CASSAVA AS ANIMAL FEED IN GHANA: PAST, PRESENT AND FUTURE

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FOREWORD

Despite its huge potential as employer of large proportion of the rural population, significant contributor to national GDP and valuable source of foreign exchange, the livestock sub-sector in West Africa is facing numerous challenges. Lack of clear policies and strategies as well as the absence or limited private and public investment are among the main ones. In addition to the more general challenges related to policy and investment, poor production levels, availability and accessibility of inputs and services are constraining the livestock sub-sector from attaining its full potential. In particular, the lack of quality feed in desired quantity throughout the year is a major hurdle for increasing livestock production. Cognizant of this fact, FAO has embarked on conducting national feed assessments in West and Central Africa with the ultimate goal of determining the availability, accessibility, demand for and use of crop residues and agro-industrial by-products for policy formulation.

In addition to the above, FAO commissioned a study on the use of cassava as animal feed in Ghana. This study, conducted in line with the FAO Regional Initiative for the Strategic objective SO3 "Reduce rural poverty" is a contribution of the livestock team to the multi-disciplinary approach of the Regional Initiative applied to the cassava value chain in Ghana. The study on cassava as animal feed is also an additional effort of FAO in exploring feed availability for increased livestock production and productivity. The publication shares findings of the study with those interested specifically in cassava as animal feed.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADG	Average Daily Gain
AIBP	Agro-Industrial By-Product
ARI	Animal Research Institute
CSIR	Council for Scientific and Industrial Research
DM	Dry Matter
EG	Economy of Gain
FAO	Food and Agriculture Organization
g	Gram
GFMA	Ghana Feed Millers Association
GDP	Gross Domestic Product
HA	Hectare
HCN	Hydrocyanic acid
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IU	International units
kg	Kilogram
LU	Livestock unit
ME	Metabolizable energy
MOFA	Ministry of Food and Agriculture
mg	Milligram
Mm	Millimetre

EXECUTIVE SUMMARY

The study on the use of cassava as animal feed in Ghana was commissioned as part of FAO's initiative supporting poverty reduction in northern part of the country. Cassava *(Manihot esculenta)* is one of the main staple food crops grown by almost all farming families in Ghana, contributing to large proportion of daily calorie intake of the population. It is used to prepare *fufu*, the local popular dish, and considered as the poor man's food. Ghana is the fourth largest cassava grower in Africa, after Nigeria, Democratic Republic of Congo and Angola. In 2010, Ghana produced 13.5 million tons of cassava. Available information suggests that, cassava is cultivated by over 90 percent of the farming population and contributes to 22 percent to the agricultural GDP, making it the right target for the fight against poverty in the country.

The multi-purpose use of cassava as food for humans and animals, making various industrial products, including its use as input for breweries, attracted many projects and programmes working on its value chain in Ghana. These projects, particularly the IFAD funded Root and Tuber Improvement Programme, introduced improved varieties for better yield, reduced post-harvest losses, improved agro-processing and better access to markets, etc. The various interventions enhanced production and marketing of cassava in the country improving income of producers and other actors involved in the value chain and generating more employment for women and youth, contributing in this way to poverty reduction.

FAO, with its comparative advantage of promoting agricultural and food production and rural development, is supporting poverty reduction initiatives in Ghana. In particular, FAO through its Strategic Objective three is implementing an initiative targeting reduction of rural poverty in Northern Ghana. One of the expected outputs of this initiative is to better equip beneficiaries create viable markets through agro-related livelihood activities linked to the cassava value chain. Among the activities contributing to this output, the livestock team has targeted linking livestock to the cassava value chain for poverty reduction, on which this study is based.

Cassava, in its different forms, has been used as animal feed in many parts of the world. Cassava foliage (leaves and stem), peels and particularly the root; fresh, dried or in silage form; alone or mixed with other feed is used in feeding different species of animals. Dried cassava roots are processed into pellets, chips and meal, mainly for poultry and pig industries.

Several studies conducted in West Africa showed that cassava in its different forms has large potential as animal feed. In countries like Ghana where livestock production is largely constrained by lack of good quality feed, the availability of alternative source of feed like cassava is important. The main ingredient for producing feed for non-ruminant animals raised in intensive production is maize. Ghana produces maize but as the quantity is not adequate to cope with the year-round demand, from time to time, the country is obliged to import it. The fact that animal feed is produced with high cost, mainly due to the elevated cost of maize, makes poultry and pig production very expensive, constituting between 60 and 75 percent of the total cost of production. Because of high cost, many farmers, particularly pig producers are shifting towards using agro-industrial by-products. Although cassava is an ideal partial substitute of maize as source of energy, livestock producers have not yet exploited this potential to the fullest. This can be attributed to the high moisture content of the cassava tuber, which makes handling, transportation and storage difficult. The poor content of cassava in protein, vitamin and some minerals could be another factor, which might have contributed to its low usage as animal feed in Ghana.

The high moisture levels of cassava which reduces its shelf-life and the high content of cyanogenic glycoside which releases toxic Hydrocyanic acid, detrimental to the health and productivity of livestock as well as its low protein content are challenges which need to be addressed for the efficient use of the crop as animal feed in Ghana. Cassava roots can be sliced to appropriate thickness and dried using solar dryers, reducing in this way the moisture levels responsible for mould infestation and mycotoxin production. Slicing and drying cassava, in addition to extending its shelf life, reduces also the level of Hydrocyanic acid to safe levels for animal feeding.

Lessons learned from projects implemented in the country in the past assist in setting up easy and affordable methods of slicing and drying cassava. The limitation of cassava due to its low content of protein, some vitamins and minerals, leading to rating it inferior to maize can also be corrected through proper balancing. In order to enhance the demand and supply of cassava based feed in Ghana it is necessary to develop viable intermediaries acting as secondary processors or bulking agents in the value chain and ensuring a consistent supply of raw and processed materials. The private sector can and should participate actively in this regard. Therefore, effective sensitization of the actors involved in the cassava value chain on its potential and policy measures enabling its use as animal feed is required. The use of cassava as animal feed in Ghana can reduce the current high cost of feed, increase livestock production and create job opportunity.

1. INTRODUCTION: GHANA

1.1 GEOGRAPHICAL LOCATION

Ghana, officially the Republic of Ghana and formerly the Gold Coast, lies within latitude 4° 44'N and 11°11' N and 3° 11'W and 1°11' E. The Republic of Togo borders Ghana on the east, Burkina Faso on the north-west and north and Côte d'Ivoire on the west. The Gulf of Guinea of the Atlantic Ocean lies south of the country, forming a coastline 550 km long (Figure 1).

Figure 1: Administrative map of Ghana

Source : http://www.nationsonline.org/oneworld/map/ghana_map.htm (Accessed on 13.03.2013)

1.2 HUMAN POPULATION

Table 1 shows the population trend of Ghana from 2006 to 2012. The rural population was lower than urban population since 2008.

Table 1: Human population trend

Value expressed in 1 000 inhabitants

Population segment	Year						
	2006	2007	2008	2009	2010	2011	2012
Total	22 171	23 712	23 264	23 824	24 392	24 966	25 546
Rural	11 541	11 524	11 631	11 736	11 837	11 935	12 028
Urban	10 756	11 189	11 633	12 088	12 555	13 031	13 518
Agricultural	12 149	12 397	12 640	12 884	13 129	13 375	13 622

Source: FAO (2013)

1.3 CONTRIBUTION OF AGRICULTURE TO FOOD SECURITY AND ECONOMY

Agriculture contributed 30.2 percent of Ghana's GDP with Real GDP Growth of 4.8 percent in 2010. Agriculture accounted for over 40 percent of export earnings while at the same time provided over 90 percent of the food needs of the country. The food balance sheet showed that domestic food (crop) production available for human consumption was 21 343 133 tonnes while the estimated national consumption was 12 220 963 tonnes leaving a net surplus of 9 123 197 tonnes. Maize is a major feed ingredient in livestock feed, and in particular that of the non-ruminant animals, and constitutes about 50-60 percent of non ruminant feed. Cassava is increasingly being used to partially replace maize in livestock feeding, therefore making it an important input into the national food security. The estimated national cassava, maize and meat consumption for 2010 were 152.9, 43.8 and 7.1 kg/capita/annum (MOFA, 2011).

2. LIVESTOCK IN GHANA

2.1 LIVESTOCK POPULATION

Population of the various species of livestock increased gradually from 2006 to 2010 at an annual growth rate of 1.13 to 10.08 percent for cattle and poultry respectively (Table 2).

Table 2: Livestock population trend

Values expressed in 1 000 animals

Species	Year					Annual growth rate %
	2006	2007	2008	2009	2010	2006 -2020
Cattle	1 392	1 407	1 425	1 438	1 454	1.13
Sheep	3 314	3 420	3 471	3 642	3 759	3.36
Goats	3 997	4 196	4 305	4 625	4 855	5.37
Pigs	477	491	520	521	536	3.09
Poultry	34 030	37 038	39 816	43 320	47 752	10.08

Source: FAO (2013)

The annual growth rate of livestock population expressed in livestock unit (LU) from 2006 to 2010 was 4.2 percent. The highest and lowest growth rates were recorded for poultry and cattle respectively (Table 3).

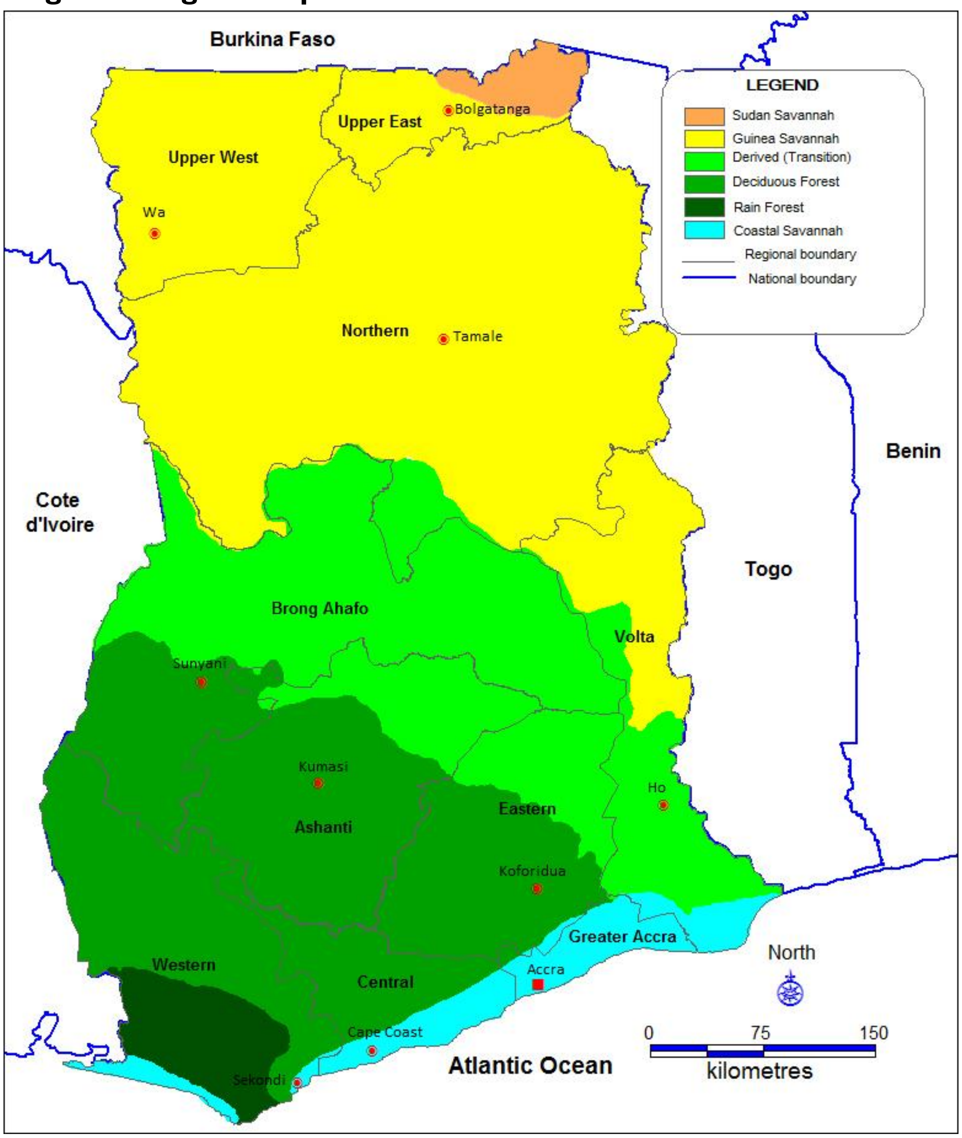
2.2 SOCIO-ECONOMIC VALUE OF LIVESTOCK

The livestock sector, including poultry, is an important component of Ghana's agriculture, and contributes, in direct products, about 6.1 percent to agriculture GDP with a growth rate of 4.7 percent (MOFA, 2011). This amount does not include the value of secondary products, such as manure, animal traction and transport which are provided to the crop sector. Livestock supplies not only meat, milk and eggs as a source of animal protein to enhance the nutritional status of the human population but also provides skins, bones, blood and horns for various uses. Manure from livestock is now an invaluable resource to crop and vegetable farmers for the maintenance of soil fertility and structure. The use of bullocks for land preparation in the Sudan and Guinea Savannah ecological zones allows farmers to crop larger areas than would have been possible in view of the high cost involved in using tractor power and occasional unavailability of tractors. Agriculture provides employment opportunities to a large part of the population, particularly in the rural areas. It offers prospects for wealth creation, income enhancement and improvement in rural livelihoods (Oppong-Anane, 2010). Out of 2.7 million farm families in 2006, 1.5 million kept livestock. Because crop farming in Ghana is rain fed, income from crop farming is only seasonal and poverty among food crop farmers is very high. Livestock provides the cash resource during the non-farming season and a safety net of capital assets to face grave financial difficulties.

2.3 LIVESTOCK FARMIMNG SYSTEMS

Ghana has five agro-ecological zones (Table 3; Figure 2). Ghana's agriculture is predominantly smallholder, traditional and rain-fed, and the farming systems vary with agro-ecological zones. However, certain general features are discernible throughout the country. The bush fallow system prevails wherever there is ample land to permit a plot to be rested enough to recoup its fertility after one to three year cultivation. Staple crops are often mixed-cropped while cash crops are usually mono-cropped. Although the majority of rural households keep some sort of livestock, livestock farming is adjunct to crop farming. Commercial poultry production predominates in the south, while cattle production is concentrated in the Savannah zones. Sheep and goat production is generally widespread throughout the country.

Figure 2: Agro-ecological map of Ghana



Source: Map produced by editors based on data compiled by SRDA (2001)

Table 3: Farming systems by agro-ecological zones

Ecological Zone	Farming system		
	Crop	Livestock	Crop - livestock
Sudan	5	5	90
Guinea	16.8	1.8	81.5
Derived	38	0	62
Forest	28	8	64
Coastal	21	9	70
National	21.8	4.7	73.8

Source: Oppong-Anane *et al.* (2008)

The major farming system practiced nationwide is mixed farming (crop-livestock system) where about 74 percent of the rural households cultivate crops and rear some livestock (Table 4). This system is more prevalent in the northern Savannah zones, for instance in 2008 only 5 percent of the households in the Sudan Savannah zone undertook livestock rearing or cropping alone, while over a third of the households in the Derived Savannah zone practiced only crop farming (Oppong-Anane *et al*., 2008).

2.3.1 Non-ruminant farming systems

Poultry: Various species of poultry are kept mainly in the rural, and a few in urban households under semi-intensive production system for home consumption and the surplus is sold. Management is rudimentary and inputs, in the form of feed and health care, are minimal with not much provision made for housing and breeding. High mortality of birds in this system results mostly from viral diseases. Intensive or commercial poultry keeping, the best organized livestock enterprise in the country, operates mainly in the peri-urban areas in the Coastal Savannah and Forest zones (Oppong-Anane *et al*., 2008). There are two major lines of the commercial poultry industry, namely layer production for eggs and broiler production for meat. Both are highly intensive high capital outlay, and demand efficient and effective management, proper feeding and effective disease prevention and control to succeed. The poultry industry consumes about 30 percent of the locally produced maize and relies heavily on imported inputs, such as fish meal, soymeal, mineral and vitamin premixes, drugs and vaccines whose prices are determined by the exchange rate. Large volumes of yellow maize are also imported to augment local supply. High costs of inputs coupled with high interest rates on bank loans have resulted in locally produced poultry not being able to compete favourably with imports (Oppong-Anane, 2010).

Pigs: Semi-extensive pig production pertains under the traditional smallholder practice in the rural areas. The system is based mainly on the indigenous Ashanti Black pig, which is found throughout the country and constitutes about 70 percent of the national pig population. Crosses between the indigenous and exotic breeds are also used in this system. The pigs are kept in pens and are given minimal feed based on household leftovers, and in particular fresh and boiled cassava and cassava peels. In some cases, the pigs are allowed to scavenge for food (Oppong-Anane, 2010).

Intensive pig production system is based mainly on the exotic Large White and Landrace breeds and their crosses. The system is practiced mainly in the southern areas of the country. This system is commercialized and may be classified as small, medium or large scale. The growth of the intensive system appears to fluctuate with the most rapid increases occurring when there is a shortage of maize and some poultry producers switch to pig farming (Oppong-Anane, 2010).

2.3.2 Ruminant Farming Systems

Sheep and Goats: Extensive sheep and goat farming system, also known as traditional small ruminant production system consists largely of free grazing village flocks of Djallonké sheep and goats normally exhibiting poor productivity. Diseases, mostly helminthiasis and *peste des petits ruminants*, are the main causes of poor productivity and high mortality among the animals. This system is progressively changing into semi-intensive system throughout the country (Oppong-Anane, 2010).

In the sheep and goat semi-intensive farming system simple pens are provided for the animals within or attached to the owner's house. The system is based on cut and carry of forages, and the use of household wastes, mainly cassava pellets and peels, and plantain peels. Various other crop residues and crop by-products are also used. The intensive system is similar to that of the semi-intensive except that in the former all the feed is provided in the pen. This system is commonly practiced in the peri-urban areas, and in particular the 'Zongo' communities comprising mainly by people of Hausa and northern Ghana extract. The system supplies fattened rams and bucks for the urban market, particularly during religious festivities. Crossbreeding of the Djallonké sheep and goats with the long-legged and larger Sahelian sires is common in the intensive system (Oppong-Anane, 2010).

Cattle: The extensive beef cattle farming system is the main cattle production system practiced in the country and is based mainly on extensive grazing by smallholder herds. It is linked with milk production system whereby milk is shared between the herdsman and the calf, with the surplus going to the market. In this system, settled farmers whose main occupation is crop cultivation own cattle. Ownership may be direct, personal and individual, or in the form of trusteeship for family property. Where a large herd is found, the family groups owning them may be several, varying widely in size and in relationship. Commercial cattle farming is mainly practiced in the Coastal and Derived Savannah zones with varying levels of management which are higher than that of the extensive system. The cattle are owed mainly by professionals and businessmen living elsewhere with little or no involvement in the management of the animals. A few farms belonging to state institutions also fall under this system. In this case, cattle may graze on sown pastures as well as natural pastures, which are often improved with forage legumes (Oppong-Anane, 2010).

Over 90 percent of the domestic milk production comes from agro-pastoral herds. Milk off-take from the herds is low, about 0.8 and 0.4 liters/cow/day in the rainy and dry seasons respectively. The local breeds of cattle used in this system have limited genetic potential for milk production and remain mediocre producers even when the best possible feeding and husbandry conditions are available. There are about a hundred households keeping between one and six dairy cows at their backyards on commercial basis, and using Friesian - Sanga crossbreds or Jersey cows in the peri-urban areas of the Greater Accra and Eastern regions in the Coastal Savannah zone (Oppong-Anane, 2010). A household that had been in the dairy business for over 15 years using Friesian - Sanga crossbreds fed the cattle on forages, wheat bran, palm kernel cake, cassava peels and cassava leaves. The cows produced on the average 2 700 kg of milk per lactation in 2007 (Oppong-Anane, 2008).

2.4 LIVESTOCK FEEDING SYSTEMS

2.4.1 Non-Ruminant Feeds and Feeding: Non-ruminant livestock production in Ghana has been severely constrained by lack of feed of good quality and consistency. It is only in the intensive systems of commercial poultry and pig production that livestock tend to be fed adequate rations for satisfactory productivity. Acute shortage of feed occurs in the intensive rearing systems due to escalating prices of maize and other major feed ingredients, including agro-industrial by-products (Table 4), thus raising the cost of poultry and pig production (Oppong-Anane, 2010). Commercial feed millers, falling under the Ghana Feed Millers Association (GFMA), supply poultry feed mostly to the medium- and small-scale poultry producers because the large-scale producers make their own feed. Only a few of the pig farms obtain their feed from the commercial feed millers, having switched to on-farm feed production to cut down on feed cost. The commercial feed millers produced mainly mash feed, a few produced concentrates, and one feed mill produced pellets feed in 2009. Most small- and medium-scale poultry producers prefer feed concentrates because it is cheaper, convenient and less bulky for transportation. About 90 percent of feed produced by commercial feed millers is layer feed. Broiler feed is primarily purchased by small-scale backyard poultry producers. However, there is a seasonal feed demand from the larger producers who raise birds for the festive seasons such as Christmas and Easter. Poultry feed accounts for about 70 percent of the total feed produced in Ghana (Oppong-Anane, 2010). GFMA was formed in 1984 with 27 members and headed by a Chief Executive. The GFMA aimed at providing the livestock industry with premium quality and affordable feed. The membership of the GFMA declined to 16 by 2012 as a result of poor patronage of their feed resulting from the folding up of a number of the medium and small scale farms as they could not compete with the low priced imported poultry products amounting to 72 418 tonnes in 2012.

Table 4: Major agro-industrial by-products production by ecological zones

Feed Resource	Sudan Savannah	Guinea Savannah	Derived Savannah	Forest	Coastal Savannah
Wheat bran				*	*
Rice bran	*	*	*	*	*
Maize bran	*	*	*	*	*
Millet mash	*	*	*		
Pito mash	*	*	*		
Brewers spent grain				*	*
Spent yeast				*	*
Oil seed cakes	*	*	*	*	*
Coconut chaff				*	
Cassava tuber & peels		*	*	*	*
Cottonseed cake		*	*		

Source: (Oppong-Anane, 2010). Blanks indicate non use of Agro-Industrial By-Product (AIBP) as a major feed ingredient.

In the northern Savannah zones, pito mash, a by-product of millet brewing, forms the bulk of pig rations, while wheat bran is the mainstay of most commercial pig units in the Forest and savannah zones. Maize and rice bran are available in all the ecological zones. Though cassava tuber and peels are used in all the zones for feeding pigs, its utilization is lower in the Sudan Savannah zone (Oppong-Anane, 2010).

The major cost item in non-ruminant intensive system is feed; conservatively this has hovered between 60 and 75 percent of the total production cost. The main ingredients for non-ruminant feed, maize, is locally produced, though inadequate to meet the year-round demand of the industry. Therefore yellow maize is regularly imported to augment local supply (Okai, 2010). Maize forms about 50-60 percent of the compound feed with poultry industry and consumes about 30 percent of all maize produced in the country. Feed prices in Ghana have been rising, primarily due to the rising cost of maize, which is higher than cassava (Table 5). As a result of the scarcity and high cost of white maize the government periodically approves of the importation of yellow maize. Attention is now being focussed on the use of AIBPs as alternative to the expensive maize as energy source in livestock feeding. This is particularly so with pig farmers. Surprisingly, cassava which has been shown to be a suitable partial substitute to maize in livestock feed is not being fully exploited for feeding non-ruminants in Ghana. This could be attributed to the challenges associated with the high water content in cassava tuber which render preservation, transportation and handling difficult. The low protein content and high crude fibre of the cassava tuber also contribute to its low usage as livestock feed in the country.

Table 5: Average wholesale prices for maize and cassava (GH¢)

Commodity	Unit of sale (kg)	2006	2007	2008	2009
Maize	100	23.6	27.5	48.2	55.9
Cassava	91	12.7	12.8	16.5	20.1

Source: MOFA (2010); GH¢/US$: 1.4 -2009; 1.1 -2008; 0.95 -2007; 9,175* -2006;
*Exchange rate prior to GH¢ devaluation (CIA, 2010)

Some AIBP and non conventional feed resources commonly used in both Ghana and Nigeria are shown in Table 6. Properly formulated and compounded feeds tend to be the norm only in the research stations, universities and large-scale commercial farms. In Ghana, the latter are very few indeed (Okai, 2010). A typical pig diet in Nigeria may contain the ingredients shown in Table 7. In Ghana however, the chemical composition may be similar but sorghum and the addition of palm oil to diets has not gained popularity as may be the case in Nigeria (Okai, 2010). Most of the commercial; feed mills also include some AIBPs in their formulations in an attempt to produce low priced diets.

Table 6: Some agro-industrial by-products and non-conventional feed resources used for pigs in Ghana and Nigeria

Brewers spent grains (wet/dried)	Mucuna (raw, cooked, processed)
Cassava (foliage, peels and tuber)	Oil palm sludge
Citrus pulp	Palm kernel meal
Cocoa pod husk	Pawpaw peels and foliage
Copra cake	Rice bran
Groundnut cake	Rubber seed meal
Groundnut skins	Sheanut cake
Maize bran	Sorghum or Guinea corn
Mango kernel meal	Watermelon rind
Molasses (fresh/dried)	Wheat bran/ offal

Source: Okai (2010)

Table 7: General composition of pig diets in Nigeria

Ingredient	Quantity of ingredient (kg) required per tonne of feed		
	Sow	Weaner	Grower
Maize	550	510	250
Sorghum			150
Cassava		150	200
Groundnut cake	100	100	
Palm kernel cake	30		
Soybean meal		50	100
Cottonseed meal		20	45
Blood meal	15	55	45
Fishmeal	80		25
Wheat offal	125	65	70
Rice bran			65
Brewer spent grains	50		
Bone meal	30	30	30
Salt	3	3	3
Vitamin-mineral premix	2	5	5
Palm oil	15	15	15

Source: Fagbenro and Adebayo (2005)

2.4.2 Ruminant Feed and Feeding: Sustenance for cattle in Ghana, and to lesser extent small ruminants, is almost entirely dependent on grazing of natural pastures and rangeland, comprising of Savannah woodlands and unimproved pastures which constitute 45 percent of the total land area (MOFA, 2011), with extreme seasonal variation in quantity and quality. Some farmers practice supplementary feeding, using crop residues including cassava peels and cassava leaves as well as cut-forages particularly during the dry season. In the more humid areas, livestock have access to crop residues but their availability is irregular and also they become scarce during the dry season. Where opportunities of sales during festivities arise, ruminant stocks are fattened with additional feed inputs. The bulk of the feed in the extensive production systems lack adequate nutrients for satisfactory productivity. Supplemental feeding is critical in these systems. In some communities where cropping is undertaken, mainly in the immediate environs of settlements, sheep and goats are let loose only after the crops have been harvested to avoid damage to crops. Otherwise they are tethered and graze in limited areas. They are, however, moved to different areas daily to ensure access to adequate forage (Oppong-Anane, 2010). Tables 8 and 9 show main feed sources used by cattle and sheep/goats respectively in 2007.

Table 8: Main feed sources for cattle by ecological zones

Feed source	Percentage respondents indicating feed item as main feed source for cattle in the ecological zones				
	Sudan Savannah	Guinea Savannah	Derived Savannah	Forest	Coastal Savannah
Natural pasture	100	85.2	94.6	73.3	100
Shrubs		3.7	5.4	20.0	
Cassava peels/leaves		7.4			
Pito mash		3.7			

Source: Oppong-Anane *et al.* (2008). Blanks indicate feed items not being major feed sources.

Table 9: Main feed sources for sheep and goats by ecological zones

Feed source	Percentage of respondents indicating main feed source for sheep and goats in the ecological zones									
	Sudan Savannah		Guinea Savannah		Derived Savannah		Forest		Coastal Savannah	
	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goats
Natural pasture	100	100	64.1	71.4	71.7	52	38.1	39.7	46	36
Shrubs			6.1	3.6	11.5	11.4	8.2	6.3	32.3	8.7
Wheat bran			2	1.8	3.8	2.9			3	4.3
Rice bran			10.2	5.4	2.4	2.4		1.6	2.3	2.2
Maize bran			2	5.2	1.3	17.1	22.2	12.8	1.2	1
Pito mash			2	3.6		2.9				
Cassava peels*			10.4	3.6	5.4	5.7	26	30	15.2	47.8
Cassava leaves*			3.2	5.4	3.9	2.9	2.8	4.8		
Plantain peels						2.7	2.7	4.8		

Source: Oppong-Anane *et al.* (2008) and *Field Data, Cassava as animal feed in Ghana: Past, Present and Future (2013). Blanks indicate feed items not being major feed sources.

3. CASSAVA

3.1 DISCRIPTION

Cassava, *Manihot esculenta* is a native of South America, and widespread throughout the tropics and subtropics, including Sub-Saharan Africa. Cassava is a perennial woody shrub with an edible root (Heuzé *et al*., 2012b). The main production areas are within latitudes 30°N and 30°S of the equator, at elevations of not more than 2,000 meters above mean sea level. Optimal growth conditions are annual average temperature over 18-20°C, annual rainfall ranging from 500 mm to 3,500 mm, high solar radiation and light, and well drained and acid soils. Cassava may withstand light frosts in altitude and cloudy conditions in the hot humid lowland equatorial belt (Heuzé and Tran, 2012).

3.2 IMPORTANCE AND USES

Cassava provides the livelihood to up to 500 million farmers and countless processors and traders around the world (FAO and IFAD, 2001). It is the staple food of many people in the tropical and sub-tropical belt and also raw material for numerous industrial applications. In Sub-Saharan Africa cassava is mainly a subsistence crop grown for food by small-scale farmers who sell the surplus (IFAD, 2012) for cash to meet family and other needs. As a perennial crop, it can be harvested as and when required and its wide harvesting period allows it to act as a famine reserve (Stone, 2002). The leaves are eaten as a vegetable, and the starchy root is eaten raw or cooked, or processed into flour and other derivatives (IFAD, 2012). Prominent among its industrial applications are the use for glue, pharmaceutical products, confectionery, spices, paper cartons, animal feed, pastries, textile, dry cell batteries, toothpaste and biodegradable products. The demand for cassava by bioenergy sectors has emerged as a significant driver in the expansion of cassava utilization for production of ethanol. In effect, about 280 litres of 96 percent pure ethanol can be produced from one tonne of cassava (UNCTAD, 2012).

3.3 NUTRITIONAL PROFILE

The principal parts of the mature cassava plant expressed as a percentage of the whole plant are leaves 6 percent; stem 44 percent and storage roots 50 percent. The roots and leaves of the cassava plant are the two nutritionally valuable parts, which offer potential as a feed source. There is considerable variation in the chemical composition of cassava root and leaves according to variety, age of plant and processing technology (Smith, 1988).

Cassava root: Cassava roots contain sucrose, maltose, glucose and fructose in limited levels. The raw starch of the cassava root has a digestibility of 48.3 percent while cooked starch has a digestibility of 77.9 percent. Cassava root is a poor source of protein. However, the quality of the protein is fairly good as far as the proportion of essential amino acid as a percentage of total nitrogen is concerned. The amino acid level of cassava roots show high levels of lysine and tryptophan in its true protein fraction. Methionine and cysteine are, however, limiting amino acids in the root. Peeling results in the loss of a part of the valuable protein content of the root because the peel contains more protein than the root flesh. The lipid fraction of cassava flour is 2.5 percent and is 50 percent extractable with conventional solvents. The extractable lipids are mainly polar in nature, the principal group being galactosy/diglycerides (Smith, 1988). The cassava root is a relatively poor source of crude protein (Table 10) and minerals (Table 11).

Cassava leaf: Cassava foliage is a potential source of high and good quality crude protein for livestock feeding (Table 10). Cassava leaf blades are especially rich in protein (average 30.5 percent) and the protein content reduces to 13 percent for whole foliage. Essential and non-essential amino acids can be found in good levels in cassava leaves. The leaves are low in methionine with values of 1.7 g/100 g of crude protein. Lysine content is high in the leaves (7.2 g/100 g crude protein). A major proportion of the leaf carbohydrate is starch; the amylose content of the leaf starch is in the range of 19-24 percent. The crude fibre content of cassava leaves is low which makes it palatable as poultry feed. However, when harvested with the tender stem the fibre becomes as high as 13.9-16.9 percent. The leaves are rich in calcium but low in phosphorus compared with maize and sorghum. Cassava foliage meal contains as high as 56 000 IU of vitamin A as compared with 14 200 IU in alfalfa meal, 66 IU in ground yellow maize and 264 IU in wheat flour. This high content of vitamin A is significant in the pigmentation of egg yolk and skin of poultry. The annual yield of cassava foliage has been reported to be as high as 90 tonnes fresh leaves/ha if harvested three times a year (IFAD and FAO, 2004).

Table 10: Chemical composition of cassava parts (% DM) except gross energy (MJ/kg DM)

Constituent	Foliage[a]		Peel[b]		Tuber[c]	
	Range	Mean	Range	Mean	Range	Mean
Crude protein	17.2-29.3	24.9	3.7-5.9	4.8	1.4-4.6	2.6
Crude fiber	10.3-24.8	17.7	10.3-31.8	21.0	2.0-5.7	3.7
NDF	24.0-58.8	42.3	15.8-35.5	19.6	0.8-3.2*	1.4*
ADF	18.1-36.4	27.2	15.6-18.6	17.1		5.3
Lignin	6.5-11.8	9.4	4.0-12.1	7.2		1.6
Ether extract	5.0-9.0	6.8	0.0-3.3	1.3	0.4-1.5	0.8
Ash	4.9-9.6	7.4	3.4-8.0	5.7	2.1-4.8	2.8
Gross Energy	49.8-22.0	19.9	16.4-17.7	17.7		17.1

Sources: [a]INRA *et al.* (2012a); [b]INRA *et al.* (2012b); [c]INRA *et al.* (2012c); *Smith (1988).
Dry matter (% as fed) Mean: Foliage22.5; Peel 28; Tuber 37.6

Table 11: Mineral content of cassava (g/kg DM) except Zinc, Copper and Iron (mg/kg DM)

Constituent	Foliage		Peel		Tubers	
	Range	Mean	Range	Mean	Range	Mean
Calcium	7.4-18.4	11.9	0.1-3.3	1.7	1.0-2.0	1.6
Phosphorus	2.3-6.2	3.7	1.0-3.2	2.1	0.2-1.9	1.2
Potassium	8.7-22.2	12.5	0.3-12.5	6.4	5.2-11.7	7.7
Magnesium	3.2-10.3	7.3	0.2-0.9	0.6	0.8-1.5	1.1
Sodium	0.5-0.7	0.6		0.3		
Zinc	20-29	25				
Copper	29-30	29				
Iron				15		

Source: INRA *et al.* (2012c).

Cassava peel: This is an important source of energy in ruminant feeding systems, serving either as the main basal diet or as a supplement. Cassava is rarely fed fresh because of the high level of cyanogenic glycoside. Sun drying, ensiling and fermentation are used to reduce the concentration of the glycosides to tolerable levels (Smith, 1988). Cassava peels are highly digestible products, with reported values of 78 percent and 81 percent for DM and OM total tract digestibility respectively. Dry matter degradability is also high, with reported values higher than 70 percent (Heuzé *et al*., 2012a).

Toxic factors in cassava: The cyanogenic glycosides of cassava (linamarin and lotaustralin) on hydrolysis release hydrocynic acid (HCN). The concentration of the glycosides varies considerably between varieties and also with climatic and cultural conditions. The normal range of cyanoglucosides content in fresh roots is from 15-400 mg/kg fresh weight. There are varieties with very low HCN content of 10 mg/kg or very high HCN content of 2 000 mg/kg. Cassava is often classified as “bitter or sweet” according to the amount of cyanide present. However, the bitterness or sweetness could not be exactly correlated with the level of cyanogenic glycosides (IFAD and FAO, 2004). Safety limit for cyanide in cassava food is 10 mg/kg dry weight and levels below 100 mg/kg dry weight are considered safe in cassava chips for feeding to different classes of livestock (FAO and IFAD, 2004).

4. CASSAVA PRODUCTION

4.1 GLOBAL PRODUCTION OF CASSAVA

Global production of cassava increased from 223 818 045 tonnes in 2006 to 230 265 639 tonnes in 2010 (Table 12). Africa contributed 52.8 percent of the global supply, with Nigeria contributing 30.8 percent of African production amounting to 37 504 100 tonnes. Cassava production in Nigeria, the highest producer globally, was 156.8 percent of that of Indonesia, the second top producer (FAO, 2013). Whereas cassava production in Africa is mainly for food, Asia encourages the development of cassava crops for industrial and energy purposes. In Latin America and the Caribbean, cassava production reduced from 36 443 530 to 32 997 971 tonnes between 2006 and 2010. Brazil dominated with 24 496 300 tonnes which was 74 percent of the regional production in 2010 (FAO, 2013).

Table 12: Global, Africa and Western Africa Production of Cassava (1 000 tonnes)

Region/Country Group	2006	2007	2008	2009	2010
Global	223 818	226 344	232 111	235 040	230 266
Africa	119 017	116 428	121 071	120 434	121 661
Western Africa	63 249	62 244	66 030	58 621	60 141

Source: FAO (2013)

4.2 PRODUCTION OF CASSAVA IN SUB SAHARAN AFRICA

The African production of cassava (121 661 234 tonnes) is almost exclusively from the sub-Saharan Africa, bordered by Mauritania, Mali, Niger, Chad and Sudan to the north and extending to the southern tip of the continent, (Table 13. It is not an important crop in the northern Africa sub-region which produced a mere 13 500 tonnes in 2010. Cassava plays a major role in alleviating the African food crisis because of its efficient food energy production, year-round availability, tolerance to extreme climatic conditions and suitability to present farming and food systems. In spite of net food importation in Africa since early 1970s and food production growing at half the population growth rate from 1970 to 1985, cassava production in Africa has increased tremendously since then with the continent producing over half of the global production, and Nigeria replacing Brazil as the leading cassava-producing country in the world (IFAD and FAO, 2004). In 2010 the major producers of cassava in Africa were Nigeria, followed by the Democratic Republic of Congo, the fourth largest producer (15 049 500 tonnes), then Angola (13 858 700 tonnes), Ghana (13 504 100 tonnes) and Mozambique (5 700 000 tonnes) holding the fifth, sixth and tenth highest producers respectively globally (FAO, 2013).

Table 13: Top cassava producing countries in Africa, 2010

Rank	Country	Production value (US $ 1 000)	Production (tonnes)
1	Nigeria	3 917 790	37 504 100
2	Indonesia	2 448 414	23 918 100
3	Thailand	2 298 781	22 005 700
4	Democratic Republic of the Congo	1 556 394	15 049 500
5	Angola	1 447 721	13 858 700
6	Ghana	1 410 678	13 504 100
7	Brazil	1 280 935	24 524 300
8	Viet Nam	890 199	8 521 670
9	India	841 950	8 059 800
10	Mozambique	595 439	5 700 000
11	Uganda	551 773	5 282 000
12	Cambodia	443 698	4 247 420
13	China	440 434	4 684 000
14	United Republic of Tanzania	437 926	4 392 170
15	Malawi	417 955	4 000 990
16	Benin	375 648	3 596 000
17	Madagascar	314 317	3 008 890
18	Cameroon	284 306	3 024 000
19	Rwanda	248 330	2 377 210
20	Côte d'Ivoire	240 979	2 306 840

Source: FAO (2013)

4.3 PRODUCTION OF CASSAVA IN WESTERN AFRICA

In 2010 five out of the 20 top producer countries of cassava were from Western Africa. The sub-region experienced a decline in production of 2.2 percent from 2006 to 2007, an increase in 2008, and a decrease again by 0.5 percent from 2008 to 2009 (Table 14).

Table 14: Global, Africa and Western Africa production of cassava (tonnes)

Region/Country	2006	2007	2008	2009	2010
Global	223 818 045	226 344 016	232 111 249	235 040 287	230 265 639
Africa	119 016 937	116 428 335	121 070 978	120 434 212	121 661 234
Western Africa	63 248 727	62 243 992	66 030 324	58 621 144	60 141 497

Source: FAO (2013)

4.4 PRODUCTION OF CASSAVA IN GHANA

Ghana was the sixth highest cassava producer country globally and the fourth highest producer in Africa in 2010 (FAO, 2013). In the same year, Ghana produced 13 504 000 tonnes of cassava, making it the most highly produced agricultural commodity in the country in terms of quantity and value. Cassava production increased progressively from 2006 to 2010 (Table 15). Cassava is second to maize as the most widely grown crop by area (875 000 ha). It is grown by most farming households. The mean cassava yield (13.8 tonnes/ha) was 28.34 percent of the achievable yield of 48.7 tonnes/ha under rain-fed condition (MOFA, 2011). The yield of cassava in the country is estimated to be 20-30 percent higher than the global and African averages, and has a potential for greater yield with improved agronomic practice, mechanization and the use of improved cassava varieties. The characteristics of the cassava varieties released in the country since 2005 are presented in Table 16.

Table 15: Production and cassava planted area in Ghana

Parameter	Year				
	2006	2007	2008	2009	2010
Area planted ('000 ha)	790	801	840	886	875
Production ('000 tonnes)	9 638	10 218	11 351	12 231	13 504

Source: MOFA (2011)

IFAD has been one of the main institutions directly involved as a sponsor of the programmes in cassava production, processing and marketing in Ghana. At the production level, one of the most innovative features of the IFAD-supported national programme, Root and Tuber Improvement Programme, has been its focus on testing and distributing new varieties of cassava (IFAD, 2012). It successfully developed new and better varieties of cassava and created an effective multiplication and distribution system thereby increasing the availability of planting materials for smallholders (IFAD, 2004). Through the programme, about 760 000 farmers have planted new varieties, and many have participated in farmer field schools that the programme set up across the country. These schools teach groups of farmers, most of them women, on how to plant the new varieties. Participants are encouraged to pass on their knowledge to other farmers in the community. A new phase, entitled the Root and Tuber Improvement and Marketing Programme, is focusing on improving market linkages between producers and consumers to improve poor rural farmers' incomes (IFAD, 2012).

Table 16: Cassava varieties released in Ghana

Name of variety & Pedigree	Year of released	Preferred ecology	Characteristics		Institution
			Distinctness, uniformity, stability	Yield & Use	
CRI-Ampong **TMS 270**	2010	Forest, coastal and forest-savannah transition	Petiole colour: purple, Stem colour: greyish brown. Mean ht: 219.5 cm. Root skin colour: deep brown	Potential yield: 45 tonnes/ha, Dry matter: 36%, Resistant to Cassava Mosaic Disease, good for flour, starch and fufu (pounded boiled cassava)	CRI, Kumasi
CRI-Broni bankye **TMS 1**	2010	Forest, coastal and forest-savannah transition	Petiole colour: yellowish green, Stem colour: light brown, Mean ht: 210. 5 cm, Root skin colour: brown.	Potential yield: 40 tonnes/ha, Dry matter: 33%, tolerant to Cassava Mosaic Disease, good for flour, starch and bakery products	CRI, Kumasi
CRI-Sika bankye **TMS 498**	2010	Forest, coastal and forest-savannah transition.	Petiole colour: yellowish green, Stem colour: greyish brown, Mean ht: 205 cm, Root skin colour: brown.	Potential yield: 40 tonnes/ha, Dry matter: 36%, tolerant to Cassava Mosaic Disease, good for flour and starch production.	CRI, Kumasi
CRI-Otuhia **TMS 396**	2010	Forest, coastal and forest-savannah transition	Petiole colour: yellowish green, Stem colour: grey, Mean ht: 189 cm, Root skin colour: brown.	Potential yield: 35 tonnes/ ha, Dry matter 39%, tolerant to Cassava Mosaic Disease, good for starch and flour production.	CRI, Kumasi

Name of variety & Pedigree	Year of released	Preferred ecology	Characteristics		Institution
			Distinctness, uniformity, stability	Yield & Use	
CRI-Agbelifia **97/ 4962**	2005	Forest, coastal and forest-savannah transition.	Petiole colour: purple, Stem colour: greyish brown, Growth habit: no branching, Root skin colour: greyish yellow.	Potential yield: 50.8 tonnes/ha, 24.4% starch and good for starch and gari (grated and fried crispy cassava product) production	CRI, Kumasi
CRI-Essam bankye 97/ 4414	2005	Forest, coastal and forest-savannah transition	Petiole colour: yellowish green, Stem colour: light brown, Branching habit: high branching, Root skin colour: pale orange.	Potential yield: 48 tonnes/ha, 21% starch, and good for fufu, bakery products.	CRI, Kumasi
CRI-Bankyeh emaa 97/ 4414	2005	Forest, coastal and forest-savannah transition	Petiole colour: purple, Stem colour: brownish orange, Branching habit: low branching, Root skin cololur: greyish orange.	Potential yield: 48 tonnes/ha, 21% starch and fufu, and good for bakery products	CRI, Kumasi
CRI-Doku duade **97/ 4489**	2005	Forest, coastal and forest-savannah transition	Petiole colour: yellowish green, Stem colour: light brown, Branching habit: intermediate branching, Root skin colour: light orange.	Potential yield: 45 tonnes/ha, 24% starch and good for starch production.	

Name of variety & Pedigree	Year of released	Preferred ecology	Characteristics		Institution
			Distinctness, uniformity, stability		
Capevars Bankye **Selection out of 514 local collections made from Central and Western Regions of Ghana.**	2005	Savanna transitional, Deciduous forest, Evergreen rain forest	Purplish petioles. Young stem is green with purplish stripes. Mature stem is light brown. The skin of the root is dark brown, the rind is light purple, and the flesh is white. It is resistant to the cassava mosaic virus disease.	Quite early maturing, within 8-12 months. High yielding (20-64 tonnes/ha). Roots are mealy all year round. Starch yield is relatively high (above 25%). It is good for fufu and ampesi (boiled cassava), gari , flour, and agbelima (cooked fermented cassava mash) and industrial starch production.	University of Cape Coast
Bankye Botan **Selection out of 514 local collections made from Central and Western Regions of Ghana.**	2005	Savannah transitional, Deciduous forest, Evergreen rain forest	The young leaves are purplish in colour; the older leaves are green, while the petioles are light green. Height of first branching is usually above 150 cm. Roots: The skin is dark grey, while the rind is light grey, and the flesh is white. It produces seeds profusely.	Early maturing. Root yield is between 20 - 60 tonnes/ha. Roots are mealy only for a short period during the dry season. Good for gari, flour for bread and pastries kokonte (dried and powdered cassava cooked meal), and for industrial starch production	University of Cape Coast

Name of variety & Pedigree	Year of released	Preferred ecology	Characteristics		Institution
			Distinctness, uniformity, stability		
CRI-Afisiafi **TMS 30572**	1993	Selection from open-pollinated seed collected from Abasafitaa.	Petiole colour: yellowish green, Stem colour: light brown, Branching habit: intermediate branching.	Potential yield: 33 tonnes/ha, Dry matter: 30%, and good for fufu,flour and gari and kokonte	CRI, Kumasi
CRI-Abasafitaa **TMS 4(2) 1425**	1993	Forest, coastal and forest-savannah transition.		Potential yield: 33 tonnes/ha, Dry matter: 30%, good for fufu, flour, kokonte, flour and gari	CRI, Kumasi
CRI-Gblemoduade	1993			Potential yield: 50 tonnes/ha, Dry matter: 20%, good for gari.	CRI, Kumasi

Source: CSD (2013).
CRI: Crop Research Institute

5. CASSAVA SUPPLY AND CONSUMPTION FOR FOOD

5.1 GLOBAL SUPPLY AND CONSUMPTION OF CASSAVA AS FOOD

Africa and West Africa supply of cassava as food in 2009 were significantly higher than global supply (Table 7) in 2009. The Sub-Saharan Africa cassava food supply was the same as for Africa since Northern Africa value was negligible (FAO, 2013). It is expected that human consumption, industrial and livestock use of cassava will continue to increase with concomitant increase in production in the near future.

Table 17: Global cassava food supply in 2009

Region/Group/Country	Food supply quantity	
	kg/capita/year	kcal/capita/day
Global	14.3	37
Africa	58.7	152
Western Africa	92.2	233
Ghana	219.0	649

Source: FAO (2013)

5.2 SUPPLY AND CONSUMPTION OF CASSAVA AS FOOD IN GHANA

Cassava supply as food in Ghana was 219 kg/capita/year in 2009 (Table 19). It was significantly higher than both the African and Western Africa supplies. Ghana's supply increased gradually from 2006 to 2009, reaching 152.9 kg/capita/year, which was significantly higher than the global average (FAO, 2013). The total cassava production available for human consumption in Ghana was 9 452 860 tonnes, with estimated net consumption of 3 703 697 tonnes in 2010, leaving a net surplus of 5 749 164 tonnes which could have been used for industrial production and animal feed (MOFA, 2011).

Table 18: Estimated consumption of cassava in Ghana

Kg/head/year					
1980	1985	1990	1995	200O	2005
145.2	146.3	148.0	149.7	151.4	152.9

Source: MOFA (2011). Estimates are based on food available for human consumption from both domestic and import sources.

Per capita consumption of cassava in Ghana has been increasing over the years and rose from 145.2 in 1985 to 152.9 kg in 2010 (Table 18; MOFA, 2011), which is 191 percent of that of Africa. The consumption accounted for annual intake of 649 kcal/capita and 1.9 kg/capita protein in 2009 (FAO, 2013). The demand for cassava in Ghana is expected to continue to grow strongly due to its wide-ranging applications; in addition to being a key component of the Ghanaian diet, it is also being used by breweries and can be used as a replacement for wheat flour in pastries as well as its increasingly use for livestock feeding (Anon, 2012). A major brewery producing beer from cassava projected using 1 500 tonnes of cassava to be supplied by 1 500 to 2 000 farmers in 2013.

The economic production values of cassava in Ghana, which is the amount available for consumption was positively correlated with the wholesale prices; gives high positive coefficient values of 0.8 (Sagoe, 2006). Nominal weighed average rural wholesale price of cassava increased by 107 percent from 2006 to 2010, while the real average rural wholesale price increased by 33.8 percent for the same period (Table19; MOFA, 2011). Prices are, however, not stable in view of the highly perishable nature of the crop and the preferred form of purchase. Processing the crops would ensure a higher sale price for the farmer (Sagoe, 2006).

Table 19: Average rural wholesale price (GH¢) per tonne (2002) as the basic price

Parameter	2006	2007	2008	2009	2010
Nominal weighed	108.0	111.3	152.8	189.5	223.6
Real	57.3	53.9	64.2	68.9	76.6

Source: MOFA (2011)

6. USE OF CASSAVA AS ANIMAL FEED

6.1 GLOBAL USE OF CASSAVA AS ANIMAL FEED

Since the early 1930s cassava has been known and used in livestock feed as a substitute of grains. Initially cassava as a substitute for grains became possible because of its cost effectiveness relative to grains (especially maize) and later because of the increased demand of maize for human and other industrial uses such as in textiles, breweries and pastries. The first large-scale commercial users of cassava as a livestock feed resource were livestock farmers in the European Union. The major users of cassava as animal feed, in the form of dried chips and pellets, are Brazil and Colombia in Latin America, the Caribbean, Nigeria in Africa, Thailand and China in Asia and the Netherlands and Spain in Europe (FAO, 2008).

Table 20: Use of cassava as animal feed ('000 tonnes) in world, Africa and Western Africa

Region/Country Group	2006	2007	2008	2009
World	75 813	76 922	72 151	78 997
Africa	35 001	33 986	36 577	36 983
Western Africa	24 685	23 546	24 685	24 258

Source: FAO (2013)

In 2006, 34.4 percent of the global cassava production of 75 813 000 tonnes was used as animal feed (Table 20). The usage increased 4.20 percent by 2009 at an annual growth rate of 1.5 percent. In 2009, a total of 36 983 000 tonnes of cassava, comprising 46.8 percent of global usage was accounted for by Africa, while Asia accounted for 27 442 000 tonnes, 34.7 percent of global usage, and Southern America, the Caribbean and Central America used 13 971 000, 171 000 and 50 000 tonnes respectively (FAO, 2013). Cassava plays a minor role as a livestock feed ingredient in Africa, with the exception of Nigeria and Angola (Table 21) despite the high production of cassava in the region. In Western Africa, Nigeria is the only country making significant use of cassava as livestock feed, which accounted for 54.7 percent of the sub-region use in 2009. However, the quantity cassava used as livestock feed in Africa is probably underestimated because cassava roots and leaves are fed to sheep, goat and pigs on small-scale farms in the cassava producing areas, either in fresh or cut-and-dried form. Cassava production and livestock rearing in such places are highly complementary because cassava processing is carried out around homes; and sheep, goats and chicken feed on by-products of cassava processing (IFAD and FAO, 2004)

Table 21: Top countries using cassava as animal feed in Africa in 2009

Country	'000 tonnes
Nigeria	20 239
Angola	7 140
Ghana	2 762
Malawi	2 200
Uganda	1 718
Mozambique	613
Tanzania, United Republic of	570
Madagascar	120
Other African countries	1 621

Source: FAO (2013)

6.2 CASSAVA AS PARTIAL OR TOTAL SUBSTITUTE FOR OTHER ENERGY SOURCES

Energy sources constitute between 15 and 60 percent of compound livestock feeds and concentrates respectively. Presently, maize constitutes the bulk of the energy source in such rations. The difficulty in obtaining foreign exchange in many African countries has considerably reduced the imports of maize and other cereals. At the same time local production of cereal grains remains grossly inadequate for human food and animal feed industries. The shortages of grains have therefore resulted in astronomical increase in their price, particularly in a few months before harvest. Cassava production has been rising steadily in many African countries and its availability has only to be matched with competitive pricing to make its use in livestock feeds feasible. In places where it is a cheap carbohydrate source, it can supply adequate calories and therefore offer great potential as animal feed. However, due to limitations such as its low content of protein, vitamins and some minerals, lack of sulphur and amino acids such as methionine, it is often rated as inferior to maize. However, when properly balanced in proteins, vitamins and minerals, its suitability as an energy source in compound rations will be fully acceptable.

Other factors that need to be considered in formulating balanced cassava rations include:

- oil supplementation or pelletizing in order to reduce its dustiness (powdery nature) and the latter to improve the starch utilization. Also addition of fats and molasses or pelletizing have been found to improve palatability of cassava diets;
- adequate supplementation of non-ruminant rations with sulphur amino acids to detoxify residual hydrocyanic acid and supply enough for productive purposes;
- synchronize the release of nitrogen from forage with energy from cassava in ruminant rations in order to obtain favourable productive responses; and
- Advantage of non-protein nitrogen in the form of urea nitrogen or poultry droppings to provide cheap nitrogen in cassava feed for ruminant animals (IFAD, 2004).

6.3 DIFFERENT FORMS OF CASSAVA USED FOR ANIMAL FEED GLOBALLY

There are various forms of cassava products and by-products used as animal feed with cassava foliage, cassava peel, cassava chip, cassava pellet, broken cassava root , cassava pomace and cassava whey as the major ones. The cassava by-products are generally found in the vicinity of factories where cassava tubers are processed into starch or flour.

Cassava foliage (leaves and stems): Cassava foliage (stems and leaves) is a valuable fodder for livestock, yielding more than 6 tonnes of crude protein/ha/year if proper agronomic practices are directed toward foliage harvesting (Heuzé and Tran, 2012). Cassava foliage is a premium choice supplement in scarce conditions. The main characteristic of cassava leaves is their high protein content (24.9 percent DM) with a good amino acid profile except methionine, which is deficient. They are good sources of minerals (Ca and trace elements) and natural pigments (xanthophylls) although P and Na contents are rather low (Heuzé and Tran, 2012).

Cassava peel (fresh, dried, boiled or ensiled): Cassava peels can be used as a roughage and as an energy feed in ruminant diets. However, sun drying, ensiling and fermentation should be used to prevent HCN poisoning when using bitter cassava varieties. Cassava peels should not be fed alone, as their protein and mineral content cannot support optimum microbial synthesis in the rumen. Its optimal utilization requires sources of readily fermentable protein and by-pass protein as well as micronutrients including sulphur, phosphorus, and vitamin B. Cassava peels are valuable feed, and significantly increases animal performances when added to ruminant diets. Cassava peels are highly degradable in the rumen (81 percent dry matter degradability) (Smith, 1988).

Cassava pellets: Cassava pellets are obtained from dried and broken cassava roots by grinding and hardening into a cylindrical shape. The cylinders are about 2-3 cm long and about 0.4-0.8 cm in diameter, and are uniform in appearance and texture. Pellets are produced by feeding dried cassava chips into the pelleting machine, followed by screening and bagging. Powdered chips which fall down during pelleting are re-pressed into pellets. There is usually about 2-3 percent loss of weight during the process. Pellets have the following advantages over chips: quality is more uniform; they occupy 25-30 percent lesser space, thus reducing the cost of transport and storage; handling charges for loading and unloading are also lower; they usually reach their destination sound and undamaged, while a great part of a cargo of sliced chips get damaged in long-distance shipment because of sweating and heating. The pellets are also resistant to insect infestation (IITA, 2005).

Cassava chips: Cassava chip is the most common form in which dried cassava roots are marketed. The chips are dried irregular slices of roots, which vary in size but should not exceed 5 cm in length so that they can be stored in silos. Processing chips consists of peeling, washing, chipping the cassava roots, and then sun drying the slices or chips. The recovery rate of chips from roots is about 20-40 percent depending on the initial dry-matter content of the cassava roots and the final moisture of the chips (IITA, 2005). Cassava chip for use in livestock feeds should preferably be white or near white in colour, free from extraneous matter, moulds, insect infestation and damage and possess no peculiar odours.

Broken cassava roots: Broken cassava roots are similar to chips in appearance, but generally thicker and longer, often 12-15 cm long and of varying thickness. They are produced mainly in Africa where local processors prefer longer roots because of the domestic demand mainly for products suitable for human consumption, as cassava is a part of the staple diet. Once processed into chips the product becomes inedible for humans (IITA, 2005).

Cassava meal: Cassava meal is the powdered residue of the chips and roots after processing to extract edible starch. It is generally inferior in quality to chips, pellets and broken roots. It has lower starch content and usually contains more sand. The demand for this product is especially by small-scale farmers who produce their own feedstuffs. Since cassava meal does not require grinding, it can be readily mixed with other feed ingredients (IITA, 2005).

Cassava pomace (also called bagase, bran or pulp): During the processing of cassava starch, the residual pulp separated in the screening process is also used as an animal feed. It is usually utilized in the wet state (75-80 percent moisture content) in the neighborhood of the processing factory but is sometimes sun dried before use. This product is considered a by-product of the cassava starch industry and represents about 10 percent by weight of the cassava roots (IITA, 2005). **Cassava pomace contains less cyanogenic glycosides than the peels. It can be dried or ensiled. In order to be ensiled, cassava pomace is ground and added either 0.5 percent salt (on fresh weight basis) or rapidly fermentable carbohydrates such as ground maize or molasses before being placed in anaerobic conditions (in pits or plastic bags). Urea and minerals may also be added. Cassava pomace has a lower feeding value than cassava roots but can be included in ruminant diets** (Heuzé *et al*., 2012a)**.** Cassava pomace is a highly variable by-product as its composition is determined by starch extraction technology used in the processing plant. Its protein content is very low (< 4 percent DM, sometimes as low as 1 percent). Starch content can vary between 15 and 50 percent and NDF content may be higher than 35 percent on dry matter basis (Heuzé *et al*. 2012b).

Cassava whey: Cassava whey is the liquid pressed out of the tuber after it has been crushed mechanically. The whey and the pomace may be mixed together and form an effluent (Heuzé *et al*., 2012b). The proximate composition (g/100 g DM) of cassava whey is: crude protein 2.46, ash 1.88, and nitrogen free extractives 95.7. Crude fibre and fat are undetectable. The DM content of whey is 3.34% (Aro *et al*., 2010).

7. THE USE OF CASSAVA AS ANIMAL FEED IN GHANA

7.1 USE OF CASSAVA IN ITS DIFFERENT FORMS FOR ANIMAL FEEDING IN GHANA

It is estimated that 2 762 000 tonnes of cassava was used as feed in 2009 (FAO, 2013). Historically and presently cassava plays a minor role as an ingredient in commercial livestock feed in Ghana. Nevertheless, feeding cassava in its different forms as foliage (leaves and stems), peels (fresh, boiled, or dried) and tuber (chopped) to pigs, sheep, goats and cattle is common in the smallholder livestock farming system. Cassava peels are sometimes considered as waste, and are disposed off as rubbish or collected by other people free of charge. The cassava used for both smallholder and commercial livestock feeding, was higher than maize (774 000 tonnes), the major ingredient in commercial livestock feeds.

The use of cassava peels as the main feed source for small ruminants was highest in the Coastal Savannah ecological zone where about 48 percent of farmers fed the peels to goats. The highest use of cassava peels for sheep feeding was in the Forest ecological zone (30 percent). The higher of use of cassava peels in these two ecological zones might be associated with high availability of cassava residue in the zones rather than the importance attributed to it as animal feed. Feeding the peels to small ruminants was uncommon in the Sudan Savannah ecological zone. Although a few farmers fed cassava foliage to small ruminants in the country it was not considered as a major feed for small ruminants in the Sudan and Coastal Savannah ecological zones (Oppong-Anane *et al*., 2008). In the semi-intensive system cassava peels, chopped tuber and pellets are common for fattening rams and bulls for the urban market. The practice of feeding cassava (fresh and boiled chips and peels) to pigs is common among smallholder famers throughout the country. Cassava is currently not being used in the preparation of poultry and pig feed in commercial feed. Cassava peels and foliage were major feed items for cattle only in the Guinea Savannah ecological zone.

From 1991 to 1996 GAFCO, a major feed miller in Ghana successfully exported cassava chips to the European Union for use as livestock feed. During that period cassava flour was used in the feeds for various livestock species. Though the feed was highly patronised by farmers, production ceased when the export ended.

7.2 THE CURRENT LEVEL OF USE OF CASSAVA AS ANIMAL FEED IN GHANA

Cassava used for animal feed in Ghana estimated at 4 percent in 2000 (Nweke, 2003) rose sharply to 18.8 percent in 2006 and then to 22.6 percent in 2009 (Table 22). The use for animal feed increased by 931 000 tonnes, from 2006 to 2009, an increase of 50.8 percent (FAO, 2013). The phenomenal usage increase of 22.8 percent from 2008 to 2009 could be partially attributed to the technology transfer efforts on the use of cassava by-products to mainly smallholder livestock farmers by the Ministry of Food and Agriculture extension agents. However, the technology needs to be further improved by delivering appropriate information tailored to the different livestock species and extended to more livestock farmers and commercial feed millers.

Table 22: Cassava production and utilization for animal feed in Ghana ('000 tonnes)

	Year			
	2006	2007	2008	2009
Total cassava production	9 638	10 218	11 351	12 231
Cassava used as animal feed	1 831	1 963	2 249	2 762
Percentage utilization for animal feed	18.8	19.2	19.8	22.6

Source: FAO (2013)

8. LIMITATION/CHALLENGES TO THE USE OF CASSAVA FOR LIVESTOCK FEEDING

There are a number of limitations to the widespread use of cassava for livestock feed. The short shelf life of cassava due to high moisture content in products could lead to spoilage during storage if measures are not taken to reduce moisture content or ensiled within a short period after processing. The high water content in the cassava tuber makes preservation, transportation and handling difficult. The low protein content and high crude fibre of the cassava tuber also contribute to the low usage of cassava as livestock feed for monogastrics.

Managing the large amounts of waste produced from cassava processing, such as cassava pulp, into livestock feed is often done at high cost. Also cassava by-products require further processing if they are to be incorporated into commercial feed thus adding to the cost of the feed. Perhaps the greatest constraint to feeding cassava to animals is the problem of cyanide toxicity which can be rectified through processing (see Section 9).

A major constraint to the use of cassava products and by-products for livestock feeding in Ghana is the problem of obtaining sufficient amounts especially for large herds. Quiet often, the by-products are not produced in sufficiently large quantities at accessible spots for easy collection and feeding to livestock on a large scale. At present, they can only be used by small-scale livestock farmers.

Lack of appropriate knowledge on the use of cassava products as livestock feed by farmers has continuously led to their underutilisation in the country. The use of cassava leaves, particularly in ruminant diets is growing. However, not much is known about the effect of frequent foliage harvest on root yields. Information from other countries should be used while local trials are on-going.

The presence of cyanogenic glycosides in cassava chips meant for feed, if not properly eliminated through thorough drying, could put a limitation to cassava use in non-ruminant feeds. Elimination of the toxic glycosides is therefore a prerequisite to the acceptance of cassava as a major ingredient in commercial feed in Ghana.

9. DETOXIFICATION OF HYDROCYNIC ACID IN CASSAVA FOR LIVRESTOCK FEEDING

Various methods are used to detoxify or reduce cyanogenic glycosides and phytate content in cassava products and by-products in order to make them safe for consumption and preserve their nutritive quality. Different processes have been found to be effective in reducing cyanogenic glycosides: sun-drying, soaking, fermentation, ensiling and combination of processes such as soaking followed by sun-drying. The problems related with cyanogenic compounds are overcome by the use of sweet varieties and / or proper post-harvest treatments as simple as sun-drying on a concrete floor. Other processes as boiling and fermentation have also been found to be efficient.

Drying: The dehydration process results in substantial reduction on the content of cyanogenic glycosidein cassava products. Drying can be carried out using solar radiation (sun-drying), electricity or fuel depending on economic viability (Tewe, 1992).

Peeling: Many methods of processing cassava commence with peeling. Fresh cassava peels contain higher amounts of cyanogenic glycosides than the pulp. They also contain and phytates. Removal of peels therefore reduces the cyanogenic glycosides considerably in the cassava tuber and also removes phytates. Peeling can effectively reduce the cyanide content by at least 50 percent in the cassava tuber (Tewe, 1992).

Soaking: Soaking of cassava roots in water provides a suitable medium for fermentation, converting cyanogenic glycoside to cyanide and allows extraction of the soluble cyanide into the water. The process removes about 20 percent of the free cyanide in fresh cassava chips after 4 hours (Tewe, 1992). Water-soaking fresh peels for 1 to 5 hours followed by sun-drying also significantly reduced cyanogenic glycosides in amounts proportional to the duration of soaking (Shoremi *et al*., 1999 cited by Heuzé *et al*., 2012a). The water used should be discarded since it contains cyanide.

Boiling: As with soaking, the free cyanide in cassava chips is rapidly lost in boiling water. About 90 percent of then free cyanide is removed within 15 minutes of boiling fresh cassava chips. Boiling destroys the enzyme linamarase (Tewe, 1992). After the treatment the water used should be discarded.

Fermentation: Fermentation reduces the cynogenic glycosides to relatively insignificant levels. Fermented cassava products have better shelf life and are often low in cyanide content (Tewe, 1992). Fermentation of a mixture of cassava peels and wastewater from fermented cassava pulp with *Saccharomyces cerevisiae* and *Lactobacillus* spp. resulted in a product with a higher protein content, lower cyanogenic glycosides and lower phytate content. Fermentation can slightly reduce phytate content down to 0.7 percent (Heuzé *et al*., 2012a.)

Ensiling: Cassava pomace contains lower cyanogenic glycosides than the peels. It can be dried or ensiled. For ensiling, cassava pomace is ground and added either 0.5 percent salt (on fresh weight basis) or rapidly fermentable carbohydrates such as ground maize or molasses before being placed in anaerobic conditions (in pits or plastic bags). Addition of urea and minerals is also possible (Heuzé *et al*., 2012a). Ensiling cassava peels also reduce cyanogenic glycosides content (Larsen *et al*., 1976). Ensiling seems to be as efficient as sun-drying (or even more efficient) to detoxify cassava peels and the resulting products can be used safely to feed livestock (Heuzé *et al*., 2012a).

10. RESPONSES OF DIFFERENT LIVESTOCK SPECIES FED CASSAVA PRODUCTS AND BY-PRODUCTS IN SUB-SAHARAN AFRICA

10.1 NON-RUMINANTS

Cassava peels

Pigs

Cassava peels are a good feed for pigs, but they must be supplemented with sources of protein and lipids in order to improve their palatability and digestibility. The fibrous nature of the feed may also limit its inclusion in pig diets. Typical inclusion rates are about 30 percent though rates up to 60 percent have been found economically sustainable due to the lower price of cassava peels compared to that of maize, for instance. Cassava peels could be introduced at up to 30 percent in piglet diets without affecting growth performance. In older pigs (35 kg), up to a 57 percent level of inclusion had no deleterious effect on daily weight gain, feed intake, feed conversion ratio and carcass characteristics and the use of cassava peels as a partial replacement for maize in young pig diets was shown to be cost effective. Cassava peel meal could be included in the diets of growing pigs up to level of 30 percent to reduce feed costs without any detrimental effect on performance, or up to 60 percent (total replacement of maize) when maize cost is high. In growing pigs, inclusion of cassava peel meals up to 38 percent with 5.4 percent palm oil gave a better economic performance than other combinations of peels and palm oil (Heuzé *et al*., 2012a).

Several methods have been tested to enhance the feeding value of cassava peels for pigs. In pigs fed a diet containing 30 percent cassava peels, adding an enzyme cocktail enhanced diet utilization, resulting in better performance comparable to pigs fed with the maize-based control diet. Biodegradation of cassava peels with *Trichoderma viride* resulted in a higher protein content (16 percent) but was not found to be more expensive without significantly improving performance (Heuzé *et al*., 2012a).

Poultry

Cassava peels can be used for poultry feeding after sun-drying, as well-processed peels contain HCN levels that are acceptable for poultry. Fermentation of cassava peels has been tested by several authors, either to lower HCN or fibre content or to increase crude protein content (Heuzé *et al*., 2012a).

Broilers

In some experiments, growth performance was maintained with broiler diets containing up to 15 percent cassava peal meal. Feed intake is generally not highly affected but depends on the feed formulation (iso-energetic diets or not). However, in other experiments performance decreased with five percent cassava peal meal in diets. This can be due in part to problems in feed formulation since there is evidence that performance is adversely affected with inadequate protein complementation. There could be an advantage in feeding fresh cassava peels for slow growing chickens. The recommendation for broilers is to limit the incorporation of cassava peel meal to 5-

10 percent depending on its quality, with appropriate feed formulation. Higher levels could be used in slow growing chicken or in situations where depression in growth performance is counterbalanced by a lower feed cost (Heuzé *et al*., 2012a).

Layers

Sun-dried cassava peels at 10 to 40 percent inclusion rates resulted in significantly lower productive performance in layers. Fifteen percent of the layers had lower egg production when 20 percent cassava peel meal was included in the diet. The effect on feed intake was not constant in these studies. Different processing techniques were tested to alleviate the negative effect of cassava peels: ensiling or boiling resulted in improved performance, but the egg production was always lower than for the maize control. These results suggest that cassava peel meal should be used carefully in layer diets, with low inclusion rates of about 5 percent (Heuzé *et al*., 2012a).

Rabbits

As a source of energy and replacement of maize dried cassava peels can be incorporated up to 30 percent in balanced feeds for growing rabbit. Water-soaked cassava peels allowed growth and carcass characteristics identical or significantly better than those obtained with the control diet containing 20 percent maize. On the other hand, a diet based on dried cassava peels (totally replacing maize) showed poor performance in growing rabbits compared with those fed the non-extruded diet Agunbiade et al., (2001) cited in Heuzé *et al*., (2012a).

Cassava pomace

Pigs

Growing and finishing pigs

Cassava pomace was found to be detrimental to the performance of growing pigs at levels as low as seven percent. Likewise, a diet containing 10 percent of cassava pomace had negative effects on the average daily weight gain and feed conversion ratio of weanling pigs though it did not affect feed intake. However, a 15 percent inclusion rate was found to be non-detrimental to piglets. Generally, older pigs seem to be less sensitive to the detrimental effects of cassava pomace: up to 30 percent cassava pomace in the diets of finishing pigs did not affect performance. It is likely that the value of cassava pomace for young pigs depends on its fibre content. Cassava root waste (included at 25 percent in the diet) could completely replace cassava root meal provided that the diet includes five percent catfish oil. This diet significantly improved growth performance without affecting carcass quality, and resulted in the highest economic benefit (Heuzé *et al*., 2012a).

Sows

Dried cassava starch residue could be included at 30 percent level in the diet of gestating sows without any effect on the reproductive performance of both gestating and lactating sows (Heuzé *et al*., 2012a).

Broilers

Cassava pomace is rich in fibre with a quite variable composition but small amounts can be included in broiler diets. With correctly energy-formulated diets, cassava pomace did not significantly decrease broiler performance when included at four percent and eight percent, while performance was depressed at 12 and 16 percent respectively (Heuzé *et al*., 2012a).

Cassava sievate

Layers

In Nigeria, cassava sieviate (by-product of garri production was used successfully in layers, causing only a minor decrease in egg production when 15 percent sievate was included in the diet. Fermentation with *Aspergillus* slightly improved the rate of la y (Heuzé *et al*., 2012a). In another experiment, feed intake and performance decreased with 10 percent pomace in the diet. Laying performance was improved by avizyme and dried pure yeast addition (Aderemi *et al*., 2006)

Rabbits

Cassava sievate introduced up to 18-20 percent in growing rabbit diets (replacing the corresponding amount of maize grain) resulted in growth performance similar to or slightly better than that obtained with the maize-based control diet. A higher inclusion level (40 percent) reduced growth rate by nine percent in comparison with that with the maize-based control diet, but the unit cost of feed to weight gain remained in favour of sievate utilisation (Heuzé *et al*., 2012a).

Cassava root

Cassava root as feed includes cassava meal residue, a mixture of cassava roots unsuitable for human consumption and of root tips from the pre-processing cleaning stage. Its composition is close to that of the roots, with a high starch level (64 percent). The cassava meal residue may be added up to 26 percent to the diet of growing rabbits from weaning to slaughter, replacing completely maize without any impairment in performance and carcass characteristics (Heuzé *et al*., 2012a).

Pigs

Due to their high starch content, cassava roots are an excellent source of energy for pigs and can be used in fresh, ensiled or dried forms. Because cassava peels are more than twice as fibrous as the root pulp, peeling improves energy digestibility and energy content. For growing-finishing pigs, it is possible to include up to 60 percent of dried cassava root in the diet. The inclusion rate depends on the growth stage of the pig. The maximum intake of cassava is about 100 g/kg DM $W^{0.60}$ for dried ground cassava. Cassava root meal is a palatable ingredient in the diets of young pigs. The main concern about the use of cassava roots in pigs is the presence of HCN, especially in bitter cultivars and there is a negative relationship between HCN content and cassava root intake (Heuzé *et al*., 2012a).

Poultry

Dried cassava tubers can be efficiently used in poultry feeding. However, grinding cassava results in high levels of fine particles which can cause lower feed intake and possibly irritation of respiratory organs. Pelleting reduces dust and increases the bulk density, favouring feed intake especially in young animals. The protein content of cassava is low, which requires good protein sources in feed formulation. In particular sulphur amino acids (methionine and cystine) have to be supplied in high enough amounts because they are involved in metabolic detoxification of HCN. The metabolizable energy (ME) value of good cassava meal (72 percent starch) is equivalent to that of maize. Lower quality cassava (lower starch, higher fibre) hase lower ME value, and the ME of unpeeled cassava meal is about 85 percent of that of maize. (Heuzé *et al*., 2012a).

Broilers

In well-formulated diets, good quality cassava can be used at high levels without reducing performance. For instance, the inclusion of 50 percent pelleted cassava results in performance comparable to that obtained with maize diets. In addition > 30 percent unpelleted cassava meal in the diet could reduce feed intake, resulting in a non-significant decrease in growth while maintaining feed efficiency. Feed consumption can be affected in young animals at high inclusion rates (50 percent) while older animals maintain their performance. While there is no fixed limit on the inclusion level of high-grade cassava in pelleted diets for grower-finisher broilers, the low protein content of cassava limits its inclusion to 30-40 percent due to formulation constraints. When diets are fed in meal form, inclusion of cassava should not be higher than 20-30 percent, particularly for young animals. Lower grade cassava root products, such as dusty, unpeeled, or high-HCN roots or roots processed with little or no quality control should be used with caution and the inclusion rate should not exceed 20 percent of the diet (Heuzé *et al*., 2012a).

Layers

High levels of cassava meal can be used in layer diets when the HCN level is low and the diet is well balanced for protein, energy, minerals and vitamins. Up to 50 percent cassava did not significantly decrease production, feed efficiency and body weight. Water consumption increased when cassava was fed in meal form, while this effect was not observed on feeding pelleted form. Egg mass produced was also improved on feeding pelleted meal. Unpeeled cassava meal could be included at 30 percent, completely replacing maize grain in the diet without adverse effects, including on egg quality. However, the low carotenoid content of cassava requires supplementation with natural or artificial pigment sources if the egg yolk colour has to be maintained. Good quality cassava meal can be used in layers without limit provided that the diet is properly balanced for nutrients. As for broilers, lower quality cassava should not exceed 20-30 percent of the diet (Heuzé *et al*., 2012a).

Rabbits

Sun-dried cassava chips are used by traditional farmers in tropical countries such as Ghana, Tanzania, Uganda and Nigeria. Cassava root slices are also a common ingredient for complete rabbit feeds in many hot-climate countries such as Cameroon. The inclusion level is generally 25 to 30 percent of the diet. Several studies have investigated the ability of sun-dried cassava root meal to replace cereal grains such as maize or barley, or other concentrate ingredients in rabbit diets. When experimental diets are correctly balanced, no differences are observed in growth or reproductive performance using usual inclusion levels up to 20-30 percent. Also, including cassava roots in the diet does not affect the quality of rabbit meat (physico-chemical composition and meat acceptability). Levels up to 45-50 percent have been tested experimentally without any adverse effects in growing rabbits or breeding doe. The main issue when formulating balanced rabbit diets with cassava roots is their very low protein content, a problem that is usually addressed by increasing the proportion of soybean meal in the diet. Cassava roots, even when sliced and dried, have a mild goitrogenic effect, as evidenced by the low levels of serum thyroxin and cholesterol and by enlarged thyroid glands. However, rabbits fed a 25 percent cassava root diet had a growth rate better than that of the control group, which indicates that the goitrogenic effect could be negligible in growing rabbits (Heuzé *et al*., 2012a)

10.2 RUMINANTS

Cassava peels

Cassava peels can be used as a roughage and as an energy feed in ruminant diets. However, sun drying, ensiling and fermentation should be used to prevent HCN poisoning when using bitter cassava varieties. Cassava peels should not be fed alone, as their protein and mineral content cannot support optimum rumen function and productivity in ruminants, and their optimal utilization requires sources of readily fermentable protein and by-pass protein as well as micronutrients including sulphur, phosphorus, and B vitamin. Cassava peels are a valuable feed, and significant increases of animal performances have been reported when they are added to ruminant diets (Heuzé *et al*., 2012a).

Cattle

In Ghana, weight gains of 0.29 or 0.33 kg/day (*vs.* 0.07 kg/day for the unsupplemented group) were recorded with cross-bred bullocks grazed and supplemented with dried or ensiled peels Because of their high degradability, cassava peels have also been used as a energy supplement in cattle: cassava peels could partly replace (30 percent of total dry matter intake) energy concentrates, with no influence on the intake, digestibility, microbial efficiency, and nitrogen retention (Heuzé *et al*., 2012a).

Sheep

Many trials have been carried out with sheep in sub-Saharan Africa. In Ghana, Djallonké lambs lost weight after consuming only cassava peels, and supplementation with *Ficus exasperata* leaves resulted in weight gains and in a significant increase in cassava peels DMI (from 44 to 58 g $W^{0.75}$). In Cameroon, sheep fed 0, 35, and 70 percent of the diet as cassava peels (and respectively 70, 35 and 0 percent *Pennisetum purpureum*), with cottonseed cake as the protein source, gained respectively 45, 107 and 227 g/d. Dry matter intake, digestibility and growth rate increased linearly with increasing dietary levels of cassava peels. Sheep may use ensiled cassava peels better than sun-dried peel. In Nigeria, sheep fed a diet containing 80 percent ensiled cassava peels had higher daily gains (81 *vs.* 59 g/d) than those fed sun-dried peels (Heuzé *et al*., 2012a).

Goats

In Nigeria, a 60:20:20 ensiled mixture of grass-legume (guinea grass and tropical kudzu *Pueraria phaseoloides*), cassava peels and poultry excreta fed to West African Dwarf goats resulted in favourable consumption and digestibility, as well as normal rumen and blood metabolites, and it was recommended to use cassava peels as an energy supplement particularly in the dry season when digestable energy content of forages is low In Red Sokoto goats, ensiling cassava peels with *Pennisetum purpureum* had beneficial effects on silage properties, intake and digestibility, and it was proposed that cassava peels form at least 30 percent of silage made from *Pennisetum purpureum* to improve productivity during the dry season (Heuzé *et al*., 2012a).

Cassava root

Both fresh and dried cassava roots are consumed by ruminants in different forms (chips, ground, pelleted). Cassava starch has a high amylopectin content (70 percent) making it a suitable energy source for ruminants when combined with non-protein nitrogen in feeds. The use of fresh cassava roots of bitter varieties is limited by their HCN content. When properly processed, they may serve as a basic energy source for intensive cattle feeding. Dried cassava roots have given satisfactory results as the principal energy source in the ruminant productions. Studies indicate that the inclusion of cassava to partly replace cereal grains (maize, barley, sorghum) with up to 30-40 percent in diets gave satisfactory animal performance and no negative effects on animal heath in finishing beef, dairy cattle, growing goats and lamb. When cassava tubers are supplemented with non-protein nitrogen, minerals, vitamins, and roughage, high performances have been registered with dairy and beef cattle, sheep, and goats. Palatability can be enhanced by the addition of molasses if pelleting is not possible (Heuzé *et al*., 2012b).

Dairy cattle

In some experiments, replacing maize with cassava resulted in lower milk yields but also lowered production costs. However, milk yield increased in other feed trials. Using cassava as an energy supplement in grazing cows had a positive effect on milk yield (increased milk by 20 percent). Supplementing a fresh or ensiled sugarcane-based diet with cassava did not change milk production (Heuzé *et al*., 2012b).

Beef cattle

In beef cattle, including cassava pellets up to 65 percent do not seem to affect health, carcass quality or overall performance when the diets are carefully balanced for nutrients. There were no significant differences in the performance of Holstein-Friesian male calves (180 kg) fed a mixed diet containing 80 percent concentrate when 40 percent of the grain was replaced by cassava, except for a small increase in DM intake. The average daily weight gain was 1 200 g and the energy conversion efficiency into live weight was reduced by 8 percent depending on the nature of the protein source (Heuzé *et al*., 2012b).

Sheep

Substitution of maize cobs with cassava (20 percent) in sheep fed pangola grass (*Digitaria eriantha*) hay improved digestibility, body weight gain, and rumen function (Smith, 1988). Supplementation levels from 20 to 80 percent increased the digestibility of a rice straw-based diet but reduced the digestibility of a molasses-urea-based diet (Heuzé *et al*., 2012b).

Goats

In goats, replacing maize grain by cassava roots reduced performance at substitution levels of 40 percent and 60 percent (Smith, 1988). Supplementation of *Gliricidia sepium* with cassava roots at 30 g/kg DM $W^{0.75}$ improved digestibility and digestible dry matter intake, but reduced growth rate (Smith, 1988). Improved digestibility and no decrease in growth rate reported with Gliricidia and *Leucaena* (3 : 1) supplemented cassava root at 15 and 30 g/kg DM $W^{0.75}$. This discrepancy between the two last studies was attributed to energy-nitrogen synchronization in the rumen (Heuzé *et al*., 2012b).

11. RESEARCH UNDERTAKEN ON CASSAVA AS ANIMAL FEED IN GHANA

Numerous studies have been undertaken on the use of cassava for animal feeding globally, and in Nigeria in particular with respect to Sub-Saharan research. Research on cassava as animal feed in Ghana is minimal, particularly for ruminant livestock, and the results are summarised in Tables 23 and 24.

Table 23: Responses of non-ruminant livestock species fed cassava products in Ghana

Livestock Species	Role and level of cassava in diet	Response	Reference
Poultry			
Broilers	15% inclusion of sun-dried cassava peels meal in ration	Growth performance was satisfactory.	Osei *et al*., 1988; Osei, 1992
Broilers	15% inclusion of fermented cassava peels	Birds on cassava diet consumed significantly more feed and had higher rate of gain than those on control diet.	Osei *et al*., 1986
Broilers and Layers	Sun-dried cassava peel meal incorporated at 150 g per kg diet.	No influence on feed consumption, liveweight gains and efficiency of feed utilization. Carcass parameters were not affected.	Osei *et al*., 1989
Broilers	Fermented and non fermented whole cassava meal in replacement of 15% maize	No difference in weight gain.	Agudu and Thomas, 1980
Broilers	Maize was partially replaced by 15% fermented cassava peel meal	Higher feed intake and weight gain on cassava peel meal diet.	Osei *et al*., 1886
Pigs			
Gilts	Cassava peels and corn cobs as partial replacement of maize as major energy source	Feed conversion efficiency, average daily weight gain, time to slaughter (80 kg) and carcass characteristics did not differ between cassava based and maize diet.	Ampadu *et al*., 1998

Livestock Species	Role and level of cassava in diet	Response	Reference
Weaners	10, 20 and 30% of sun-dry homogenous dry mixture of bovine blood, milled cassava peels and water at ratio of 6: 2.5: 4 as partial replacement of maize	No significant differences between daily feed intake, daily weight gain and final body weight.	Mettle *et al.*, 2009
Weaners	5, 10 and 15% cassava foliage meal as replacement of maize	No adverse effect on the growth rate, feed conversion efficiency. Feed cost tended to decrease as the level of cassava meal increased.	Okai, 1981
Growers	10% cassava meal (+ 40% cocoa husk meal (CHM) 40% cassava meal + 10% CHM	Pigs on 40% cassava meal and 10% CHM had higher daily weight gain than those on 10% cassava meal and 40% CHM. Feed conversion efficiency was significantly lower in the 40% than the 10% cassava meal diets (3.3 vs 12.4).	Barnes and Oddoye, 1985.
Piglets, weaners, and grower-finishers	Total replacement of maize with AIBP containing cassava and cassava peels on smallholder farms	Average daily gain and days to slaughter of the pigs on AIBP and maize diets were similar. Economic gain by pigs on the AIBP diets was better than those on maize diet.	Rhule *et al.*, 2007

Table 24: Responses of ruminant livestock species fed cassava products in Ghana

Livestock Species	Role and level of cassava in diet	Response	Reference
Sheep			
Lambs	0, 15 and 30% sun-dried cassava pulp as a substitute for cassava peels diet.	Haematology, carcass weight, principal organ weights and growth rate were similar.	Otsina *et al.*, 2007
Lambs	*Ficus exasperata* leaves supplementation with cassava peels	Weight gains increased in lambs supplemented cassava peels.	Baah *et al.*, 1999
Cattle			
Bullocks, cross-bred	Grazing supplementation with dried or ensiled peels	Significant difference in weight gains, 0.07, 0.29 and 0.33 kg/day for the control, dry and ensiled peels diets respectively.	Larsen *et al.*, 1976

12. EVALUATION OF PRACTICAL ADVANTAGES AND DISADVANTAGES OF USING CASSAVA AND ITS DIFFERENT FRACTIONS AND PREPARATIONS *VIS-A-VIS* OTHER FEED COMPONENTS USED IN GHANA

12.1 FEED COMPONENTS USED IN GHANA

While maize constitutes the major energy source in non-ruminant diets in Ghana, fishmeal and soybean meal are the main sources of crude protein in the diets. Other oil seed cakes, such copra cake and palm kernel cake are also used as sources of both energy and crude protein. Cassava is mainly used as energy source by small-scale farmers. Maize typically forms from 50 to 70 percent of the total feed formulation. The inclusion level of oil seed cakes ranges from 10 to 25 percent in poultry diets. With the exception of maize, almost all the other ingredients are imported and are not always available. Yellow maize is imported at times to supplement local supply. The main ingredients used as sources of various nutrients in non-ruminant feed may be classified as:

Energy source

- Cereals (mainly maize), cereal by-products such as wheat bran, rice bran, maize bran
- Cassava
- Vegetable oils

Plant protein source

- Soymeal, copra cake, palm kennel cake, cotton seed cake

Animal protein sources

- Fish meal

Mineral supplements

- Dicalcium phosphate, bone meal, shell grit

- Trace minerals premixes
- Sodium chloride

Miscellaneous

- Vitamin supplements
- Crystalline amino acids (methionine, lysine, threonine)

Non nutritive feed additives

- Enzymes, antibiotics, probiotics

12.2 CASSAVA PRODUCTS AND BY-PRODUCTS FOR NON-RUMINANT FEEDING

Foliage: Cassava foliage can be included in poultry and pig diets as a source of protein. With CP of about 24 percent it has a higher value than maize (nine percent) which is the most expensive component of non-ruminant diet in Ghana. The amino acid profile is comparable to that of soyabean meal, one of the major sources of CP in non-ruminant diet. However, its use is limited due to the inadequacy of the material and lack of information on its use. Use of a feed ingredient by the feed industry required that it is available regularly and in large quantities. The disadvantage with the use of cassava foliage is that it is harvested only at the time of uprooting the tubers by which time there is a reduction of the biomass as well quality. The foliage contains HCN and must be detoxified. The high crude fibre content also puts a limitation on the inclusion level in the diet. Although cassava foliage has a high carotene content which gives a good yolk colour, grinding the dried foliage for use in the feed produces a lot of dust which is hazardous to the health of operators.

Chips/Pellets: Chips and pellets are high energy sources for non-ruminant animal feeding. The energy value is similar to that of maize which they replace in the diet. The disadvantage of cassava is that it has moisture content which makes storage difficult in the natural form. It requires further processing which adds to costs leading to high prices. The cost of drying cassava to moisture content of 12 percent for storage can be very expensive depending on the method employed. To go round this, very simple and rudimentary techniques have been used. A disadvantage with the use of cassava chips/pellets for livestock feeding may be the availability of adequate or required quantities of the material to achieve the set targets of operations. The other disadvantage is that HCN in the cassava has to be detoxified. Nevertheless cassava is a highly digestible source of energy for pig feeding in Ghana.

Cassava pulp: It is a by-product of starch extraction, with a high fibre content compared to maize. Cassava pulp can be considered a good source of energy for poultry and pigs. The method of extracting starch requires large quantities of water. The material therefore has a much higher than normal level of water compared to the cassava root and maize. Pulp decomposes very easily and produces very offensive odour. The challenge in using the pulp is the high moisture which has to be dried. The pulp has to be used not far from the production site as high transportation charges are incurred if used at places far away from the production site.

Since pigs are fed wet with a feed to water ratio of two to one, there is an advantage in feeding cassava pulp in locations having shortage of water. It can be best used fresh and wet or ensiled.

Cassava peels: Cassava peels can be used for poultry feeding after sun-drying, ensiling or fermentation to prevent HCN poisoning. Growth performance could be maintained with broiler diets containing up to 15 percent cassava peal meal. Feed intake is generally not highly affected but depends whether the feed is iso-energetic or not. However, in some experiments performance decreased with 5 percent cassava peal meal in diets. This can be due in part to problems in feed formulation since there is evidence that performance decreases with inadequate protein supplementation. It is recommended that inclusion level of cassava peel meal is limited to 5-10 percent depending on its quality, with appropriate feed formulation when fed to broilers. Higher levels could be used in slow growing chicken or in situations where depression in growth performance is counterbalanced by a lower feed cost and increased profit. Cassava peel meal should be used carefully in layer diets, with low inclusion rates (e.g. five percent). Cassava peels may be fed fresh to chicken under semi-intensive and extensive systems.

12.3 CASSAVA PRODUCTS AND BY-PRODUCTS FOR RUMINANT FEEDING

Foliage: Cassava foliage could efficiently serve as a protein and roughage supplement in ruminant diets but it is difficult to get sufficient amounts to feed sheep, goats and cattle and in particular on a large scale. Small-scale farmers tend to feed cassava foliage to sheep and goats albeit in small quantities. Cassava foliage has higher digestibility than grasses normally grazed by ruminant animals. It could be considered a good source of nitrogen required for rumen microbial protein synthesis.

Cassava peels: Cassava peels is a valuable feed, and gives satisfactory performances when fed as a supplement to ruminants. The peels can be used as a roughage and as an energy feed in ruminant diets. However, sun drying, ensiling or fermentation should be used to prevent HCN poisoning when using bitter cassava varieties. Cassava peels should not be fed alone, as their protein and mineral content cannot support optimum rumen function and productivity, and their optimal utilization requires sources of readily fermentable protein and by-pass protein as well as micronutrients including sulphur, phosphorus, and B vitamin. The disadvantage with the peel as a source of energy is its high degradability but a very low nitrogen content. Peels must therefore be fed with a source of nitrogen which is equally rapidly released during fermentation. In the rumen it is necessary for the efficient utilization of energy and nitrogen. The nitrogenous source may, however, be a non-protein such as poultry manure.

Cassava chips and pellets: These are not normally fed to ruminants. The high digestibility of the starch and sugars present may eventually upset the rumen pH and the micro flora. Microbial synthesis and energy utilization may be adversely affected. Cassava tuber meal from chips and pellets could be incorporated into multinutrient blocks containing urea, molasses, vitamins, minerals and by-products such as brans. Such a block would represent a vast source of low-cost nutrients that could address the nutrient deficiencies in ruminants especially during the dry season when protein and energy contents in forages are low.

13. THE STEPS NEEDED TO REALISE SUSTAINABLE AND SUCCESSFUL USE OF CASSAVA BASED FEED RESOURCES IN GHANA AND FUTURE RESEARCH NEEDS

Cassava, its parts and by-products have the potential to be a major ingredient of livestock feed in Ghana. In West Africa, and in particular Nigeria, the crop is well known as a viable poultry feed ingredient, but the level of utilization in Ghana, particularly that of the cassava chips and pellets has been low, due to a number of constraints. Cassava based non-ruminant feed used to be patronised by poultry and pig farmers in the country when the feed was produced by GAFCO. It is expected that livestock owners would again patronise cassava based feed if the necessary awareness is created and the quality and availability of the cassava products are assured. The steps needed to realise sustainable and successful use of cassava based feed resources in Ghana include:

- Research scientists should formulate appropriate diets for various types of livestock using information from other countries. However, it may be necessary to undertake on-farm trials for the benefit of farmers and feed millers and the findings diffused to all stakeholders. Feed millers should be informed to use appropriate cassava based feed formulations in order to produce quality feed at lower cost thereby improving income of the farmers as well as theirs.
- Appropriate technologies and machinery for the production of cassava products of guaranteed quality that meet the nutritional needs of fast growing non-ruminant livestock should be introduced to stakeholders and they should be encouraged to use them.
- An enabling environment should be created to entice farmers and entrepreneurs to take up production of good quality feed-standard cassava products in large quantities.
- Strategic awareness programme, including workshops and presentations in the media, should be undertaken by the extension services on the potential and economic benefits of using cassava for livestock feed.

Future research and development issues for expanding the use of cassava based products for feed in Ghana include:

- Dynamics of cassava and livestock products traded across seasons.
- Modernizing cassava production and development of cost effective technologies to enhance productivity and quality of products and by-products for livestock feeding.
- Establishment of pilot projects to demonstrate feasibility of cassava-based feeding systems.
- Evaluation of the feeding value of cassava products and by-products and the development of appropriate feeding systems or packages based on these products to ensure optimal response.
- Agronomic studies (e.g. planting density, fertilizer and water requirements and cutting intervals etc.) on the production of cassava foliage for livestock feeding.
- Increase the crude protein content of cassava and by-products by inoculation and microbial means.

- Design appropriate silos for storage of cassava products and by-products using locally available materials.
- Entrepreneurial development of the value chain for cassava products and by-products for livestock feeding.

14. SWOT ANALYSIS

In view of the improvement in the production and productivity of cassava in Ghana and sub-Saharan Africa in general there is a need to maximize the use of cassava and its by-products as animal feed for the benefit of all stakeholders in the value chain. There is a need thereforeto evaluate the strengths, weaknesses, opportunities and threats associated with using cassava and cassava by-products for feeding livestock in Ghana.

14.1 STRENGTH

- Cassava can be substituted as a feed ingredient for maize and/or other grains in livestock feeding.
- The standards required for using feed grade cassava products are not as stringent as for cassava food products.
- Competitive pricing of cassava products for feed can be achieved through reduced processing cost such as the use of whole unpeeled storage roots to eliminate peeling costs.
- The presence of HCN makes cassava products insect-resistant and easy to store. Adding 15 percent cassava root meal to a concentrate feed improve its resistance to pests.
- Cassava is a drought resistant crop capable of withstanding extreme weather conditions and survives on marginal and not very fertile soils.
- Crop production in Ghana is rain-fed making the cultivation of crops such as maize used as feed ingredients seasonal. Cassava on the other hand is available throughout the year maintaining a high quality.

14.2 WEAKNESS

- Unreliable supply of cassava by-products (pellets and foliage) during the fattening period in the peri-urban areas for feeding of livestock.
- Excessively fine (powdery) nature of cassava meal influences the feed intake negatively and diminishes consumption of cassava meal.
- Lack of and inadequate appropriate processing equipment.
- Contamination with sand and mould during drying of by-products.
- Feeding cassava products to livestock above recommended levels affect performance.
- Cassava has a short shell life due to its high moisture content and must be processed soon after harvesting to avoid deterioration.

14.3 OPPORTUNITIES

- With animal protein consumption projected to increase in the continent, there is tremendous potential for increased usage of cassava in animal feed.
- Availability of maize, which is the main energy source in compound livestock feeds, is being threatened as many developing nations cannot afford importation of maize due to its high cost. Cassava products can fill this gap.
- Local production of maize is hampered by escalating costs of fertilizer and unfavourable weather conditions. The need for cassava as an alternative energy source becomes imperative in order to ensure adequate energy supply in livestock feed.
- The increased use of cassava in livestock feed will generate employment opportunities for the youth leading to alleviation of poverty.
- There is a high potential of using of cassava peels as supplement in livestock diet.
- Cassava has a potential for greater yield than other starchy crops, particularly with improved agronomic practices, mechanization and improved cassava varieties.
- Cassava is high yielding and a good substitute of cereal in feed industry. It would mean less land for cultivation and reduced pressure on land.
- Government policies can influence the use of cassava as a livestock feed by putting restrictions on the importation of maize.
- There will be a high demand for cassava products and by-products for livestock feeding following drought and unusual rainfall patterns, as a result of ongoing global warming, that would affect productivity of maize.
- Ghana has corps of highly-trained animal scientists whose expertise will be employed in the feed formulations and management of cassava in feeding livestock.
- Currently the by-products from cassava processing, peels and pulp are left at the production sites to rot and their use in livestock feeding will minimize environmental pollution.
- Cassava leaves have very high protein levels and these could be exploited for the nutritional improvement of cassava meal as livestock feed.
- Manure from increased livestock production as a result of increased cassava feed use will improve soil fertility of farmlands.

14.4 THREATS

- Cassava processing produces large amounts of waste, which is generally considered to contribute significantly to environmental pollution. Cassava wastes are left to rot away or burnt off to create space for the accumulation of new generation of waste heaps emitting carbon dioxide and producing a strong offensive smell.
- The large scale processing of cassava to meet the demand for animal feed could exert pressure on land as farmers clear more land to produce more cassava.
- Polyethylene sheets used in drying of cassava chips and pellets for livestock feed can lead to environmental pollution.

- Unpredictable weather makes sun-drying of cassava unreliable.
- Cassava production in Ghana depends mostly on the use of low efficiency technology leading to low yields, and increasing market price.
- The bulk of cassava is produced by small-holder farmers in 0.5 to 2 hectare plots in rural areas. Roads to the production areas are nonexistent and with an aging workforce bulk supply for continuous feed production will be a challenge.
- The conservative attitude of feed millers towards the use of cassava for livestock feed
- Other industrial use of cassava such as production of starch for export may increase market prices making cassava use for livestock feeding uneconomical.

15. CONCLUSION

Cassava is a staple food of Ghanaians and is the most highly produced crop in the country in terms of quantity. Production of cassava has increased over the last decade and there is a potential for higher yield and production. Studies undertaken in West African on the use of cassava, its products and by-products for livestock feeding have shown the potential of the crop as a major feed ingredient and in particular, for partial replacement of maize in commercial feed. However, the use of cassava in the past and present as commercial livestock feed ingredient in Ghana has been low. It is important that an advantage is taken of the vast potential of cassava as livestock feed to cut down on the use of the more expensive maize as the main energy source particularly in non-ruminant diets. The Ministry of Food and Agriculture, agricultural extension agencies, professional livestock societies, livestock farmer associations and non-governmental organisations ought to create awareness among stakeholders on the need to use cassava, its products and by products in livestock feed for economic gain of farmers and other actor in the value chain. Commercial feed millers should be encouraged to use cassava in the formulation of livestock feed so that farmers obtain quality feed at affordable prices while feed millers also increase sales and profits from increased demand for feed. Government policies should influence the use of cassava as a livestock feed by putting restrictions on the importation of maize while ensuring that the action does not affect livestock production.

For interventions to be effective in increasing the use of cassava for livestock feeding in Ghana, the two major challenges which are the high moisture level in cassava which reduces the shelf life of products to about 2 to 3 days, and the high content of cyanogenic glycoside which releases toxic HCN detrimental to the health and productivity of livestock will have to be fully addressed. The high moisture in the cassava products results in mould infestation and mycotoxin production. The traditional methods of sun-drying meant to address these problems have not been very effective especially during the rainy season when most cassava is harvested. The problem is aggravated particularly in the humid zone of the country. A method envisaged for reducing HCN and moisture in cassava products is by the use of solar dryers. Cassava tubers could be sliced to appropriate thickness using mechanical cutters for effective drying in solar dryers within a few hours. The moisture level will be reduced for storage while at the same time reducing the HCN to safe level for livestock feeding. There is therefore a need to revisit a DFID funded project in the early 1990s which developed a system of drying chips for food consumption and animal feed in Ghana, based on tray and polyethylene sheet for drying of mini-chips that produced a high quality product after two days. The mini-chipper developed in that project reduced the processor's discomfort and physiological strain and allowed a faster work rate. Locally available materials could be utilized for manufacturing of the peelers, and fabrication of the mini-chippers and solar dryers. The local artisans could be trained to construct chippers and dryers of varying capacities to suit different farms.

The cassava based feed value chain involves actors in the production of the product (farmers), processing into chips and pellets, collection and bulking, feed milling, marketing of prepared feed and livestock farming, as well as their relationships as they move cassava and its products and by-products from the fields through to the end markets. There is a major role for the private sector, farmers, co-operatives and entrepreneurs in the value chain by going into collecting of cassava products and by-products for value addition. The key to enhancing the demand and supply of cassava based feed in Ghana is to develop viable intermediaries acting as secondary processors or bulking agents in the value chain and ensuring a consistent supply of raw and processed materials.

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