Proximate composition of selected potential feedstuffs for Nile tilapia (*Oreochromis niloticus* Linnaeus) production in Kenya

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Nährstoffgehalt ausgewählter potenzieller Futtermittel für die Erzeugung von Tilapia (*Oreochromis niloticus* L.) in Kenia

1 Introduction

Nutrition is vital in fish farming because feed costs represent 40–50 % of the total variable production costs (SHANG, 1992; CRAIG and HELFRICH, 2002). For several decades, fishmeal has been used as the main source of protein in fish feeds (TACON and JACKSON, 1985; TACON, 1993; EL-SAIDY and GABER, 2004; ALCESTE and JORY, 2000). However, the periodically occurring low availability, competition and continuously fluctuating prices of fishmeal are affecting aquaculture feed production and consequently the profitability (WATANABE, 1988; WATANABE and PONGMANEERAT, 1991; LIM and DOMINAY, 1990). As a result, a lot of effort has been focussed on feed alternatives to fishmeal both from plant and animal protein sources (EL-SAIDY and GABER, 2004; EL-SAYED, 1998; FERNANDES et al., 1999; FASAKIN et al., 1999; RINCHARD et al., 2002; HOSSAIN et al., 2002).

In order to enhance aquacultural production, improve food security, and reduce the level of poverty in developing

Zusammenfassung

Agrarische Nebenprodukte wurden nach ihrer lokalen Verfügbarkeit in verschiedenen Regionen Kenias beurteilt und beprobt. Vier Proben tierischer und 23 Proben pflanzlicher Herkunft wurden einer Futtermittelanalyse unterzogen, um ihren potenziellen Futterwert für die Erzeugung von Tilapia in Teichwirtschaft, die auf Nutzung lokaler Ressourcen basiert, abzuschätzen. Aufgrund der Verfügbarkeit, der Konkurrenz zu anderen Verwertungspfaden, dem Gehalt an Protein und Rohfaser sowie der Praktikabilität der Inaktivierung möglicher antinutritiver Inhaltsstoffe wurden folgende Nebenprodukte als potenzielle Futtermittel eingestuft: Federnmehl, extrahierte Teeblätter sowie Blätter von *Ipomoea batatus*, *Manihot esculenta* und *Papaya carica*. Weiters können bei gegebener regionaler Verfügbarkeit verschiedene Kuchen von Ölsaaten sowie Getreidekleien verwertet werden, während Getreidespelzen allenfalls als organische Dünger in der Teichwirtschaft verwendet werden können.

Schlagworte: Aquakultur, Tilapia, Nährstoffe, Nebenprodukte, Futter.

Summary

Agricultural by-products were sampled depending on their local availability in three regions of Kenya. Proximate analysis was performed on 4 and 23 samples of animal and plant origin, respectively, to estimate their potential nutritive value for utilization as feedstuffs for tilapia grown in a low-input pond culture system, which greatly relies on local resources. Based on their availability, potential competition with other uses, content of protein and fibre and the feasibility of removal of antinutritional factors, feather meal, boiled tea leaves residues, leaves of *Ipomoea batatus*, *Manihot esculenta* and *Papaya carica* were identified as most promising potential feedstuffs. In addition, different seed cakes and cereal brans may be utilized where available and grain husks may serve as organic fertilizers in low-intensity aquacultures.

Key words: Tilapia, fish, nutrient, by-product, feed.

countries, a search for cheap and locally available feedstuffs is required. Kenya is endowed with many by-products from agricultural processing, which are usually not utilized for human consumption, but may have a high potential in tilapia feeds. Nile tilapia, *Oreochromis niloticus* L., is one of the commercially important species among the farmed tilapias in Kenya and many other tropical and sub-tropical countries. This is due to its fast growth, resistance to diseases and the ability to feed on the lowest trophic level (PULLIN, 1988). The adults of this species consume large quantities of plant materials, which are largely dominated by live algae, detritus and the associated bacteria (MORIARTY, 1973; GETACHEW, 1987; DIANA et al., 1991). Many of these agricultural by-products have been evaluated for inclusion in poultry and livestock feeds (GOMEZ, 1982; LAWRENCE and MUGERWA, 1974; LEDGER and TILLMAN, 1972; JACKSON and FULTON, 1971; BAUSTAD, 1974); however only a few have been evaluated for their potential as tilapia feeds (WAIDBACHER et al., 2006; LITI et al., 2005; MAINA et al., 2002; LITI et al., 2006).

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 and evaluate the potential of selected by-products for use as feedstuffs in tilapia, using both laboratory analyses and information from the literature. 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 under different culture conditions. One key element of the underlying concept of this work is that the targeted feedstuffs are not directly consumed by human. Therefore it is anticipated that their transformation into high quality fish protein in low-input pond culture systems, which greatly rely on local resources, can be a major contribution to improving the protein supply for the local human population.

2 Materials and methods

The present study surveyed selected potential feedstuffs with a specific focus on sources of plant origin. Selection of the feedstuffs was based on regional and temporal availability, and likely costs in Kenya. Analyses were conducted at Sagana laboratory of the Kenya Fisheries Department. Agricultural by-products available in Lake Victoria basin, central and eastern Kenya were targeted (Table 4). Samples were collected during a period of three months (April to July 2005) from the different regions and seasonality did not affect their availability. They 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 °C. Poultry feathers were ground to smaller sizes by the use of a hammer mill prior to hydrolysing and cooked in an autoclave at a pressure of 1.1 bars and a temperature of about 105 °C, for 3 hours before being subjected to the processing described above.

Analyses of crude protein, crude fibre, ether extracts, ash and moisture content were done in triplicates, generally following the procedure by AOAC (1995). 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 M 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 analysed 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).

3 Results

Data on proximate composition of selected feedstuffs are presented in Table 1 (a–e). The proximate composition of feedstuffs from animal origin is presented in Table 1a. Crude protein content of animal feedstuffs ranged between 551–808 g/kg DM. Among this group of feedstuffs, Omena fish (*Rastrineobola argentea*) had the lowest CP levels while hydrolysed feather meal (HFM) had the highest. Ether extracts (EE) were generally low in animal feedstuffs with the exception of *R.argentea*. The ash content was also quite variable (35–228g/kg DM) while CF and NFE contents were low.

Crude protein (CP) levels in feedstuffs of plant origin ranged from 72–353 g/kg DM (Table 1b). Leaves of arrow root (*Maranta arundinacea*), cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatus*) had a CP content of over 308 g/kg DM, while leaves of leucaena (*Leucaena leucocephalus*), papaya (*Carica papaya*), boiled tea (*Camellia sinensis)* leaves residue (BTLR) and water fern (*Azolla pinnata*) had CP levels of between 230 and 282 g/kg DM. Banana (*Musa paradisiaca*) leaves, papaya fruit peels, pyrethrum (*Anacyclus* spp) waste as well as whole water hyacinth (*Eichhornia crassipes*) had CP levels between 133–180 g/kg DM. Banana peels and stem as well as pyrethrum leaves showed CP levels below 100 g/kg DM. Papaya and banana leaves had a higher CP content than either their fruit peels or the stem.

Table 1a: Proximate composition of locally available feedstuffs of animal origin (±s)
Tabelle 1a: Nährstoffgehalt lokaler Futtermittel tierischer Herkunft (±s)

Product	No of samples	*DM	CP	EE	CF	NfE	Ash
		g/kg			g/kg DM		
Freshwater shrimp meal FSM	4	877±1.7	635±3.3	13±1.3	50±1.8	67±2.1	228±2.5
Hydrolysed feather meal BHFM	3	891±1.0	797±2.1	24±1.5	48±1.5	96±2.0	35±1.5
Hydrolysed feather meal IHFM	3	897±1.5	808±1.7	19±2.1	31±1.0	43±1.6	100±1.0
Omena (*Rastrineobola argentea*)	4	879±0.6	551±1.7	187±1.5	13±0.6	68±1.0	182±1.5

*DM = Dry matter, CP = Crude Protein, EE = Ether Extracts, CF = Crude Fibre, NfE = N-free Extracts,
BHFM = Broiler hydrolysed feather meal, IHFM = Indigenous hydrolysed feather meal.

Table 1b: Proximate composition of different plant parts and by-products (±s)
Tabelle 1b: Nährstoffgehalt verschiedener Pflanzenteile bzw. pflanzlicher Nebenprodukte (±s)

Product	No of samples	*DM g/kg	CP	EE	CF g/kg DM	NfE	Ash
Arrow root leaves	3	903±2.6	335±1.0	85±1.5	106±4.6	381±2.1	93±2.3
Banana peel	4	901±2.1	72±1.7	79±1.3	113±2.6	627±1.7	109±2.8
Banana stem	4	926±1.0	100±1.8	50±2.2	441±1.7	205±3.5	205±4.5
Banana leaves	4	899±1.0	170±1.8	127±1.4	241±1.8	337±1.3	124±3.6
Boiled tea leaves residue	4	919±1.7	279±2.2	149±1.3	148±1.7	377±1.9	47±1.9
Casssava leaves	5	919±3.6	308±4.8	86±4.1	156±4.0	368±2.1	82±5.2
Leucaena leaves	3	929±1.0	280±1.5	71±1.5	158±2.1	391±1.0	99±2.0
Papaya peel	4	839±1.3	179±2.4	18±3.1	194±2.2	456±4.0	154±03.4
Papaya leaves	4	903±2.9	282±5.0	105±2.5	130±1.3	329±3.3	154±1.2
Pyrethrum whole	2	890±0.7	150±1.4	45±0.7	282±3.5	420±1.4	104±4.2
Sweet potato leaves	5	892±1.6	353±3.6	43±3.7	105±3.6	388±1.1	104±3.6
Water fern, whole	4	888±2.4	232±1.9	49±0.8	302±3.6	239±1.3	179±3.4
Water hyacinth, whole	2	895±1.4	133±4.2	18±1.4	260±2.8	407±4.2	188±3.5

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

Table 1c: Proximate composition of selected seed meals (±s)
Tabelle 1c: Nährstoffgehalt ausgewählter Samen bzw. Nebenprodukte (±s)

Product	No of samples	*DM g/kg	CP	EE	CF g/kg DM	NfE	Ash
Cottonseed cake	5	893±2.0	388±7.2	107±1.0	249±4.5	192±2.6	63±4.6
Mango seed embryo	2	907±1.4	70±0.7	97±1.4	37±0.7	771±2.1	24±1.4
Papaya seed meal	4	945±1.7	264±21	316±1.3	119±1.0	203±1.6	98±1.3
Sunflower seed cake	5	929±0.4	259±0.1	54±0.8	368±0.2	266±0.8	51±0.1

*DM = Dry matter in g/kg, CP = Crude Protein, EE = Ether Extracts, CF = Crude Fibre, NfE = N-Free Extracts,

Table 1d: Proximate composition of selected cereal brans (±s)
Tabelle 1d: Nährstoffgehalt ausgewählter Kleien (±s)

Product	No of samples	*DM g/kg	CP	EE	CF g/kg DM	NfE	Ash
Maize bran	5	894±3.0	118±4.6	107±2.7	55±0.7	691±1.9	29±1.3
Rice bran	5	923±4.2	70±3.8	41±1.6	309±2.4	349±3.5	229±2.2
Wheat bran	5	882±1.6	171±6.2	58±2.3	127±2.3	582±6.9	60±2.6

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

Table 1e: Proximate composition of selected seed husks (±s)
Tabelle 1e: Nährstoffgehalt ausgewählter pflanzlicher Nebenprodukte (±s)

Product	No of samples	*DM g/kg	CP	EE	CF g/kg DM	NfE	Ash
Coffee husks	4	893±1.9	47±1.8	36±0.6	383±2.6	418±3.6	115±2.8
Coffee pulp	4	874±1.9	172±2.2	60±1.3	281±2.2	320±1.9	168±1.3
Cotton husks	3	906±4.9	173±4.4	55±1.0	587±1.5	153±1.5	36±0.6

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

Ether extracts (EE) were generally low in all plant feedstuffs with exception of BTLR, banana and papaya leaves which contained over 100 g/kg DM. Crude fibre (CF) was generally high and variable among feedstuffs of plant origin and ranged between 105–441 g/kg DM; only arrowroot and sweet potato leaves contained CF levels below 110 g/kg DM (Table 1b). Banana stem had the highest CF content. Nitrogen free extracts (NFE) were generally high in feedstuffs of plant origin with most of them in the range of 320–420 g/kg DM. Banana peel had NFE value above 480 g/kg DM while banana stem and water fern had NFE values below 250 g/kg DM. Ash content was generally low, banana stem had the highest ash values while BTLR had the lowest.

The nutrient content of the seeds and seed cakes was generally high and is presented in (Table 1c): Cotton (*Gossypium spp*) seed cake (CSC) had the highest protein content among the seeds and seed cakes that were tested. Papaya (*Carica papaya*) seed meal (PSM) and sunflower (*Helianthus annuus*) seed cake (SFSC) had similar CP values while mango (*Mangifera indica*) seed embryo (MSE) had the lowest CP value. EE was generally low in CSC, SFSC and MSE but high in PSM. Crude fibre levels varied greatly with SFSC having the highest and MSE the least. Ash levels were generally low in all the seeds. MSE were especially rich in NFE.

Proximate composition data of the three cereal brans are presented in (Table 1d). Wheat (*Triticum aestivum*) bran (WB) had the highest CP content while rice (*Oryza sativa*) bran (RB) had the lowest, EE in maize (*Zea mays*) bran (MB) was nearly double the amount recorded in WB, while RB registered the least. WB and MB had low ash contents but were high in NFE, while RB had the highest ash level and the lowest NFE among the brans. Crude fibre was nearly 2–6 times higher in rice bran than in wheat and maize bran, respectively.

Data on proximate composition for seed husks are presented in (Table 1e). The seed husks were generally of low nutritive value with exceptionally high crude fibre content and low CP content, coffee (*Coffea arabica*) pulp and cotton husk had moderate CP levels of 172 and 173 g/kg DM respectively. Coffee pulp and husks had NFE values of over 320 g/kg DM. The ash content was low in cotton husk but high in coffee pulp and coffee husk.

4 Discussion and Conclusions

The present results indicated that the protein content of feedstuffs from animal origin was higher than that of plant by-products. Nevertheless, the costs of these feed components from animal origin are generally high and therefore they are unlikely to be cost-effective for semi-intensive tilapia production systems. The exception in the category of the animal feedstuffs was the hydrolysed feather meal, which also had the highest level of CP (Table 1a, 3). Utilization of HFM in tilapia feeds is economically feasible since the costs involved for procurement were essentially transport costs. However, despite the high CP level and low

Table 2: Selected toxic constituents for the analysed components
Tabelle 2: Toxische Inhaltsstoffe der untersuchten Futtermittel

Product	Toxic Factor	Effect	Preventative Treatment
Manihot esculenta	Linamarin	Cyanide poisoning when bruised in water	Peeling (fresh), washing, boiling (JAUNCEY and ROSS, 1982; TEWE, 1991)
Leuceana leucocephalus	Mimosine	Reproductive disorders, teratogenic effects (D'MELLO, 1991)	Boiling, addition of ferrous sulphate solution (DUKE, 1983), soaking (WEE and WANG, 1987)
Papaya carica leaves and green fruit	Benzyl isothiocyanate (BITC) Lectins	Irritation of mucus epithelial membrane	Heat treatment plus extraction or soaking (MAKKAR and BECKER, 1999)
Gosspyium spp	Gossypol	Complex formation with lysine, growth depression	Screw-pressing or solvent extraction (JAUNCEY and ROSS, 1982)
Zea mays	Dhurrin	HCN due to hydrolysis of cyanogenetic glycoside	Proper storage (JAUNCEY and ROSS, 1982)

Table 3: Comparison of nutritive levels of common selected animal and plant by-products of the current and previous studies (ADCP, 1983, 1987)
Tabelle 3: Gegenüberstellung des Nährstoffgehalts ausgewählter tierischer und pflanzlicher Nebenprodukte im Vergleich zu früheren Untersuchungen (ADCP, 1983, 1987)

Product	*DM g/kg	CP	EE	CF g/kg DM	NfE	Ash
Sweet potato (*Ipomoea batatus*) leaves						
Current study	902	358	34	86	95	466
Israel	892	194	37	259	105	408
Malaysia	913	188	23	113	188	488
Trinidad	877	219	34	150	180	417
Cotton (*Gossyium spp.*) seed cake						
Current study	902	393	81	485	217	301
Egypt	879	264	57	66	242	371
USA	989	461	7	71	151	310
Israel	923	477	54	66	125	278
Fresh water shrimp (*Caridina nilotica*)						
Current study	878	638	12	179	51	120
India	–	455	–	221	–	–
Madagascar	–	736	66	186	–	–
Malaysia	795	455	21	400	–	124
Hydrolysed feather meal (Indigenous)						
Current study	893	807	18	70	31	74
Hydrolysed feather (Broiler)						
Current study	893	796	4	15	23	178
USA	930	914	39	38	4	5
Sunflower (*Helianthus annuus*) cake,						
Current study	931	259	44	44	345	326
Uganda	910	341	143	66	132	318
Nigeria	–	411	–	–	–	–
Rice (*Oryza sativa*) bran						
Current study	916	74	34	194	309	395
India	913	137	54	181	200	488
Malaysia	899	109	108	136	169	454
Maize (*Zea mays*) bran						
Current study	887	120	82	22	51	738
Tanzania	890	106	48	13	19	814
Thailand	880	109	50	34	29	768
Wheat (*Triticum aestivum*) bran						
Current study	876	174	43	44	108	651
Tanzania	876	169	38	64	113	616
Malaysia	881	188	46	54	97	616
India	907	139	83	46	131	601

Table 4: Sampling site and number of samples
Tabelle 4: Anzahl der Proben je Futtermittel und Ort der Probenziehung

Product	No of samples	Sampling site and (no. of samples per site)
Freshwater shrimp meal	4	Lake Victoria Kisumu (4)
Broiler chicken feathers	3	Sagana (1), Machakos (1), Kisumu (1)
Indigenous chicken feathers	3	Sagana (1), Machakos (1), Kisumu (1)
Omena fish	4	Lake victoria Kisumu (4)
Arrow root leaves	3	Sagana (1), Machakos (1), Kisumu (1)
Banana peel	4	Sagana (2), Machakos (1), Kisii (1)
Banana stem	4	Sagana (2), Machakos (1), Kisii (1)
Banana leaves	4	Sagana (1), Machakos (1), Kisii (2)
Boiled tea leaves residue	4	Sagana (2), Machakos (1), Kisumu (1)
Casssava leaves	5	Sagana (2), Machakos (2), Kisumu (1)
Leucaena leaves	3	Sagana (2), Machakos (1)
Papaya peel	4	Sagana (2), Athiriver (2)
Papaya leaves	4	Sagana (2), Athiriver (2)
Pyrethrum whole	2	Naivasha (1), Nakuru (1)
Sweet potato leaves	5	Sagana (2), Machakos (3)
Water fern, whole	4	Sangoro fishponds (2), Sagana fishponds (2)
Water hyacinth, whole	4	Lake Victoria (2), Nairobi dam (2)
Cottonseed cake	5	Nairobi (2), Makueni (2), Kisumu (1)
Mango seed embryo	2	Sagana (1), Machakos (1)
Papaya seeds	4	Sagana (2), Nairobi (2)
Sunflower seed cake	5	Kitale(2), Nairobi(2), Machakos (1)
Maize bran	5	Kitale (1), Sagana (2), Machakos (2)
Rice bran	5	Sagana (2), Kisumu (3)
Wheat bran	5	Nyeri (3), Eldoret (2)
Coffee husks	4	Machakos (2), Sagana (2)
Coffee pulp	4	Machakos (2), Sagana (2)
Cotton husks	3	Machakos (1), Makueni (1), Sagana (1)

costs, feather meal is an uncommon ingredient in the fish feed industry. Among others, its unbalanced amino acid profile is probably one reason for its limited exploitation. TACON et al. (1984) reported high CP in HFM but also cautioned on the deficiency in some essential amino acids, which included methionine, lysine, histidine and tryptophan. Some fish feeding trials indicated that HFM could only be included up to 20 % in diets for *Labeo rohita* without adverse effects on growth (HASAN et al., 1997). Nevertheless, HFM could possibly be included in tilapia feeds at even higher levels under semi-intensive culture conditions, where nutrient deficiencies might be supplemented by natural pond food. LI and YAKUPITIYAGE (2002) reported that pond fertilization provides exogenous elementary nutrients that enhance natural food productivity for omnivorous fish like tilapia. Consequently, depending on the actual conditions, phytoplankton and zooplankton may be an important source of nutrients, supplementing diets of fish raised in pond culture (RAKOCY and MCGINTY, 1989). The ash content in HFM was markedly higher in the feathers of indigenous chickens than in those of broiler chickens (Table 1a). The difference might be attributed to contamination of the feathers with inorganic soil particles during dust bathing. Broilers are usually confined in pens and do not have access to inorganic substrate for dust bathing (LACY, 2002).

Freshwater shrimp meal (FSM) ranked second to HFM in terms of CP (Table 1a, 3), which was within the range of 490–740 g/kg DM as reported by JAUNCEY and ROSS (1982). Although FSM has a high potential for inclusion in tilapia feeds because it is not used as human food, it suffers several limitations. In previous studies LITI et al. (2005) reported higher costs of fish production with diets containing FSM compared to those containing all plant protein feedstuffs. In addition, FSM is periodically scarce in the Kenyan market due to seasonal closures of the Omena (*Rastrineobola argentea*) fishery in Lake Victoria, in which FSM is a by-product. Besides this, there is usually stiff competition from other feedmills such as the poultry feed industry. These limitations make FSM a less competitive candidate in tilapia feeds.

The protein content of *R. argentea* is high (Table 1a, 3), and from a nutritional point of view it may be a suitable source of dietary protein in fish feeds. However, *R. argentea* is directly used as human food and thus inclusion in tilapia feeds might imply direct competition with the ultimate target. This, coupled with cost implications, reduces its feasibility for utilization in low-input pond fish production systems.

All plant leaves with the exception of banana leaves contained crude protein levels above 25 % (Table 1b, 3) and thus may have a high potential for inclusion in tilapia feeds. However, no plant protein can on its own support good growth of fish due to deficiency in at least one essential amino acid (JAUNCEY and ROSS, 1982). However, utilization may be feasible in semi-intensive production systems, where autotrophic and heterotrophic food material may supply the deficient amino acids (RAKOCY and MCGINTY, 1989; LI and YAKUPITIYAGE, 2002). Based on their proximate composition, leaf meals with exception of banana have a high potential for inclusion in tilapia feeds, as they all had protein contents above 250 mg kg^{-1} feed, which was close to the value recommended for inclusion in the grow-out diets for *O. niloticus* (SANTIAGO and LOVELL, 1988). The suitability of these feedstuffs for use in tilapia 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. Cassava, arrowroot and sweet potato are tuber plants and their roots are commonly used as human food. Their leaves are rarely consumed by human in many regions of Kenya, and thus may be available for use in tilapia feeds. Compared to values from previous research (ADCP, 1983; 1987; TAN, 1970), sweet potato leaves registered higher CP levels than reported from other countries (Table 3). All the other feedstuffs were in the same range as results from previous studies (Table 3). Several of the by-products mentioned herein are likely to contain components which may affect their nutritive value. In the case of Cassava, a toxic component known as Linamarin has to be considered (Table 2). Linamarin causes cyanide poisoning, but the toxicity may be removed by boiling and/or sun drying (JAUNCEY and ROSS, 1982; TEWE, 1991).

Literature on the utilization of *papaya carica* leaf meals in fish feeds is scarce. The limited available information (REYES and FERMIN, 2003) indicate that *papaya carica* leaf meal could be a good protein source because of its amino acid profile (GERPACIO and CASTILLO, 1979). In Kenya, papaya leaf meals are not used for human food. The papaya leaf and the unripe fruit contain papain, which degrades protein into amino acids (CHAPLIN, 2005). BUCHANAN (1969) reported that papain promotes proteolytic digestion and thereby increases the protein digestibility of papaya leaf meal. Therefore, future studies on papaya leaves may be directed towards improvement of feed digestibility. *P. carica* peels contain lectins, which are toxic compounds relevant to fish and other animals (MAKKAR and BECKER, 1997; CANO ASSELIECH et al., 1989), but can be destroyed by heat treatment followed by aqueous methanol extraction or soaking in water for 24 hours under refrigerated conditions (Table 2; MAKKAR and BECKER, 1999). If antinutritional components can be inactivated, papaya leaves may be a valuable feed component in tilapia production systems, which are based on local resources, due to their high protein content and proteolytic properties.

Information on the use of *Leucaena* leaf meal in fish feeds is limited (SANTIAGO et al., 1988), but it is widely used in livestock feeds (DUKE, 1983). The plant is rich in the amino acid leucine, which enhances its potential for inclusion in fish feeds. However, the presence of mimosine (Table 2), which is toxic to most animals, may limit its application in fish feeds (D'MELLO, 1991). Difference in growth response of male and female tilapia has been observed when fed a diet containing *Leucaena* leaf meal: males seemed to tolerate it better than females. However, the production of fry was significantly reduced beyond the 40 % inclusion level (SANTIAGO et al., 1988). D'MELLO (1991) noted that mimosine causes disruption of reproductive processes and teratogenic effects in animals. Mimosine toxicity can be removed through boiling in an open vessel or by addition of ferrous sulphate solution (DUKE, 1983) and/or soaking in water at 30ºC for 48 hours (Table 2; WEE and WANG, 1987).

Boiled tea leaves residue (BTLR) is a by-product of a popular beverage in Kenya and is readily available in all parts of the country. Due to the usual way of preparing milk tea in Kenya, BTLR is likely to contain remnants of milk, which will improve its nutritive value. BTLR contains high levels of CP and EE (Table 1b), which make it a potential ingredient for inclusion in tilapia feeds. There are no reports on antinutritional factors in BTLR and as they were not analysed in the present study, a critical evaluation of antinutritional compounds prior to utilization is essential.

The nutritional quality of oilseed by-products has been extensively evaluated (OLVERA et al., 2002; EL-SAYED, 1990; MAINA et al., 2002; EL-SAIDY and GABER, 2004). 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 1c, 3; JAUNCEY and ROSS, 1982). The levels of nutrients and toxic compounds in seed residues depend largely on the methods of processing and may also vary between strains (LIENER, 1980). The limit in inclusion levels of CSC is determined by the level of gossypol (LIN et al., 1988; RINCHARD et al., 2002; EL-SAIDY and GABER, 2004), a toxic phenolic compound that is found in the pigment glands of the cotton plant (BERARDI and GOLDBLATT, 1980). Gossypol has been associated with reduced fingerling recruitment in *O. niloticus* (LITI et al., 2005).

The suitability of sunflower seed cake (SFSC) as a fish feed has been evaluated (OLVERA et al., 2002; JACKSON et al., 1982; MAINA et al., 2002). SFSC contains a high level of protein (Table 1c, 3), which may vary according to the quality of the original seed and the method of processing (JAUNCEY and ROSS, 1982). A wide variety of products are available on the Kenyan market, ranging from low quality straw to high quality meals. Among the different by-products of sunflower seed, GOHL (1975) recommended that dehulled cakes are the by-product to be included in tilapia feeds because of their high protein and relatively low CF levels. Sunflowers are widely grown in many parts of Kenya; therefore their by-products have a high quantitative potential for use in fish feeds. The oilseed meal of papaya (PSM) contains high amounts of protein (Table 1c). Although information on the potential inclusion levels in fish feeds is rare or even missing, PSM may quantitatively have a high potential in the fish feed industry throughout Kenya, where papaya plants are abundant. Mango stone seeds are also available in great amounts, mainly in the drier areas of Eastern Kenya. However, due to the low CP content of the seed (Table 1c), it is unlikely to become an important food component for tilapia in the future.

The use of cereal brans in Kenya has recently been evaluated: LITI et al. (2006) fed wheat, maize and rice brans to *O. niloticus* and evaluated the 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 (LITI et al., 2006). The authors reported that rice bran (RB) was nutritionally inferior to WB and MB. The low nutritive quality of RB was attributed to poor processing methods. RB is reportedly mixed with hulls (VEVERICA et al., 1998; LITI et al., 2006) resulting in high levels of crude fibre and a low protein content (Table 1d, 3). GOHL (1975) reported a general deficiency of lysine in cereal by-products, but deficient nutrients might be supplemented by natural pond food in semi-intensive culture systems (NRC 1993). Cereal brans are generally cheap and readily available in most Kenyan regions, and may therefore be an important feed component in semi-intensive tilapia production.

Seed pulp/husks are quite cheap and abundantly available from processing factories. However, most seed pulps and husks are of low nutritive quality, due to high fibre contents (Table 1e) and eventually their low acceptability by fish (ULLAO and VERRTH, 2002). Nevertheless, they may be utilized as feed components in semi-intensive production of tilapia, where they may be either consumed directly by the fish or serve as organic fertilizers and thereby indirectly enhance the food basis for tilapia (NRC, 1993).

From the data presented here and from information provided by the literature, it can be concluded that the currently underutilized leaves of *Camellia sinensis* (residues), *Ipomoea batatus*, *Manihot esculenta*, *Papaya carica* and hydrolysed feather meal may have a high potential as feedstuffs for tilapia grown in semi-intensive pond culture which relies greatly on local resources. This estimation is mainly based on the actual contents of protein and crude fibre, the possibility and practicability of removing antinutritional constituents, and on the local availability and the potential competition with other uses. However, before wholescale utilization there is need for further research to evaluate among others the amino acid profile, digestibility and antinutritional factors.

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