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Potentiality of new feed ingredients for aquaculture: A review

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ABSTRACT

The continuous demand for alternative protein sources for fish due to its short supply, high prices and competition with the human food. A review of unconventional feeds in fish nutrition was carried out to provide information on supplemental feed for effective Aquaculture. Non-conventional dietary energy and protein sources,especially from plant origin can be used to replace expensive protein sources. There is a continuous demand for alternative protein sources for fish due to short supply, cereals and oilseed mealsfor sustainable aquaculture production. The solid waste materials like distillers dried grain soluble, breweries waste, ghee residue and agricultural plant materials like jute, leucaena, moringa, cassava, rain tree and spirulina can find a place in formulation of aquafeed as one of the inexpensive feed ingredients. The non-conventional feed ingredients to be incorporated in fish feed up to recommended levels.

Key words: Breweries waste, Distillers grain soluble, Ghee residue, Jute leaf, Non-conventional feed, Rain tree pod.

Fisheries sector occupies an important position in the development of livelihood, employment generation, export earnings, food and nutritional security of the country (Ayoola, 2010). Indian fisheries occupy the second position in global fish production after China (Paul and Giri, 2015). The fish production during first two quarters of 2015-16 has also shown an increasing trend and is estimated as 7.54 MT (DAHAD, 2015-16). The demand of fish feed have increased due to the rapid expansions of the aquaculture industry with the advancement of culture techniques. Worldwide aquaculture industry depends on the availability of low cost and high quality feeds. As a result of continuous increase of global fish farming, the requirement of alternative cost-effective and good protein source is similarly important. Expenditure on feed alone accounts to 60% of total fish production costs (Paul and Giri, 2015). Fish meal is the major protein source in aquafeed industries because of its balanced amino acid profiles, high content of protein, and good source of essential fatty fatty acids (Abdelghanty, 2003). But due to its increasing global demand, high cost, fluctuating quality as well as its uncertain availability emphasis has been given to the development of cost-effective, high quality, alternative protein sources for partial or complete replacement of fish meal (Gallagher, 1994). To make aquaculture more profitable and in order to reduce the cost of feed, there is an urgent need to identify and incorporate the qualitative and quantitative requirement of dietary protein, as it is the costliest among the various ingredients used for the preparation of fish feeds. The non-conventional feed ingredients include all types of feedstuffs from animal (silkworm, Slaughter house by productsetc.), plant wastes (maize bran, ricebran, brewers wasteetc.) and wastes from animal sources. Paul (1999) reported earlier about some of the unconventional feed ingredients that could be used for feeding of fish. Among such alternative protein sources distillers grains with soluble, breweries waste, ghee residue etc. are utilized as a source of dietary ingredients in fish culture as reported elsewhere (Paul *et al*., 2012a,b). These ingredients also contain trace mineralsto some extent but its availability depends on its form (organic and inorganic) (Chanda *et al*., 2015). Keeping in view of the above facts a review paper is prepared which will reflect the possibility of utilization of non-conventional feed ingredient as aqua feed. Some of the new feed ingredients are mentioned below.

Distillers Dried Grain Soluble (DDGS): DDGS is a valuable feed ingredient and is one of the three co-products produced in dry grind ethanol plants, along with fuel ethanol and carbon dioxide (Shurson, 2003). DDG in aquafeed presents a substantial economic value as it is less expensive than other protein/energy sources like soybean meal.Corn DDGS is a free-flowing granular product with color ranging from yellow/tan to dark brown and has a bulk density of 13.8 to 17.8 kg per cubic foot.

Chemical characteristics of DDGS: Maize DDGS is a high energy, mid-protein, highly digestible phosphorus ingredient. Fat content ranges from 10.9 to 12.6% (Lim *et al*., 2011) and the total fat is comprised of linoleic acid (55.7per cent),

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linolenic acid (7.8 percent) and DHA (0.14 percent). Corn DDGS are rich in vitamin A, niacin and choline, and contain several minerals, including phosphorus (Lim *et al.*, 2011). Lim and Yildirin-aksoy (2008) reported that DDGS is a good source of vitamin, minerals and essential amino acids. DDGS contain substantial amount of yeast. Yeasts are also rich in protein, B-complex vitamins and β-glucan.

Use of DDGS in fish feeds: DDGS has been used in fish diets since the late 1940s. Philips *et al.* (1964) reported that 21% DDGS provided with 24% FM, 5% CSM, 10% brewer's yeast in brown trout (*Salmotrutta*) showed a growth similar to that of fish fed meat-meal mixtures. General level of information of DDGS in Fish Feed is represented in Table 1. Early studies demonstrated that up to 35% DDGS without lysine supplementation (Webster *et al.*, 1992) could be used to partially replace soybean meal and fish meal in channel catfish diets without affecting fish growth. Webster *et al.* (1993) reported that 30% DDGS can be used as a replacement of a mixture of SBM and CM in channel catfish containing 8% fish meal. Li *et al.* (2011) found the same weight gain, feed efficiency ratio (FER), protein efficiency (PER) in fish fed diets with up to 30% wheat DDGS or up to 40% with lysine supplementation in nile tilapia. Robinson and Li (2008) reported that up to 30-40% DDGS with supplemental lysine could be used in channel catfish. Lim

Table 1: Level of incorporation of feed ingredients in fish feed.

Particulars	Species	Level of Incorporation	References
Distillers dried grain soluble (DDGS)	*Salmo trutta*	21%	Philips *et al.*, (1964)
	Ictalurus punctatus	35%	Wbster *et al.*, (1992)
	Ictalurus punctatus	30%	Wbster *et al.*, (1993)
	Oreochromis niloticus	29%	Wu *et al.*, (1994)
	Ictalurus punctatus	35-40%	Lim *et al.*, (2007)
	Ictalurus punctatus	30-40%	Robinson and Li (2008)
	Oreochromis niloticus	20%	Schaeffer *et al.*, (2009)
	Ictalurus punctatus	30%	Li *et al.* (2010)
	Perca flavescans	49.5%	Schaeffer *et al.*, (2011)
	Cirrhinus mrigala	30%	Paul *et al.* , (2012)
Breweries waste (BW)	*Labeo rohita and Catla catla*	30%	Kaur and Saxena (2004)
	Oreochromis niloticus	25%	Zerai *et al.* (2008)
	Catla catla	15%	Singh *et al.* (2014)
Brewer's dried yeast slurry	*Clarias gariepinus*	14%	Solomon *et al.* (2017)
	Dicentrarchus labrax	30%	Oliva-Telesand Goncalves (2001)
	Oncorhynchus mykiss	25%	Rumsey *et al.* (1991)
Ghee residue (GR)	*Labeo rohita*	20%	Paul *et al.* (2012)
	Labeo rohita	24%	Singh *et al.* (2015)
	Labeo rohita	20%	Singh *et al.* (2017)
Corchorius olitorius	*Labeo rohita*	20%	Singh *et al* (2016)
Manihotesculenta(Cassava) leaf meal	*Oreochromis niloticus*	10%	Nnaji *et al.*, (2010)
Cassava peel	*Oreochromis niloticus*	10%	Ugwu *et al.*, (2004)
Cassava root meal	*Ctenopharyngodonidella*	30%	Lacerda *et al.*, (2005)
	Macrobrachium rosenbergii	5%	Gomes *et al.* (1996)
	Hybrid catfish	66%	Abu *et al.*(2010)
Leucaenaleucocephala	*Oreochromis niloticus*	25%	Wee and Wang (1987)
	M. rosenbergii	25%	Mamat *et al.*(2017)
	Clarias gariepinus	30%	Amisah *et al.*(2009)
	Clarias gariepinus	20%	Timamiyu *et al.* (2015)
Samaneasaman (pod)	*Labeo rohita*	30%	Rath *et al.*(2014)
	Catla catla	30%	Rath *et al.*(2017)
Spirulina sp.	*Oplegnathus fasciatus*	26%	Kim *et al.*(2013)
	Catla catla and Labeo rohita	Up to 30%	Nandeesha *et al.* (2001)
	Pangasianod ongigas	10%	Tongsiri *et al.*(2010)
	Pangasius sutchi	5%	Jana *et al.*(2014)
	Anabas testudineus	5%	HtayHtay Win (2007)
	Ctenopharyngodonidella	10%	ThetHla Su (2007)
	Cyprinuscarpio	Up to 30%	Nandeesha *et al.* (1998)
Moringaoleifera	*Pangasiusbocourti*	20%	Puycha *et al.* (2017)
	Oreochromisniloticus	12%	Magouz *et al.* (2016)
	Clariasgariepinus	10%	Adewumu (2014)
	Cyprinuscarpio	20%	Yuangsoi and Masumoto (2012)
	Oreochromisniloticus	10%	Ritcher *et al.* (2003)

et al. (2009) reported that DDGS is considered as an acceptable ingredient in diets for rainbow trout, channel catfish, tilapia and sunshine bass. Xhou *et al.* (2010) suggested that growth in channel catfish juveniles fed diets with 35-40% DDGS was equivalent to fish fed a standard commercial anufactured formulation.Dietary inclusion of DDGS in nile tilapia improved feed consumption, feed efficiency and growth (Lim *et al*., 2007) and in mrigal incorporation of DDGS upto 30% resulted higher growth and feed conversion (Paul *et al*., 2012a). In yellow perch (*Perca flavescens*) a mixture of DDGS and soybean meal can be incorporated up to 49.5 % without negative effects on growth (Schaeffer *et al.* 2011). DDGS can be incorporated in the diet of *Oreochromis niloticus* at 20% level without affecting growth performance and body composition (Schaeffer *et al*., 2009). Cheng and Hardy (2000) were the first authors who assess the bioavailability of amino acids and protein digestibility of DDGS. Wu *et al.* (1994) reported diets containing either maize gluten meal (18%) or DDGS (29%), and 32% or 36% crude protein, resulted in higher weight gains for tilapia than fish fed a commercial fish feed containing 36% crude protein and fish meal. Li *et al*. (2010) reported that 30% level of DDGS can be incorporated in the diet of *Ictalurus punctatus.*

Breweries waste (BW): In the manufacture of beer, various residues, by-products and wastes are generated. The most common ones are spent grain, spent hops and surplus yeast along with desired products and there is increasing demands to ensure total utilization of such waste products to address economic and environmental concerns, which are generated from the main raw materials (Mussatto, 2009).These materials are considered to be good sources of un-degradable protein and water soluble vitamins (Taylor *et al*., 2009).

Chemical properties of breweries waste: It contains cellulose, hemicelluloses, lignin, high protein content, high amounts of calcium, magnesium and phosphorus (Khidzir *et al*., 2010). The most abundant monosaccharides found in BSG are xylose, glucose and arabinose (Mussatto, 2009). Others include minerals, vitamins and amino acids. The vitamins include (ppm): biotin (0.1), choline (1800), folic acid (0.2), niacin (44), pantothenic acid (8.5), riboflavin (1.5), thiamine (0.7) and pyridoxine (0.7) and it also contains lipids (between 3.9 and 10%), ash (2.5 to 4.5%) and phenolic compounds (Mussatto *et al*., 2006). Kaur and Saxena, 2004 reported that BSG is rich in water soluble vitamins. Santos *et al*. (2003) found 24.2% protein, 3.9% lipid and 3.4% ash in oven-dried BSG. Singh *et al*. (2014) reported that breweries waste contains 43.51% crude protein, 1.05% lipids and 8.33% total ash.

Use of brewery waste in fish feed: Kaur and Saxena (2004) reported that a diet containing 30% brewery waste showed better growth performance in terms of higher weight gain in *C.catla* and L. *rohita* than the control. In Nile tilapia, when brewery waste along with cotton seed meal was used a good results in terms of FCR were obtained (Middendrop, 1995). Muzinic *et al*. (2004) reported that fish meal and shrimp meal can be totally replaced with soybean meal and brewer's grain with yeast (BGY) in diets for juvenile red claw crayfish. Zerai *et al*. (2008) concluded that 50% of the fish meal protein in a typical commercial diet could be replaced with brewer's waste (25%) with no adverse effect on growth and feed utilization for *Oreochromis niloticus*. Singh *et al.* (2014) reported that the breweries waste can be incorporated upto 15% level with other feed ingredients in the feed of *Catla catla* fingerlings without any adverse effect. Rumsey *et al*. (1991) reported that diet containing 25% brewer's dried yeast when fed to rainbow trout grew better.Oliva-Teles and Goncalves (2001) found that up to 30% brewers yeast in the diet improved feed efficiencyand 50% of the fish meal in a totally fish meal protein–based diet can be replaced with brewer's yeast in sea bass, *Dicentrarchus labrax*, with no adverse effect on growth. Solomon *et al*. (2017) concluded that the optimal range of inclusion and substitution of soybean meal with dried brewer's yeast slurry meal in *C. gariepinus* feed liesup to 14% of dry matter.

Ghee residue (GR): Dairy products are important sources of dietary fat in India. Gharita (ghee) was produced in ancient India as far back as 1500 BC (Achaya, 1997). Chemically ghee isa complex lipid of mixed glycerides together with asmall amount of free fatty acids, phospholipids, sterolsand their esters, fat soluble vitamins (A, D, E and K), carotenoids, carbonyl compounds, hydrocarbons,charred casein, moisture and traces of trace elementslike copper and iron. India is the global leader in milk production and about 30- 35% of total milk produced is being utilized for ghee production and present ghee production in India is 112 million tonnes (Gandhi *et al*., 2013). Ghee residue (GR) is a brownish solid mass obtained as a byproduct during manufacture of ghee from mixed milk (cow and buffalo). It has smooth to granular texture with glossy exterior due to the presence of excessive fat. It is slightly sweet in taste and has pleasant odour.

Chemical properties of ghee-residue: Ghee residue is a nutritious food containing fat, denatured protein, burnt lactose and minerals. According to Wadhwa (1997) 11 free amino acids and 2 amines were detected in GR Ghee residue is one of the byproducts of Dairy plant industry, containing in dry matter 25.8% crude protein, 12.3% lactose, 14.4 MJ of apparent ME/g, 16.5 MJ of true ME/kg, 43.7 gross protein value, 8.9% ash, 0.88% calcium, 0.50% phosphorus, 14.4% nitrogen free extract and no crude fibre (Arumugam *et al*., 1989). Relwani, (1978) reported that the chemical composition (%) of GR varies as fat (32-70), proteins (12-39), moisture (8-30) and ash (1-8). GR is a rich source of natural antioxidants. Singh *et al*. (2015) reported that ghee residue contains 22.07% crude protein, 12.32% fat and 4.02% total ash (% DM basis). The by-product GR thrown as a waste matter is nutritionally a rich source of proteins, fat and nitrogenous compounds.

Use of ghee residue as feed: It is one of the Agro-industrial wastes which can be utilized as an Aquaculture feed ingredients. Kapoor and Pal, (1979) reported that the proteins efficiency ratio of GR as 2.55 and it can serve as a good source of animal proteins. Arumugam *et al*. (1989) reported that GR supplemented with lysine and methionine can be incorporated in chick starter diets up to 35.4% without any adverse effect. Singh *et al*. (2015) reported that ghee residue can be incorporated in rohu juveniles upto 24% level whereas, Paul *et al*. (2012b) concluded that ghee residue can be incorporated in the feed of rohu fingerlings up to 20% under laboratory condition. Incorporation of ghee residue improve the PUFA content of fish (Singh *et al*., 2015); these PUFA has health benefit to human being (Das *et al.*, 2009) Loganathan *et al*. (2015) concluded that GR could be included in the diet of broiler chicken up to 25% level. Singh *et al*. (2017) reported that the incorporation of 20% ghee residue along with other feed ingredients showed better growth performance in rohu fingerlings under field condition.

Jute (*Corchorus olitorius*): Jute (*Corchorus olitorius*) belongs to the genus of about 40-100 species of flowering plant in the family Tiliaceae. Total area under the crop cultivation of India in the year 2011 was 768,000h and the total production was 1799,000 bales (FAO, 2011). It is an erect, annual herb and its length varies from 20 cm to 1.5 m. The stems are angular with strongly branched and fibrous. Leaves are alternate, simple, lanceolate to ovate-lanceolate.

Chemical properties of jute leaf: The jute leaves are good source of proteins and they are also rich in magnesium, iron and calcium (Dansi *et al*., 2008). Jute leaf also contains a good amount of lipid (Saidu and Jideobi, 2009). This is also rich in potassium, phosphorous, ascorbic acid, carotene and contain a large amount of mucilaginous polysaccharides (Islam, 2010). Choudhary *et al*. (2013) reported that the *C. olitorius* leaf has a good amount of protein, iron, β-carotene and potassium. Idirs *et al*. (2009) reported that jute leaf contains 12.54% crude protein. The concentration of calcium in *C. olitorius*23.3mg/gas reported elsewhere (Onwardi *et al*., 2009). Singh *et al*. (2016) reported that jute leaf contains 16.78% crude protein, 9.98% fat, 3.9% crude fibre and 9.20% ash (% DM basis).

Use of Jute leaf: It has been reported that compounds such as carotenoids, flavonoids and vitamin C, isolated from leaves of *C. olitorius*, exhibit significant antioxidant characteristics (Khan *et al*., 2006). It has demulcent, diuretic, purgative and tonic properties and it is served as a lactagogue (Farah *et al*., 2006). Zakaria *et al*.(2006) reported that it is used in folkore medicine in the treatment of gonorrhea, chronic cystisis, dysuria, pain and fever and also possess antibacterial activity. It is known to contain high levels of iron and folate which are useful for the prevention of anemia Oyedele *et al*. (2006). Leaves of *C. olitorius* have been reported to have ethno-medicinal importance as a demulcent and febrifuge (Nishiumi *et al*., 2006) and also possess anti-inflammatory, analgesic and antimicrobial activities (Das *et al*., 2010). Antinutrient present in the leaves of *C.olitorius* is usually eliminated during cooking (Akwaowo *et al*., 2000). Although the leaves are widely recognized as a food source for human in most parts of Africa and some parts of Asia, there is a paucity of information on the use of this ingredient as dietary protein sources for aquaculture species. Singh *et al*. (2016) reported that jute leaf powder can be incorporated in the feed of rohu fingerlings up to 20%.

Cassava waste (*Manihot esculentacrantz*): Although cassava roots/tubers and leaves are cheap sources of dietary energy and protein, the extent of their practical use in aquaculture feeds has been limited. Cassava starch has excellent binding properties. World cassava output increased by 4.6% between 2013 and 2014 (FAO, 2014).

Chemical properties of cassava waste: Cassava pulp is usually collected wet from factories and fed directly to pigs with a protein concentrate (Devendra, 1980).The root is composed almost exclusively of carbohydrate, as well as approximately 1% to 3% crude protein (Stupak *et al*., 2006). Cassava residue is rich in fiber and residual starch (Leaes *et al*., 2013).Cassava leaves are highly nutritious and have 16.6% to 39.9% protein (Khieu *et al*., 2005), and mineral levels, as well as being a valuable source of vitamin B_1, B_2 and C and carotenes (Adewusi and Bradbury, 1993). The protein content of cassava flour, peels and leaves is also low at approximately 3.6%, 5.5% and 21% respectively (Iyayi and Losel, 2001). Gomes *et al*. (2005) found that cassava starch contains 17% amylose and 83% amylopectin. Ravindran (1991) stated that sun-drying can eliminate almost 90% of initial cyanide content.

Use as feed: Kana *et al*. (2012) found that body weight was highest in birds fed diets in which 50% of the maize was replaced by cassava flour meal. It was found that 15% cassava meal can substitute coconut meal in broiler diets with no negative effect on growth performance (Ravindran *et al*., 1986).Cassava leaf meal included at 10% in Nile tilapia fingerling diets gave the best growth, feed conversion ratio and survival (Nnaji *et al*. 2010). Ugwu *et al*. (2004) reported that the 10% inclusion rate of cassava peel was recommended for feeding nile tilapia. Lacerda *et al*. (2005) reported that the 30% inclusion level of cassava root meal can replace up to 100% maize grain in the diet of *Ctenopharyngodon idella* fingerlings with no detrimental effect on growth performance. Abu *et al*. (2010) reported that the 66% inclusion level of cassava root meal in the diet of hybrid catfish fingerlings give the optimal growth performance. Gomes *et al*.(1996) reported that 51% of cassava root meal can replaced 100% of maize grain in the diet of *Macrobrachiumrosenbergii*.

Subabul (*Leucaena leucocephala*): *Leucaena leucocephala* is a leguminous, multipurpose tree and provides fuel wood, green manure, improves degraded lands and can be used as a cover crop. It has bipinnate leaves, lanceolate leaflets and has flat pods containing small seeds. Leaf meal from *Leucaena leucocephala* is a potential source of protein.

Chemical properties of subabul leaf: *Leucaena* leaf is known to contain about 22.7% crude protein (Atawodi *et al.***,** 2008). Amino acid analysis of *Leucaena* leaf meal showed methionine levels ranging from 1.32% to 2.0% (Jackson *et al*., 1982). Amisah *et al*. (2009) reported that 23.54% of protein level found in *Leucaeana* leaf. Francis *et al*. (2001) reported that "mimosine" present in it can be reduced by different processing techniques resulted in better palatability and growth in fish.

Use in fish feeds: The growth response of *T. mossambica* improved with increments in amount of leaf meal (Pantastico and Baldia, 1979). Wee and Wang (1987) showed that inclusion of soaked *Leucaena* leaf meal up to 25% of the total protein has not any adverse effects on growth of *O.niloticus*. Improved growth performance was seen in Indian Major Carp with leucaena as a dietary protein source (Ghatnekar *et al*., 1983). Hasan *et al*. (1990) investigated the use of leucaena leaf meals as a dietary protein source for the fry of *L. rohita*. Osman *et al*. (1996) reported that weight gain, specific growth rate, feed conversion ratio and protein utilization parameters were significantly (p< 0.05) increased by the higher percentage of dried or cooked leucaena leaf meal (LLM) in tilapia diets. Mamat *et al*. (2017) reported that L. *leucocephala* meal could replace fish mealup to 25% in diets for *M. rosenbergii* juveniles. Amisah *et al*. (2009) concluded that *Leucaeana leucocephala* leaf meal may be included in the diets of *Clarias gariepinus*at inclusion levels of up to 30%. Tiamiyu *et al.* (2015) reported that *Leucaeana leuc ocephala* leaf meal can be included in the diets of *Clarias gariepinus* at 20% levels without adverse effect.

Rain tree (*Samanea saman*): Rain tree (*Samanea saman*) is a fast growing tropical tree under the family Fabaceae. The fruit (pod) is well known as cow tamarind or monkey pod and often browsed by ruminants (Devendra, 1989). Tree size reaches 15 – 25m in height and the tree has a short stout trunk of about 1 – 2m. A full grown tree can produce 500 - 600 kg pods in a year. It is identified as a good source of protein (25.2%) and energy (20.4 kj g^{-1}) for carp feed (Rath *et al*., 2014).

Chemical properties of rain tree seed, pod and leaf: Crude protein content of the RTP as reported by earlier authors varied widely from 19-28% (Babayemi *et al*., 2010). The amino acid profiles of RTS (rain tree seed) as studied by earlier workers showed a high tryptophan (16.24%) and lysine (14.98 %), however methionine and proline were the limiting amino acids (Esuoso, 1996). The pod contains 15.18% moisture, 9.45% crude protein, 8.34% crude fiber, 8.82% crude fat, 5.12% ash and 53.09% nitrogen free extract (Barcelo and Barcelo, 2012). The leaves are fairly rich in protein containing about 22 – 27% crude protein (Staples and Elevitch, 2006). Rath *et al*. (2014) reported the 1.7% lipid level in RTP and 10.5% in RTS (rain tree seed). Esuoso (1996) reported that the lipid of RTS contained nine fatty acids out of which unsaturated acids accounted over 90% of the total fatty acid content.

Use as feed: Flores (2002) reported that rain tree pods contain 13 – 18% protein, are edible and nutritious for livestock. Offoh (2011) reported that *Samanea saman* pods supplemented in the diet of sheep showed increase in feed intake and growth performance. Thole *et al*. (1992) replaced rice bran with RTP in the feed of heifers at 20% incorporation level without any adverse effect on growth. Rath *et al*. (2014) reported that RTP can be incorporated at 30% substituting 25% groundnut oil cake and 42% rice bran in the diet of L. *rohita* larvae without any adverse effect on growth and survival. Rath *et al*. (2017) reported that 30% level of processed or raw rain tree pod can be incorporated in the diet of *Catla catla* fry.

Spirulina *(Spirulina sp.)*: Spirulina is one of the most frequently used microalgae in aquatic animal feeds due to its high contents of protein (60-70%), vitamins, essential amino acids, minerals, essential fatty acids and antioxidant pigments such as carotenoids (Nakagawa and Montgomery, 2007).

Use as animal feed: Tongsiri *et al*. (2010) showed that replacement of 5% FM with spirulina (10%) resulted in the best growth performance of *Pangasianodon gigas*. Jana *et al*. (2014) reported that the 5% inclusion level of spirulina in *Pangasius sutchi*can raise its growth performance and survival ability. Olvera-Novoa *et al*. (1998) reported that spirulina can replace up to 20% of FM protein in diets for *O. mossambicus*. Nandeesha *et al*. (1998) reported that fish meal can be replaced up to 100% by spirulina in diets for *C. carpio*. Palmegiano *et al*. (2005) stated that 60% of fish meal can be replaced with spirulina, an inclusion level of 50% gave the greatest growth rate, a better favourable feed conversion rate and the highest protein efficiencyin diets for Siberian sturgeon (*Acipenser baeri*). Nandeesha *et al*. (2001) found that spirulina (up to 30%) can partially or totally replaced the fish meal in the diets of catla and rohu. Htay Htay Win (2007) reported that addition of 5% *S. platensis* in the diet showed the best growth performance and survival rate in *Anabas testudineus*. Similarly ThetHla Su (2007) also observed that 10% of *S. platensis* incorporated into formulated diet of *Ctenopharyngodon idellus* fingerlings resulted in good health and better growth performance. Kim *et al*. (2013) reported that the 26% inclusion of spirulina can replace up to 15 % FM protein in the diet for parrot fish *(Oplegnathus fasciatus)*.

Moringa/drumstick *(Moringa oleifera Lam)*: *Moringa oleifera* is a fast-growing plant. The plant is a good source of protein, vitamins, amino acids, β-carotene and various phenolics. Moringa leaves have arelatively high crude protein content which varies from 25 - 32% (Soliva *et al.,* 2005). Essential amino acids found in moringa leaf are methionine, cysteine, typtophan and lysine.

Useas feed: Puycha *et al*. (2017) reported that moringa leaf could be included in the Bocourti's catfish (*Pangasius bocourti*) diet at 10% level without a negative effect on the growth, feed utilization, digestibility and serum biochemistry. Adewumu (2014) reported that *Moringa oleifera* leaf meal can be used to replace up to 10% of the fish meal in *C.gariepinus* fry diet, without adverse effects on survival and growth performance.Ogbe *et al*. (2012) reported that moringa is nutritionally rich and can be included in fish diet at low levels. Yuangsoi and Masumoto (2012) reported that moringa leaf diet contains ingredients could be used for fancy carp (*Cyprinu scarpio*) diets up to 20% soybean protein replacement without negative effect on growth and digestibility. Tilapia fed with raw moringa leaf meal revealed that 10% of replacement of fish meal-based dietary protein did not cause any adverse effecton growth performance (Ritcher *et al*., 2003).Magouz *et al*. (2016) concluded that inclusion of 12% of *Moringa oleifera* leaves can be recommended as a partial feed substitution in the diet of Nile tilapia without any adverse effects on growth performance parameter, efficiency of feed utilization and body composition.

CONCLUSION

The solid waste feed ingredients, agro-industrial by-products and leaf meal have lot of potentialities in formulation of aqua feed. The dried distillers grain soluble can be used up to 50% in fish feed. The ingredients *viz*., breweries waste can be incorporated up to 30%, ghee residue up to 24%. The plant leaf materials can be incorporated in fish feed also as one of the ingredients; such as *Corchorus olitorius* (Jute leaf) up to 20%, *Leucaena leucocephala* (Subabul) up to 30%, *Samanea saman* (Rain tree pod) up to 30%, *Moringa oleifera* (Drumstick) up to 20%, *Spirulina* sp. up to 30%, *Manihot esculenta* (Cassava) leaf meal and peel up to 10% and cassava root meal up to 30%. The feed cost can be reduced to a great extent if these ingredients can be used as fish feed.

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