Alternative Feed Resources in Aquaculture: The Role of Underutilized Plants – A Review

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Abstract. Feed plays an important role in the development and sustainability of the aquaculture industry. Feedstuffs are either of plant or animal origins. Some plants despite their potentials are underutilized in fish feed industry. The cost effectiveness, availability and sustainability potentials of these plants coupled with their nutritional composition make them fit to compete favourably well with the commonly utilized plants. Leaves and seeds of plants such as Moringaoleifera, Gliricida sepium, Leucaenaleucocephala, alfalfa, sweet potato, velvet bean, cucumber, squash, broad bean, papaya, azolla, water hyacinth, duckweeds, etc. have been discovered to possess the requirements needed for use as a feedstuff in the fish feed industry. This paper therefore reviewed extensively; the potential use of various plant products as ingredients in fish feed industry.

Keywords: Aquaculture, Underutilized, Plants, Fish Nutrition, Anti-nutritional Factors

1. Introduction

Fish has been identified to be an affordable source of high quality protein animal source for which demand and consumption in many developing countries has been increasing [1]. According to [2], animal protein consumption of average Nigerian falls below the 33% mark recommended by [3]. The increasing demand to meet the required protein production can be satisfied through intensive fish culture [2] as wild catch has been found insufficient to meet the demands for fish [4]. For an optimum productivity in aquaculture to be achieved with profitability, feed and feeding among other factors must be given careful attention [5].

High cost of quality fish feed is one of the problems militating against the development of aquaculture [6]. This might not be unconnected to the scarcity and high cost of some conventional protein feedstuffs like Soybean meal and fish meal due to an ever increasing demand as staple food for man, raw material in industries and as feed ingredients in farm animals [7]. Expensive feeds will significantly increase cost of production and in return reduce the profitability. Therefore, to beat down cost and increase profitability in an aquaculture business, the introduction of protein of plant sources that would favourably compete with the conventional protein sources in term of nutritional qualities is inevitable [8]. Although, limitations do exist to the use of plant sources in fish nutrition because of
certain problems which includes; low amount of protein, presence of anti-nutrients which will no doubt affect palatability and digestibility of feed by fish [9, 10]. However, over the years, measures like drying soaking, fermentation, toasting etc. have been taken to either reduce to a bare minimum or to remove the anti-nutrients in these unconventional feed stuffs [11]. This paper is aimed at reviewing the potentials of the various underutilized plants and they can be incorporated into the fish feed industry as feedstuffs for optimal fish production.

2. THE ROLE OF UNDERUTILIZED PLANTS IN FISH NUTRITION.

Literature is replete on the importance of plant protein in fish nutrition for various commercially culture fish species [10]. These plants are valuable not only for their availability and economic benefits but also for their potentials in reducing the chances of eutrophication in ponds because their products contain smaller amount of phosphate and nitrogen when compared to animal protein.

2.1 UNDERUTILIZED TERRESTRIAL PLANTS

2.1.1. MORINGA (Moringaoleifera)

In recent times, researchers have paid attention to Moringaoleifera, known as drumstick tree, due to its economic and important uses. It is a fast growing member of the Moringaceae family and this tree is widely tropics and sub-tropics). The total dry matter (DM) yield of M. oleifera can be up to 24-ton ha⁻¹·year⁻¹[12, 13] and the crude protein content of the leaf ranged between 23 % and 28 % [13, 14, 15]. The detailed proximate composition of M. oleifera is presented in Table 1.

Table 1: Proximate composition of Moringaoleifera leaves

| Nutrients       | Percentage composition |
|-----------------|------------------------|
| Moisture content| 8.19                   |
| Crude protein   | 28.03                  |
| Crude lipid     | 2.25                   |
| Crude fibre     | 18.87                  |
| Total ash       | 6.81                   |
| Nitrogen free extracts | 35.85                  |

Source: [13]

Saponins and phenols (anti-nutrients), in the leaf of M. oleifera [15] can be removed using various methods including soaking in water, air drying at room temperature or grinding [16]. Meal from Moringa leaves was reported to have positive effect on ruminants: improved feeding behaviour in goats [17], improved weights in sheep [18] and improved milk yield in dual purpose cows [19]. Also, increased protein content and certain amino acids – methionine and tryptophan contents was observed when added to the diets of Clarias gariepinus[18]. These nutrients improve fish health, maximise growth and hence productivity in aquaculture [10, 19, 20]. Nile tilapia and common carps are other fish species whose diets have successfully been augmented up to 30% level of inclusion with meals from Moringa leaves without any recorded defects in term of growth performance [21, 22].
2.1.2. GLIRICIDIA (*Gliricidia sepium*)

*Gliricidia* belongs to the sub-family Papilionoideae and the tribe Robinieae [23]. According to [24], it is believed to be the most widely cultivated multipurpose tree after *Leucaenaleucocephala*.

The protein content of *Gliricidia sepium* ranged between 16 and 30% according to various reports [2, 25, 26, 27]. The proximate compositions are presented in Table 2. Although there is scarcity of information about the digestibility of *Gliricidia* in fish, [28] reported a high digestibility in the ruminants when compared to other multi-purpose tree forages and that in cases of low digestibility, leaves of legumes can be added to improve it [28]. However, despite the good combination of proximate composition and minerals, *Gliricidia* has been reported to be low in phosphorus and calcium [2].

### Table 2: Proximate composition of *Gliricidia sepium* leaves

| Nutrient          | Composition |
|-------------------|-------------|
| Dry matter (%)    | 86.26       |
| Crude protein (%) | 16.88       |
| Ether extract (%) | 1.14        |
| Crude fibre (%)   | 16.97       |
| Ash (%)           | 10.37       |
| Organic matter    | 89.63       |
| Gross Energy (Kcal/g) | 3.01 |
| Calcium           | 0.20        |
| Phosphorus        | 0.40        |

Source: [2]

Like many other plants, *Gliricidia sepium* contain some anti-nutrients, notably HCN and cyanogens [26], saponin, Phytate, Tannin and Cyanide [2], phenols and flavonoid compounds [29].

2.1.3. LEUCAENA

*Leucaenaleucocephala* is a multi-purpose tree that provides fuel wood, green manure, improves degraded lands and cover for soils [6]. It is fast growing and drought-resistant [10, 31]. The use of *Leucaenaleucocephala* has been reported to reduce feed cost and it has been discovered to have the nutritive values that are in right proportion [6, 32]. The leaves of *Leucaenaleucocephala* have been reported to contain a crude protein that is above 20% as shown in table 3 [33, 34]. The seeds also contain α-carotene with rich amino acid profile [34].

### Table 3: Proximate composition of *Leucaenaleucocephala* leaves

|          | MC % | CP % | EE % | CF % | ASH % |
|----------|------|------|------|------|-------|
| LLM      | 6.70 | 22.76| 4.60 | 22.29| 9.73  |

MC = Moisture Content; CP = Crude Protein; EE = Ether extract; CF = Crude Fibre; NFE = Nitrogen Free Extract; LLM = *Leucaenaleucocephala* Leaf Meal.
The leaves and seeds contain mimosine, an ANF [35] which is a toxic non-protein amino acid that can inhibit growth in animals [36]. When included at 20% in the diet of Oreochromis niloticus, an improved growth performance was observed [6]. Similar results were obtained with Clarias gariepinus [10, 36].

2.1.4. VELVET BEAN (*Mucuna utilis*)

Velvet bean (*Mucuna utilis*), is a tropical legume belonging to the family Leguminosae [37]. It is widely cultivated as a cover crop and highly productive (200 to 600 kg seed/ha) [38]. *Mucuna utilis* is native to South Asia and Malaysia, but is presently widely grown throughout the tropics [39]. *Mucuna* contains a high level of protein, vitamins and minerals [42]. The seed is known to contain high protein (25.4% to 35%), starch (31.2% to 39.5%), desirable amino acid profile, fatty acids vitamins and minerals with good nutritional properties [43]. [45] reported that processing improves the nutrient, especially protein values in velvet beans.

However, the seeds of velvet beans are known to contain some ANFs such as tannins, lectins, phytic acid, cyanogens, trypsin inhibitors and 3-4 di-hydroxyl-L-phenylalanine (L-Dopa) [46, 47]. Common and effective method for detoxifying some these ANFs includes the use of heat as they are thermo-labile. The most potent ANF known in velvet beans is L-DOPA. L-DOPA content of the seed can be degraded by methods described by [47, 48].

2.1.5. SWEET POTATO (*Ipomoea batatas*)

Sweet potato is a world-wide cultivated crop. It is an important food crop in most developing countries of the world. Both the leaves and peels from the roots can be of great use in the fish feed industry.

The leaves contain high protein, good amino acid profile, minerals, vitamins and fibre content [10, 49,50, 51]. The leaves of *Ipomoea batatas* can be harvested many times within a year. Invertase and protase inhibitors are the prominent ANFs in these leaves, but simple methods like drying, boiling or steaming can reduce them to the barest minimum tolerable to fish [51]. Table 5 shows the proximate composition of *Ipomeabatatas*.

| Table 4: Proximate Composition of *Ipomeabatatas* leaves. |
|---|---|---|---|---|---|---|
| IPL | MC % | CP % | EE % | CF % | ASH % | NFE |
|---|---|---|---|---|---|---|
| 72 | 28.91 | 4.71 | 8.55 | 6.02 | 41.16 |

MC = Moisture Content; CP = Crude Protein; EE = Ether extract; CF = Crude Fibre; NFE = Nitrogen Free Extract; GLM = *Ipomeabatatas* leaves.

Source: [50].

Sweet potato peels is rich in nutrients: it contains adequate quantities of calories and other micronutrients. However, it lacks tryptophan and Sulphur [52, 53]. The proximate composition of *Ipomeabatatas* peels is presented in Table 5.
### Table 5: Proximate composition of *Ipomeabatatas* peels.

|          | MC % | CP % | EE % | CF % | ASH % | NFE     |
|----------|------|------|------|------|-------|---------|
| IPP      | 8.91 | 5.91 | 4.71 | 3.55 | 6.02  | 71.16   |

**Source:** [54]

A replacement level of between 50 and 75% of yellow maize with sweet potato peels in the diets of *Clarias gariepinus* have been recommended by [54] for good growth.

#### 2.1.6. Alfalfa Plants (*Medicago sativa*)

*Medicago sativa* is a flowering plant that is grown as forage for cattle due to its high nutritional value[10, 55]. With the increased interest in bio-fuels and leaf protein concentrates, refining alfalfa into a digestible ingredient for fish feeds is becoming a possibility [56]. The inclusion of alfalfa leaf meal up to 35% in the diets of tilapia did not compromise the growth and survival of the fish. Likewise, common carps and sea bream have had their growth enhanced when their diets were augmented with alfalfa leaf meals up to 40% level of inclusion [10, 57, 58]. However, some authors suggested a lower level of inclusion as they argued that an increased inclusion level might not be good for the fish [9, 59]. The proximate composition of Alfalfa leaves according to [55] are presented in table 6.

### Table 6: Proximate compositions of Chloroplastic Alfalfa leave Protein.

|          | MC % | CP % | EE % | CF % | ASH % | NFE     |
|----------|------|------|------|------|-------|---------|
| CALP     | 1.84 | 53.22| 6.77 | 1.92 | 4.81  | 31.44   |

**Source:** [55]

#### 2.2. UNDERUTILIZED AQUATIC PLANTS

Many aquatic plants (macrophytes) have been reportedly used as fertilizers, mulch, compost, food and fodder [60]. Also, there are reports that leaves of some aquatic plants have been used in fish nutrition because of their good nutrient profile and availability with resultant reduction of cost of producing the feed [10, 60, 61, 62, 63].

##### 2.2.1. WATER HYACINTH (*Eichhorniacrassipes*)

*Eichhorniacrassipes*, an invasive, herbaceous, free-floating aquatic plant is the most noisome aquatic plant. However, new research development points towards the use of water hyacinth as an alternative protein source although this development is still at laboratory research level [64, 65]. This activity is aimed at serving dual purposes, namely, to remove the plant from
waterways and reduce the cost of fish production while not denying the fish their required nutrients.

A limiting factor to the use of water hyacinth as a feed resource in fish is its high crude fibre content [66, 67, 68]. Table 7 shows the proximate composition of *Eichhorniacrassipes*.

### Table 7: Proximate composition of Water Hyacinth Meals (WHMs)

| WHMs   | Crude protein (%) | Crude lipid (%) | Crude fibre (%) | Ash (%) | NFE (%) |
|--------|-------------------|-----------------|-----------------|---------|---------|
| WPM    | 24.17             | 2.37            | 19.62           | 11.35   | 42.49   |
| WLM    | 28.20             | 4.70            | 14.79           | 7.03    | 45.28   |

NFE = Nitrogen Free Extract; WPM = Water Hyacinth Protein Meal; WLM = Water Hyacinth Leaf Meal

Source: [65]

Various authors have recommended composting and/or fermentation as methods that can help to reduce the fibre content, improve palatability, and also improve the protein content of water hyacinth plant meal [60]. Water hyacinth after fermentation has been included in the diets of Nile tilapia (*Oreochromis niloticus*) by up to 25% inclusion level [70]. A replacement level as high as 75% of fish meal with composted water hyacinth meal in the diets of *O. niloticus* has also been suggested by [71].

### 2.2.2. AZOLLA (*Azollapinnata*)

Azolla is a free-floating aquatic fern that grows rapidly with a nuemenon to have twice its size in just ten days. It is capable of understanding and fixing atmospheric nitrogen [10]. *Azollapinnata* is a high biomass plant with good CP content [72] ranging between 20 and 30% on a dry matter basis [73], its rich in lysine (a limiting essential amino acid) [74] with an ability to store phosphorus and potassium from water. It has also been found to be rich in iron, copper, manganese [75], vitamins A, B12 and beta-carotene [10]. The proximate composition of Azolla according to is presented in Table 8.

### Table 8: Proximate composition of Azolla Leaf Meals (ALM)

| Nutrients             | Percentage Composition |
|-----------------------|------------------------|
| Moisture content      | 83.84                  |
| Crude protein         | 28.92                  |
| Ether extract         | 6.31                   |
| Crude fibre           | 6.92                   |
| Ash                   | 4.81                   |
| Nitrogen free extract | 31.44                  |

Source: [73]

The inclusion of Azolla in the diets of many fish species has been reported to have improved growth performance and nutrient utilization [63]. However, an inclusion level of up to 50% was observed to reduce the protein utilization capacity of *Labeorohitafry* [10, 61]. Some
reports suggested a replacement level of up to 25% fishmeal in tilapia [10, 70], 45% in Cirrhinus mrigala fry [10, 63] and 42% in Oreochromis niloticus fry [10, 76].

2.2.3. DUCKWEED
Duckweed is a floating aquatic weed that grows in tropical and sub-tropical freshwaters. The four genera of duckweed are Lemna, Spirodela, Wolfilla and Wolffiella [10]. The plant is very rich in nutrients (Table 9). Different authors reported varying amount of nutrients in duckweed [10, 77, 78]. Fresh duckweed has been successfully used as feedstuffs for common carp, Thai sharputi, raj puti, silver carp, mrigal and tilapia [10, 77].

Table 9: Proximate composition of Duckweed Leaf Meals (DLM)

|        | MC % | CP % | EE % | CF %   | ASH % | NFE   |
|--------|------|------|------|--------|-------|-------|
| DLM    | 79.84| 38.75| 5.31 | .23.47 | 6.81  | 21.34 |

MC = Moisture Content; CP = Crude Protein; EE = Ether extract; CF = Crude Fibre; NFE = Nitrogen Free Extract; DLM = Duckweed Leaf Meal
Source: [78]

In order to reduce ANFs and improve palatability of duckweed, [10] suggested fermentation of the leaf before its addition to fish feed. It has also been reported that fish meal can be substituted up to 20% level with duckweed meal in the diets of common carp [78], while improved growth was observed in mango tilapia fed 10% duckweed substituted meal [77]. Furthermore, [79] reported that fish meal can be replaced up to 30% level in the diets of Nile tilapia without hampering their growth.

CONCLUSION
With the recent developments in aquaculture, there is a need to look into a sustainable means of fish feeding without driving up the cost of production. The potentials of the reviewed plants in this work have placed them in good position to either replace partially or in some cases even replace the usual sources of protein in fish feeds that are unnecessarily increasing production costs. Many of these plants can be gotten all the year round at little or no cost. Therefore, their usage could reduce the cost of feed production hence, promoting a sustainable aquaculture practice.

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