin of error. Due to the fact that the proportion of the population in the study sites was unknown, the values in the formula above were set as p = 0.5, Z = 1.96, and E = 0.062 respectively.

The questionnaire was pretested in Wundanyi subcounty and corrections done for further administration in other villages. Key data collected during the face-to-face interviews included household demographic data, cassava production and acreage, varieties of cassava planted and preferred characteristics, livestock keeping, cassava and by-products use as livestock feed. This was conducted with either the household head or the available person of the household provided he/she was knowledgeable of cassava production and use. The questionnaire was pretested in Wundanyi subcounty and corrections done for further administration in other villages. A local field assistant was at hand for interpretation of the questionnaire in the local dialect where it was needful.

Data analysis

Multiple response data for farmers', which included the cassava varieties grown, type of livestock kept and part of cassava fed to each type of animal were arranged in groups for multiple response analysis on the Statistical Package for Social Sciences (SPSS) software Version 21. The researchers also took notes including ranks, explanations, lists and identification that arose from lead questions. A cleaned report was also prepared on the responses from each lead question. Data for the respective counties were indicated as frequencies in cross tabulations, and the percentages of the households sampled. To determine any association between the dependent variables, a Chi-square test was used (feeding of cassava peels and occurrence of cyanide poisoning) and independent variables (Land under cassava cultivation, County, household gender, number of animals kept and variety fed to livestock) in the respective counties at 5% significance level.

3.3 Results & Discussion.

3.3.1 Social economic characteristics

The social demographic characteristics of the respondents in the study are shown in Table 3.

Table 3: Socio-economic characteristics of cassava producing households in the study area.

*HH; Household Head. *Vendorss; end sellers of household items, water vendors, motorcycle spare parts, electrical appliances. **Others; boda boda rider/owner, charcoal burning, photography and tailoring*

Social economic characteristics		**County Kilifi**		**Taita Taveta**		**Totals**	
		n=121	**%**	**n=126**	**%**	**n=247**	**%**
Respondent gender	Male	47	38.8	58	46.0	105	42.5
	Female	74	61.2	68	54.0	142	57.5
Age	Youth <35 years	27	22.3	29	23.0	56	22.7
	Middle aged (36-50) years	48	39.7	38	30.2	86	34.8
	Upper middle aged (51-60) years	19	15.7	25	19.8	44	17.8
	Above 61 years	27	22.3	34	27.0	61	24.7
Household Head	Female	48	39.7	60	46.9	108	43.7
	Male	73	60.3	67	53.1	140	57.1
HH Education level	None (did not attend school)	28	23.1	23	18.3	51	20.6
	Primary	63	52.1	73	57.9	136	55.1
	Secondary	22	18.2	24	19.0	46	18.6
	Tertiary	8	6.6	6	4.8	14	5.7
Economic activity	Farmer	55	45.5	56	43.1	111	44.9
	*Vendors	14	11.6	28	21.5	42	17.0
	Artisan trader	14	11.6	8	6.2	22	8.9
	Fishing	23	19.0	2	1.5	25	10.1
	Employment	13	10.7	27	20.8	40	16.2
	**Others	2	1.7	9	6.9	11	4.5

Majority of respondents were females (57.5 %) most of them being middle aged (34.8%) in both counties which can be attributed to the fact that women generally play major roles in the households and farm activities as reported earlier (Kidasi *et al.*, 2021). Men on other hand, have been reported to dominate farming of cash crops where farm returns are high (Ogunlela & Mukhtar, 2009). Majority of the cassava farmers fell between the middle age and upper middle age bracket (52.6%). The participation of youth in cassava production was low (at 22.7%) occasioned by the fact that the crop is still considered poor man’s commodity in these areas (Kidasi *et al.*, 2021).

The respondents mean age was 48.82±15.08 years with (34.8%) of the respondents being middle aged that is 36-50 years old. Majority of the cassava producing households (57.1%) were male-headed and about 14.2% with a 6-member household size. The results of this study concurs with Kenya National Bureau of Statistics (2019) population survey findings on household demographics.

More than half of the respondents (55.1%) had attained basic primary education with a few (5.7 %) having attained tertiary education with 20.6% being illiterate (did not attend school). Low education level among farmers and its implication on farm productivity has been reported (Nyakoi *et al.*, 2016; Rahiel, et al 2018 and Kidasi *et al* 2021) in Ethiopia and Kenya.

There was a significant (χ^2=27.433[a], p<0.001) correlation between the level of education and the respondent's gender with females being less educated in comparison to males. This was attributed to the beliefs where women were considered inferior to men even in education and the fact that most women had low interest in education in Kenya (Mareng, 2010; Nyaga, 2015). In comparing the two counties, the respondents' level of education differed (χ^2=47.627[a], p<0.001) with Taita Taveta having more educated respondents compared to Kilifi County. The lower level of education is correlated with lower level of technological skills uptake that require formal knowledge (Chege and Sifuna *et al.*, 2006).

The main source of livelihood for the respondent was agriculture (44.9%) with 45.5% and 43.1% in Kilifi and Taita Taveta respectively engaging in farming as the primary livelihood activity. Other livelihood activities included vendors (17.0%), formal employment (16.2%), fishing (10.1%), informal artisans and traders (8.9%) Osano *et al*. (2020) earlier reported a higher percentage (80%) of households engaging in maize, cassava, cowpeas and beans production in Taita Taveta County. However, yields of these conventional crops have been declining over the years due to climatic change coupled with erratic rainfall patterns, lowered soil fertility, crop pests and diseases that may have discouraged most of the farmers hence the lower percentage in the current study. Motaroki *et al*. (2021) reported a 50%, 38.4% and 28.3% reduction in area under maize, bean and green gram in Taita Taveta County that was attributed to lower-than-normal rainfall patterns in the area.

3.3.2 Cassava production

In Kilifi County, the area under cassava varied from small kitchen gardens of 0.1 acres to large parcels of land 7 acres with a mean of 0.8 acres. In Taita Taveta County, the land under cassava ranged from 0.1 to 2acres with average of 0.6 acres per farmer. In both counties, cassava was intercropped with maize, beans, Irish potatoes, sweet potatoes and peas. Cassava production has been reported to occupy partly 0.8% (5,779 Ha) of land under agriculture in Kilifi County owing to the preference of others. In 2012 and 2014, 170 Ha and 58Ha of land was reported to be under cassava production in Taita Taveta county respectively with the reduction in production being attributed to under reporting, lack of clean planting materials of high yielding varieties (Economic Review on agriculture, 2015)

The types of cassava varieties grown in the study area are as shown in Figure 2. The most common varieties grown in Taita Taveta were Kibandameno (67.7%) and Girikacha (48.8%); named from distributer ADC while Tajirika (42.5%) and Kibandameno (67.5%) were the most popular in Kilifi County. The choice was attributed to variety productivity, specific tuber traits and the planting materials available in each location as farmers mostly relied on their neighbors for cassava cuttings (Kidasi et al, 2021). Other varieties included Shibe, Nzalauka, Karibuni and Karembo mostly being the traditional unimproved types that were not popular due to their low production potential and high HCN content.

Kibandameno cassava variety was the most preferred variety by respondents (44.7% and 36% in Kilifi and Taita Taveta respectively) for feeding animals and this was attributed to its availability in the areas. This cassava variety has also been attributed to low cyanide levels and fibre content in comparison to others in the area (Nekesa et al, 2016).

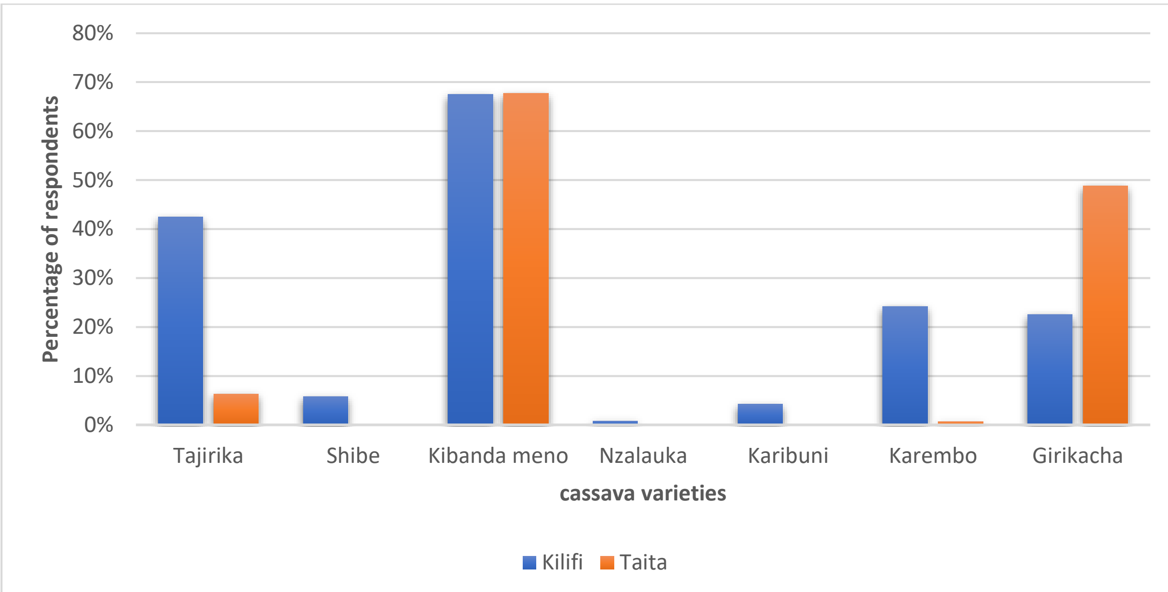

Figure 2: Proportion of cassava production by varieties in Kilifi and Taita Taveta

3.3.3 Livestock ownership and utilization of cassava and by products as animal feed

The livestock ownership by the respondents in Kilifi and Taita Taveta counties is shown in the Table 4.

Table 4: Livestock ownership by the respondents in Kilifi and Taita Taveta Counties

Animal type	Kilifi		Taita Taveta	
	*No	%	* No	%
[a]Cattle	55	11.0	48	9.6
Goat	68	13.6	69	13.8
Sheep	7	1.4	16	3.2
Poultry	97	19.4	90	18.0
Others (Donkey, pigs)	26	5.2	23	4.6

[a]Main type of livestock owned *No- Number of animals per household

The proportion of livestock population was as follows; poultry (19.4 and 18%) and goats (13.6 and 13.8%) were predominant in both Kilifi and Taita Taveta respectively with sheep (1.4 and 3.2) being the least kept in both counties. The high number of poultry and goats could be attributed to the fact that among the livestock kept, they require less inputs, taking less time to maturity and have higher multiplication potential (short reproduction cycles). Wamugi et al., (2016) reported a 3% ownership of sheep in comparison to 42%, 33% and 22% of poultry, goats and cattle respectively in Kilifi County. The arid and semi-arid climate conditions in Kilifi and Taita Taveta and high ambient temperatures makes sheep rearing unfavorable in the areas (Okeyo *et al.*, 2018).

The parts of the cassava plant fed to various types of animals in the 2 counties is shown in Table 5.

Table 4: Proportion of households feeding cassava products to livestock in Kilifi and Taita Taveta counties

Part of cassava plant fed	Cattle		Poultry		Goats		Sheep	
	Kilifi	**Taita Taveta**	**Kilifi**	**Taita Taveta**	**Kilifi**	**Taita Taveta**	**Kilifi**	**Taita Taveta**
Leaves	68	7	8	3	57	26	3	5
Tuber	60	11	76	51	27	4	1	2
Peels	55	3	36	1	33	0	1	1
Stems	2	21	0	0	1	1	1	0
Total	**185**	**42**	**120**	**55**	**118**	**31**	**6**	**8**

All parts of the cassava plant were utilized to feed animals in the study area as shown in Table 5. All parts of cassava plant have previously been reported to be nutritious and a good source of energy, vitamins and protein for livestock (Kobawila *et al*., 2005).

The respondents mostly fed cassava leaves to cattle (n=68 and 7) and goats (n=57 and 26) in Kilifi and Taita Taveta respectively. This is due to the fact that ruminants have the ability to digest the complex fibrous material in the leaves through microbial fermentation (Marjuki *et al.*, 2008). A higher number of respondents fed cassava leaves to cattle and goats in Kilifi (n=68 and 57) in comparison to Taita Taveta (n=7 and 26). This is attributed to more improved sweet cassava varieties being grown in Kilifi compared to local unimproved cultivars in Taita Taveta that have high levels of cyanogenic glycosides impeding their use in animal feeding (Githunguri *et al.*, 2017).

Cassava tubers were the most common product fed to poultry (n=76 and 51) followed by peels (n=36 and 1) and leaves (8 and 3) in Kilifi and Taita Taveta respectively. During data collection, it was noted that most of the cassava tuber fed to poultry and other livestock were the smaller left-over tubers from processing for human consumption and overgrown tubers with higher water content.

A higher proportion of the respondents in Kilifi (n=36) fed cassava peels to poultry than Taita Taveta (n=1). The sheep mainly fed on cassava leaves (n=3 and 5) followed by tuber (n= 1 and 2) in Kilifi and Taita Taveta respectively but their feeding on cassava-based products was low mostly from the fact that few households owned sheep (n= 23) the lowest of all categories of livestock kept by respondents Table 4. The number of respondents who fed cassava peels to livestock was fewer when compared to those feeding leaves and tubers. In Kilifi, 55 of the respondents fed peels to cattle while only 3 in Taita Taveta County. This was attributed to the fear of cyanide poisoning mostly associated with the feeding of cassava peels to livestock.

The respondents indicated that there was increased egg production (25.1%) and improved market weight of chicken (21.9%) fed on cassava-based rations. These findings contradicts those of Aderemi *et al*., (2012) who indicated that inclusion of unprocessed cassava peels in poultry led to low feed intake and low egg production associated with the effect of increased fibre forming complexes with other nutrients preventing absorption. The difference could be attributed to the difference in level of inclusion, cassava cultivars used, maturity and geological growing locations that ultimately affects the nutritional composition of the cassava products available in the two studies (Kortei *et al*., 2014).

Feeding of cassava stems to livestock was rare in both counties as seen on Table 5. The use of cassava stems as animal feed is limited by the presence of the poisonous cyanogenic glucosides, low protein and high fibre contents (Kutay Yildiz & Banu Dokuzeylul, 2017; Mushumbusi *et al*., 2020). Various methods have been used to in order improve the nutritional composition, reduce the cyanogenic glycosides and antinutritive components in cassava products including drying, fermenting and peeling (Udensi *et al*., 2005 and Montagnac *et al*., 2009).

At the household level, 28.34% of the respondents discarded the cassava peels, leaves, damaged tubers near the homestead after processing for human consumption, posing environmental nuisance as they were left to rot. This could be attributed to the lack of knowledge on how these could be harnessed into valuable animal feeds.

Sun-drying was the commonest method used to process cassava by-products for use in animal feeding (99.6%) by the respondents. Sun-drying is a cheap method of reducing cyanogenic glucoside content (by >50%) in cassava and is thus a common practice for processing peels before feeding livestock (Montagnac *et al*., 2009). Additionally, drying in combination with steaming and parboiling has been used to lower the cyanide content of the cassava peels to safe levels for use in livestock (Kobawila *et al.*, 2005 and Tefera *et al.*, 2014). The main problems associated with use of cassava peels for animal feed in the study area were reluctance by animals to feed on them (23.3%) and occurrence of cyanide poisoning (20.4%).

3.3.4 Cyanide poisoning in livestock

The proportion of farmers who had observed the occurrence of cyanide poisoning in different types of livestock in Kilifi and Taita Taveta counties is shown in Figure 3.

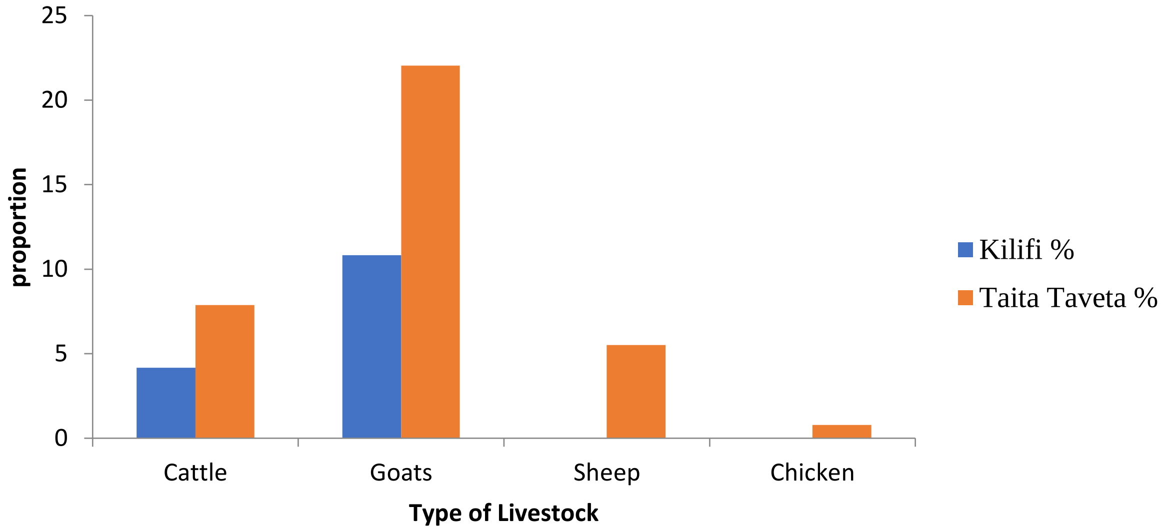

Figure 3: Proportion of farmers reporting case of cyanide poisoning in livestock in Kilifi and Taita Taveta over recent past

Cyanide poisoning in livestock was associated with a history of consumption of fresh unprocessed cassava products in large quantities followed by respiratory distress and nervous signs then sudden death of the suspected cases. Cyanide poisoning in livestock was common in goats and higher occurrence in Taita Taveta (22%) compared to Kilifi (11%). The goats were the most affected as they were kept in larger numbers in comparison to other livestock types owned by the respondents (Table 4). In Taita Taveta, 8% of the farmers reported that they had experienced cyanide poisoning from feeding of cassava-based meals to cattle. The poisoning could be attributed to the fact that most of the respondents fed the cassava tubers and peels directly to the animals without any processing and the fact that the majority of the cassava grown in Taita Taveta is the local unimproved varieties with high cyanogenic glycosides (Kidasi *et al.*, 2021).

Cassava products have been associated with acute and chronic cyanide poisoning in both humans and livestock (Kutay *et al.*, 2017). Majority of the respondents (86.6%) indicated that they had no knowledge on the safe use of cassava peels as livestock feed. This is in agreement with earlier observation that use of cassava peels in animals feeds was limited due to safety issues because cyanide in cassava is concentrated in the peels thus posing a greater risk (Odediran *et al.*, 2015).

According to the respondents, most of the animals affected by cyanide poisoning (69.8%) died before any treatment was initiated by a veterinarian and were either buried or slaughtered for dog consumption. The high cases of deaths can be attributed to the rapid action and potency of the cyanide poison especially in ruminants (Kutay *et al.*, 2017). Hydro-cyanide poisoning is more prevalent in ruminants amongst the domestic animals being attributed to the faster hydrolysis of linamarin and lotaustralin by the microorganisms in their rumen (Banu, 2017).

In conclusion, cassava farmers in Kilifi and Taita Taveta kept different livestock species while growing a variety of cassava cultivars, sourcing the planting materials from neighbors and relatives. 97% of the respondents in Taita Taveta composted the cassava peels in comparison to 43% in Kilifi County. Cassava tubers leaves and peels were fed to livestock without processing resulting in reported cases of cyanide poisoning. To increase usage of cassava peels in livestock diets, there is need for dissemination of novel technologies on their processing to array farmers fears and encourage adoption

CHAPTER FOUR: EFFECTS OF INCLUSION OF SUN DRIED AND FERMENTED CASSAVA PEEL MEAL ON GROWTH PERFORMANCE AND CARCASS TRAITS OF BROILER CHICKENS

Abstract

To meet the need for alternative feed resources, study was carried to assess the effect of inclusion of sun-dried and *Aspergillus Oryzae* fermented cassava peels meal (CPM) in broiler chicken diets on performance and carcass traits. Two hundred and ten (210) broiler chicks were fed on seven (7) diets formulated to include 0% CPM, 5% sun-dried cassava peel meal (SC5), 10% sun-dried cassava peel meal (SC10) and 15% sun-dried cassava peel meal (SC15) and 5% fermented cassava peel meal (FC5), 10% fermented cassava peel meal (FC10) and 15% fermented cassava peel meal (FC15). The birds were fed on both starter and finisher rations formulated to be iso-nitrogenous and iso-caloric. On day 42 of the feeding trial, one bird was randomly selected from each replicate, fasted overnight and sacrificed for determination of the carcass characteristics. At the conclusion of the feeding period, four birds were randomly selected for each of the seven diets and placed in metabolic cages for determination of apparent digestibility of the diets using the total collection method.

Fermentation with *A. Oryze* decreased crude fibre and hydrogen cyanide content of the cassava peels by 34.4% and 56.66% respectively while the crude protein increased by 45.21%. The results also showed that inclusion of 15% fermented cassava (FC15) peels meal resulted in significantly ($p<0.05$) higher body weight gain (64.72g/d) in comparison with control and sun-dried cassava peel treatments while the 15% sun-dried cassava peel meal (SC15) treatment had significantly ($p<0.05$) lower body weight gain (59.41) compared to control (62.97g/d). The average daily feed intake (DFI) was influenced by the treatment with FC15 recording the lowest (114.8g/d). The feed conversion efficiency was influenced by treatments ($p<0.05$) with SC15 (2.12) and FC15 (1.77) being the highest and the lowest feed conversion ratio respectively. The absolute and dressing percentage weights of the breast, abdominal fat, thigh and drumstick were not influenced ($P< 0.05$) by the diets. The apparent digestibility of crude protein and dry matter were not affected by treatment ($P< 0.05$). The apparent digestibility of crude fibre was influenced by treatments ($p<0.001$) with FC15 (39.98%) being the highest in comparison with C (36.74%). There was a significant ($p<0.05$) reduction of 19 KES in cost of feed per kilogram weight gain for diet FC15 compared to the control.

From the findings of this study, *Aspergillus Oryzae* fermented peels had lower levels of CF and hydro-cyanide, higher crude protein and could be included up to 15% in broiler rations resulting in better body weight gain, daily feed intake and feed conversion ratio and reduced cost of daily body weight gain.

Key words: broilers, cassava peels, performance, digestibility, *Aspergillus Oryzae*.

4.1 Introduction

Poultry production in the developing countries has been constrained by inadequate feed resources (both energy and protein sources) and where available they are expensive due to competition with human food (Bakshi *et al.*, 2016). In Kenya maize is the major energy source in poultry feeds but its primarily grown for human food. This competition results in high cost of feed and subsequently poultry products (FAO 2013). This scenario calls for alternative feed resources that can be used to reduce reliance on maize.

Cassava is grown in most of the drier parts of Kenya including coastal, eastern and western regions with the resultant peels from tuber processing being discarded posing environmental hazard (Githunguri & Gatheru, 2017). Cassava peels, owing to their high levels of starch and complex carbohydrates content have been used in various industries including confectionery, mushroom and paint production but their use in animal feeding has been hampered by high levels of antinutritive factors, low protein and high fibre content (Kortei *et al*., 2014). Hydrogen cyanide (HCN) is one of the main anti-nutritive factors impeding cassava products use in livestock feeds as it forms complexes with cytochrome oxidase lowering oxygen carrying capacity of blood leading to hypoxia, respiratory distress and eventually leads to death (Ufaysa, 2019). To improve their utilization, there is need for processing to reduce the HCN and fibre contents and improve the protein quantities of cassava-based products. Processing using sun drying is the most commonly used method due to low costs involved as one only needs presence of sun for a few days to dry the cassava products until the moisture is below 12% (Ngiki *et al.,* 2014).

Fermentation of CPM has proved to be highly effective in reducing the hydrogen cyanide content by 95% (Sudharmono *et al.,* 2016). Though inclusion of cassava pulp fermented with *Aspergillus Oryzae* has been reported by Khempaka *et al.* (2014) to enhance the performance of broiler chicken, the effects of inclusion of the cassava peels meal fermented with this microorganism in broiler chicken diets has not been documented.

The aim of this study was to determine the effects of inclusion of sun-dried cassava peel meal and fermented cassava peel meal on performance of broiler chicken and the economic implication of the inclusion of the meals in broiler diets.

4.2 Materials and methods

4.2.1 Introduction

A feeding trial was conducted to evaluate the carcass characteristics, performance and economic implication of inclusion of sun-dried and *Aspergillus Oryzae* fermented cassava peels in broiler diets.

The feeding trial was conducted for a period of two months (42 days) at the poultry unit, Department of Animal Production, University of Nairobi (Latitude 1° 25'S and Longitude 36° 73'E and at altitude 1930m above sea level). The area received an average rainfall of 94mm/monthly and temperature of 17.7°C during the study period (World weather updates, 2021; *retrieved on 7/31/2021 at 5:50PM).*

4.2.2 Preparation of Cassava peels

Cassava (var. Kibadameno pink) tubers were purchased from farmers in Kilifi County then transported to the University of Nairobi Pilot Plant for manual peeling (using knives) and processing. The tubers were thoroughly cleaned with water to eliminate soil dirt prior to peeling. The cassava peels were weighed and then divided into two (2) equal portions for processing either through fermentation or sun drying. The peeled tubers were processed into flour and cassava chips for human consumption.

4.2.3 Preparation of Sun-Dried Cassava Peal Meal (SCPM)

Fresh raw cassava peels (CP) were spread on canvass in the sun daily with constant turning (approximately 3-4 times a day) to quicken the drying until the moisture content was below 14%. The peels were then stored in hermetic bags until time for the feeding trial when they were milled through a hammer mill to pass through a 2mm sieve. Prior to diet formulation, the materials were analyzed for proximate components, HCN, calcium and phosphorus.

4.2.4 Preparation of Fermented Cassava Peel Meal (FCPM)

The fermented cassava peels were prepared by a slightly modified procedure of Khempaka *et al.* (2018). The *Aspergillus oryzae* culture was obtained from the Department of Veterinary Pathology, Microbiology and Parasitology (VPMP), Faculty of Veterinary Medicine, University of Nairobi and maintained on a Potato-Dextrose-Agar (PDA) medium. The microbial slants were grown at 30℃ for 3 days before being stored at 4℃. Before the inoculating the microorganisms into the substrate, the *A. oryzae* spores were carefully dislodged from the Potato Dextrose Agar (PDA) slant culture using 0.85% Sodium Chloride (NaCl) under sterile conditions to be further used in preparing the bulk *A. oryzae* starter. A kilogram of rice was soaked in water for an hour and autoclaved at 121℃ for 15 minutes then allowed to cool on a tray. Then, 100ml of the stock solution of *A. oryzae* spores was mixed thoroughly with the steamed rice in a juice blender and the mixture then spread on the tray and covered with aluminum foil, incubated for 4 days and then dried for 2 days and ground to pass through a 1mm sieve. Colony counting method was used to count the number of spores in a gram of the starter used to ferment the peels.

A batch of fifty (50) kg of fresh raw cassava peels was placed into a plastic bag and autoclaved at 121°C for 15 minutes (precooking the peels) allowed to cool in the bags then thoroughly mixed with 500g of the *A. oryzae* starter (1.56×10^6CFU/g). The mixture was then incubated in a horizontal 50kg capacity feed mixer for 3 days at room temperature being turned daily. The peels were removed from the mixer at the end of the fermentation period and then sun dried until the moisture level was below 14% and later milled to pass through a 2mm mesh sieve. Before diet formulation, the materials were analyzed for proximate components DM, CP, EE, CF, Ash and cyanide content.

4.2.5 Experimental Diets

The feeding trial diets were formulated to contain a minimum 3000 Kcal/kg, 220g CP/kg for broiler starter and 3000 Kcal, 180g/kg for broiler finisher diets (KEBS, 2019).

Seven diets were formulated, a control and 3 each containing either sundried cassava peel meal (SCPM) or fermented cassava peel meal (FCPM) at various inclusion levels offered to 30 birds per treatment in three replicates of 10 birds each per treatment. The diets were as follows; treatment A (0% cassava peels), B (5%SCPM), C (10% SCPM), D (15% SCPM), E (5% FCPM), F (10% FCPM) and G (15% FCPM). The diets were formulated so as to be iso-calorific and iso-nitrogenous replacing 10.04%, 19.58% and 28.15% of maize during the starter phase and 2.88%, 8.47% and 15.25% during the finisher phase for both sun-dried and fermented cassava peels.

Table 5: Experimental broiler starter feed ingredients (% as fed)

Broiler Starter Mash							
Ingredient (%)	**C**	**SC5**	**CS10**	**SC15**	**FC5**	**FC10**	**FC15**
Maize	59.75	53.75	48.05	42.93	53.8	48.1	42.9
Wheat Pollard	7.1	7	7	6.6	7	7	6.6
Omena (silver cyprinid)	10.09	10	10	10	10	10	10
Soya Bean Meal	21.19	20.37	21	21	20.4	21	21
Cassava Peels	0	5	10	15	5	10	15
Oil (vegetable)	0	1.5	2	2.5	1.5	2	2.5
Lime Stone Powder Coral	0.94	0.95	0.96	0.97	0.95	0.96	0.97
Toxin B/Mold Inhib	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vitamin Premix*	0.275	0.275	0.275	0.275	0.275	0.275	0.275
Table Salt (Nacl) Iodised	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Coccidiostat	0.05	0.5	0.05	0.05	0.5	0.05	0.05
Monocalcium phosphate	0	0	0	0	0	0	0
DL-Methionine	0.08	0.09	0.1	0.11	0.09	0.11	0.11
L-lysine HCl	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Enzyme**	0.015	0.015	0.015	0.015	0.02	0.02	0.02
Calculated nutrient content							
ME (Kcal/kg)	3027	3058	3032	3011	3021	3042	3037
CP	21.5	21.1	21	20.8	21.2	20.8	21.1

Table 7: Experimental broiler finisher feed ingredients (% as fed)

Broiler Finisher Mash							
Ingredient (%)	**C**	**SC5**	**CS10**	**SC15**	**FC5**	**FC10**	**FC15**
Maize	59	57.3	54	50	59.08	54	50
Wheat Pollard	17.61	12.8	9.92	8.75	12.5	9.92	8.75
Omena (silver cyprinid)	9.1	12	10	10.1	11	10	10.1
Soya Bean Meal	11	9.5	12	12	9.1	12	12
Cassava Peels	0	5	10	15	5	10	15
Oil (vegetable)	1	1	1.9	2	1	1.9	2
Lime Stone Powder Coral	1.22	1.16	1.1	1.04	1.16	1.1	1.04
Toxin B/Mold Inhib	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Vitamin Premix*	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Table Salt (Nacl) Iodised	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Coccidiostat	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Monocalcium phosphate	0.1	0.1	0.2	0.1	0.1	0.2	0.1
DL-Methionine	0.15	0.2	0.15	0.15	0.2	0.15	0.15
L-lysine HCl	0.17	0.2	0.18	0.2	0.2	0.18	0.2
Enzyme**	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Calculated nutrient content							
ME (Kcal/kg)	3056	3046	3067	3038	3015	3068	3027
CP	18.2	18	18	17.9	18	18.3	18.2

*Vitamin mineral premix- The composition of the premix was: vitamin A, 10,000,000 IU; vitamin D3 2,000,000 IU; vitamin E, 24,000 *IU; vitamin K3, 3,200 mg; Cobalt, 200 mg; Iodine, 1,400 mg; choline chloride, 350,000 mg; folic acid, 960 mg; thiamine, 1,600 mg; pyridoxine, 4,000 mg; Biotin, 96 mg; vitamin B12, 24 mg; Copper, 5,000 mg; Iron, 40,000 mg; Manganese, 150,000 mg; Zinc, 45,000 mg; riboflavin, 5,600 mg; Nicotinic acid, 32,000mg; pantothenic acid, 8,000 mg and Selenium, 120 mg; ** Phytase enzyme; C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal, FC15= 15% Fermented Cassava Peel Meal*

4.2.6 Experimental design and birds

A completely randomized study design with 30 birds per treatment replicated 3 times (10 birds/ replicate) was used.

Cobb 500 broiler chicks were purchased from a commercial hatchery and raised for 47 days inclusive of 5 days for acclimatization and 42 days for feed trials. The chicks were reared together in a round deep litter brooder that was covered with wood shavings as bedding during the acclimatization period. Infrared bulbs were suspended about 40cm above the brooder floor to offer heat source and fed on the control diet *ad libitum*. After acclimatization, the chicks were feather-sexed for even distribution to 21 brooder cages that accommodated 10 chicks each and allocated the 7 test diets.

Fresh clean water was provided at will to the birds and the routine vaccination schedule observed according to the hatchery specifications. The birds were fed for 3 weeks on starter and 3 weeks on finisher diets.

Figure 4: Experimental birds at day old and at 2 weeks of age during feeding trial

4.2.7 Data Collection

Growth and feed intake

The initial and subsequent body weights of the birds were taken by placing the birds from each cage into a tared plastic bucket and the weight recorded on a weekly basis. The total feed intake was also monitored on a weekly basis by placing a known amount of feed in a bucket for each cage. The weekly feed consumed by the birds in a cage for the week was calculated by the difference of the total feed offered for the week subtracted from the weight of the feed left at the end of the week. The average daily weight gain (ADG) and average daily feed intake then calculated. The Feed Conversion Ratio (FCR) was calculated by dividing the ADFI (g) by the ADG (g) over that period. Mortality was also recorded as it occurred.

Figure 5: Birds being weighed at the end 4th week

Carcass characteristics

One bird from each replicate cage was fasted overnight on day 42 and sacrificed to determine the breast, abdominal fat, carcass dressing percentage, liver and thigh muscle weights. The dressed carcass was weighed immediately after plucking of the feathers, feet and head were removed then the carcass parts including thigh, breast wings and internal organs (abdominal fat, heart, liver and spleen) were harvested and weighed. The carcass dressing (without head, visceral organs and feet) percentage was calculated as a percentage of the live body weight, while the wings, drumstick, abdominal fat and breast were expressed as a percentage of the dressed carcass weight without head and feet.

Figure 6: Dressed carcass of one of the sacrificed birds being weighed

Determination of meat pH and color

The breast and thighs of the sacrificed birds were wrapped with aluminum foils, labeled respectively and aged at 0°C for 24 hours. The pH of each of these parts was separately determined by directly inserting the probe of a pH meter (HANNA: Professional portable pH meter- HI98163) into the muscle. The pH meter was calibrated with a buffer solution before measurements were taken. The pH was measured by penetration of the meter electrodes deep into the inside of the breast (*m. pectoralis major*) muscle from the sternum bone side (Robertson, 1977).

A color-meter (mini-scan spectrophotometer with CIELAB; L*, a*, a*) was used to determine the meat color. The latter is used to determine the opposite color scale based on opponent color theory of human color vision with a*(redness) indicating the redness when positive and greenness when negative. b* (yellowness) indicates yellowness when positive or blueness when negative. The L* (lightness) is used to describe the relationship between the reflected and absorbed light, with value of 100 for white and of 0 for black. The color measurements were performed on the ventral side of the cranial third of breast muscle using color meter (Dzinic *et al.*, 2013).

Digestibility trial

On day 42 at termination of the feeding trial, 4 birds were randomly selected from each diet and transferred into metabolic cages measuring 300mm width by 450mm length by 300mm height to determine digestibility of the rations. The birds were allowed two days to familiarize with the cages before collection of data on daily feed intake and fecal excretion was recorded for the next 3 days. Every bird was offered a pre-determined amount of feed each day. The daily feed consumed by each bird was calculated by the difference of the feed amount offered for the day subtracted from the weight of the feed left the following morning. The total feed intake (ADFI) was then calculated at the end of the digestibility trial. The daily fecal material collected was weighed, thoroughly mixed and a sample collected. The weighed sample was oven-dried at 60°C for 48 hours and the weight recorded and then stored for chemical analysis.

The following formulae were used to compute the apparent dry matter and apparent nutrient (X) digestibility;

*Amount of X (g) in feed=% X in feed/100*Net feed intake on DM basis*

*Amount of X (g) defecated= % X in fecal/100*Net fecal output in DM basis*

Amount of X (g) Digested = X (g) in fecal- X (g) defecated

*Apparent X %= X (g) digested/X (g) in feed*100*

DM digestibility= 100{Feed % DM/100*Net feed intake - Fecal %DM/100*Net fecal}/Feed % DM*

4.2.8 Chemical Analysis

The chemical contents of the raw materials, experimental diets and fecal materials were determined using the procedures as detailed by the Association of Official Analytical Chemist (AOAC, 2005). The Dry Matter (DM) composition was determined by oven drying the feed sample at 105°C temperatures for 12 hours (method no 967.03). For determining the Ash component, the feed or the fecal sample was burned in a muffle furnace at 600°C for 3 hours (method no 942.05). The Ether Extract (EE) was determined by exposing the respective sample in diethyl ether using solvent extractor SER 148/6 and weighing the dried extract (method no 920.29). The crude Protein (CP) was determined using the Kjeldahl method using an automatic Kjeldahl digestion unit- DKL/20 and automatic Kjeldahl analyzer (UDK 159) to determine the Nitrogen (N) content of the sample (method no 988.05). The CP was estimate by multiplying the N content by the factor 6.25. For the determination of Crude Fibre (CF) content, sulfuric acid and potassium chloride were used to digest the sample (method no 962.09).

4.2.9 Hydrogen Cyanide analysis

Hydrogen cyanide content in the peels was determined by strong acid hydrolysis as detailed below and by Bradbury *et al.* (1991).

The cassava peels were cut into small pieces and blended for 3 minutes in a household blender in 60ml 0.1M sulphuric acid to extract of the cyanogens. The cassava peels materials were then filtered using Watman No 1 filter paper and filtrate collected in a volumetric flask. The resultant filtrate was then heated in a stoppered test tube in a water bath using 4ml strong sulphuric acid (4.0M) at a 100°C for 50 minutes. The mixture was then cooled at room temperature followed by addition of 5.0ml of sodium hydroxide (3.6MNaOH) solution and allowed to stand for 5 minutes.

The sample produced cyanohydrins which rapidly decomposed to cyanide ions on addition of the alkali.

The amount of the cyanide was determined by titration of the cyanide ions with silver nitride ($AgNO_3$). A 0.2M Acetate buffer was added, followed by 0.4ml of 5g/L chloramine-T and pyridine/barbituric acid (König reaction) with a purple solution being produced which was then measured spectrophotometrically at 600nm wavelength. The intensity of the color produced depended on pH and phosphate concentration thereby indicating the cyanide content of the peels.

4.2.10 Economic Analysis

To determine the economic implication of using sun-dried and fermented cassava peels in broiler diets the cost benefit analysis was computed.

This is a methodological approach used to evaluate all the costs are expressed in monetary terms to determine the economic feasibility against alternate project(s). In this study, other production costs like water, housing, drinkers, feeders, electricity were not included in the calculation with the assumption that they were constant for all the treatments. The costs of the feed were calculated from the prices of the ingredient based on purchase prices at the time of diets formulation as shown in appendix 1. The costs of the dry peels were calculated based on the costs of the labor of peeling the tuber, drying and fermenting the resultant peels. The total feed cost was calculated from the total feed consumed by a group of birds multiplied by the kilogram cost of the respective feed given to the particular group.

The feed intake (kg) per bird was calculated from the total feed consumed by the group divided by the number of birds at the end of the feeding period. The cost benefit analysis was then calculated based on the total feed intake (in kgs) and divided by respective weight gain (in kgs) per bird in respective feeding period either starter, finisher or entire feeding phase. The analysis for the entire feeding period was calculated based on the weight gain of the birds and the total feed intake for each bird during the whole feed trial period. The return on investment (RoI) was then calculated using the formula below based on feed costs per bird and the sale of value per bird liveweight.

*RoI={S-C}/C*100*

S= Sale of live bird in KES

C=Total feed cost per bird

4.2.11 Statistical analysis

Feed intake, weight gain and the broiler carcass characteristics were analyzed using one-way analysis of variance (ANOVA) using GENSTAT software with inclusion levels being factors. Each cage represented a replicate while each bird as a sampling unit. Tukey test was used to separate least square means at different levels of cassava peels inclusion and orthogonal and polynomial contrast statement used to compare performance of 5% SCPM against 5%FCPM, 10%SCPM against 10% FCPM and 15%SCPM against 15%FCPM. The level of statistical significance was preset at $p \leq 0.05$.

4.3 Results and discussion

4.3.1 Chemical composition of processed cassava peel meal

The chemical composition of the fermented and sundried cassava peel meal is shown in Table 8.

Table 8: Chemical composition (%DM) of the processed cassava peels used in the formulation

Component	Fermented cassava peels	Sundried cassava peels
DM* %	86.89±0.31	88.20 ±0.17
Crude Protein	11.53±0.21	7.94±0.82
Crude Fibre	9.40±0.25	14.33±0.18
Ether Extracts	1.72±0.51	1.46±0.25
Ash	7.66±0.61	3.70±0.51
Cyanide content (mg/kg)	5.47±0.16	9.87 ± 0.28

**DM after drying*

The CP content of the fermented cassava peels was 11.53% representing 45.21% increase compared with sundried peels. The increase was attributable to the ability of the microorganisms to utilize the carbohydrates in the peels as a source of carbon, the ability to excrete extracellular enzymes such as linamarase, amylase and cellulase and their increase in growth and proliferation in the form of single celled proteins (Obohet et al., 2002). Oboh (2006) fermented cassava peels with a mixture of *L. Coryneformis* and *Lactobacillus Delbruckii* bacteria and reported an increase of 21.5% in the protein content of the peels. They attributed increase to the secretion of extracellular enzymes like linamarase, cellulase and amylases into the cassava mash by the fermenting organisms as they utilized the cassava starch as a source of carbon. Higher increase in the CP content of the FC peels have been reported by Sudharmono et al., (2016), a 79.8% increase in the protein content of the peels after a 10 day fermentation period with yeast. The differences with the current study was attributed to the difference in fermentation time (3 days vs 10 days) as longer time leads to higher multiplication of the microorganisms and hence the higher CP.

The CF content of the fermented peels was 9.4% representing a 34.4% decrease compared with the sundried peels. Oboh, (2006) reported a CF reduction of 36.3% of peels fermented by moulds of *Trichoderma sp.*, which is comparable with this study. The reduction in CF content could be attributed to the ability of the microorganisms used in the current study to breakdown the complex fibrous material through secretion of hydrolyzing and oxidizing enzymes with subsequent utilization of the resultant digestible fibre (Uguru *et al.*, 2022).

There was an increase in the ash content of the CPM from 3.70% for sun dried to 7.66% for the fermented cassava meal which is suggestive of microbial presence and multiplication in the FCPM. This agrees with the work done by Dayal et al., (2018) who reported significant increase in the ash component of cassava peels fermented with yeast and amylolytic lactic acid bacteria mixture. The increased ash content in the peels could also be attributed to the proliferation of microorganisms as reported by Oboh et al., (2006) and loss of organic matter during microbial fermentation as microorganisms degrade carbohydrates and proteins in the peels.

The cyanide content of the fermented peels was 5.47mg/kg and sundried peels was 9.87 mg/kg representing 56.66% and 21.77% decrease in the HCN content when compared with the initial amount in the wet cassava peels (12.62mg/kg). The reduction in the hydrogen cyanide content is attributable to the fact that the HCN is highly soluble in water and highly heat labile for the fermented and sun-dried peels respectively (Uzochukwu et al 2013; Pido et al., 1979). The cyanide reduction by sun drying was lower than by fermentation as the earlier method has ability to reduce about 85% and less than 1% of unbound and bound HCN respectively while fermentation can reduce up to 95% of the HCN (Zvauya & Muzondo, 1995). The HCN content in the fermented peels was similar with findings by Oboh, (2006) who reported HCN of 6.2mg/kg in cassava peels after seven-day fermentation period.

4.3.2 Chemical composition of the diets

The chemical composition of the starter and finisher experimental diets is shown in Table 9. The CP during the starter period ranged from 21.47% to 22.93% while during the finisher period it ranged from 18.11% to 18.93%. The target for the crude protein (CP) in the diet was at least 21%

and 18% during the starter and finisher period respectively. The slight deviations were attributed to the variation in quality of the raw materials used in the study and mixing and sampling errors. Diets with SC had slightly higher crude fibre contents (SC15 at 6.4% and SC10 at 6.2%) in both the starter and finisher formulations respectively as a result of sun-dried cassava peels having higher fibre amount. The analyzed nutrient composition of the diets met the requirements for both starter and finisher phases for CP, CF and ME (KEBS, 2009).

Table 9: Chemical composition of the test diets

	Broiler Starter Mash							Broiler Finisher Mash						
	C	SC5	SC10	SC15	FC5	FC10	FC15	C	SC5	SC10	SC15	FC5	FC10	FC15
Dry Matter (DM)	89.44	88.88	89.02	89.00	88.91	89.20	89.40	89.98	90.13	89.77	89.17	89.91	90.44	90.00
Crude Protein (CP)	22.93	21.47	22.49	22.53	22.81	21.71	22.61	18.11	18.93	18.24	18.48	18.45	18.65	18.86
Ether Extract (EE)	6.2	6.5	6.8	6.2	6.5	7.9	7.2	6.5	6.1	6.9	6.9	6.1	7.9	6.9
Crude Fibre CF)	6.2	6.1	6.30	6.40	5.9	5.8	6.1	5.6	6.1	6.2	6.1	5.6	5.8	5.7
Ash	6.9	7.10	7.30	7.50	7.2	8.5	11	7.7	7.4	7.9	7.7	8.3	8.7	9.5
ME (Kcal/kg) *	3027	3058	3032	3011	3021	3042	3037	3056	3046.4	3067.29	3038	3015	3068	3027

C= Control Diet (0% cassava peels), SC5= 5% Sun-Dried Cassava Peel Meal, SC10= 10% Sun-Dried Cassava Peel Meal, SC15= 15% Sun-Dried Cassava Peel Meal, FC5= 5% Fermented Cassava Peal Meal, FC10= 10% Fermented Cassava Peel Meal, FC15= 15% Fermented Cassava Peel Meal.
** = Estimated*

4.3.3 Feed intake, weight gain and FCR

The effect of inclusion of sundried and fermented cassava peel meal on feed intake, weight gain and feed conversion ratio of the chicken during the different growth phases is shown in Table 10.

Table 10. Effect of inclusion of SCPM and FCPM on FI, BWG and FCR of broiler chicken during Starter, finisher and entire feeding period

	Treatments								
	Control	**SC5**	**SC10**	**SC15**	**FC5**	**FC10**	**FC15**	SEM	*P-value*
Starter phase (d1-d21)									
Initial weight (g) d1	87.23	89.39	90.43	88.73	89.33	89.91	87.74	2.67	0.383
Final weight (g) d21	1036	962	1013	967	1095	1048	1040	19.3	0.409
ADFI (g/day)	79.8[a]	84.7[ab]	86.4[ab]	90.5[b]	82.7[a]	79.7[a]	82.0[a]	1.39	0.002
BWG g/day	45.2	41.6	43.9	41.8	47.6	45.6	45.3	1.93	0.425
FCR	1.76	2.04	1.97	2.16	1.74	1.75	1.83	0.10	0.138
Finisher phase (d22-d42)									
Initial weight (g) d22	1036	962	1,013	967	1095	1048	1040	23.14	0.409
Final weight (g) d42	2732[ab]	2587[a]	2624[ab]	2584[a]	2766[ab]	2773[ab]	2806[b]	68.53	0.013
ADFI (g/day)	170.6[b]	157.3[ab]	162.8[ab]	160.8[ab]	168.9[b]	160.5[ab]	147.6[a]	3.16	0.004
BWG g/day	80.74	77.37	76.72	76.98	79.57	82.17	84.07	2.22	0.213
FCR	2.11[b]	2.03[ab]	2.13[b]	2.21[b]	2.08[b]	1.96[ab]	1.76[a]	0.08	0.005
Entire Feeding period									
Initial weight d1 (g)	87.23	89.39	90.43	88.73	89.33	89.91	87.74	9.88	0.94
Final weight d42 (g)	2732[ab]	2587[a]	2624[ab]	2584[a]	2766[ab]	2773[ab]	2806[b]	71.60	0.013
ADFI (g/day)	125.2[b]	121.0[ab]	124.6[b]	125.7[b]	125.8[b]	120.1[ab]	114.8[a]	2.07	0.014
BWG g/day	62.97[ab]	59.47[ab]	60.32[ab]	59.41[a]	63.6[ab]	63.88[ab]	64.72[b]	1.08	0.011
FCR	1.97[ab]	2.02[b]	2.01[b]	2.12[b]	1.99[ab]	1.93[ab]	1.77[a]	0.047	0.005

Means in a row with no/similar superscript are not significantly different (p>0.05); ADFI- Average Daily; FCR-Feed Conversion Ratio; BWG-Body Weight Gain; SC5,10,15-Sundried Cassava Peel Meal at 5%,10%, 15%; FC5,10,15- Fermented Cassava Peel Meal at 5%,10% and 15% inclusion levels

During the starter phase, the mean ADFI varied from 79.75g/d in treatment FC10 to 90.52 g/d in treatment SC15. The ADFI increased significantly with increase in inclusion of sun-dried peels (p=0.002) but was not affected by the inclusion of fermented peels. This could be attributed to the lower retention of the resultant diets with sun-dried peels hence birds tend to eat more to be satiated (Babatunde et al., 2013). The mean body weight gain ranged from 41.57 to 47.62g/d and was similar for birds in all treatments. The body weight gains from the current study were higher than as reported by Obikaonu & Udedibie, (2006) who observed a mean FI and ADG of 70.72 and 19.66g/d when chicks were fed sun-dried CPM during the starter phase. The control diet in their study had significantly higher BWG (29.1g/d) and DFI (76.06g) in comparison with those with CPM. The FCR during starter phase in the current study ranged from 1.74 to 2.04 with no significant difference (p>0.05) among the treatments. Dairo, (2011) fed broiler starter chicks on fermented CPM and reported a similar range of FCR (1.93 to 1.96) with the current study. The FCR in current study within the range (1.76-2) recommended by the breeder from which the chicks were sourced.

During the finisher phase, the mean ADFI ranged from 157.27 to 162.79 g/d for the birds on sun-dried CPM and 147.59 to 168.9 for those on fermented CPM. The ADFI decreased significantly (p<0.05) with increase in fermented CPM (significant at FC15) when compared to the control. The mean BWG varied from 76.72 to 84.07 g/d and was similar (p>0.05) for birds in all the treatments. The slightly, though non-significant, higher BWG in birds on FC peels meal could be attributed to the fermentation process improving the digestibility of the peels by decreasing the fibre, antinutritive factors and HCN content. The FCR in the current study ranged from 2.03 to 2.21 and 1.76 to 2.08 in birds on sundried and fermented CPM respectively being significantly (p<0.05) influenced by the level of inclusion. The FCR recorded in this phase are above the breeder recommended range (1.51- 1.80). The difference could be attributed to feed wastage, feed balancing problem diet and weather condition in the current study.

Over the whole growth phase, the ADFI varied from 114.8 to 126.8g/d for those on fermented CPM with the highest inclusion having the lowest daily feed intake which significantly differed with the control ($p<0.05$). The ADFI increased with increase in SC in the diet. This is due to the considerably higher crude fiber content in the diets with higher inclusion of SC peels meal, which made the birds to eat more to cover their energy needs as the fiber component was not fully assimilated. Dairo (2011a) reported lower feed intake (range 92.17 to 95.03g/d) and weight gain (range 23.68 to 26.08g/d) in comparison with the current study when they fed a mixture of caged manure and fermented cassava peels to broiler chicken. The BWT gain ranged from 59.47 g/d for treatment SC15 to 64.72g/d in treatment FC15. Compared with the control, the sundried CPM diets had similar body weight gains while treatment FC15 had the highest gain of 64.72g/d. The FCR in the current study varied from 1.77 in FC15 to 2.12 in SC15 and was affected by treatment. Birds on fermented peels (FC15) had a significantly ($p=0.005$) lower FCR in comparison with those on SC peels meal. Studies conducted by Dairo, (2011) and Oyebimpe et al., (2006) reported higher FCR ranges (3.64 to 3.87 and 2.66 to 2.69 respectively) when broiler chicken were fed fermented and sun-dried CPM. A high FCR is attributed to high feed intake accompanied by low body weight gain indicating the low conversion efficiency of the feed which could be due to low digestibility, high levels of antinutritive factors or less balanced in nutrients (Aggrey et al., 2010). The significantly higher FCR during the entire feeding period in SC treatments in the current study was attributed to higher daily feed intake accompanied by lower body weight gain due to non-starch polysaccharides and tannins common in cassava peels.

Other studies where sun-dried cassava peels were fed to chicken showed that inclusion of SC peels meal had no effect to feed intake; Adekeye *et al*. (2021) reported that broiler chicken fed on sun-dried high-quality cassava peels at different levels (150, 200, 250 kg/t) had no significant effect on feed intake and BWG compared with the control. Osei and Duodu (1988) reported that birds fed on diets with fermented cassava peel meal (FCPM) recorded higher consumption in comparison to those fed on the diet without the cassava peel meal, though the difference was not significant. In addition, the growth rate and feed conversion ratio of the birds on FCPM diets were also similar to the values registered by their counterparts.

Taking into consideration all the performance indices during the entire feeding period, it was observed that SC15 had the lowest performance that was attributed to the high content of fibre in the diet. The high indigestible fibre and HCN content in this diet decreased feed digestibility resulting in depressed weight gain observed as compared to the other experimental diets and the control. This diet had the lowest apparent digestibility of CF (33.02%) in comparison with other treatments (range 35.44-39.94) as seen on Table 13. In contrast, layer birds could tolerate higher inclusion cassava peels in their diet owing to their lower energy requirement in comparison to broiler chickens (Avinesh et al., 2018). According to the study by Oladunjoye et al. (2010) replacing maize with 50% sun-dried peels meal in laying hen diets had no effect on egg parameters and blood characteristics.

4.3.4 Comparison of the effects of SCPM and FCPM inclusion in broiler diets

Orthogonal and polynomial contrast statements were used to compare the broiler chicken performance with inclusion of either SC or FC CPM at similar inclusion levels (5%, 10% and 15%) as shown in Table 11.

Table 6: Orthogonal contrasts of performance at similar inclusion levels of processed CPM

p values of treatments comparison			
	SC5 vs FC5	**SC10 vs FC10**	**SC15 vs FC15**
Starter phase (d1-d21)			
ADFI (g/day)	0.282	0.993	0.067
BWG g/day	0.060	0.993	0.954
FCR	0.097	0.982	0.631
Finisher phase (d22-d42)			
ADFI (g/day)	0.096	0.552	0.094
BWG1 g/day	0.513	0.109	0.101
FCR	0.332	0.115	0.015*
Entire Feeding period			
ADFI g/day	0.079	0.473	0.001*
BWG g/day	0.002*	0.044*	0.032*
FCR	0.579	0.008*	0.012*

*P values with * are significant comparison. IW- Initial Weight, BWG-Body Weight Gain; ADFI-Average Daily Feed Intake; FCR- Feed Conversion Ratio*

At 5% inclusion of either fermented or sundried CPM, the average daily feed intake was similar during starter, finisher and whole feeding phase. For the same two (2) diets, the average body weight gain was similar for the starter and finisher phase but differed when the whole growing period (p=0.002) was considered with FC5 treatment BW (63.6) being higher than SC5 (59.47) as collaborated by data on Table 9. The FCR of the two diets were similar in all the feeding phases.

At 10% inclusion level, the ADFI was similar during the starter, finisher and the whole feeding period. The daily weight gain and FCR of the two diets were comparable during the starter and finisher feeding phase. Considering the whole feeding period, the BWG (p=0.44) and FCR (p=0.008) were affected by treatment in agreement with data in Table 9.

At 15% inclusion level of either fermented or sun-dried CPM, the daily feed intake was similar during the starter and finisher phase but varied with the treatment during the whole feeding period (p=0.001) with treatment FC15 having lower intake than SC15 (Table 9). The BWG related during the starter and finisher phases were similar but were different (p=0.032) when the whole growth period was considered with FC15 having higher weight gain than SC15. The FCR for the two diets were similar during the starter period but different during the finisher (p=0.015) and the whole feeding period (p=0.0121) with SC15 having higher FCR than FC15 treatment as collaborated by data on Table 9 above.

The higher ADFI in SC15 treatment during the entire feeding period was attributed to the significantly higher CF content in the sun-dried peels. The negative impact of the CF in the peels is its bulkiness, low calorific density so the birds had to increase the intake to be satisfied (Zambare, 2010). In contrast, Obikaonu et al., (2006) reported no significant difference in BWG and ADFI on broiler chicken fed on SC and FC peel meals. However, their finding concurs with the current study on the significant difference observed in FCR. The difference could be attributed to the difference in cassava peels quality, maturity and the type of birds (young) used in the previous study that might not have been used to these diets.

For all dietary comparisons, the average BWG for the whole feeding period varied (p=0.002, 0.044 and 0.032 at 5, 10 and 15% inclusion levels respectively) with the diets. The performance data on Table 9 indicated that FC diets had higher BWG than SC diets. This could be associated with the ability of the microorganisms to reduce the HCN, fibre, tannins and improve the CP and amino acid content hence digestibility and retention (Okrathok et al., 2018). The ability of *A. Oryzae* to improve the nutritive value of cassava peels meal is from its capacity to secrete amylases, glucoamylases, and cellulases that hydrolyze the cassava peels during fermentation and utilize the fiber and starch as carbon as a source of energy for microbial growth that ultimately resulted to peels with higher CP. The improved FCR observed in FC10 and FC15 treatments during the entire feeding period can be attributed to the improved amino acid profiles and digestibility of the resultant diets leading to better weight gain per gram of feed offered.

From this study, it can be concluded that *Aspergillus Oryzae* fermentation of cassava peels improved the FCR, body weight gain and daily intake of the broiler chicken in comparison to sun-drying probably due to reduced HCN and CF content, improved the CP content and digestibility resulting in better performance.

4.3.4 Carcass characteristics

The effect of inclusion of SC and FC peels meal in broiler diets on carcass characteristics (absolute weights of the live bird, eviscerated carcass with and without feet and head, wings, drumstick, abdominal fat, thigh, breast) are shown in Table 12.

The live bird weight varied from 2339g/bird for treatment FC5 to 2637g/bird for FC15. The weight of the eviscerated carcass with head and legs reflected the trend of live weight and ranged from 1926g in treatment FC5 to 2201g for FC15. Birds on SC treatments recorded lower weights (1996 to 2036g/b). All weights of all other body parts reflected the carcass weight tending to be higher (though non-significantly) for FC15 except for the wings whose weight was significantly higher for FC10 and FC15.

The dressing percentage of the carcass (76.08 to 77.84%), breast (35.76 to 38.89%), abdominal fat (0.86 to 1.36%), wings (9.88 to 10.49%), thigh (14.74 to 16.61%) and drumstick (12.05 to 13.31%) were not influenced ($P>0.05$) by the diets. Babatunde et al., (2013) reported lower range of the percentage breast weight (29.49 and 29.18%) but higher drumstick percentages (26.08-26.7%) when compared to the current study for broiler chicken fed SC peels meal at 10 and 20% inclusion levels.

Consumers of broiler meat gauge the quality of broiler meat through various factors including tenderness, water holding capacity, visual appearance, abdominal fat content and high ratio of leg and breast meat (Hascik et al., 2010; and Onsongo et al., 2018).

Previous studies with broilers fed cassava products reported varying dressing percentages for abdominal fat, thigh, drumstick and breast. Khempaka et al., (2009) fed 4-16% dried cassava pulp diets to broiler chicken and reported higher abdominal fat (1.3 to 2.64%), higher thigh dressing percentages (19.42 to 21.43%) but lower carcass percent (67.50 to 69.20%) in comparison to the current study. The percentage drumstick and breast weights in their study were not influenced by the treatments. Animashahun et al., (2022) study on broiler chicken fed on fortified fermented cassava stump observed that similar percentage breast (26.66 to 27.35%), higher thigh (20.90 to 21.68%) and lower drumstick (19.05 to 19.58%) in comparison with the current study were not affected by treatment.

Table 7: Effect of inclusion of SC and FC peel meals in broiler rations on carcass traits

	MEAN+SE							SEM	P-VALUE
	C	SC5	SC10	SC15	FC5	FC10	FC15		
Weights (g)									
Weight of live bird (g)	2487[ab]	2446[ab]	2474[ab]	2476[ab]	2339[a]	2509[ab]	2637[b]	57.90	0.092
Dressed carcass with head and feet (g)	2038[ab]	1996[ab]	2036[ab]	2036[ab]	1926[a]	2082[ab]	2201[b]	50.20	0.051
Dressed carcass without head and feet (g)	1898[ab]	1940[ab]	1902[ab]	1884[ab]	1870[ab]	1801[a]	2053[b]	43.70	0.037
Breast (g)	659.1	669.0	694.7	745.0	681.0	727.2	743.2	29.70	0.545
Thigh (g)	287.6	275.7	280.1	301.7	321.7	317.7	284.8	14.56	0.222
Wings (g)	192.2[ab]	178.2[a]	187.1[ab]	192.4[ab]	195.2[ab]	203.1[b]	202.4[b]	4.68	0.027
Drum sticks (g)	242.1	227.6	217.1	235.6	257.7	2667	248.9	13.71	0.226
Abdominal fat (g)	22.53	21.60	18.23	17.70	21.47	22.53	25.93	5.19	0.931
Percent weights (%)									
*Carcass	76.4	76.4	76.1	76.9	77.0	77.3	77.8	0.58	0.409
Dressing									
Breast	36.5	38.9	35.5	38.1	37.9	35.8	36.3	1.21	0.389
Thigh	15.2	14.7	16.6	15.9	15.6	16.6	15.4	0.67	0.573
Wings	10.1	10.4	9.9	10.1	9.9	10.5	9.9	0.25	0.423
Drum sticks	12.8	12.2	13.2	12.4	12.1	13.3	13.0	0.57	0.593
Abdominal fat	1.2	1.2	1.2	1.4	1.2	0.9	0.9	0.27	0.874

*Means in a row with no/similar superscript are not significantly different (p>0.05); BWG-Body Weight Gain; ADFI- Average Daily; FCR-Feed Conversion Ratio; SC5,10,15-Sundried Cassava Peel Meal at 5%,10%, 15%; FC5,10,15- Fermented Cassava Peel Meal at 5%,10% and 15% inclusion levels; *Carcass without head and feet expressed as a percentage of bird liveweight; **Expressed as a percentage of Carcass weight without head and feet*

The effect of inclusion of SC and FC in broiler diets on physiochemical properties of broiler chicken meat is shown in Table 12 below.

4.3.5 Effect of inclusion of Sundried and fermented cassava peel meal in broiler diets on digestibility

The effect of inclusion of sundried and fermented cassava peel meal in broiler diets on digestibility of dry matter, crude protein and crude fibre is shown in Table 13.

Table 8: Effect of SCPM and FCPM supplementation on the apparent digestibility of DM, CP and CF in broiler chicken diets

Treatments	**C**	**SC5**	**SC10**	**SC15**	**FC5**	**FC10**	**FC15**	**SEM**	**P-Value**
DM %	73.95	73.96	72.71	69.39	74.22	74.90	75.36	1.355	0.088
ApCP %	68.08	65.89	65.59	64.13	68.58	69.67	70.4	1.786	0.174
ApCF %	36.74^{b}	36.27^{b}	35.44^{ab}	33.02^{a}	36.83^{b}	37.69^{bc}	39.98^{c}	0.549	<0.001

Means in a row with no/similar superscript letter are not significantly different (p>0.05; Ap CP- Crude Protein Apparent digestibility; DM- Dry Matter; ApCF- Crude Fibre Apparently digested; SCPM- Sundried Cassava Peel Meal; FCPM- Fermented Cassava Peel Meal.

The apparent digestibility of DM ranged from 69.39% for SC15 to 75.3% for FC15 but the differences were not significant (p>0.05). The renge in DM digestibility in this study was slightly higher than 60.20 to 69.09% and 67.3to 69.8% reported by Foluke & Olufemi, (2013) and Khempaka et al., (2014) when broiler chicken were fed sun-dried and fermented cassava peels respectively.

The apparent digestibility of CP% ranged from 64.13% for SC10 treatment to 70.4% for SC15 treatment though they were not affected by the treatment. The CP apparent digestibility seemed to decrease with increased inclusion of SC peel meal in the diets.

The CF apparent digestibility ranged from 33.02 for SC15 and 39.98% for FC15 treatment and was significant (p=<0.001) between treatments. The CF digestibility decrease with increased inclusion of SC and increased with increased levels of FC peels meals in the diets respectively. This is could be attributed to the ability of A. Oryzae to secrete hydrolyzing enzymes including cellulases, amylases and glucoamylases that break down the CF in the cassava peels (Begum et al., (2009). A study conducted by Abel, (2014) on broilers fed on diets with fermented cassava peels included by upto 40% had CF apparent digestibility of 46.51 to 53.64% that decreased on increased level of the peels in the diets. The difference could be attributed to the source of the cassava peels and probable difference in maturity of the tubers that determines the acid detergent fibre content in the cassava peels used in both studies.

From these results, it can be concluded that fermentation of cassava peels with *A. Oryzae* improves the CF digestibility that could be attributed to secretion of fibre and structural carbohydrates digesting enzymes like cellulase, amylase and glucoamylases (Okrathok et al., 2018). The improved fibre digestibility leads to better nutrient retention hence the appreciable weight gain, favorable DFI and FCR as collaborated by the earlier finding (Table 9) on performance of broiler chicken.

4.3.4 The Cost benefit analysis

The analysis of the cost-benefit of the inclusion of SC and FC cassava peels in the diets of broiler chicken is shown in Table 14.

Table 9: Cost-benefit analyses of the test diets fed to the broiler chicken

	Treatments								
	C	SC5	SC10	SC15	FC5	FC10	FC15	SEM	P-Value
Cost of feed (Ksh/kg)									
Starter diet	60.97	60.7	60.28	59.86	60.98	60.84	60.7		
Finisher diet	58.97	51.93	53.08	52.61	52.21	53.63	53.46		
Feed intake (kg/bird)									
Starter phase	1.68^{a}	1.67^{a}	1.81^{bc}	1.90^{c}	1.74^{ab}	1.74^{ab}	1.81^{bc}	0.03	<0.001
Finisher phase	3.58	3.42	3.42	3.37	3.55	3.30	3.37	0.07	0.124
Cumulative feed intake	5.26	5.09	5.23	5.27	5.30	5.04	5.19	0.08	0.272
Cost of feeding (Ksh/bird)									
Starter phase	102.1^{ab}	101.6^{a}	108.9^{ab}	113.8^{c}	106.2^{ab}	105.7^{ab}	110.1^{bc}	1.73	0.002
Finisher phase	211.3	177.6	181.8	177.4	185.1	177.1	180.6	3.73	0.060
Total feed cost (C)	313.4^{b}	279.2^{a}	290.6^{a}	291.5^{a}	291.4^{a}	282.8^{a}	290.7^{a}	4.38	0.002
Liveweight at end of feeding period (g/bird)	2.73	2.59	2.62	2.58	2.77	2.77	2.81	0.05	0.013
Cost per kg liveweight	114.1^{c}	108.0^{ab}	111.0^{bc}	112.7^{c}	105.1^{ab}	102.2^{a}	103.6^{ab}	1.66	<0.001
Sale of birds[1] (S)	601.0^{ab}	569.0^{ab}	577.2^{ab}	568.5^{a}	610.1^{ab}	608.5^{ab}	617.3^{b}	10.10	0.012
Gross profit margin[2] (P)	287.6^{ab}	289.8^{ab}	286.6^{ab}	277.3^{a}	318.7^{b}	325.7^{b}	326.6^{b}	8.40	0.002
Cost benefit ratio[3] (CBR)	1.91^{a}	2.04^{bc}	1.99^{ab}	1.95^{ab}	2.09^{bc}	2.15^{d}	2.13^{c}	0.03	<0.001
Return on Investment[4] (RoI)*	91.8^{a}	103.8^{bc}	98.6^{bc}	95.2^{ab}	109.4^{bc}	115.2^{c}	112.6^{c}	3.10	<0.001

*Means in a row with no/similar superscript letter are not significantly different (p>0.05); BW- Body Weight; FI- Feed Intake; SCPM- Sundried Cassava Peel Meal; FCPM- Fermented Cassava Peel Meal; [1]220 Ksh/Kg live weight; [2]P=S-C; [3]CBR=S/C; [4]RoI={S-C}/C*100; Currency exchange rate at the time of study (1USD=112Ksh)*

**ROI here is sorely based on cost of feeds and as detailed on the materials and methods section for this chapter*

The average feeding cost during the starter feeding period ranged from 101.6Ksh/bird for SC5 treatment to 110.1Ksh/bird for FC15 and was significantly affected by treatments. The cost of feeding during the finisher period was not affected by treatment. During the whole feeding period, the feeding cost varied from lowest of 279.2 for SC5 treatment to 291.5Ksh/bird in SC15 for the CPM diets and were significantly affected by treatment. The control recorded the highest cost (313.4Ksh/bird) in compared with others. The average sale of birds and cost benefit ratio ranged from 568.5 for SC15 to 617.3 Ksh/bird for FC15 and from 2.2 in SC to 2.4 in FC15 respectively and significantly differed between treatments. The gross profit margin varied from 277.3 for SC15 to 326.6 Ksh/bird for FC15 treatment. The return on investment varied from 95.2 for SC15 to 115.2Ksh/bird for FC10 treatment.

In conclusion the birds on FC15 and FC10 diets had the highest gross margin and offered the highest return on investment (326.6 and 115.2 Ksh/bird respectively) when compared with others. The SC15 diets had the highest feed cost during the whole feeding period (291.5Ksh/bird) but lower return on investment (95.2Ksh/bird) in comparison with other treatments while the birds on control diets had the lowest return on investment (91.8 Ksh/bird) amongst all the groups.

CHAPTER FIVE: GENERAL DICUSSION

The only cassava peels processing method was sun-drying in both Kilifi and Taita Taveta counties. Earlier studies had reported a cyanogenic glucoside reduction of more than 50% in cassava peels which is also very cheap and readily available in sub-Saharan Africa (Montagnac *et al.,* 2009).

In ruminants, the occurrence of cyanide poisoning is higher in comparison to other animal species owing to the rapid action through microbial action in the earlier (Kutay et al., 2017). The respondents fed higher amount of cassava leaves fed to cattle and goats in Kilifi in comparison to Taita Tateva that was attributed to more improved sweet cassava varieties being grown in Kilifi compared to local unimproved cultivars in Taita Taveta that have high levels of cyanogenic glycosides impeding their use in animal feeding (Githunguri et al., 2017). The finding that sheep were fed less on cassava-based products in both counties was attributed to few the households owning sheep (n= 23) and the fact that they were the lowest of all categories of livestock kept by respondents.

The reduction in the hydrogen cyanide content through sun-drying is attributable to the fact that the HCN is highly heat labile (Uzochukwu et al 2013). During fermentation, Aspergillus Oryzae produces linamarase enzyme that degrades the glycosides in the cassava peels (Okrathok et al., 2018). Oboh, (2006) reported a hydro-cyanide of 6.2mg/kg in cassava peels after seven-day fermentation period which is comparable to the current study.

The birds on fermented cassava peel meal 15% had lower average daily feed intake in comparison to control treatment during the entire feeding period that was attributed to the improved nutrient digestibility of fermented diet resulting in the birds consuming less to cover their energy needs. The results differed with the finding by Dairo *et al*. (2011) who reported lower ADFI (range 92.17

to 95.03g/d) when they fed a mixture of fermented cassava peels and caged layers manure to broiler chicken for 56-day period.

The birds on fermented cassava peel meal 15% had lower Feed Conversion Ratio (FCR) that was attributed to the lower feed intake recorded for the birds. The significantly higher FCR during the entire feeding period for the birds on sun-dried cassava peel meal was attributed to higher feed intake accompanied by lower body weight gain due to higher HCN, non-starch polysaccharides and tannins common in unprocessed and sun-dried cassava peels.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

The objective of this study was to explore the cassava production and utilization of tuber and other byproducts as livestock feed in Kilifi and Taita Taveta counties and the effect of supplementing diets of broiler chickens with sun-dried and *Aspergillus Oryzae* fermented cassava peels on performance.

5.1 Conclusions

It was concluded that;

1. Because of varietal differences, there was greater use of cassava and it's by products in livestock feeding in Kilifi than in Taita Taveta County.

2. The inclusion of 15% *A. Oryzae* fermented cassava peels in broiler diets improved body weight gain (BWG), daily feed intake (DFI), and feed conversion ratio (FCR).

3. The inclusion of 10 and 15% fermented cassava peel meal (FCPM) in the broiler diets resulted in the highest gross margins and had the highest return on investment.

5.2 Recommendation

Aspergillus Oryzae fermented CPM can be incorporated in rations to lower the cost of broiler production while maintaining carcass quality.

5.3 Areas for further research

There is a need for further research on the effects of *Aspergillus Oryae* fermented and sundried cassava peels inclusion on the sensory evaluation of broiler chicken to enrich the available scientific information on this.

More research should be done on the utilization of sun-dried and *Aspergillus Oryae* fermented cassava peels by broiler chicken beyond 15% and by other monogastric animals (Poultry and swine) and their performance while encouraging the production and processing of cassava in Kenya for increased availability of the by products for use in animal feeding.

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APPENDICES

Appendix 1: Feed Ingredient costs

S.No.	Ingredient	Rate (KES/Kg)
1	Maize	30
2	Wheat Pollard	32
3	Omena (silver cyprinid)	125
4	Soya Bean Meal	120
6	Oil (veg)	70
7	Lime Stone Powder Coral	6
8	Toxin B/Mold Inhib	400
9	Vitamin Premix	275
10	Table Salt (Nacl) Iodised	35
11	Coccidiostat	300
12	DL-Methionine	450

13	L-lysine HCl	350
14	Enzyme	1250

Prices were obtained from the Kenyan market on 15th September 2021

Appendix 2: Costs of preparing sundried and fermented cassava peel meals

	Persons/quantity	Days	Rate	Amount (KES)
Sundried cassava peel meal (SC)				
Manual peeling of cassava tubers	5	1	300	1500
Drying SC	1	4	300	1200
Total costs (T)				**2700**
Resultant dry peels (Kg)	160			
Cost per kg of SC peels				16.9
Fermented cassava peel meal (FC)				
Manual peeling of cassava tubers	5	1	300	1500
Drying FC	1	4	300	1200
Fermenting FC	1	3	300	900
Total costs (T)				**3600**
Resultant dry peels (Kg)	160			
Cost per kg of FC peels				22.5

Appendix 3: Field Survey questionnaire

Project title: RU/2018/CARP+/04:
Capacity building for micro propagation and certification of cassava planting materials to enhance productivity, incomes and food and nutrition security for small holder farmers in Coastal Kenya

Introduction:
The goal of the project is to increase cassava productivity, reduce the effect of major cassava diseases caused by viruses and bacteria and understand the uses of cassava in livestock production. The current practice is that farmers acquire planting materials from each other or KALRO centers and in the process, this has been a very effective method of distributing infected or diseased planting materials. In addition, many cassava producing countries in Africa including Kenya have no protocol to produce and certify health cassava planting materials. Thus, the integration of greenhouse technology as a protected environment will allow KEPHIS to certify cassava planting materials emanating from these greenhouses to ensure that the multiplication and distribution of these materials are disease free. New innovative methods for inclusion of cassava and byproducts of processing will ensure that poultry feed manufacturers have a protocol and inclusion levels in locally grown cassava varieties and ways to reduce cyanide associated with cassava and it's by products.

Questionnaire 1: Cassava production and utilization as livestock feeds by farmers
Introduction and verbal consent taking
My name is **Mwangi Elijah** Undertaking this research on behalf of University of Nairobi and RUFORUM on capacity building for micro propagation and certification of cassava planting materials to enhance productivity, incomes and food and nutrition security for small holder farmers in Coastal Kenya. I would like to invite you on behalf of the University of Nairobi to take part in this study that is aimed at understanding the use of cassava and it's by products in livestock production. I am requesting you to help us learn more about cassava production, marketing and utilization. All that you will say will be confidential for purposes of this study and participation is voluntary. If you agree, I will ask you some questions.

Yes [ ]
No [ ]

Questionnaire No:	Interview Date:

Enumerator Name:	

SECTION 1

1

County ……………………..……..
Sub-County ……………………..
Location ……………….……….
Village …………………………
Ward …………………………...

<u>GPRS Coordinates</u>
Longitude (E) …………....
Latitude (S) ……………..
Altitude …………………

2

Name of the respondent
……………………………..

Sex: Female [ ] Male [ ]

Head of household (sex)

Female [ ] Male [ ]

Age of the farmer …………….. **years**
<u>Household composition</u>

Age group		**Number in HH**
Youth	<35	
Middle aged	36-50	
Upper middle aged	51-60	
Retiree	>60	
Total		

3

Respondent main occupation (you may tick more than once)
Formal employment [ ]
Casual employment time [ ]
Business person [ ]
Full farmer [ ]
Other (specify) ………………..

Do you participate in other farming activities?
Yes [ ]
No [ ]

Specify …………………………………….

4

Academic qualification
Years of schooling ……………
Level of education
None [ ]
Primary [ ]
Secondary [ ]
Tertiary [ ]

Marital status
Single [ ]
Married [ ]
Divorced [ ]
Widowed [ ]
Separated [ ]

5

Do you own one or more of these livestock?

Animal	**Number**
Cow	
Goat	
Sheep	
Chicken	
Others (specify)	
Total	

SECTION 2

1. What is the total current area under crops in acres? …………… Acres

< 0.5 [ ] < 0.5-1 [ ]

> 1-2 [ ] > 2 [ ]

2. Do you grow cassava on this farm? Yes [ ] No [ ]

3. In which months do you plant cassava?

Long rain

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Short rain

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

4. What variety do you prefer to plant in long rain?

Kibada meno [ ] Tajirika [ ] Shibe [ ]

Nzalauka [ ] Karibuni [ ] Karembo [ ] Girikacha [ ]

Others (Specify) …………………..

5. What variety do you prefer to plant in short rain?

Kibada meno [ ] Tajirika [ ] Shibe [ ]

Nzalauka [ ] Karibuni [ ] Karembo [ ] Girikacha [ ]

Others (Specify) …………………..

6. What is the total area under cassava currently? ………………… Acres

< 0.5 [ ] < 0.5-1 [ ]

> 1-2 [ ] > 2 [ ]

7. What quantity do you harvest from the farm in one season? ……………. Kg or No of sacks…………

8. What is the quantity harvested per plant? …………………. Kg and No. of tubers…………

9. Of the quantity harvested per season how much do you;

a) Sell? ………………….. Kg or sacks ……… b) Own consumption? …………….. Kg or sacks ……….

c) Animal feeds? …………………… Kg or sacks ……….

d) Give to family and friends? ……………….. Kg or sacks ……….

NB: *Skip question 9 and 10 if 5 (total) = 0*

10. a) What part of the cassava plant do you usually feed poultry? (you can tick more than once)

Leaves [ ] Whole tuber [ ]

Cassava peels [ ]

b) What part of the cassava plant do you usually feed cattle? (you can tick more than once)

Leaves [ ] Whole tuber [ ]

Cassava peels [ ]

c) What part of the cassava plant do you usually feed goat? (you can tick more than once)

Leaves [ ] Whole tuber [ ]

Cassava peels [ ]

d) What part of the cassava plant do you usually feed sheep? (you can tick more than once)

Leaves [ ] Whole tuber [ ]

Cassava peels [ ]

11. Of the following varieties which one do you prefer for livestock feeding? (you can tick more than once)

Kibada meno [ ] Tajirika [ ] Shibe [ ]

Nzalauka [ ] Karibuni [ ] Karembo [ ] Girikacha [ ]

SECTION 3

1. How do you prepare cassava tubers for household consumption

   Clean/wash [ ]

   Grate [ ]

   Peel [ ]

   Other method [ ]

2. How do you use the cassava peels (you can tick more than once)

Discard [ ]

Use as animal feed [ ]

Manure in gardening [ ]

3. Do you normally use the following processing methods before feeding the peels to animals? (you can tick more than once)

   Sun drying [ ]

   Fermenting [ ]

   Milling into flour [ ]

4. What is the main problem associated with cassava peels feeding to chicken? (you can tick more than once)

   Cyanide poisoning [ ]

   Reluctance by animals to feed [ ]

   Stunted growth [ ]

   Other (specify)

5. a) Have you got any knowledge on the safe use of cassava peels in livestock?

   Yes [ ]   No [ ]

   b) If yes explain?

   ……………………………..

6. a) Have you ever got case of cyanide poisoning in livestock on your farm?

   Yes [ ]   No [ ]

   b) If yes, which type of livestock was it?

   Cattle [ ]   Goats [ ]

   Sheep [ ]   Chicken [ ]

   c) How did you know that it is cyanide poisoning?

   Own assumption [ ]

   Clinical examination by clinician [ ]

   d) What steps did you take?

   Culled the animal [ ]

   Saughered [ ]

7. Other feeds given to poultry apart from cassava (you can tick more than once)

Commercial feeds [ ]

None [ ]

Own formulation [ ]

8. What are the benefits of feeding cassava peels in poultry? (you can tick more than once)

Higher weight at market [ ]

More eggs produced [ ]

Low feed costs [ ]