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NUTRITIVE VALUE AND AVAILABILITY OF COMMONLY USED FEED INGREDIENTS FOR FARMED NILE TILAPIA (*OREOCHROMIS NILOTICUS* L.) AND AFRICAN CATFISH (*CLARIAS GARIEPINUS*, BURCHELL) IN KENYA, RWANDA AND TANZANIA

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ABSTRACT

Commonly utilized feed ingredients for culture of Nile tilapia (*Oreochromis niloticus)* and African catfish (*Clarias gariepinus)* from Kenya, Tanzania and Rwanda were collected over a period of six months (January - June 2010) and evaluated for their nutritive composition through proximate analysis. Most of the fish feed ingredients were found in all the three countries except a few that were unique to one or two countries as detailed in the results. Feed ingredients of animal origin exhibited significantly ($P<0.05$) higher crude protein levels (407 - 635 g/kg DM) compared to the feed ingredients of plant based origin. Freshwater shrimps (*Caridina nilotica*) contained the highest crude protein levels of 635 g/kg DM. Feed ingredients of animal origin had low ether extracts (EE) with an exception of Omena fish (*Rastrineobola argentea)*. Crude fibre (CF) was generally higher on feed ingredients of plant origin and ranged between 55- 368 g/kg DM while Nitrogen Free Extracts (NfE) and ash content were higher in the feedstuffs of plant origin with an exception of maize bran which had the lowest value. Omena fish and freshwater shrimp had higher ash content of 182 and 228g/kg DM compared to other feed ingredients of animal origin, which may indicate contamination with soil particles during drying process. Based on the feed ingredient availability, potential competition with other human uses, content of crude protein and crude fibre and the feasibility of removal of anti-nutritional factors, *C. nilotica*, blood meal, meat and bone meal, were identified as most promising sources of animal based protein. Cotton *(Gossypium spp)* and sunflower (*Helianthus annuus*) seed cakes provided the best option as source of processed plant based protein. Leaves of gallant soldier (*Galisonga parviflora*), sweet potato (*Ipomoea batatus*), cassava (*Manihot esculenta*) and papaya (*Papaya carica*) were identified as high potential feedstuffs of plant origin either processed or in raw form for small-scale fish farming. We recommend that in well fertilized semi-intensive ponds, maize (*Zea mays*), wheat (*Triticum aestivum*) and rice (*Oryza sativa*) bran may be utilized where available to supplement natural pond food.

Key words: Tilapia, catfish, feed, East Africa

INTRODUCTION

Aquaculture in East Africa like many other sub-Saharan countries is under-developed and contributes less than 1% to global aquaculture production [1]. The cost of fish feeds, among other factors, has been identified as one of the key factors limiting aquaculture development in the region. Victoria Research Initiative (VicRes) through the Inter University Council of East Africa (IUCEA) in an effort to contribute towards solving the problem of high feed cost in the region funded the collection, processing and analysis of 30 different locally utilized feed ingredients for culture of Nile tilapia (*Oreochromis niloticus*, L.) and African catfish (*Clarias gariepinus*), in Kenya, Tanzania and Rwanda.

Protein is the most expensive component in fish feeds. Traditionally fishmeal has been used as the main source of animal protein in fish feeds and is the most preferred source of animal protein due to balanced amino acid profiles [2, 3, 4, 5]. However, fishmeal has continuously experienced fluctuating prices, competition from other animal feed manufacturers thus affecting aquaculture feed production and consequently profitability [6, 7, 8]. As a result, a lot of effort has been focused on feed alternatives to fishmeal both from plant and animal protein sources worldwide [9, 10, 11]. In order to enhance fish farming yields, improve food security, reduce the level of poverty in developing countries and create employment, a search for cheap and locally available feedstuffs is necessary.

The Eastern Africa region has many agro-industrial by-products from agricultural processing, which are usually not utilized for human consumption, but may have a high potential in tilapia and catfish feeds. *C. gariepinus* and *O. niloticus* are the most commercially important species among the farmed fish in the East African countries [12, 13, 14, 15]. Although most of these agro-industrial by-products have been evaluated for inclusion in poultry and livestock feeds [16, 17, 18, 19, 20] only a few have been evaluated for their potential as fish feeds [21, 22, 23, 24]. Development of a feed for fish production involves evaluation of proximate composition, digestibility and performance efficiency as well as cost implications and conditions of application.

The current study was undertaken to determine what fish farmers are currently utilizing as fish feeds for *C. gariepinus* and *O. niloticus* in Kenya, Rwanda and Tanzania and to determine the nutritive value for the utilized feed ingredients by using laboratory analyses. Data from the current study are expected to form a basis for further evaluation of the effects of selected feed components on digestibility and fish growth in the three countries. Ultimately it is anticipated that value addition of the already utilized fish feeds in the East African region will be a major contribution towards production of quality fish feed, cutting fish feed cost and improving the returns from fish farming in the region.

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MATERIALS AND METHODS

Study area

The collection of feed ingredients was conducted in three East African countries (Kenya, Tanzania and Rwanda). Two sites were chosen from each country and ingredient samples were collected during a period of six months (January – June, 2010). The collection sites are shown in Figure 1 below.

KEY:

(A) Bidii - Luanda region; (B) Bigege - Kisii region; (C) Ukerewe island; (D) Magu - Mwanza region ; (E) Kigembe Gisakara - Butare region; (F) Kicukiro-Kigali region

Figure 1: Map of Lake Victoria basin showing the collection sites of ingredients

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Ingredients Proximate Analysis

The collected feed ingredients were analyzed at National Aquaculture Research, Development & Training Center (NARDTC) – Sagana - Kenya, which lies at latitude 0° 39'S, longitude 37° 12'E, and at an altitude of 1230 m above sea level. The ingredients were sun-dried and ground to coarse particles using a blender liquidizer (model A989, Hampshire, UK). They were further ground into finer particles using an electric grinder fitted with a 1 mm sieve (Thomas-Wiley intermediate mill, 3348-L10 series, USA) and dried in an oven to a constant weight at 60 ^{o}C. Analyses of crude protein, crude fibre, ether extracts, ash and moisture content were done in triplicates, following the procedure by Association of Official Analytical Chemists (AOAC) [25]. Dry matter (DM) was determined by drying 5 grams of sample in an oven for six hours to constant weight at 105 °C. Crude protein was quantified by the standard micro-Kjeldahl Nitrogen method, using a sample size of 0.4 g, a Behroset InKje digestion apparatus and a Behr S 1 steam distillation apparatus (both: Labor-Technik GmbH, Düsseldorf, Germany). The distillate containing ammonia was trapped in 4 % boric acid solution prior to titration with 0.1N HCl. Crude protein was estimated by multiplying the nitrogen content with a factor of 6.25. Ether extracts were analyzed using a sample size of 2 g in a Soxhlet extractor with petroleum ether (boiling point 40–60 °C). Crude fiber (CF) was determined by boiling 1 g of sample in a standard solution of 3.13 % H_2SO_4 for 10 minutes. The remaining sample was rinsed with hot water followed by boiling in 3.13 % NaOH for another 10 minutes. Thereafter the remaining sample was rinsed repeatedly with hot water followed by acetone. The residue was oven dried at 60 °C for 4 hours, cooled in a desiccator and weighed. The residue was ashed at 550 °C in a muffle furnace overnight. CF was quantified by expressing the loss in weight after ashing as a percentage of the original weight of the sample. Nitrogen Free Extracts were estimated by difference (DM-CP-EE-CF-Ash). The type of sample and some basic information on their availability are summarized in Table 2.

RESULTS

Proximate Analyses of Feed Ingredients from Kenya, Tanzania and Rwanda

A checklist of the feed ingredients samples and some basic information on their availability and cost are presented in Table 1. Most of the feeds were found in all countries except a few that were unique to one or two countries (Table 1). Apart from the feeds that were being used by the farmers a few other feedstuffs found in abundance in the study sites such as water fern and water hyacinth were also collected for proximate analysis for future use. Sweet potato, Avocado, Lucerne and Papaya were found in all the three countries (Table 1). The proximate composition of different feed ingredients analyzed in Kenya, Tanzania and Rwanda are shown in Table 2, 3 and 4 respectively. Omena (*Rastrineobola argentea*) commonly used as fish meal in East African countries was not available in Rwanda as a fish feed ingredient but was analyzed in both Kenya and Tanzania and the CP level were similar (551g/kg DM) in the two countries (Table 2 and 3). Although, maize bran was a common ingredient found in all the three countries, its CP level was slightly higher but not significantly (P>0.05) different in Rwanda compared to Tanzania and Kenya (Table 2, 3 4). Feed ingredients of animal origin exhibited high CP levels (407 - 635 g/kg DM) compared to the feed ingredients of plant origin and Fresh water shrimp (*C. nilotica*) contained the highest CP levels of 635 g/kg DM (Table 2, 3 4). Feed ingredients of animal origin also had low ether extracts (EE) with an exception of *R. argentea* which had higher quantity of EE.

Crude fibre was generally higher in feedstuff of plant origin and ranged between 55-368g/kg DM while Nitrogen Free Extracts (NfE) and Ash content were higher in the feedstuff of plant origin with an exception of maize bran which had the lowest value. In feedstuff of animal origin, Omena and freshwater shrimp which had higher ash content of 182 and 228g/kg DM compared to other animal feedstuff. The results of the proximate analysis of the present study were different from the results obtained from previous studies in other countries (Table 5, 6, 7).

DISCUSSIONS

Most of the feed ingredients analyzed were found in all the three countries (Kenya, Rwanda and Tanzania) except a few which were unique to one or two countries. The protein content of feed ingredients of animal origin were significantly higher (P<0.05) than those of plant origin in all the three countries. Unfortunately the costs of feed ingredients of animal origin are generally high and unlikely to be economically viable for semi-intensive culture of *O. niloticus* and *C. gariepinus* when their percent inclusion in the diet formulations is over 25%. In the present study, Freshwater shrimp meal (FSM) recorded the highest CP levels (Table 2, 3) of all the ingredients that were analyzed. Although FSM has previously been reported [26, 27] to have high potential for inclusion in *O. niloticus* diets due to high protein content and lack of competition as human food, it has suffered several limitations among others, competition as an ingredient in poultry and livestock feed manufacturing industries. There has also been persistent unavailability of FSM from Lake Victoria where it occurs as a by-product of the Omena (*R. argentea*) fishery when fishing of omena is banned in Lake Victoria. These limitations make FSM a less competitive ingredient in fish feed production.

The protein content of *R. argentea* is high (Table 3), and suitable as a high quality source of dietary protein in fish feeds where it has been used for decades. However, in the L. Victoria region *R. argentea* is directly used as human food and thus inclusion in fish feeds leads to direct competition with the ultimate target. This, coupled with high cost reduces its feasibility for utilization as a feed ingredient in semi-intensive culture systems. However, *R. argentea* can be used in formulations for intensive systems where fish stocking densities and financial returns are high. Blood, meat & bone meal, offal's and other slaughter wastes can also be used in *O. niloticus* and *C. gariepinus* diet formulations owing to their high crude protein levels and relatively low cost but there is need to ensure proper pre-processing to ensure parasites and zoonotic organisms are eliminated. All plant leaves ingredients with the exception of banana leaves contained crude protein levels above 25 % (Table 3, 4) and thus may have a high potential for inclusion in *O. niloticus and C. gariepinus* feeds. However, no plant protein can on its own support good growth of fish due to deficiency in at least one essential amino acid [28].Their utilization may be feasible in semi-intensive production systems, where autotrophic and heterotrophic food material may supply the deficient amino acids [29, 30]. Based on their proximate composition, leaf meals with exception of banana leaves have a high potential for inclusion in *O. niloticus* and *C. gariepinus* feeds, as they all had protein contents above 250 mg kg^{-1} feed, which is close to the value recommended for inclusion in the grow out diets for *O. niloticus* [31]. The suitability of these feedstuffs for use in *O. niloticus* and *C. gariepinus* feeds is further made feasible by the fact that with the exception of arrowroot, they grow well in low rainfall areas, which form a greater portion of Kenya, Tanzania and Rwanda. Cassava, arrowroot and sweet potato are tuber plants and their roots are commonly used as human food. The leaves are rarely consumed by humans in East Africa region, and may be available for use in *O. niloticus* and *C. gariepinus* feeds. Compared to values from previous research [32] sweet potato, pawpaw and cassava leaves registered higher CP levels than reported in previous studies as indicated in Table 5, 6, 7 [33, 34]. The CP of other feedstuffs including water fern, kitchen wastes and arrow root leaves were in the same range as shown from results of previous studies in other countries in Table 5, 6, 7 [35, 36, 37, 38, 39, 40, 41]. From literature, it is indicated that several of the agricultural by-products studied contain components which may affect their nutritive value. In the case of cassava, a toxic component known as Linamarin has to be considered. Linamarin causes cyanide poisoning, but the toxicity may be removed by boiling and/or sun drying [42]. Literature on the utilization of Papaya (*C. papaya)* leaf meals in fish feeds is scarce. The limited available information indicates that papaya leaf meal could be a good protein source because of its amino acid profile [43, 44]. The papaya leaf and the unripe papaya fruit contain papain, which degrades protein into amino acids [45]. It has been reported that papain promotes proteolytic digestion and thereby increases the protein digestibility of papaya leaf meal [46]. *C. papaya* peels contain lectins, which are toxic compounds relevant to fish and other animals [47, 48], but can be destroyed by heat treatment followed by aqueous methanol extraction or soaking in water for 24 hours under refrigerated conditions [49]. Information on the use of Lucerne leaf meal in fish feeds is limited [50], but it is widely used in livestock feeds [51]. The plant is rich in the amino acid leucine, which enhances its potential for inclusion in fish feeds. However, the presence of mimosine which is toxic to most animals, may limit its application in fish feeds [52]. Difference in growth response of male and female tilapia has been observed when fed a diet containing Lucerne leaf meal: males seemed to tolerate it better than females. However, the production of fry was significantly reduced beyond the 40 % inclusion level. Mimosine is known to cause disruption of reproductive processes and teratogenic effects in animals [53]. Mimosine toxicity can be removed through boiling in an open vessel or by addition of ferrous sulphate solution and/or soaking in water at 30°C for 48 hours [54]. The nutritional quality of oil-seed by-products has been extensively evaluated [55, 56]. Seed residues have generally high CP levels but may be low in cystine, methionine and lysine, which are frequently lacking in plant protein sources (Table 5, 6, 7). The levels of nutrients and toxic compounds in seed residues depend largely on the methods of processing and may also vary between strains [57]. The limit in inclusion levels of CSC is determined by the level of gossypol [58, 59], a toxic phenolic compound that is found in the pigment glands of the cotton plant [60]. Gossypol has been associated with reduced fingerling recruitment in *O. niloticus*. The suitability of sunflower seed cake (SFSC) as a fish feed has been evaluated [61, 62]. SFSC contains a high level of protein (Table 5, 6, 7), which may vary according to the quality of the original seed and the method of processing. Among the different by-products of sunflower seed, dehulled cakes are recommended to be included in fish feeds because of their high protein and relatively low CF levels [63]. Sunflowers are widely grown in many parts of East African region; therefore their by-products have a high quantitative potential for use in fish feeds. Although SFSC is not available in the sites in Rwanda, they are farmed in other parts of the country and can be grown and incorporated into fish feeds.

Papaya seeds and peels may quantitatively have a high potential in the fish feed industry throughout the three countries, where papaya plants are abundant. Mango stone seeds are also available in great amounts, mainly in the drier areas of Kenya. However, due to the low CP content of the seed (Table 5), it is unlikely to become an important food component for *O. niloticus* and *C. gariepinus*. The use of cereal brans in Kenya has recently been evaluated: wheat, maize and rice brans were fed to *O. niloticus* and growth performance in fertilized ponds. Both wheat bran (WB) and maize bran (MB) promoted good growth of Nile tilapia and can substitute each other, depending on whichever of the two is locally available. A general deficiency of lysine in cereal by-products has been reported, but deficient nutrients might be supplemented by natural pond food in semi-intensive culture systems [63]. Cereal brans are generally cheap and readily available in most East Africa region, and may therefore be an important feed component in semi-intensive *O. niloticus and C. gariepinus* production. Seed pulp/husks are quite cheap and abundantly available from agricultural processing factories. However, most seed pulps and husks are of low nutritive quality, due to high fibre content as shown in table 5, 6, 7 and eventually their low acceptability by fish. Nevertheless, they may be utilized as feed components in semi-intensive fish production, where they may be either consumed directly by the fish or serve as organic fertilizers and thereby indirectly enhance their food value for the cultured fish [63].

CONCLUSION AND RECOMMENDATIONS

In conclusion based on the feed ingredient availability, potential competition with other human uses, content of protein and fibre and the feasibility of removal of anti-nutritional factors, freshwater shrimps, blood meal, meat and bone meal, were identified as most promising sources of animal based protein. Cotton and sunflower seed cakes, leaves of gallant soldier, sweet potato, cassava and papaya were identified as high potential feedstuffs of plant origin either processed or raw. The research team also recommended that in well fertilized semi-intensive ponds maize, wheat and rice bran may be utilized.

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Table 1: Checklist of commonly utilized feed ingredients in Kenya, Tanzania and Rwanda

Ingredient	**Country**					
	Kenya		Rwanda		Tanzania	
	Occurrence	Cost US $	Occurrence	Cost US $	Occurrence	Cost US $
Fish meal (*Rastrineobola argentea*)	✓	0.76			✓	0.40
Shrimp (*Caridina nilotica*) meal	✓	0.5			✓	0.40
Cow (*Bos taurus*) blood meal	✓	0.00	✓	0.35	✓	
Cow (*Bos taurus*) offal's			✓	0.88		
Cow (*Bos taurus*) bone Meal	✓	0.63				
Cassava (*Manihot esculenta*) leaves	✓	Na		Na	✓	Na
Cassava (*Manihot esculenta*) flour					✓	0.07
Premix	✓				✓	
Soya bean (*Glycine max*) flour	✓	0.70				
Rice (*Oryza sativa*) bran	✓	0.08	✓	0.09		0.09
Rice (*Oryza sativa*) polishings	✓	0.16				
Maize (*Zea mays*) bran	✓	0.25	✓	0.44	✓	0.14
Wheat (*Triticum aestivum*) bran	✓	0.08	✓	0.53		0.00
Wheat (*Triticum aestivum*) pollard	✓	0.15				
Maize (*Zea mays*) corn glutten	✓	0.78				
Arrow root (*Maranta arundinacea*) leaves	✓	Na	✓	Na	✓	Na
Sweet Potato (*Ipomoea batatus*) leaves	✓	Na	✓	Na	✓	Na
Banana *(Musa paradisiaca)* leaves			✓	Na		
Papaya (*Carica papaya*) leaves	✓	Na	✓	Na	✓	Na
Mchicha (*Amaranthus blitum*)	✓	Na	✓	Na	✓	Na

Gallant soldier (*Galisonga parviflora*)	✓	Na				
Avocado (*Persea americana*)	✓	Na	✓	Na	✓	Na
Lucerne (*Chamaecytisus palmensis*)	✓	Na	✓	Na	✓	Na
Sunflower (*Helianthus annuus*) seed cake	✓	0.19			✓	0.12
Peanut (*Arachis hypogaea*) cake			✓	0.15		
Cotton (*Gossypium spp*) seed cake	✓	0.23			✓	1.72
Cabbage (*Brassica oleracea*)		Na	✓	0.09	✓	0.40
Concentrate			✓	0.35		
Kitchen wastes			✓	Na		

¶*Na = Not applicable; the feedstuff may be sourced off farm, off field or the household at no defined cost*

Table 2: Proximate composition of different feed ingredients analysed in Kenya, ($\bar{x}$ ±S.E)

Product	n	*DM	CP	EE	CF	NfE	Ash
		g/kg	g/kg DM				
Fish meal(*Rastrineobola argentea*)	9	879±0.6	551±1.7	187±1.5	13±0.6	68±1.0	182±1.5
Shrimp (*Caridina nilotica*) meal	7	877±1.7	635±3.3	13±1.3	50±1.8	67±2.1	228±2.5
Maize (*Zea mays*) bran	8	894±3.0	118±4.6	107±2.7	55±0.7	349±3.5	29±1.3
Wheat (*Triticum aestivum*) bran	8	882±1.6	171±6.2	58±2.3	127±2.3	582±6.9	60±2.6
Rice (*Oryza sativa*) bran	5	923±4.2	70±3.8	41±1.6	309±2.4	349±3.5	229±2.2
Arrow root (*Maranta arundinacea*) leaves	6	903±2.6	335±1.0	85±1.5	106±4.6	381±2.1	93±2.3
Banana *(Musa paradisiaca)* peel	5	901±2.1	72±1.7	79±1.3	113±2.6	627±1.7	109±2.8
Banana *(Musa paradisiaca))* stem	7	926±1.0	100±1.8	50±2.2	441±1.7	205±3.5	205±4.5
Banana *(Musa paradisiaca)* leaves	6	899±1.0	170±1.8	127±1.4	241±01.8	337±1.3	124±3.6
Cotton (*Gossypium spp*) seed cake	5	892±2.0	388±7.2	107±1.0	249±4.5	192±2.6	63±4.6
Sunflower (*Helianthus annuus*) seed cake	5	929±0.4	259±0.1	54±0.8	368±0.2	266±0.8	51±0.1
Cassava (*Manihot esculenta*) leaves	5	919±3.6	308±4.8	86±4.1	156±4.0	368±2.1	82±5.2
Papaya (*Carica papaya*) peel	6	839±1.3	179±2.4	18±3.1	194±2.2	456±4.0	154±03.4
Papaya (*Carica papaya*) leaves	7	903±2.9	282±5.0	105±2.5	130±1.3	329±3.3	154±1.2
Papaya (*Carica papaya*) seed meal	4	945±1.7	264±21	316±1.3	119±1.0	203±1.6	98±1.3
Sweet potato (*Ipomoea batatus*) leaves	5	892±1.6	353±3.6	43±3.7	105±3.6	388±1.1	104±3.6
Water fern, (*Salvinia auriculata*)	6	888±2.4	232±1.9	49±0.8	302±3.6	239±1.3	179±3.4
Mango (*Mangifera indica*) seed embryo	2	907±1.4	70±0.7	97±1.4	37±0.7	771±2.1	24±1.4
Coffee (*Coffea arabica)* husks	4	893±1.9	47±1.8	36±0.6	383±2.6	418±3.6	115±2.8
Cotton (*Gossypium spp*) husks	3	906±4.9	173±4.4	55±1.0	587±1.5	153±1.5	36±0.6
Brewery by-product	6	919±1.9	264±0.3	291±0.1	158 ±0.6	221±0.5	66±0.4
Tilapia (*Oreochromis spp*) fillet remains	7	916±1.4	580±1.7	181±1.5	67±1.7	75±1.7	97±1.4
Catfish (*Clarias gariepinus)* fillet remain	6	923±2.5	570±2.4	192±2.3	73±2.4	96±2.4	69±2.2
Sorghum (*Sorghum bicolor)* beetle	4	948±1.2	461±1.6	165±1.5	109±1.4	224±1.5	41±1.2

DM=Dry matter, CP=Crude Protein, EE=Ether Extracts, CF= Crude Fibre, NfE=N-free Extracts.

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Table 3: Proximate composition of different feed ingredients analysed in Tanzania ($\bar{x}$ ±S.E)

Product	n	*DM	CP	EE	CF	NfE	Ash
		g/kg	g/kg DM				
Fish meal (*Rastrineobola argentea*)	9	892±1.7	551±1.7	187±1.5	13±0.6	67±1.0	182±1.5
Fresh water shrimp (*Caridina nilotica*)	8	877±1.7	635±3.3	13±1.3	50±1.8	74±2.1	228±2.5
Cow (*Bos taurus*) blood meal	9	908±1.6	420±1.5	18±1.6	11±1.5	453±1.7	98±1.7
Cow (*Bos taurus*) offals	8	912±1.8	409±1.9	98±1.6	88±1.6	310±1.6	95±1.6
Cassava (*Manihot esculenta*) leaves	9	912±4.7	286±4.8	84±4.1	145±4.	388±2.1	97±5.2
Cassava (*Manihot esculenta*) flour	9	920±4.5	24±4.8	13±4.6	70±4.6	801±4.6	92±4.6
Maize (*Zea mays*) bran	8	894±3.2	118±3.6	107±3.7	155±3.7	591±3.5	29±3.3
Maize(*Zea mays*) corn glutten	9	913±3.0	550±4.6	187±2.7	89±0.7	62±3.5	112±1.3
Arrow root (*Maranta arundinacea*) leaves	9	901±2.9	314±1.0	85±1.5	106±4.6	402±2.1	93±2.3
Sweet Potatoe (*Ipomoea batatus*) leaves	8	897±1.6	334±3.6	48±3.7	116±36	389±1.1	113±3.6
Papaya (*Carica papaya*)	9	902±2.9	279±5.0	107±2.5	128±13	325±3.3	161±1.2
Mchicha (*Amaranthus blitum*)	8	891±1.6	359±3.6	53±3.7	107±36	384±1.1	97±3.6
Avocado (*Persea americana*)	9	903±2.9	182±5.0	405±2.5	130±13	159±3.3	124±1.2
Lucerne (*Chamaecytisus palmensis*)	9	898±1.7	329±2.6	56±3.7	112±36	388±1.1	107±3.6
Sunflower (*Helianthus annuus*) seed cake	8	929±0.4	259±0.1	54±0.8	368±02	268±0.8	51±0.1
Cotton (*Gossypium spp*) seed cake	9	892±2.0	388±7.2	107±1.0	249±45	193±2.6	63±4.6
Cabbage (*Brassica oleracea*)	8	901±3.4	219±3.2	47±3.3	98±3.4	499±1.1	137±3.2

DM=Dry matter, CP=Crude Protein, EE=Ether Extracts, CF= Crude Fibre, NfE=N-free Extracts.

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Table 4: Proximate composition of different feed ingredients analysed in Rwanda ($\bar{x}$ ±S.E)

Product	n	*DM	CP	EE	CF	NfE	Ash
		g/kg	g/kg DM				
Cow (*Bos taurus*) blood meal	9	912±1.5	459±1.6	39±1.6	16±1.8	387±1.0	99±1.0
Cow (*Bos taurus*) offals	8	909±1.6	407±1.7	98±1.6	98±1.4	300±1.0	97±1.6
Rice (*Oryza sativa*) bran	9	921±4.3	75±3.7	45±2.5	311±2.4	338±1.0	231±2.4
Maize (*Zea mays*) bran	8	899±3.0	120±4.5	109±2.6	155±2.7	584±1.0	32±1.3
Wheat (*Triticum aestivum*) bran	9	888±1.7	178±6.2	67±2.3	122±2.3	563±1.0	70±2.6
Arrow root (*Maranta arundinacea*) leaves	9	905±2.7	322±1.3	83±1.5	109±4.6	389±1.0	97±2.3
Sweet Potatoe (*Ipomoea batatus*) leaves	8	895±1.8	359±3.8	53±3.8	112±3.4	372±1.0	104±3.6
Banana *(Musa paradisiaca)* leaves	9	899±1.0	170±1.8	127±1.4	241±1.8	338±1.0	124±3.6
Papaya (*Carica papaya*) leaves	9	903±2.9	282±5.0	105±2.5	130±1.3	329±1.0	154±1.2
Mchicha (*Amaranthus blitum*)	8	891±1.6	359±3.6	53±3.7	107±36	384±1.0	97±3.6
Avocado (*Persea americana*)	8	903±2.9	182±5.0	405±2.5	130±1.3	159±1.0	124±1.2
Lucerne (*Chamaecytisus palmensis*)	8	898±1.7	329±2.6	56±3.7	112±3.6	396±1.0	107±3.6
Peanut (*Arachis hypogaea*) cake	8	921±1.4	229±0.1	94±0.8	68±0.2	547±1.0	62±0.1
Cabbage (*Brassica oleracea*)	9	900±2.3	211±3.3	57±3.3	98±3.4	497±1.0	137±3.2
Kitchen wastes	9	865±2.1	189±2.2	86±1.4	142±1.4	462±1.0	121±1.2

DM=Dry matter, CP=Crude Protein, EE=Ether Extracts, CF= Crude Fibre, NfE=N-free Extracts.

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Table 5: Comparison of nutritive levels of selected common animal and plant feed ingredients of the current study in Kenya, Tanzania & Rwanda and previous studies elsewhere in the world.

Product	*DM	CP	EE	CF	NfE	Ash
	g/kg	g/kg DM				
Fresh water shrimp (*Caridina nilotica*) meal						
Current study	903	635	85	106	81	93
Kenya						
India	-	455	-	-	-	221-
Madagascar	-	736	66	-	-	186-
Malaysia	795	455	21	400	-	124
Maize (*Zea mays*) bran						
Current study	894	118	107	55	349	29
Tanzania	890	106	48	13	19	814
Thailand	880	109	50	34	29	768
Wheat (*Triticum aestivum*) bran						
Current study	882	171	58	127	582	60
Tanzania	876	169	38	64	113	616
India	-	128	31	86	-	45
Malaysia	881	188	46	54	97	616
India	907	139	83	46	131	601
Rice (*Oryza sativa*) bran						
Current study	923	70	41	309	349	229
India	913	137	54	181	488	181
Thailand	886	174	27	104	509	106
Malaysia	899	109	108	136	454	136

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Arrow root (*Maranta arundinacea*) leaves						
Current study	903	335	85	106	381	93
Banana*(Musa paradisiaca)* peel						
Current study	901	72	79	113	627	109
Nigeria	141	79	-	-	-	134
Cotton (*Gossyium spp*) seed cake						
Current study	892	388	107	249	192	63
Egypt	879	264	57	66	242	371
USA	989	461	7	71	151	310
Israel	923	477	54	66	125	278
Sunflower (*Helianthus annuus*) cake						
Current study	929	259	54	368	266	51
Uganda	910	341	143	132	318	66
Rwanda	918	269	-	69	-	.0
Nigeria	-	411	-	-	-	-
China	-	316	89	24	-	64
Cassava (*Manihot esculenta*) leaves						
Current study	919	308	86	156	368	82
Nigeria	256	147		-	-	161
Papaya (*Carica papaya*) leaves						
Current study	903	282	105	130	329	154
Nigeria	184	91	56	-	-	172
Sweet potato (*Ipomoea batatus*) leaves						
Current study	892	353	43	105	388	104
Israel	892	194	37	259	105	408

Malaysia	913	188	23	113	188	488
Trinidad	877	219	34	150	180	417
Nigeria	946	28.55	-	-	-	475
Water fern (*Salvinia auriculata*)						
Current study	888	232	49	302	239	179
India	-	116	28	204	469	183
Cotton (*Gossyium spp*) husks						
Current study	878	638	12	179	51	120
Brewery by-product						
Current study	-	455	-	-	-	221-
India	291	243	52	196	451	58
Tilapia (*Oreochromis spp*) fillet remains						
Current study	-	736	66	-	-	186-
Catfish (*Clarias gariepinus*) fillet remain						
Current study	795	455	21	400	-	124

DM*=Dry matter,* ***CP****=Crude Protein,* ***EE****=Ether Extracts,* ***CF****= Crude Fibre,* ***NfE****=N-free Extracts.*

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