Locally available feedstuffs for small-scale aquaculture in Ethiopia – a review

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Lokal verfügbare Futtermittel für kleinbäuerliche Aquakultur in Äthiopien – eine Übersicht

1 Introduction

With an average annual growth rate of 11 percent over the past decade and an expected continuation of this trend, aquaculture is the fastest growing food producing sector in the world today (Aguilar-Manjarrez & Nath, 1998; FAO, 2006). If it is designed to be sustainable, it will be a very promising answer to the challenge of providing additional food and employment to a growing world population. In Ethiopia, the main source of fish is capture freshwater fishery (FAO, 2005a). The reasons for this are the lacking access to marine fish resources and the fact that local aquaculture is not well developed. Despite the annual per capita fish production being less than 240 g, the demand for fish has increased in the last decade; thereby current fish production can meet only 79 percent of the country's demand for fish (FAO, 2005a). As a consequence, most of the easily accessible Ethiopian lakes are over-exploited and their fish production is declining at an alarming rate. Supported by experience from other countries, aquaculture – if developed in a sustainable way – may be the best alternative in this serious situation (Watanabe, 2002; Yang et al., 2006). The aquaculture activity in Ethiopia has been limited to introduction of exotic freshwater fish species and distribution of indigenous and exotic fish species to man-made and natural water bodies throughout the country by actors on dif-

Zusammenfassung

Die Futtermittel-Verfügbarkeit stellt einen wichtigen limitierenden Faktor für die Entwicklung von Aquakultursystemen in Äthiopien dar. Auf der Grundlage von Ergebnissen der Weender Analyse wurden 7 Kategorien von lokal verfügbaren Futtermitteln hinsichtlich ihrer Eignung für einen Einsatz in der Aquakultur beurteilt.

Die potenziell bestgeeigneten Futtermittel gehören den Gruppen der industriellen Nebenprodukte, Grünfutterpflanzen, Getreide- und Leguminosensamen sowie dem Laub von Futterbäumen und Sträuchern an. Wurzeln und Knollen sowie die Gruppe der übrigen Futtermittel wurden wegen ihres geringen Futterwertes als wenig geeignet eingestuft. Ernterückstände, die wegen der großen Bedeutung des Ackerbaus in Äthiopien häufig gut verfügbar wären, weisen in der Regel einen sehr niedrigen Rohnährstoffgehalt auf. Wenn diese Ressource in Zukunft für die Aquakultur genutzt werden soll, muss an Möglichkeiten zur Verbesserung des Futterwerts der Ernterückstände gearbeitet werden.

Schlagworte: Aquakultur, Äthiopien, Fisch, Futtermittel, Nährstoffanalyse.

Summary

The lack of suitable feedstuffs is a major factor limiting the development of aquaculture in Ethiopia. Available datasets of proximate analysis were used to assess the suitability as a fish feed of 7 groups of locally available feed materials. The most promising components were found among agro-industrial by-products, herbaceous forages, cereal and legume seeds and leaves of fodder trees and shrubs. Roots and tubers, other feed crops and less common feeds were found to be less suitable. Because of the dominant role of crop farming in Ethiopia, crop residues are widely available, but are mostly of poor nutritional value. Therefore emphasis has to be given to assess possibilities for improving the nutritional value of crop residues if they are to be utilized for aquaculture in the future.

Key words: Aquaculture, Ethiopia, fish, feed, proximate analysis.

ferent levels. Mostly, Nile tilapia (*Oreochromis niloticus L.*) has been introduced throughout the country, because of its adaptive abilities and its suitability to match Ethiopian consumers' preferences. As a consequence of its natural occurrence plus its introduction into different water bodies, it is contributing about 40.9 % of the 13,253 tons of commercial fish catch in 2007/2008 (MoARD, 2008). The commercial fish catch composition of Ethiopia for the years indicated above is presented in Figure 1.

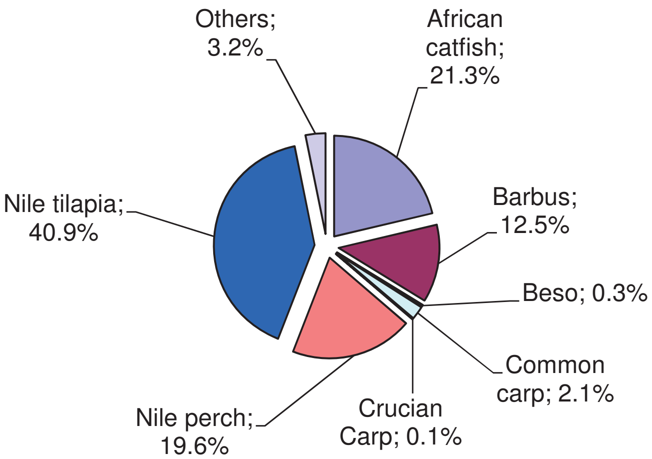

Figure 1: Species composition of commercial fish catch of Ethiopia in 2007/2008 (MoARD, 2008)
Abbildung 1: Zusammensetzung der in Äthiopien 2007/2008 gefangenen Fischarten

Other species introduced in water bodies were Common carp (*Cyprinus corpio*), *Tilapia zillii*, Catfish (*Clarias gariepinus*) and in some cases trout species and Grass carp *(Ctenopharyngodon idella)* (SHIBRU, 1973; SHIBRU AND FISSEHA, 1981) and fish harvesting has already started in some of the respective water bodies, resulting in a significant supply of fish for the local communities and the markets of major cities (FAO, 2005a). In order to further develop aquaculture as an alternative means for achieving food security and poverty reduction in rural areas (FAO, 2005a: CSA, 2007), the Ethiopian Government now considers it as an integral part of rural and agricultural development policies and strategies (EFDR, 2001). In the course of a recently implemented project, funded by the European Commission (OEAW, 2009), a cage culture technology was introduced which is expected to play an important role in promoting the development of small-scale, community-based aquaculture in Ethiopia and other East African countries. However, challenges for this development are not only a lack of knowledge and institutional support, but also a shortage of several production factors, among them the lack of reasonably priced and locally available fish feed of sufficient nutritional quality. Therefore, the purpose of this review is to identify categories of feed components which are most promising to be used in aquaculture production systems which aim at a moderate growth rate of the cultured fish, but at the same time at a maximum self-sufficiency. This shall also provide a baseline for future work on feed resource development for Ethiopian aquaculture.

2 Factors relevant to the development of feed resources for aquaculture in Ethiopia

2.1 Nutrition ecology of fish

Fish occupy virtually every possible trophic level, from herbivorous species feeding on unicellular algae, to secondary and tertiary carnivores which predate on other fish, amphibians, birds and mammals (KEENLEYSIDE, 1979; GERKING, 1994). Some species also form part of the decomposer food chain, utilizing detritus or scavenging carcasses. Several authors have reported that relevant Ethiopian fish species show great flexibility in their trophic ecology (KEENLEYSIDE, 1979; DILL, 1983; GERKING, 1994). The use of higher protein levels in fish feeds (NRC, 1993) as compared to diets for livestock is mainly caused by the lower energy requirement of fish for maintenance of normal body functions relative to warm-blooded animals. At least 24 % of CP was found to be essential for a satisfactory growth of *O. niloticus* under typical East African production conditions (LITI et al., 2005). Feedstuffs with low fibre contents are more appropriate in diet formulation (NRC, 1993). Therefore, in feed formulations for fish, feedstuffs should be utilized which have a relatively high protein and fat content, and at the same time contain only little fibre.

2.2 Feed components for Nile tilapia

Besides other factors, the dominant role of *O. niloticus* in commercial fisheries in tropical and sub-tropical countries is connected to its ability to feed on various trophic levels (PULLIN, 1988; FAO, 1996), even on blue-green algae, green algae and diatoms (MORIARTY & MORIARTY, 1973; MORIARTY, 1973; GETACHEW, 1987; KHALLAF & ALN-NA-

Ei, 1987). While under natural conditions, the fry of *O. niloticus* feeds mainly on zooplankton, the adults ingest large quantities of plant material, dominated by living algae, as well as detritus and the associated bacteria (Moriarty, 1973; Getachew, 1987; Getachew & Fernando, 1989; Diana et al., 1991; Dempster et al., 1993).

Commercial aquaculture feeds for *O. niloticus* usually contain 7 to 15 percent of feedstuffs of animal origin, mostly fish meal to supplement amino acids (Teichert-Coddington et al., 1997). The replacement of fish meal by other ingredients of either animal or plant origin in aquatic animal feed has been advocated for many years because of the rising cost and uncertain availability of fishmeal (Kaushik, 1990; Higgs et al., 1995). Several alternative feed ingredients of animal origin have been investigated, including fishery by-products, shrimp meal, housefly maggot meal, hydrolysed feather meal, poultry by-product meal, meat and bone meal and blood meal (NRC, 1993; Munguti et al., 2006; Ogunji et al., 2008). Despite their usually high crude protein content, inclusion levels of most of these fishmeal substitutes are limited by their low contents of certain essential amino acids (EAA), mainly isoleucine, lysine, and methionine (Tacon & Jackson, 1985; NRC, 1993).

Many studies have also been conducted in order to examine the options for replacement of fishmeal by plant proteins in tilapia feed (Shiau et al., 1987, 1990; Wee & Shu, 1989; Webster et al., 1992; Fontainhas-Fernandes et al., 1999). A great variety of plant materials have been tested, mainly different by-products from the processing of oil seeds and fruits or different grains and legumes. Furthermore, various aquatic plants such as *Azolla pinnata*, duckweed (Lemnaceae) and single-cell proteins were studied (Davies et al., 1990; El-Sayed & Tacon, 1997; El-Sayed, 1999; Rinchard et al., 2002; Coyle et al., 2004; Ogunji, 2004). Although soybean meal is deficient in methionine and contains a number of anti-nutritional factors (ANF) (De la pena et al., 1987; Fagbenro, 1998), it is generally considered to be one of the most suitable plant protein sources in terms of its EAA profile (Tacon, 1995). On the other hand, as leguminous seeds are used for human consumption in most developing countries, their use for aquafeed would compete with the ultimate goal of securing human nutrition (Munguti et al., 2006). Due to this conflict of interest, research has been done on other feed components such as agricultural and agro-industrial by-products. However, the results of the utilization of by-products from processing of oil seeds as fishmeal substitutes have not been consistent (Jackson et al., 1982; EL-Sayed, 1990; Hossain et al., 2002; Maina et al., 2002; Olvera et al., 2002; EL-Saidy & Gaber, 2004) or have indicated growth depression (Mbahinzirek et al., 2001; Sklan et al., 2004), mainly due to imbalanced dietary amino acid profiles (Jauncey & Ross, 1982) or the presence of ANF (Bureau et al., 1998; Rinchard et al., 2002).

The inclusion of more than 30–40 % of aquatic plants into diets of *O. nolitícus* frequently resulted in low growth rates, mainly because of high levels of fibre, resulting in low nutrient digestibility (Riechert & Trede, 1977; Almazan et al., 1986; Edwards, 1987; Okeyo, 1988; Mbagwu et al., 1990; Wee, 1991; El-Sayed, 1992; Fasakin et al., 1999; Setlikova & Adamek 2004).

2.3 Environmental conditions for the production of feed components

Ethiopia is ecologically extremely heterogeneous, which is mainly attributed to a high altitude variation (CSA, 2008a), resulting in a highly diversified flora and fauna (IBC, 2005). The diversified flora together with a vast supply of agricultural and industrial by-products can be seen as a potential asset for a sustainable development and utilization of fish feed resources. However, due to a lack of sufficient studies on the nutritive value of these by-products for fish, local feedstuffs which can be utilized in aquaculture are yet to be identified.

3 Identification of suitable feed components for small-scale aquaculture of Nile tilapia in Ethiopia

Commercially produced compound feeds are readily available for aquaculture in developed countries. In most developing countries formulated feeds for fish are scarce or entirely unavailable (FAO, 2005b). Although some developing countries are importing formulated fish feeds, these are usually too expensive for an economically viable fish production. Since feed costs represent 40–50 % of the total variable production costs (Craig & Helfrich, 2002), locally produced and reasonably priced feedstuffs of sufficient nutritional quality are a key element in the development of aquaculture in countries like Ethiopia (Gabriel et al., 2007). The inclusion of locally available feed components will essentially depend on their nutrient content. However, no solid database is existing of the feeding value of feedstuffs intended to be used in fish in Ethiopia, but thanks to its leading position in Africa in terms of its livestock population (CSA, 2008b), sufficient data is available on feedstuffs for livestock (SEYOUM & FEKEDE, 2006; ADUGNA, 2007; SEYOUM et al., 2007; ILRI, 2008; YITAYE et al., 2008; TADESSA et al., 2009a, b). From these sources, composition data for a total of 906 feed samples were available and were grouped in 7 feed categories. The available proximate composition data is summarized for 7 feed categories and presented in Table 1.

The potential of some of these feedstuffs for utilization in aquaculture as single feed component or as ingredient in formulated diets has been tested in Eastern Africa (LITI et al., 2006; ASSMANN, 2009; MUNGUTI et al., 2009). However, in order to successfully utilize these potential feed components, for some feedstuffs their palatability, acceptability, and digestibility need to be improved by grinding, chopping and mixing with other feedstuffs. Results from experiments with fish or livestock indicate that some of them may need to be supplemented with certain nutrient or energy sources, such as molasses, or may need to be treated with enzymes (WESTON & HOGAN, 1967; CAN et al., 2004; NAWANNA et al., 2008).

24 % CP content as the minimum requirement for *O. niloticus* growth (LITI et al., 2005) cannot be reached with simplified diet formulation as used by small scale producers in Ethiopia. However, fish perform well on wheat bran, maize bran and rice bran (LITI et al., 2006) which contain less CP. Thus 200 g/kg DM of CP content is used herein as a limit for the selection of potential feedstuffs. In the selection of fish feed attention should also be given to the fibre content as higher fibre concentrations can lead to growth depression, due to poor digestion and faster gastric emptying which affects feed intake and nutrient utilisation (NRC, 1993). For this review purpose, feed with less than 300 g/kg DM ADF and 500 g/kg DM NDF are selected as potential feed components for small-scale aquaculture. The potential feedstuffs that were selected based on their CP and NDF or ADF contents are presented in Table 2.

3.1 Crop residues

Data were available for a total of 158 individual samples from 29 different feedstuffs within this category. Out of the total feed samples analysed under this category only 3.3 % of the sample had a CP superior to 200 g/kg. Moreover, this

Table 1: Selected average nutrient content for different categories of feedstuffs
Tabelle 1: Gehalt an ausgewählten Inhaltsstoffen von verschiedenen Futtermittel-Gruppen

Feed categories	No of feed samples analyzed	Nutrient content*						
			DM [g/kg]	OM [g/kg DM]	CP [g/kg DM]	NDF [g/kg DM]	ADF [g/kg DM]	ADL [g/kg DM]
Crop residues	158	$\bar{X}$±S Min-Max	882±139.1 267-973	911±37.9 798–987	76±48.7 11–231	651±126.0 314–943	446±101.4 42–758	84±47.8 15–302
Agro-industrial by-products	110	$\bar{X}$±S Min-Max	886±146.4 86-972	918±79.4 514–983	237±148.6 34–832	339±172.0 9–884	193±110.1 11–501	50±34.8 2–212
Herbaceous forage	267	$\bar{X}$±S Min-Max	847±184.0 153-957	889±32.1 798–974	133±70.7 23–328	557±164.8 166–845	368±80.9 113–527	66±27.0 10–171
Cereal and legumes green	73	$\bar{X}$±S Min-Max	890±84.5 319-954	896±40.8 763–984	108±67.4 12–290	546±111.1 230–730	338±78.5 147–472	53±30.8 2–169
Leaves of fodder trees and shrubs	252	$\bar{X}$±S Min-Max	860±173.0 67-964	898±46.2 656–1000	179±58.6 27–364	415±130.6 49–879	304±108.5 88–692	121±78.7 27–469
Roots and tubers	22	$\bar{X}$±S Min-Max	401±361.7 45–947	872±60.5 750–965	102±55.4 20–221	493±15.8 170–731	335±158.4 88–535	70±47.4 11–194
Other Food crops and less common feeds	24	$\bar{X}$±S Min-Max	746.6±277.5 159-938	855±45.0 797–922	76±39.6 9–169	582±177.3 248–817	347±57.0 278–396	79±38.4 42–184

* DM = dry matter, OM = Organic matter, CP = crude protein, ADF = acid detergent fibre, NDF = neutral detergent fibre and ADL = acid detergent lignin

Table 2: Selected potential feedstuffs for small-scale aquaculture based on their CP and NDF or ADF contents
Tabelle 2: Auswahl potenzieller Futtermittel für kleinbäuerliche Aquakultur auf Basis des Gehalts an Rohprotein und NDF oder ADF

Feed types	Nutrient content*					
	DM [g/kg]	OM [g/kg DM]	CP [g/kg DM]	NDF [g/kg DM]	ADF [g/kg DM]	ADL [g/kg DM]
Crop residues						
Chickpea: aerial	591	n.a.	207	432	n.a.	61
Lathyrus pea aerial	468	n.a.	201	481	n.a.	55
Agro-industrial by-products						
Beans grain	911	n.a.	237	480	n.a.	16
Blood meal	928	n.a.	832	n.a.	n.a.	n.a.
Blood, meat and bone meal	924	n.a.	530	n.a.	n.a.	n.a.
Brewery by-product	916	958	249	639	231	47
Brewer's dried yeast	907	924	530	9	11	2
Chickpea grain	901	969	221	n.a.	n.a.	n.a.
Cottonseed cake	921	925	339	480	236	71
Faba bean grain	919	n.a.	276	490	n.a.	25
Fish meal	921	514	503	198	n.a.	n.a.
Flax cake	940	n.a.	288	369	n.a.	37
Groundnut cake	927	950	555	164	87	17
Home made beverage by-product	395	954	203	492	255	n.a.
Linseed cake	920	928	295	319	192	68
Meat and bone meal	925	760	494	257	121	61
Mustard cake	928	n.a.	392	474	n.a.	43
Noug cake	930	897	331	363	309	114
Peanut cake	928	924	517	169	n.a.	41
Peas grain	900	969	269	486	n.a.	12
Rapeseed cake	909	912	361	267	201	81
Sesame cake	923	864	250	251	278	41
Soybean cake	929	954	261	389	n.a.	n.a.
Sunflower cake	928	940	268	169	n.a.	41
Urea molasses	885	705	364	122	44	10
Herbaceous forage						
Acheyranthes aspera	947	n.a.	229	326	313	n.a.
Alfalfa	810	888	205	415	316	68
Chamaecrista rotundifolia	910	948	328	279	n.a.	n.a.
Clover spp	914	885	205	372	298	57
Jasminum abyssinicum	944	n.a.	215	404	380	n.a.
Lablab	910	890	204	380	281	58
Macroptilium spp	905	923	238	n.a.	n.a.	n.a.
Neonotonia wightii	910	896	207	412	n.a.	n.a.
Nicotina tabacum leaf	944	n.a.	224	388	370	n.a.
Trigonella foenum grain	950	n.a.	237	236	180	n.a.
Vetch spp	775	884	219	435	346	79
Cereal and legume plants, green						
Cajanus cajan	613	938	243	407	356	128
Cowpea forage	896	872	216	418	273	40
Cowpea leaf and aerial hay	903	832	201	311	206	39
Cowpea seed	883	960	262	n.a.	n.a.	n.a.
Leaves of fodder trees and shrubs						
Acacia spp	842	917	204	460	264	131
Albizia gummifera	948	n.a.	206	276	248	n.a.
Albizia spp.	921	924	243	n.a.	514	334
Boscia angustifolia	921	885	206	n.a.	n.a.	n.a.
Cadaba farinosa	911	865	261	n.a.	n.a.	n.a.
Chamaecytisus spp	919	937	204	398	244	86
Cordia africana	946	n.a.	242	345	330	n.a.
Cordia spp	908	826	210	406	622	327

Feed types	Nutrient content*					
	DM [g/kg]	OM [g/kg DM]	CP [g/kg DM]	NDF [g/kg DM]	ADF [g/kg DM]^	ADL [g/kg DM]
Croton macrostachyus	936	891	247	354	290	n.a.
Dombeya torrida	947	n.a.	238	331	321	n.a.
Draceana steudneri	946	n.a.	222	353	328	n.a.
Drumstick tree	900	849	277	202	n.a.	n.a.
Dwarf koa	907	949	215	482	n.a.	n.a.
Erythrina brucei	947	n.a.	238	329	317	n.a.
Ficus vasts	946	n.a.	295	381	363	n.a.
Gliricidia spp	899	899	223	404	261	106
Grewia ferruginea	947	n.a.	229	317	300	n.a.
Hamessa omacho	951	913	356	n.a.	n.a.	n.a.
Leucaena spp	794	906	224	333	230	97
Lippia adoensis	946	n.e.	216	352	331	n.a.
Mesquite	939	881	213	367	n.a.	n.a.
Millettia sp	931	878	221	n.a.	478	284
Ricinus communis	368	n.a.	229	344	n.a.	73
Rungia grandis	942	n.a.	232	314	303	n.a.
Ruminex nervosis	948	n.a.	250	311	307	n.a.
Sesbania spp	912	928	201	319	221	62
Utrica simensis	944	n.a.	250	396	389	n.a.
Vernonia spp	929	880	213	347	348	118
Roots and tubers						
Cassava tops	219	907	221	351	n.a.	87

* DM = dry matter, OM = Organic matter, CP = crude protein, ADF = acid detergent fibre, NDF= neutral detergent, ADL = acid detergent lignin and n.a. = data not available

feed category contained a high percentage of fibre: only 4.8 % and 15.5 % of the samples had ADF and NDF of less than 300 g/kg and 500 g/kg, respectively.

3.2 Agro-industrial by-products

Data were available for a total of 110 individual samples from 36 different feedstuffs which fell into this category. Out of the total feed samples analysed under this category about 50.5 % of the sample contained more than 200 g/kg CP. In addition to this relatively promising finding, 74.1 % and 74.4 % of the samples contained less than 300 g/kg and 500 g/kg of ADF and NDF, respectively. The percentages of the feedstuffs within feed categories with a CP content of more than 200g/kg are presented in Figure 2.

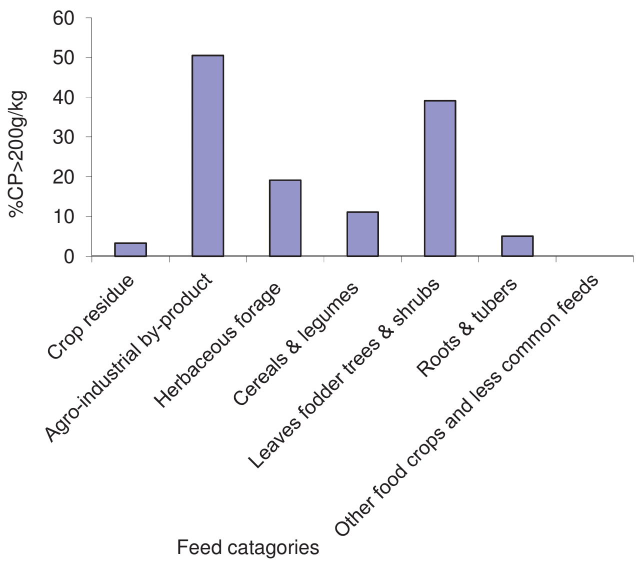

Figure 2: Percentage of feedstuffs within each category containing more than 200 g/kg crude protein (DM basis).
Abbildung 2: Anteil an Futtermitteln je Kategorie mit einem Rohproteingehalt über 200 g/kg Trockenmasse.

3.3 Herbaceous forage

Data were available for a total of 267 individual samples from 64 different feedstuffs which fell into this category. Out of the total feed samples analysed under this category about 19.1 % of the sample had a CP content of more than

200 g/kg. The available proximate data showed that in this category of feed 17.8 % and 42.5 % of the analysed samples contained less than 300 g/kg and 500 g/kg of ADF and NDF, respectively.

3.4 Leaves of fodder trees and shrubs

Data were available for a total of 252 individual samples from 69 different feedstuffs which fell into this category. Out of the total feed samples analysed under this category about 39.1 % of the sample had CP of more than 200g/kg. In addition to this relatively favourable situation, 51.6 % and 75.4 % of the samples contained less than 300 g/kg and 500 g/kg of ADF and NDF, respectively.

3.5 Cereals and legumes

Data were available for a total of 73 individual samples from 21 different feedstuffs which fell into this category. Out of these, about 11.1 % contained more than 200 g/kg of CP. 23.8 % and 24.2 % of the samples showed ADF and NDF values of less than 300 g/kg and 500 g/kg, respectively (Figure 3).

3.6 Roots and tubers

Data were available for a total of 22 individual samples from 5 different feedstuffs which fell into this category. Only 5 % of the samples had CP contents higher than 200 g/kg. Concerning its fibre contents, data is available only for NDF and about 42.9 % of the samples contained less than 500 g/kg of NDF.

3.7 Other food crops and less common feeds

No potential protein sources could be found within this category: none of the 24 individual samples from 11 different feedstuffs contained more than 200 g/kg of CP. Concerning its fibre content, data is available only for NDF and only 21.4 % of the samples showed a NDF value of less than 500 g/kg.

4 Conclusions and recommendations

The available results for proximate analysis show that feedstuffs in the categories of agro-industrial by-products, herbaceous forages, cereals and legume grains, fodder trees and shrubs include several potential feed components for developing aqua-feeds for small-scale aquaculture of *O. niloticus* in Ethiopia as targeted herein. In contrast, crop residues, roots and tubers and other food crops and less common feeds were found to be probably less important even for low protein diets which are likely to be used in this type of aquaculture.

Generally, the nutrient content of crop residues was found to be very low, but in terms of availability it is one of the most prominent feed sources throughout the country.

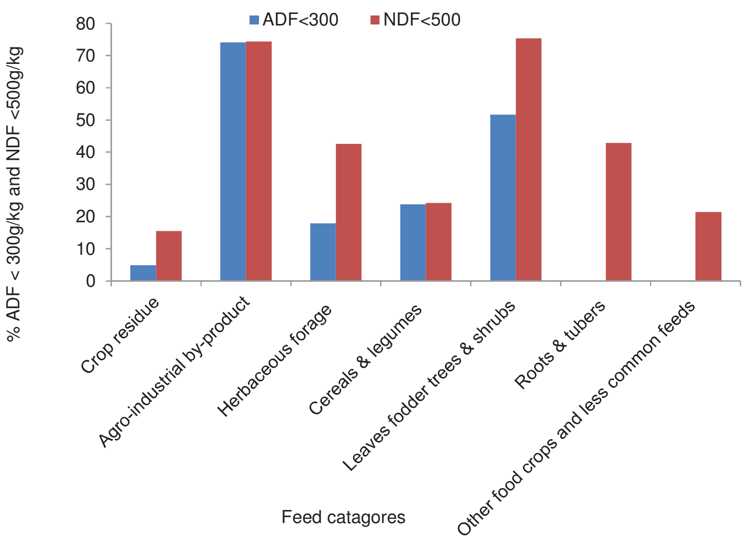

Figure 3: Percentages of feedstuffs within each category containing less than 300 g/kg DM and 500 g/kg DM of ADF and NDF, respectively.

Abbildung 3: Anteil an Futtermitteln je Kategorie mit einem Gehalt unter 300 g ADF/kg bzw. unter 500 g NDF/kg Trockenmasse.

Thus emphasis should be given to assess possibilities for an increased use of this resource and for improving its nutritional value.

Despite the importance of the proximate composition data that are available from databases for livestock feed, these databases frequently lack information about the lipid content and do not yield information about the presence of anti-nutritional factors (ANF). Since both ANF and ether extract content are crucial for including feed components into fish diets, emphasis should be given to these important parameters in future studies.

The proximate analysis conducted so far included several potential feedstuffs which could be utilized for small-scale aquaculture in Ethiopia. However, there are still some feed resources with a high potential which are currently not utilized for aquaculture or livestock production. Thus future research needs to consider the utilization of these resources for the benefit of the local communities. These include fishes which are not used for human consumption, fish offal from fish-processing plants and pelagic invertebrates. Nevertheless, if relevant quantities of fish or invertebrates are to be used for feed, special attention should be given to the ecological importance of these organisms in natural water bodies. Furthermore, the use of fish protein should not be targeted as a common option for the production of fish feed for small-scale, sustainable aquaculture. Another potential animal protein source could be different, locally collected insects.

The contribution of the feed resources analysed so far for the growth and production performance of livestock has been repeatedly evaluated. However, no data are available on the effects of these feedstuffs on the growth and production performance of fish as well as the acceptance of these feeds by fish. Thus further research on the growth response of fish to locally available feedstuffs needs to be conducted in order to select appropriate feed for the development of small-scale, sustainable tilapia aquaculture in Ethiopia.

The availability and quality of feed components in Ethiopia vary with altitude, rainfall, soil type and cropping intensity. Because of the general shortage of feed and of the conflicts of interest related to this, availability of potential feed components needs to be addressed in addition to nutritional quality of potential feed resources in future studies.

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