MORINGA PLANT AND IT USE AS FEED IN AQUACULTURE DEVELOPMENT: A REVIEW

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ABSTRACT

Aquaculture, an important source for animal protein utilizes a lot of fishmeal regarded as the best protein source in fish feeds. For making feeds, aquaculture sector alone consumed the equivalent of about 23.8 million metric tons (mmt) of fish or 87% of non-food fish by 2006. By 2011, the non-food uses of world fisheries were 23.2 mmt out of a total fish production of 154 mmt. The use of fishmeal is therefore substantial; 15.0 mmt being used in 2010. In Nigeria for example, small forage pelagic fish used in fishmeal production contributes 51% of total fish supply. Because most of the conventional plant/animal feed sources are equally in great demand for human consumption, there is an urgent need to examine other products from little researched plants such as moringa (Moringa oleifera Lam) as alternative source of protein in aquaculture feeds. There is a dearth of information on the use of moringa leaf or seed meals as fish feed ingredients. An extensive search and analyses of published data on moringa and any of its use in aquaculture were therefore carried out. It was reported to be hardy, high yielding and thrive in diverse ecological zones. Its leaves, the kernel and the fat-free kernel meals contain 26.4 %, 36.7 % and 61.4 % of crude protein, respectively. The kernel contains over 40 % of good quality oil comparable to olive oil. The leaves and pods are rich in vitamins and minerals. Moringa leaves are free from anti-nutritional factors except for saponins and phenols. Studies on the use of moringa in fish feed production are few and far between as is discovered in this review. Combination of seed and leaf meals in desired proportion might result in obtaining a plant-based protein source that could favourably replace fishmeal in fish feeds. Hence, this review on available information on M. oleifera used in fish feeds exposes the need for further research.

Keywords: Fish feed ingredients, Fishmeal, Alternative protein sources, *Moringa oleifera,* Anti-nutritional factors

INTRODUCTION

Naylor *et al.* (2000) reported that as the world's human population continues to increase beyond six billion, there is a corresponding reliance on farmed fish production as an important source of animal protein. FAO (2000) projected world fishery production in 2010 to range between 107 and 144 million metric tons (mmt). By 2008, actual global aquatic animals' production totaled 52.9 mmt. Around three quarters of the world's capture fisheries are fully or overexploited (Huntington and Hasan, 2009). Aquaculture, has been the fastest growing food sector for over 25 years, supplying 49% (8.6 kg/capita) of total global food fish supply (17.6

kg/capita) in 2010 (Tacon, 2011). Considering this increasing global population and recognizing that no additional supplies from marine capture fisheries, it has been estimated that, to maintain the current level of per-capita consumption by 2030, the world will require at least another 23 mmt of aquatic animal food to be provided by aquaculture (FAO, 2012). The volume of farm-produced aquatic animals represented 46.7% of the global food fish supply in that year (FAO, 2012). It is expected that most of the increase in fish production will come from aquaculture, the fastest growing food production sector. It was further predicted that aquaculture sector would contribute more than 50% of total world fish production by the year 2030 (FAO, 2000). Hardy (2000) disclosed that the proportion of global fishmeal production used in fish feeds increased from 10 to 35% since 1985. He predicted that fishmeal needs for aquaculture in 2010 would be 2.8 mmt which he regarded as 44% of the 10-year average global fishmeal production of 6.5 mmt. Hardy (2000), therefore, predicted that about 3 million metric tonnes of fishmeal equivalent alternative protein sources would be required in aquaculture sector by the year 2010 to replace fishmeal, which is considered as an ideal inclusion in fish feed production. The actual aquafeed production by 2009 was 68.3 mmt worth $106 billion (US) (Allan, 2010). Aquaculture which utilizes a lot of fishmeal is set to remain one of the fastest-growing animal food-producing sectors and, in the next decade, total production from both capture and aquaculture will exceed that of beef, pork or poultry (FAO 2012). Fishmeal has been regarded as the best protein source in fish feeds. The proportion of global fishmeal production used in fish feeds has increased from 10 – 35% in the last 15 years. Aquaculture sector alone consumed the equivalent of about 23.8 mmt of fish (live weight equivalent) or 87% of non-food fish in the form of feed inputs in 2006 (Tacon and Metian, 2009). The non-food uses of world fisheries are 23.2 mmt out of a total fish production of 154 mmt by 2011 (FAO, 2012). The use of fishmeal is therefore substantial. In Nigeria for example, small forage pelagic fish used in fishmeal production contributed 51% of total fish supply (Tacon and Metian, 2009).

There is no doubt that many studies are on-going to identify the needed protein alternative sources be it animal or plant products. However, Tacon and Forster (2001) have advocated the development of non-human grade feed resources whose growth can cope with the projected and desired fast growth of aquaculture sector to minimize any conflict with human food security interests. It is worthy of note that causes of recent outbreaks of diseases in livestock have been linked to feeding animal products to animals that do not normally consume them and this prediction has cast doubt concerning the suitability of feeding animal-derived proteins to non-carnivorous species such as tilapia.

In the search for alternative protein sources, we advocate that greater efforts should be directed towards the use of plant ingredients to replace fishmeal particularly for non carnivorous species. There have been many fish feed trials in the past using a number of plant-derived protein sources to test their suitability for some fish species (Heller, 1996; Hossain and Becker, 2001; Siddhuraju and Becker, 2001, Richter *et al.,* 2003; Ogbe and Affiku, 2011; Sirimongkolvorakul *et al.,* 2012). Many of these trials have concentrated on plant species such as groundnut, palm kernel cakes, soybean, sunflower seed, rapeseed, cotton seed meals, corn and wheat gluten (Francis *et al.,* 2002). Realizing that these plant feed sources are equally in great demand for human consumption, there is an urgent need to examine other products from little researched and unknown plants as aquaculture feed ingredient alternatives. Some of these plants include moringa plant (*Moringa oleifera*), *Jatropha curcas, Sesbania* spp. and *Mucuna puriens*. Unfortunately, ingredients from these plants contain high levels of anti-nutritional factors such as glucosinolates, phytates, protease inhibitors, non-starch polysaccharides (NSPs), saponins, tannins, lectins and gossypols which have been found to have a bitter taste that could result in poor acceptability of feed to the fish under trial. Francis *et al.* (2001) reviewed the effects of anti-nutrients on finfish and revealed that the use of hydrothermal treatment and soaking with water is efficient in removing high levels of anti-nutrients. Hardy (2000) also suggested the inclusion of phytase to high phytate diets to increase the availability of dietary phosphorus to various fish species. Siddhuraju *et al*. (2002) advocated the use of γ ray irradiation in neutralizing the negative effects of certain anti-nutrients such as saponins. Such treatments are likely to come in handy in for *Moringa* used in feed feeds. This paper reviews available information on *Moringa* plant regarding its potentials to contribute to fish feed ingredients.

MATERIALS AND METHODS

An extensive literature search and analyses of published data on *Moringa* and any of its use in aquaculture were carried out to effect this review.

RESULTS AND DISCUSSION

***Moringa oleifera* as Possible Fish Ingredient:** *Moringa oleifera* Lam or "drum stick" (derived from the shape of the pods) is regarded as a "miracle or wonder plant". This plant has many domestic names depending on the geographical location. In Nigeria, the Igbos call it "*okwe oyibo*", the Yorubas call it "*ewe-igbale*" while the Hausas call it "*sogele*" (Isaac, 2012). According to Isaac (2012) *Moringa* plant contains weight for weight four times the calcium in milk, four times the vitamin A in carrots, two times the protein in milk, three times the potassium in banana and seven times the vitamin C in oranges. *Moringa* plant is non–toxic even at high concentration. It is easily digestible, easy to conserve and easy to use as supplement or on most foods. *Moringa* plant or its processed products has no caffeine like other beverages, thus escaping adverse effects on health.

Moringa plant is native to the sub-Himalayan regions of Northwest India (Foidl *et al*., 2001; Isaac, 2012). The plant now thrives in many countries of Africa, Arabia, South East Asia, the Pacific and Caribbean Islands as well as South America, producing flowers and fruits at all seasons (Isaac, 2012). It can grow in variety of soil conditions, from well drained sandy or loamy soils to heavier clay soils. Currently the young seeds and pods are used as vegetables, the extracted oil from the kernels for industrial purposes, the water extract as a water purifier, the seed cake as fertilizer and feed and various parts (e.g. roots, bark, sap, leaves, oil and flowers) of the plant are used in traditional medicine in several countries (Foidl *et al*., 2001). Moreover, *Moringa* micronutrient liquid is a natural anti-helmintic product and Fahey (2005) reported that because *Moringa* plant is full of leaves at the end of the dry season in the tropics, when other foods are typically scarce, this plant is specially promising as a traditional food source in Africa. Adesina *et al.* (2008) also reported that seeds of *Moringa* are effective as natural coagulant in water. Similarly, Adesina and Omitoyin (2011) reported that moringa fresh root-bark extract is effective as organic piscicide in aquaculture pond management. *Moringa* extracts have also been proven to show potentials of sanitizers or preservatives by inhibiting the growth of the test organisms, which range from food-borne pathogens to spoilage causing organisms in foods (Bukar *et al.,* 2010).

Moringa plant is fast growing and high yielding. Makkar and Becker (1999) reported a high biomass production of up to 120 tons dry matter (DM)/ha/yr in eight cuttings after planting one million seeds/ha. The plant starts to bear pods 6 – 8 months after planting but regular fruiting commences after the second year. The plant fruits for 30 – 40 years.

Nutrient Composition: Makkar and Becker (1997) worked extensively on the chemical composition of *M. oleifera* parts (Table 1). They reported that moringa leaves, the kernel and the fat free kernel meals contain 26.4%, 36.7% and 61.4% of crude protein, respectively. This has placed *Moringa* plant parts as potential protein source. *Moringa* kernel contains over 40% by weight of oil – the fatty acid composition is said to be similar to that of olive oil. The seed oil contains 3% palmitic acid, 7.4% stearic acid, 8.6% behenic acid and 65.7% of oleic acid among other fatty acids.

Table 1: Moringa oleifera nutritional value of leaves and pods

Nutrients	Pod	Leaves	Leave powder
Moisture (%)	86.9	75.0	7.5
Calories	26	92	205
Protein (g)	2.5	6.7	27.1
Fat (g)	0.1	1.7	2.3
Carbohydrate (g)	3.7	13.4	38.2
Fiber (g)	4.8	0.9	19.2
Minerals (g)	2.0	2.3	-
Ca (mg)	30	440	2,003
Mg (mg)	24	24	368
P (mg)	110	70	204
K (mg)	259	259	1,324
Cu (mg)	3.1	1.1	0.57
Fe (mg)	5.3	7	28.2
S (mg)	137	137	870
Oxalic acid (mg)	10	101	1.6%
Vitamin A - B carotene (mg)	0.11	6.8	16.3
Vitamin B -choline (mg)	423	423	-
Vitamin B1 -thiamin (mg)	0.05	0.21	2.64
Vitamin B2 -riboflavin (mg)	0.07	0.05	20.5
Vitamin B3 -nicotinic acid (mg)	0.2	0.8	8.2
Vitamin C -ascorbic acid (mg	120	220	17.3
Vitamin E -tocopherol acetate (mg)	-	-	113
Arginine (g/16g N)	3.6	6.0	1.33%
Histidine (g/16g N)	1.1	2.1	0.61%
Lysine (g/16g N)	1.5	4.3	1.32%
Tryptophan (g/16g N)	0.8	1.9	0.43%
Phenylanaline (g/16g N)	4.3	6.4	1.39%
Methionine (g/16g N)	1.4	2.0	0.35%
Threonine (g/16g N)	3.9	4.9	1.19%
Leucine (g/16g N)	6.5	9.3	1.95%
Isoleucine (g/16g N)	4.4	6.3	0.83%
Valine (g/16g N)	5.4	7.1	1.06%

Analysis of Moringa pods, fresh (raw) leaves and dried leaf powder have shown them to contain the above per 100 grams of edible portion. **Source:** Fahey (2005)

According to Makkar and Becker (1997), in addition to high macronutrient content, *Moringa* leaves and pods are rich in vitamins and minerals such as calcium, phosphorus, magnesium, ascorbic acid and tocopherol. The high true protein content of leaves (26.4% in DM), the presence of adequate levels of essential amino acids (higher than levels present in the FAO (2000) reference protein), and low levels of anti-nutrients are sure indicators of their high nutritive quality.

The high pepsin soluble nitrogen (82 – 91%) and the low acid detergent insoluble protein (1 – 2%) values for the seed meal suggest that most of the protein in the meal is available to most animals (Makkar and Becker, 1997). However, the seed meal is deficient in lysine, leucine, phenylalanine + tyrosine and threonine when compared to the standard FAO (2000) protein. Interestingly, the high content of these deficient amino acids in the leaf meal adequately compensates for them in the seed meal. Combination of seed and leaf meals in desired proportions might result in obtaining a plant-based protein that would favourably replace fishmeal in fish feeds.

Moringa Anti-nutrient Contents: Reports by Makkar and Becker (1997) strongly indicate that moringa leaves are free from anti-nutrients except for saponins (8.1%) and phenols (4.4 %). However, the concentration of phenols is much below the toxic threshold levels reported for animals. Saponins are inactive as far as haemolytic properties are concerned.

Makkar and Becker (1999) further reported that glucosinolates, lectins and alkaloids that form the major anti nutrient substances in moringa seed meal could be easily removed by water extraction, although this method is capable of removing some soluble nutrients.

Bau *et al.* (1994) reported that the solid state fermentation of the seed meal by the use of *Rhizopus oligosporus* could be considered in *Moringa* studies since this mould has been found to degrade glycosinolates in defatted rapeseed meal.

Moringa in Fish Feed Trials: In agriculture, the use of *Moringa* in feed production is known especially for poultry feeds (Du *et al*., 2007; Oduro *et al*., 2008; Olugbemi *et al*., 2010; Zanu *et al*., 2012). There are virtually little known clear reports of utilizing *Moringa* seed or leaf meals as fish feed ingredients for replacement of fishmeal. However, Richter *et al*. (2003) in their preliminary laboratory feeding trials using *Tilapia niloticus* indicated that there was growth reducing effect at high levels (more than 50%) of inclusion of raw leaf meal of moringa. They suggested that moringa leaf meal could be included up to 10% of dietary protein in Nile tilapia. In their fishmeal replacement study, Afuang *et al*. (2003) fed *Oreochromis niloticus* (initial weights of 15.5 – 17.0 g) on varying amounts and extracts of moringa leaf meals to replace fishmeal and found that the relative liver weight was significantly influenced ($p < 0.05$). They reported that the hepatosomatic index (HSI) ranging from 1.5 to 2.7 correlated with body lipid incorporation and was obviously influenced by dietary nutrient intake and availability. In another study with methanolic extract of moringa not as replacement for fishmeal but as replacement for wheat meal, Dongmeza *et al*. (2006) conducted a research with diets 1 (control without any moringa product), 2, 3 (containing 10.6 and 17.7% of moringa leaf meal methanol extract), 4, 5 (containing 9.3 and 15.4%, respectively of a tannin-reduced fraction), 6, 7 (containing 2.6 and 4.3%, respectively of a saponin-enriched fraction), 8 and 9 (containing 7 and 11.6% of a tannin- and saponin-reduced fraction, respectively).

They reported that at the end of the experiment, a significant reduction ($P < 0.05$) of the growth performance of all the fish fed diets containing 80% methanolic extract of moringa or the extract fractions was generally observed when they were compared to the fish fed with the control diet. The whole body moisture, ash and crude protein of the fish fed diets containing moringa crude extract or extract fractions were not significantly different ($p > 0.05$) to those of the control group. Body lipid was significantly reduced for the fish fed the diets when compared to control. Muscle and plasma cholesterol levels were generally reduced for the fish fed diets containing moringa extract and extract fractions (except for the diet containing 15.4% of a tannin-reduced fraction of the methanolic extract of moringa (group 5) which showed higher muscle cholesterol than that of the control). The fish in the 10.6% moringa leaf meal methanol extract (groups 2) and 15.4%, respectively of a tannin-reduced fraction (group 5) had significantly lower hepatosomatic indices when compared to control. On the other hand, the intestinal somatic indices (ISI) of the groups 2, 3, 4, 5, 6 and 7 were generally higher than the control group and the groups 8 and 9 had lower ISI than the control group. They concluded that the relatively high total phenolics and saponins in diets 2 to 9 may have contributed to the poorer growth performance in these groups.

From more recent feed studies, it was discovered that pre-feeding of *Puntius altus* with leaf semi-powder extract of *M. oleifera* would be protective in reducing lead burdens in fish exposed to environments contaminated with waterborne lead (Sirimongkolvorakul *et al.,* 2012). Yuangsoi and Masumoto (2012) also worked on partial replacement of soybean meal not fishmeal with moringa leaf for fancy carp (*Cyprinus carpio*) (Table 2). The study indicated that the tested moringa leaf diet contained ingredients that could be used for fancy carp diets with possibly not over 20 g/kg soybean protein replacement without negative effect on growth and digestibility.

By processing moringa leaf meal (MLM), cassava leaf meal (CLM) and cassava root meal (CRM) in an attempt to remove the most significant anti-nutritional factors and substituting each ingredient for fishmeal in

Table 2: Ingredients and chemical composition of practical moringa leave meal based diets used in aquaculture

Ingredient (g Kg-1)	Protein replacement in soybean meal by moringa leaves (g kg-1)		
	0	**200**	**500**
Fish meal	320	320	320
Soybean meal	230	184	115
Moringa leaves	0	88	220
Wheat Flour	120	120	120
Cellulose	160	117.6	54.1
Fish oil	35	35	35
Soybean oil	35	35	35
Guar gum	10	10	10
Dicalcuim phosphate	20	20	20
Premix	70	70	70
L-Methionine	0	4	9
Total	1000	1000	1000
Nutrient composition by analysis (g kg-1 dry weight on basis)			
Protein	35.63 ± 1.95	34.67 ± 0.03	35.12 ± 1.07
Fat	9.39 ± 0.01	9.42 ± 0.04	9.37 ± 0.14
Fiber	2.11 ± 0.78	2.10 ± 0.17	2.18 ± 0.25
Dry matter	67. 60 ± 0.23	68.04 ± 0.28	67.68 ± 0.25
Ash	11.79 ± 0.09	11.52 ± 0.05	11.93 ± 0.45
Amino acid composition (g kg-1dry weight on basis)			
Histidine	2.50 ± 0.01	2.58 ± 0.02	2.74 ± 0.01
Arginine	20.38 ± 0.01	18.50 ± 0.01	15.86 ± 0.10
Asparagine	3.28 ± 0.03	3.83 ± 0.02	5.88 ± 0.03
Glutamic acid	3.19 ± 0.01	3.44 ± 0.04	4.45 ± 0.04
Alanine	4.36 ± 0.09	4.08 ± 0.01	4.03 ± 0.01
Proline	2.52± 0.02	3.30 ± 0.04	3.87 ± 0.05
Methionine	1.27 ± 0.03	1.08 ± 0.01	0.79 ±0.01
Valine	3.33 ± 0.03	3.30 ± 0.03	3.52 ± 0.04
Trytophane	n.d.	n.d.	n.d.
Leucine	9.33 ± 0.06	9.30 ± 0.04	9.53 ± 0.04
Lysine	6.11 ± 0.02	9.08 ± 0.01	10.53 ± 0.02
Cysteine	10.06 ± 0.10	8.62 ± 0.03	8.86 ± 0.07

Source: *Yuangsoi and Masumoto (2012)*

isonitrogenous (30g 100g^{-1}), isolipidic (10g 100g^{-1}) and isoenergetic (18 kJ g^{-1}) diets containing graded levels of the processed ingredients, Madalla (2008) fed to *Oreochromis niloticus* to their apparent appetite but not exceeding 10% of their body weight for a period of 8 weeks. He reported that:

a. inclusion of either of the leaf meals, even at the lowest level of 15g 100g^{-1} of total dietary protein, led to a significant reduction in feed intake, growth and feed utilization.

b. Liver and small intestine did not show any histopathological changes which could be linked to dietary treatment. Conversely, cassava root meal could replace up to 75% of wheat meal in the diet without significantly affecting performance.

c. The performance of leaf meals was marginally improved by a combination of blending and feeding stimulants, whereby a blend containing 1 part MLM and 2 parts CLM could provide up to 20g 100g^{-1} of dietary protein without significantly reducing performance.

d. Biological and economic performance of practical diets containing 30 – 50 g 100g^{-1} of dietary protein from moringa and cassava blends (LMB) with feeding stimulants was significantly lower than a fish meal (FM) based diet but comparable to a soybean meal-based diet (SBM).

e. The suitability of MLM and CLM as novel protein sources in *O. niloticus* diets will depend on i) improving reduction/removal of inherent anti-nutritional factors in MLM.

Reporting on the use of temperature treatment on moringa used in fish diets, Tagwireyi *et al.* (2009) reported that heat treatment methods they employed might have increased the digestibility of proteins and other dietary components such as starch related compounds leading to high FCR of 1.1 and PER of 1.9 - 2.0 in fish fed with moringa-treated diets. Also, they reported that steam treatment employed in their study might have resulted in little protein being denaturated thus making more quality protein to be made available in steamed leaves than in boiled leaves. They additionally reported that though boiling broke cell components like cell walls and cell membranes of plants cells, some of the nutrients not specifically mentioned within the cells of boiled moringa leaves were lost to boiling water during the heat treatment process. The soluble cell components such as soluble proteins and glucose molecules might have dissolved in water during boiling. This could have caused the reduction of essential amino acids (EAA) in diets. Boiling was thought to have caused the inactivation of anti-nutrients such as saponins, phytates, phenols and tannins that bind some quality proteins and inhibit digestion in fish. Some of their conclusions though speculative is interesting. Hussien *et al.* (2012) reported that *M. oleifera* leaf powder in the diet and Levamisol HCl as freshwater bath in addition to being a feed ingredient was useful in the treatment of the nematode *Anguillicola crassus which* infests eels (*Anguilla anguilla*).

Conclusion: We are face to face with a non timber forest product (NTFP), *Moringa oleifera* Lam regarded as a "wonder or miracle plant". In agriculture, particularly in aquaculture, there is virtually little known data for the integration of this plant in fish nutrition research. Hence, this plant presents an important area for aquaculture nutrition research.

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