Productive and physiological response of small ruminants fed Cassava (*Manihot esculenta* Crantz) and cassava by-products in their diets: A review

[1]Jiwuba, P. C. and [2]Jiwuba, L. C.

[1]Department of Animal Production Technology, Federal College of Agriculture, P.M.B., 7008, – Ishiagu, Ebonyi State, Nigeria.

[2]Biotechnology Programme, National Root Crops Research Institute, P.M.B., 7006, – Umudike, Abia State.

Corresponding author: E-mail: jiwubapc@gmail.com; jiwubapc@yahoo.com, +2348063622456

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Abstract

The heavy demand for conventional feedstuffs like maize, sorghum, soya bean, and groundnut meal by industries, humans and animals has led to hike in their prices with resultant high cost of livestock feeds. This therefore has necessitated the search and utilization of alternative non-competitive feed resources in other to partially or totally replace the expensive cereals and legume grains in small ruminant diets. The potential of many roots and tubers have not been fully known in sheep and goat nutrition. The identification, processing, incorporation and use of roots in sheep and goat diets will go a long way in reducing the dependence on conventional feedstuffs. Cassava is a tropical crop that is majorly cultivated for its starchy root. Its by-products like cassava peel, cassava leaf meal, cassava root sievate, cassava foliage, etc have been reported to be high in energy, digestible fibre, protein, vitamins and minerals and could contribute significantly to the nutritional needs of small ruminants. The leaf meal has moderate protein values with amino acid profile similar to soybeans. However, cassava has been implicated with high levels of cyanogenic glucosides, which produce cyanide (HCN) toxin that are harmful to sheep and goats. Efforts have been made to processed cassava and remove toxic substances by sun drying, milling, ensiling and solid state fermentation with great success. Research to date has studied the effects of cassava and its by-products on physiology and productive performance of sheep and goat. The use of cassava in sheep and goat diets and their effects on blood chemistry and haematology have been reported. This review covers the nutrient composition of cassava and some of its by-products and their effects on growth, carcass indices, organ weight and blood constituents of sheep and goats.

Key words: Cassava, blood characteristics, body weight gain, feed intake, sheep, goats.

Introduction

Cassava (*Manihot esculenta Crantz*) is one of the most important crops cultivated in Nigeria and many humid Tropical countries. Cassava production is vital as it is seen as the future of food security in Nigeria (Jiwuba et al., 2018 a); with approximately one billion people currently depend on it as a major carbohydrate source (Ezenwaka et al., 2018). In addition, cassava has been used as a feedstuff for livestock. The value of cassava or its by-products as feedstuff in ruminant feeding programme have attracted the attention of researchers in developed and developing countries of the world (Yousuf et al., 2007; Rosly et al., 2010; Guimarães et al., 2014; Ukanwoko and Ibeawuchi, 2014; Maciel et al., 2015; Abatan et al., 2015; Ogundipe and Akinlade, 2016; Jiwuba et al., 2016; Jiwuba and Ezenwaka, 2016; Jiwuba et al., 2017; Jiwuba et al., 2018 a; Jiwuba et al., 2018 b; Jiwuba et al., 2018 c; Jiwuba et al., 2018 d). Cassava has been reported (Jiwuba et al., 2018 b; Ezenwaka et al., 2018) to be a hard, drought and disease tolerant crop, which require little inputs with high underground storage ability and can be planted in a poor soil with flexible harvesting dates. It originated in South America, but has spread throughout tropical areas of Africa where it adapted favourably, by the Portuguese explorers in the sixteenth century. However, cassava did not become important until in the late nineteenth century when processing techniques were introduced by more slaves who returned to their homeland (Ekanem et al., 2010). Cassava is a heterozygous plant and can be propagated vegetatively through stem cuttings or sexually by seed. It is a perennial crop but could be harvested between seven to twenty four months after planting. It belongs to the *Euphorbiaceae* family and grows to 3–5 meters in height, with palmate leaves bearing three to nine lobes and covered with a shiny, waxy epidermis borne on a long, slender petiole. The leaves are dark green above, light green below, and only grow towards the end of the branches. The mature plant can either have spreading stems or erect stems with various amounts of terminal branching. The mature stem is cylindrical, with a diameter varying from 2–6 cm; both the thickness and the colour vary with the age of the plant and the variety. Mature stems are either silver or gray, purple and brown depending on the cultivar. The mature cassava root has three major tissues; bark (periderm), peel (cortex) and parenchyma.

Cassava is well known for its storage root, which is high in starch (Chanjula et al., 2007; Jiwuba and Ezenwaka, 2016; Jiwuba et al., 2018 a). The metabolizable energy (ME) of cassava root meal has been reported (Buitrago et al., 2002; Olugbemi et al., 2010) to range between 3,000 to 3,279 kcal/kg. The leaves are very rich source of protein, vitamin B, C, Carotene, Calcium and Iron (Adewusi and Bradbury, 1993; Rosly et al., 2010; Jiwuba and Udemba, 2019). Cassava leaf protein is compared favourably with soyabean amino acid profile except for methionine, lysine and isoleucine, which are lower in cassava leaves. Cassava have been reported to be indispensable medicinal therapy in the management of diabetes and cardiovascular complications including heart disease due the presence of alkaloids and flavonoid glycosides which abound in cassava (Chen and Li, 2007; Osipitan et al., 2015; Pinto-Zevallos et al., 2016). However, the utilization of cassava products is hindered by potentially toxic substance; cyanogenic glucosides. Rosly et al. (2010) observed liver periportal necrosis among sheep and goats fed cassava forages. Nevertheless, physical/mechanical, chemical or biological treatment of cassava or cassava by-products have been shown to improve weight gain, feed intake, digestibility, feed efficiency, blood profile, dressing percentage and organ characteristics in sheep and goats (Yousuf et al., 2007; Fasae et al., 2010; Tilahun et al., 2013; Guimarães et al., 2014; Oni et al., 2014; Abatan et al., 2015; Maciel et al., 2015; Jiwuba et al., 2016; Jiwuba and Ezenwaka, 2016; Cardoso et al., 2016; Jiwuba et al., 2017; Jiwuba et al., 2018 a; Jiwuba et al., 2018 b; Jiwuba et al., 2018 c; Jiwuba and Udemba, 2019). Remarkably, Nigeria is the world largest producer of cassava, thus making it or its byproducts readily available for sheep and goat feeding. In this review, we will address the nutritional potential of some cassava by-products as well as an attempt made to use cassava or cassava by-products in sheep and goat diets.

Chemical composition

The chemical composition of cassava root sievate meal (CRSM), cassava root meal (CRM), cassava peel meal (CPM) and cassava leaf meal (CLM) reported by several authors (Devendra, 1983; Fasae et al., 2010; Olafadehan, 2011; Ojebiyi et al., 2013; Ukanwoko and Ibeawuchi, 2014; Dierenfeld and Fagbenro 2014; Jiwuba et al., 2016; Unigwe et al., 2017; Jiwuba et al., 2018) is summarized in Table 1. Cassava root is high in starch and hence can be described as an energy-dense food. Few authors (Ojebiyi et al. 2013; Jiwuba et al., 2018 c) analysed CRSM and reported that CRSM contains moderate energy (2.31–17.79 MJ/Kg), carbohydrate (68.14%), fibre (1.22–18.96%) and small amount of protein (2.00–2.57%), minerals (1.71–1.80%) and fat (0.28–2.7%). Cassava root sievate can either be a garri or fufu processing waste product. Cassava root sievate accounts for about 25 percent of the entire plant (Aderemi and Nworgu, 2007) and is generally poorly discarded as waste heaps near streams or homes where they are washed, fermented and processed, creating a strong odour and pollution (Jiwuba et al., 2018 b). Due to its palatability and high energy content, cassava root sievate, if well processed, may be useful for feeding sheep and goats. Dierenfeld and Fagbenro (2014) reported that CRM contains 2.9–3.9%, 18.8%, 0.7, 3.6–3.9% and 59.2% of crude protein (CP), crude fibre (CF), fat, ash and carbohydrate respectively. The root meal produces about 250000 calories/hectare/d (Okigbo, 1980) therefore ranks higher than maize, rice, sorghum, and wheat. The root is high in carbohydrate of about 32–35% on fresh weight, and 80–90% on a dry matter basis. Of all the carbohydrates in cassava root, 80% is starch and 83% is in the form of amylopectin, and 17% is amylose (Gil and Buitrago, 2002; Rawel and Kroll, 2003). The roots in addition, contain traceable amounts of the hexose sugars (glucose, sucrose, maltose and fructose). Nonetheless, the fibre content of CRM mainly depends on the cassava variety, cassava plant size and age. The fibre content in fresh cassava root can range from 0.8 to 7.7 percent (Smith, 1988; FAO, 2001) and 3.9 to 18.8 percent in the meal. The protein content is low and on a DM basis can vary from 1 to 3 per cent (Buitrago, 1990). Several authors (Ukanwoko and Ibeawuchi, 2014; Jiwuba et al., 2016; Unigwe et al., 2017; Olafadehan, 2011) revealed the chemical composition of CPM in Nigeria. Their result showed that CPM is a good source of energy (3.64–16.44 MJ/kg) and nitrogen free extract (55.67–71%) with relatively low amount of CP (4.86–9.23%), fat (1.19–3.41%), mineral (2.23–9.74%) and CF (9.87–14.21%). Cassava peel is the primary by-product with marginal discarded root in cassava processing. Cassava peel accounts for approximately 10–13% of root weight and is readily available in countries where cassava is grown and processed for food or industrial use. Cassava peel in Nigeria, where cassava is the main staple energy food, can accumulate and often pose problems with disposal. CPM composition depends on many factors, including variety, maturity stage and the proportions of peels and tubers in the mixture. The results obtained for CRSM, CRM and CPM indicated that they could successfully be a good substitute for maize in terms of energy and NFE. Proximate composition revealed that CLM is a good source of protein (17.66–47.20%), mineral (6.10–9.987%), carbohydrates (51.90–52.28%) and energy (19.75–20.11 MJ/kg) (Devendra, 1983; Fasae et al., 2010; Dierenfeld and Fagbenro, 2014; Jiwuba et al., 2018 c). The protein content of CLM is higher than that found in maize and has a good essential amino acid (EAA) profile comparable to that of soyabean meal and groundnut meal. It is noteworthy to state that the CP and energy value reported for CLM is enough to maintain the rumen microbes and to ensure the better functioning of the rumen ecosystem. Fresh cassava leaves can be eaten after air-dried, coarsely milled or fed wholly or incorporated as a source of protein and carotene in small ruminant diets. Crude protein values of 17.66–25.1 percent (Iheukwumere et al., 2008; Jiwuba et al., 2018 d) have been recorded for CLM in Nigeria. Elsewhere, Eggum (1970) noted that 85 per cent of the protein from the cassava leaf occur as true protein. CLM protein has been compared in terms of essential amino acids to that of soybean meals. Fasuyi (2005) further recorded high and equivalent CLM protein content with some rich known protein sources of plant and animal origin. This gave a strong indication of the feeding importance of CLM to small ruminants while acting as a supplement to the dry season. CLM has an EAA profile that is highly comparable with soybean meal (SBM) (Table 2); thus making it an inestimable feedstuff of great importance.

The high HCN (Olafadehan, 2011) and fast spoilage at the fresh state pose a question of use for sheep and goats at the fresh state. The content of cyanide in cassava varied from 75 to 1,000 mg/kg depending on the plant variety and age, soil conditions, fertilizer presence, and temperature, among other factors (Ngiki et al., 2014). Cassava contains two forms of cyanogenic glucosides; linamarin (93%), and either lotaustralin or ethyl linamarin (7%). Cassava peel contains cyanoglycosides, linamarin and lotausralin, which yield HCN during hydrolysis (Oboh, 2006) and have been reported to be toxic to livestock and humans. Oboh (2006) also reported that cassava peels contain a higher percentage of HCN compared to root and leaves; hence making the peel as a ruminant animal feed relatively unsuitable in its raw form. Ravindran (1991) claimed that sun-drying alone in a cassava sample could eliminate around 90 per cent of the initial cyanide value. Olafadehan (2011) reported a reduction of HCN from 710.98 mg/kg from unprocessed cassava peel meal to 165.36 mg/kg in a sundried cassava peel meal; this explicitly demonstrated the efficacy of processing method in cassava peels detoxification before use in ruminant feeding. Similarly, Okah et al. (2017) reported that ensiling cassava peel meal reduced the cyanide content to 6.25 ppm of the initial value of 27.30 ppm after an ensiling period of 21 days. Generally, processing has been recorded to reduce the HCN level dramatically and enhanced performance of animals fed processed cassava byproducts.

Effects on feed intake, body weight gain and feed conversion ratio

Several researchers have reported the effect of different forms of cassava diets on feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR) in sheep and goat. Tables 3 and 4 summarized body weight changes, feed intake and feed efficiency data of sheep and goat fed graded levels of cassava by product-based diets. Yousuf et al. (2007) in a 56-day feeding trial to assess the replacement value of cassava leaf meal (CLM) for cotton seed at 0, 25, 50, 75 and 100% cake reported no effect on dry matter intake, with a significant improved feed utilization

Table 1. Composition of some cassava by products, maize, soybean meal (SBM) and groundnut cake (GNC).

Constituents (%)	Cassava root sievate meal	Cassava root meal	Cassava peel meal	Cassava leaf meal	Maize	Soya bean meal	Groundnut meal
Dry matter	88.60–91.72	92.7	87.31–92.12	89.12–93.00	86.00–91.66	91.97–93.40	91.78–97.3
Crude protein	2.00–2.57	2.9–3.9	4.86–9.23	17.66–47.2	8.20–9.43	38.90–46.51	41.73–46.37
Crude fibre	1.22–18.96	18.8	9.87–14.21	5.38–7.90	3.60	2.34–6.90	2.37–4.61
Ether Extract	0.28–2.71	0.7	1.19–3.41	3.93–5.50	2.22–5.14	10.10	7.7–8.6
Ash	1.71–1.80	3.6–3.9	2.23–9.74	6.10–9.87	1.80	8.10	5.76–6.75
NFE	68.14	59.2	55.67–71.00	51.90–52.28	74.00	21.09	31.99–33.22
Gross energy (MJ/kg)[a] Metabolizable energy (Kcal/Kg DM)[b]	2.31–17.79[a]	3870[b]	3.64–16.44[a]	19.75–20.11[a]	3602.11[b]	3570.95[b]	19.12–0.18[a]
References	1; 2	9; 15	3; 4; 5;12	1; 9; 10; 13	6; 8; 11	7; 8	14

(1) Jiwuba et al. (2018); 2 Ojebiyi et al. (2013); 3 Jiwuba et al. (2016); (4) Unigwe et al. (2017); (5) Ukanwoko and Ibeawuchi (2014); (6) Banaszkiewicz (2000); (7) Guimarães et al. (2014); (8) Abera et al. (2016); (9) Dierenfeld and Fagbenro (2014); (10) Fasae et al. (2010); (11) Metwally and Abd El-Galil (2011); (12) Olafadehan (2011) (13) Devendra (1983); (14) Ghosh and Mandal, (2015); (15) Tion and Adeka 2000).

Table 2. Essential amino acid profile of some cassava by products, maize, soybean meal (SBM) and groundnut cake (GNC)

Essential amino acids	Cassava root meal (g/100 g dry sample powder)	Cassava peel meal (g/100 g protein)	Cassava leaf meal (g/16 g N)	Maize (% dry matter)	Soya bean meal (g/16 g N)	Groundnut meal (on % dry matter basis)
Arginine	0.145–0.340	3.23	5.6–6.1	0.37	6.79	4.6–4.87
Histidine	0.020–0.050	1.08	2.3–2.8	0.23	2.58	1.0–1.3
Isoleucine	0.031–0.067	2.3	5.1–5.6	0.28	4.24	1.49–1.86
Leucine	0.055–0.097	4.17	9.2–9.6	-	8.21	2.87–2.83
Lysine	0.043–0.109	2.42	6.3–6.8	0.26	0.26	1.69–1.96
Methionine	0.019–0.027	0.54	2.1–2.5	0.17	1.50	0.53–0.71
phenylalanine	0.041–0.065	2.82	5.9–6.3	0.39	4.93	2.2–1.98
Threonine	0.030–0.069	2.27	4.5–5.0	0.29	3.99	1.18–1.33
Tryptophan	0.019–0.047	1.99	4.3–4.8	-	1.05	0.48–0.43
Valine	0.054–0.087	3.10	5.8–6.3	0.39	5.22	1.86–1.71
References	1	2; 3	4; 5	6	7	8

(1)OECD (2009); (2) Chikezie et al. (2016); (3) Mutayoba et al. (2012); (4) Fasuyi and Aletor (2005); (5) Eggum (1970); 6 NRC (1998); (7) Ghosh and Mandal, (2015); 8 Banaszkiewicz (2000)

efficiency and body weight gain (32.32–37.14) advantage over the control (24.46) group among the experimental WAD goats. In another experiment with WAD sheep, Odusanya et al. (2017) observed improved (P < 0.05) dry matter intake (DMI) for sheep fed 20 and 30% CLM and best final body weight (FBW), total weight gain (TWG) and daily weight gain (DWG) among sheep fed 20% CLM diets for 90-day feeding trial. In a similar study, Fikrae (2014) recorded improved (P < 0.05) DMI and FBW in sheep fed 60% CLM with a corresponding better (P < 0.05) body weight change (BWC) and DWG among the sheep fed 30, 45 and 60% CLM containing diets for 90 days. Interestingly, Oni et al. (2010) reported significant progressively increased linear, quadratic and cubic relationships for total weight gain (TWG), BWG and FCR with increasing levels of dried cassava leaves (0–60%). They recorded the highest BWG in goats fed 60% of dried cassava leaves (DCL) in the diet (52.9 g/d) and lowest for the control (33.8 g/d). Fasae et al. (2010) reported that WAD goats fed 60% cassava foliage (CF) had the highest (P < 0.05) dry matter intake (DMI) of 386.86 g with DWG of 46.55 g/day. Noteworthy, Guimarães et al. (2014) and Akiwande et al. (2017) reported no change (P ≤ 0.05) in DMI, FBW, BWG and FCR among sheep and goat fed CPM diets respectively in comparison with the control diet. In contrast, Jiwuba and Ezenwaka (2016) record an improved linear progressive (P < 0.05) BWG and FCR with an increasing levels of CPM. They also reported highest daily feed intake (DFI) for WAD goats fed 20 and 30% cassava peel, the authors conclude. Jiwuba et al. (2017) obtained similar results in sheep fed cassava peel diets at 10, 20 and 30% for 87 days. In a similar Ajayi and Omotoso (2018) in a 105-day feeding trial reported linear improvement (P < 0.05) in total feed intake and body weight gain among sheep fed 30, 45 and 60% of cassava peel silage over the control (100% *Panicum maximum*) group. Conversely, Adebowale (1981) in a 180-day feeding trial reported reduced (P < 0.05) FBW, BWG, FI and FCR in sheep fed fermented cassava peel (FCP) diets at 40 and 60% compared to the control fed 0 % FCP. In another study, Jiwuba et al. (2018 a) showed that WAD goats fed cassava sievate meal (CSM) in a 98-day feeding trial had improved (P < 0.05) FBW, BWG and FCR. The authors attributed the improved weight gain and FCR to the high energy and fibre values, which may have supported growth and feed utilization efficiency among the goats. Similarly Jiwuba and Udemba observed ($P < 0.05$) progressive BWG among goats fed cassava root sieviate-cassava leaf meal based diets and attributed to balanced energy and protein values of the cassava root sieviate-cassava leaf meal containing diets. Hue et al. (2010) reported higher HCN concentration in fresh cassava foliage, wilted cassava foliage and cassava hay to be 333, 217 and 60 mg/kg DM respectively, and the amount consumed was significantly different among treatments, 114.6, 86.6 and 25.5 mg/day for in fresh cassava foliage, wilted cassava foliage and cassava hay respectively.

Effects on carcass and organ weights

Some researchers have reported the effect of different forms of cassava diets on carcass and organ indices of sheep and goat (Table 5 and 6). Jiwuba et al. (2018 b) reported that feeding of Provitamin A cassava peel at 0, 10, 20 and 30% dietary levels to WAD goat for 97 experimental days improved warm carcass weight, dressing percentage, and loin weights. The organ (liver, lungs, heart, kidney and spleen) weights were reduced at the treatment groups (T2, T3 and T4). The author suggested that the reduced liver weight at 10, 20 and 30% dietary levels was due the absence or tolerable levels of toxic factors or consequently, due to lesser deposition of re-

Table 3. Comparison of feed intake and feed conversion ratio of small ruminants fed cassava based diets

Form	Inclusion rates	FI (CTL)	FI (cassava)	FCR (CTL)	FCR (cassava)	Animal type	References
CLM	0, 25. 50, 75, 100	308.47	305.88–319.71	12.61	8.31–9.56	Goat	Yousuf et al. (2007)
CLM	0, 10, 20, 30	263.99	279.22–354.37	10.18	9.75–11.27	Sheep	Odusanya et al. (2017)
CLM	0, 15, 30, 45, 60	761.88	768.21–787.15	0.09	0.08–0.09	Sheep	Fikrae (2014)
DCL	0, 20, 40, 60	259	285–298	14.3	10.0–12.3	Goat	Oni et al. (2010)
CF	0, 30, 60	311.15	350.15–386.86	8.95	8.31–8.52	Goat	Fasae et al. (2010)
CP	0, 10, 20, 30	6.69	5.48–6.15	0.167	0.170–0.190	Sheep	Guimarães et al. (2014)
CP	0, 10, 20, 30	315.27	317.84–322.43	10.10	5.91–8.00	Goat	Jiwuba and Ezenwaka (2016)
CP	0, 10, 20, 30	53.70	11.00–14.33	4.24	3.50–5.22	Sheep	Jiwuba et al. (2017)
CP	0, 15, 30	95.96	96.04–96.48	8.77	12.80–14.26	Goat	Akiwande et al. (2017)
CPS	0, 30, 45, 60	566	768–840	15.74	18.23–22.33	Sheep	Ajayi and Omotoso (2018)
FCP	0, 20, 40, 60	89.2	64.7–83.6	7.42	7.77–11.80	Sheep	Adebowale (1981)
CSM	0, 20, 40, 60	29.62	29.98–31.14	12.44	7.36–8.50	Goat	Jiwuba et al. (2018)

CLM= cassava leaf meal; DCL= dried cassava leaves; CF= cassava foliage; CP= cassava peel; CPS= cassava peel silage; FCP= fermented cassava peel; CSM= cassava sievate meal

Table 4. Comparison of final body weight and weight gain of small ruminants fed cassava based diets

Form	Inclusion rates	FBW (CTL)	FBW (cassava)	WG (CTL)	WG (cassava)	Type of animal	References
CLM	0, 25. 50, 75, 100	10.21	10.61–10.92	24.46	32.32–37.14	Goat	Yousuf et al. (2007)
CLM	0, 10, 20, 30	17.54	17.64–18.35	3.84	3.56–4.35	Sheep	Odusanya et al. (2017)
CLM	0, 15, 30, 45, 60	24.95	25.02–25.72	4.95	5.06–5.80	Sheep	Fikrae (2014)
DCL	0, 20, 40, 60	10.4	11.3–12.4	3.78	4.78–5.92	Goat	Oni et al. (2010)
CF	0, 30, 60	12.01	13.28–13.39	2.92	3.45–3.91	Goat	Fasae et al. (2010)
CP	0, 10, 20, 30	31.33	30.00–32.89	0.149	0.153–154	Sheep	Guimarães et al. (2014)
CP	0, 10, 20, 30	9.33	10.12–11.65	2.31	2.94–4.04	Goat	Jiwuba and Ezenwaka (2016)
CP	0, 10, 20, 30	12.77	11.00–14.33	4.24	3.50–5.22	Sheep	Jiwuba et al. (2017)
CP	0, 15, 30	28.00	25.75–26.90	13.12	9.52–10.90	Goat	Akiwande et al. (2017)
CPS	0, 30, 45, 60	13.84	13.71–14.26	35.95	34.40–46.07	Sheep	Ajayi and Omotoso (2018)
FCP	0, 20, 40, 60	26.9	20.7–25.4	12.0	5.5–12	Sheep	Adebowale (1981)
CSM	0, 20, 40, 60	8.72	9.83–10.78	2.38	3.62–4.23	Goat	Jiwuba et al. (2018)

CLM = cassava leaf meal; DCL = dried cassava leaves; CF = cassava foliage; CP = cassava peel; CPS = cassava peel silage; FCP = fermented cassava peel; CSM = cassava sievate meal

serve substances such as glycogen among the goats fed the respective diets. The authors also suggested that the enhanced dressing percentage at 30% dietary level was due to better nutritional plane of the diet as was evident by the chemical composition of the diets. Odusanya et al. (2017) also reported increase (P < 0.05) in dressing percentage in sheep fed 20 and 30% CLM in comparison with the control. In another experiment, Adebowale (1981) reported reduced (P < 0.05) weights of the head and plucks among the WAD sheep fed 10, 40 and 60% fermented cassava peel (FCP) in comparison to the control diet. They further reported increased (P < 0.05) weights of the heart, hide and kidney plus pelvic fat among the 40 and 60% FCP compared to those fed control diet. Ukanwoko and Ibeawuchi (2012) observed that feeding 10, 20 and 30% CLM to WAD goats through 60 days did not affect carcass weight, dressing percentage, loin, heart, testicles, liver, spleen and lungs. The results of Fikrae (2014) showed non-significant effect on Horo sheep fed CLM at 0, 15, 30, 45, 60% CLM for 90 days on carcass weights, dressing percentage, cut parts, offals and organ weights. Cardoso et al. (2016) observed similar meat cut weights, visceral weights and organ weights in sheep fed 0, 33, 66, 100% cassava wastewater dregs (CWD) when compared with the control. It could therefore be established in this review that inclusion of dietary CPM or CLM at 30% and above definitely reduced liver, kidney, lungs, heart and enhanced carcass weight and dressing percentage in small ruminant. Hence, processing methods could be used to reduce the HCN to content of cassava to tolerable level in sheep and goat and more studies should be done to determine the optimal inclusion rate of CLM or CPM with the best carcass and organ weight in small ruminant. Rosly et al. (2010) reported increase liver weight in sheep and goats fed 4 and 7 mg/kg cassava forage, with 7 mg/kg showing higher liver weight. The authors attributed this to the detoxification of HCN to thiocyanate that occurs in the liver. Knowing that raw cassava or cassava byproduct contained toxic factors, chiefly HCN that would influence negatively on an organ weight and general performance of small ruminant, and most studies employed some kinds of processing.

Effect on haematology

Oni et al. (2012) reported no effect of dried cassava leaves (DCL) at 10, 20 and 30%, on packed cell volume (PCV), haemoglobin (Hb), red blood cells (RBC), mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC), white blood cell (WBC), basophil, eosinophils and monocyte in WAD goats through 116-day feeding trial. However, neutrophil and lymphocytes were affected ($P < 0.05$) at 10, 20 and 30% DCL diets. The authors attributed the reduced lymphocytes concentration to physio-

Table 5. Comparison of relative dressing percentage of sheep and goat fed cassava based diets

Form	Inclusion levels	Dressing percentage (CTL)	Dressing percentage (cassava)	Duration of study	Type of animal	References
CP	0, 10, 20, 30	39.72	46.05–54.42	97 days	Goat	Jiwuba et al. (2018 b)
FCP	0, 20, 40, 60	47.6	45.2–48.1	180 days	Sheep	Adebowale (1981)
CLM	0, 15, 30, 45, 60	44.76	43.96–44.48	90 days	Sheep	Fikrae (2014)
CLM	0, 10, 20, 30	45.0	43.8–47.8	60 days	Goat	Ukanwoko and. Ibeawuchi (2012)
CLM	0, 10, 20, 30	45.20	45.70–47.30	90 days	Sheep	Odusanya et al. (2017)

CRSCLM = cassava root sievate-cassava leaf meal; CWD = cassava wastewater dregs; CLM = cassava leaf meal; CP = cassava peel; FCP = fermented cassava peel

Table 6. Comparison of relative liver weight of sheep and goat fed cassava based diets

Form	Inclusion levels	Liver (CTL)	Liver (cassava)	Duration of study	Type of animal	References
CP	0, 10, 20, 30	2.11	1.67–1.73	97 days	Goat	Jiwuba et al. (2018 b)
CL	0, 45, 75	1.82	2.00–2.19	21 days	Sheep	Rosly et al. (2010)
CL	0, 45, 75	1.77	1.97–2.29	21 days	Goat	Rosly et al. (2010)
FCP	0, 20, 40, 60	1.68	1.73–189	180 days	Sheep	Adebowale (1981)
CWD	0, 33, 66, 100	0.714	0.693–0.759	70 days	Sheep	Cardoso et al. (2016)
CLM	0, 15, 30, 45, 60	209.00	210.00–212.00	90 days	Sheep	Fikrae (2014)
CLM	0, 10, 20, 30	1.8	1.8–1.9	60 days	Goat	Ukanwoko and. Ibeawuchi (2012)

CWD = cassava wastewater dregs; CLM = cassava leaf meal; CP = cassava peel; FCP = fermented cassava peel logical stress response arising from the animal's social behaviour such as aggressiveness and hierarchical fights. Noteworthy, all the haematological parameters examined in this study fell within the normal range values for WAD goats as reported by Daramola et al. (2005) (Table 7), this may indicate the safety of feeding WAD goats with cassava dried leaves as it maintained the normal blood formation, transportation and health of the goats. Jiwuba et al. (2016) observed that feeding WAD goats with Provitamin A cassava peel meal at 10, 20 and 30% improved ($P < 0.05$) PCV, Hb, MCHC, mean cell volume (MCV), WBC, lymphocyte and neutrophil. The significant effect of provitamin A CPM diets on haematological indices of WAD goats is in agreement with the findings of Kalio and Anyanwu (2016) but varied with the results of Baiden et al. (2007) and could be attributed partly to the inclusion rate, cassava variety, age of the goats, processing methods of the peel and the duration of trial. Fasae et al. (2010) reported that inclusion of 30 and 60% cassava foliage in goat diet resulted to similar PCV and Hb values with the control. Ukanwoko and Ironkwe (2012) reported that feeding 15% of CLM to goats had similar PCV, RBC, WBC, lymphocyte, neutrophil, monocyte and eosonophil with 15% Gliricidia and Leucaena leaf meals. Jiwuba et al. (2018 d) reported that replacement of maize offal with fufu sievate meal at 20, 40 and 60% had positive effect on RBC, MCH and lymphocyte; nevertheless, Hb, MCV, MCHC, WBC and neutrophil remained similar in comparison with the reference values of Fraser and Mays (1986) and Daramola et al. (2005). These findings indicated that 60% inclusion of fufu sieviate in the diets of goats had no adverse effect on the haematological parameters. Ogundu et al. (2018) reported that replacement of brewer's dried grain with cassava peel in the diet of goats at 13, 26 and 39% had no effect on Hb, MCV, MCH, MCHC, WBC, lymphocyte, eosinophil and basophil in comparison with the control. Kalio and Anyanwu (2016) reported significant ($P > 0.05$) increase in PCV, RBC, WBC, MCV and MCH in WAD does fed cassava peel in comparison to those on ripped plantain peel. The difference may be attributed to the differences in the plane of nutrition and due to lower levels of iron in ripped plantain peel. Ukanwoko and Ironkwe (2012) similarly reported improvement

Table 7. Mean range of haematological parameters of goats

Parameters	Fraser and Mays (1986)	Daramola et al. (2005)	Oni et al. (2012)	Jiwuba et al. (2016)	Oni et al. (2017)	Jiwuba et al. (2018)	Ogundu et al. (2018)
Packed cell volume (%)	22.0–38.0	21–35	24.0–27.5	28.87–32.91	22.50–25.50	27.21–33.10	25.00–30.25
Haemoglobin (g/dl)	8.0–12.0	7–15	7.9–9.0	10.77–13.23	7.45–8.50	7.83–9.91	8.08–9.50
Red blood cells ($x10^6$/µl)	8.0–18.0	9.2–13.5	11.4–13.0	10.94–11.01	7.50–9.10	10.52–13.11	15.63–19.78
Mean cell haemoglobin concentration (g/dl)	30.0–36.0	32–34.6	32.8–33.4	31.05–34.25	33.00–34.40	29.92–31.61	30.45–31.95
Mean cell volume (fl)	16.0–25.0	-	-	17.04–19.04	-	15.78–17.72	14.75–16.35
Mean cell haemoglobin (Pg)	5.2–8.0	-	6.9–7.1	6.13–6.34	9.13–10.40	5.11–7.02	4.73–5.18
White blood cell ($\times10^9$/l)	4.0–13.0	6.8–20.1	7.8–13.5	8.82–11.69	5.30–7.50	7.15–9.40	10.65–13.30
Lymphocyte (%)	50.0–70.0	47–82	50.0–63.5	61.50–67.13	59.33–70.67	59.79–65.31	77.25–81.70
Neutrophil (%)	30.0–48.0	17–52	35.0–49.5	32.78–38.14	29.00–39.67	30.06–33.13	12.00–19.50

(P > 0.05) on Hb and MCHC on WAD goats fed cassava leaf meal over the goats fed *Gliricidia* leaf meal. Oni et al. (2017) reported that goats fed 100 : 400 : 475 g/kg DM of cassava peel, cassava leaves and cowpea haulm respectively resulted to significant improvement in RBC and lymphocyte, but the PCV was reduced (P < 0.05) at 500 : 200 : 275 g/kg DM of cassava peel, cassava leaves and cowpea haulm respectively, substitution levels. The depressive effect of cassava based diets on WBC as reported by Oni et al. (2017) confirms the findings earlier reported in goats fed cassava peel (Kalio and Anyanwu, 2016) but varied with increased WBC value in goats fed Provitamin A cassava peel diets reported by Jiwuba et al. (2016). The observed differences in the studies could be attributed to the cassava varieties and processing method.

Baiden et al. (2007) reported significant (P < 0.05) effect of cassava pulp at 15 and 30% on Hb and PCV and no effect on WBC and RBC in WAD sheep through nine weeks feeding; however, Hb, PCV, RBC and WBC were improved at 15 and 30% of cassava pulp diets. The authors perhaps attribute the improvement (P < 0.05) in Hb and PCV for the sheep to nutritional or phytogenic properties of cassava pulp. Odusanya et al. (2017) observed that feeding WAD sheep with CL at 10, 20 and 30% had no adverse effects on PCV, RBC and Hb while 10, 20 and 30% CL influenced WBC count. The non-significant effect of CL diets on blood constituents of sheep is in agreement with the results of Fasae et al. (2010) but varies with the results of Anaeto et al. (2013) and could be attributed partly to the age of the sheep, inclusion rates and the duration of feeding. Ogundipe and Akinlade (2016) observed that addition of 50% CPM in sheep diet improved RBC, Hb and WBC, while diet containing 70% CPM reduced PCV values. Jiwuba et al. (2017) observed that WAD sheep fed CPM had blood constituents well compared with the reference values reported by Radostits et al. (2006). Fasae et al. (2015) reported that sheep fed cassava leaves had comparable PCV, RBC and Hb values with the sheep on cassava peel diet, this confirm the safety of cassava by products in sheep feeding programme.

Effect on serum biochemistry

Gomes et al. (2005) and Promthong et al. (2005) compared cassava starch to maize starch and found that cassava starch contains 17% amylose and 83% amylopectin, compared with maize starch that has 28% amylose and 72% amylopectin. Some studies have documented the energy density of cassava root and crude protein of cassava leaf meal in sheep and goats.

Table 8. Mean range of haematological parameters of sheep

Parameters	Radostits et al. (2006)	Baiden et al. (2007)	Odusanya et al. (2017)	Jiwuba et al. (2017)	Fasae et al. (2015)
Packed cell volume (%)	27–45	28.5–34.3	31.34–34.33	29.71–33.30	30.00–36.00
Haemoglobin (g/dl)	9.0–15.0	9.45–11.8	10.77–12.00	9.35–10.60	10.10–12.00
Red blood cells ($x10^6$/μl)	9.0–15.0	8.23–11.1	11.00–13.40	12.08–12.99	10.55–12.45
Mean cell haemoglobin concentration (g/dl)	31.0–34.0	-	-	33.69–36.50	-
Mean cell volume (fl)	28–40	-	-	32.70–34.80	-
Mean cell haemoglobin (Pg)	8.0–12.0	-	-	9.50–10.44	-
White blood cell ($\times10^9$/l)	4.0–12.0	6.94–10.5	7.55–12.63	15.0–16.82	8.80–13.80
Lymphocyte (%)	-	46–57	-	-	-
Neutrophil (%)	-	43–52	-	-	-

Oni et al. (2012) reported an increased serum glucose, though within the normal physiological range for goats fed 20, 40 and 60% cassava leaf meal in comparison with the other reported values (Ajayi et al., 2012; Akinrinmade and Akinrinde, 2012; Kalio et al. 2014) (Table 9). These findings confirmed the results of Jiwuba et al. (2018 d) who reported that replacement of maize offal with 20, 40 and 60% cassava sievate in goat diets increased serum glucose, urea and creatinine; hence suggesting that the quality of the diets were not compromised and that there was no kidney damage among the experimental goats. In a comparative study with WAD does fed different crop by product (yam peels, cassava peels, sweet potato peels and ripe plantain peels), Kalio and Anyanwu (2016) reported increased serum potassium and reduced serum cholesterol, urea, sodium and inorganic phosphorus values for goats on cassava peel diets. The significantly (P > 0.05) lower cholesterol value reported for WAD goats on cassava peel diet gave a clear evidence of susceptibility of heart related diseases. Serum glucose, creatinine, sodium and chlorine levels of the goats were not influenced by crop by products. Jiwuba et al. (2016) reported that goats fed Provitamin A cassava peel meal in their diets had improved total protein, globulin, albumin, creatinine and AST values. Oni et al. (2017) recorded significantly (P > 0.05) values for goat fed cassava peel and leaves in their diets for total protein, globulin, creatinine, urea, glucose and serum alanine aminotransferase (ALT). The higher values of total protein and globulin may be attributed that cassava peels and leaves could contain low levels of tannins that are known to reduce nutrient permeability in gut walls as well as increase excretion of endogenous protein, which is subsequently passed out in the faeces and so may not alter protein metabolism.

Conclusion

Numerous studies have shown that cassava and cassava by products have the potential nutritional attributes that are useful when considering its incorporation in sheep and goat diets, but the presence of toxic factor like HCN seems to limit its utilization by small ruminants in fresh state. Foliage from cassava be used as a feed supplement, but processing to reduce the HCN content before feeding is strongly recommended. Raw cassava root or cassava leaves may not be recommendable for sheep and goat production, but processed cassava by products can be successfully incorporated into small ruminant feeding system to enhance sheep and goat production.

Table 9. Mean range of serum biochemical parameters for goats

Parameters	Kaneko et al. (1997)	Aiello and Mays, 1998)	Oni et al. (2012)	Jiwuba et al. (2016)	Oni et al. (2017)	Jiwuba et al. (2018)
Total bilirubin (μmol/l)	0–1.71	1.7–4.3	-	0.18–0.22	-	-
Cholesterol (mg/ dl)	80–130	1.7–3.5	-	61.4–63.07	-	-
Creatinine (mg/ dl)	1.0–1.8	60–135	0.8–1.2	11.11–1.34	0.5–1.50	0.81–1.03
Glucose (mg/ dl)	50–75	2.7–4.2	47.4–54.0	-	45.0–58.0	2.83–3.73
Total protein (g/l)	64.0–70.0	61–75	70.2–71.1	66.21–73.32	29.0–60.70	6.85–7.70
Albumin (g/l)	27.0–39.0	24–36	31.7–37.4	32.20–34.98	29.0–30.3	-
Globulin (g/l)	27.0–41 .0	27–44	33.9–38.7	34.01–38.99	26.0–30.4	-
Urea (mg/ dl)	10–20	3.7–9.3	28.1–35.8	13.11-17.85	12.5-17.33	3.68-4.86
ALT (U/l)	6–19	15–52	7.0–16.8	26.75–27.25	50.33–6.33	16.93–18.87
AST (U/l)	167–513	66–230	18.8–29.3	19.61–27.12	16.5–23.33	17.04–19.51

Conflict of interest

The authors declare that they have no conflict of interest.

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