may also be obtained using the feed with mixed protein of plant and animal origin. To achieve a balance nutritional composition in fish feed, a more diverse choice should be made in selecting feed ingredients. Products derived from ipil ipil have been shown to be important ingredients for practical feed of tilapia fish. The findings in the present study shown that ipil ipil leaf meal could be used as protein substitute up to 25% and optimum level 15% in the diet of growing tilapia. However, further studies are needed to justify the long term effect and benefit of ipil ipil leaf for fish health and fish production.

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Fermented feed ingredients as fish meal replacer in aquafeed production

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Feed is the most significant input for most aquaculture systems. Among feed ingredients, fish meal is a major component of feed costs. This has stimulated the evaluation of a variety of alternative dietary protein sources for partially or totally replacing fish meal protein in aquaculture feeds. Use of cheap animal protein ingredients like shrimp head meal waste as such is limited by the presence of exoskeletal chitin and ash content though it contains high levels of protein with an excellent amino acid profile. Similarly use of plant based ingredients in fish feed formulations have certain limitations viz., amino acid imbalance, low protein content and anti-nutritional factors. Utilization of seaweeds and other aquatic plants is also limited due to the presence of high crude fiber and low protein content.

Fermentation is a unique process which will improve the nutritional value of feed ingredients. Fermentation reduces the presence of exoskeletal chitin in shrimp head meal, anti-nutritional factors and fibre in plant based feed ingredients thus improves their nutritive value. Further bacterial fermentation hold promise for growth enhancement and immunostimulants in aquaculture. Fermentation also increases the availability of certain vitamins viz., riboflavin, cyanogobalamine, thiamine, niacin, B6, B12 and folic acid levels in some feed ingredients.

Fermented shrimp head meal

Fermentation is an important tool to reduce the chitin and ash content in shrimp head meal. Fermentation increases the total available protein, calcium and phosphorus. Lactic acid bacterial fermentation has been used successfully in fish insolation (Hall and Silva, 1994). *Lactobacillus plantarum* is used for fermentation of shrimp head meal. The amino acid profile of fermented shrimp head meal is relatively high except for histidine and tryptophan. Biologically ensiled shrimp head silage meal can effectively replace fish meal up to 30% in the diet of African catfish *Clarias gariepinus* fingerlings (Nwanna, 2003). Chitinoclastic and proteolytic bacterial strains could also be used to ferment prawn shell waste in order to improve the nutrient content; an increase in nutrient content was noted in terms of protein, lipid and total sugar in fermented product. Fermented shell waste has been used in both hatchery and grow out diets of *Penaeus indicus* (Amar, et al., 2006)

Nutritive value of fermented sesame seed meal, linseed meal, black gram seed meal and grass pea meal

Anti-nutritional factors such as phytic acid, tannin and crude fiber from raw seed meal viz., sesame seed meal, linseed meal, black gram meal can be reduced by fermentation with lactic acid bacteria. Soaking of raw seed meal in water at 28-30°C for 30 minutes followed by fermentation results in an increase in protein and lipid content and elimination of phytic acid and tannin. Fermented sesame seed meal incorporated at 400g kg-1 in diets of rohu resulted in good growth (Mukhopadhyay, et al., 1999). Inclusion of fermented linseed meal in the rohu diet up to 30-40% was recorded (Mukhopadhyay, et al., 2001). Fermented black gram can also partially or totally replace the fish meal in diet of tilapia. Fermentation of black gram can reduce the level of anti-nutritional factors and it has been included in the diet of carps viz, catla, rohu and mrigal (Ramachandran, et al., 2007). Fermentation of grass pea with *Bacillus* sp. reduces the crude fiber (Ramachandran, et al., 2005).

Fermented barley, wheat gluten as an alternative protein source

Diet palatability and amino acid profile were increased by fermentation of barley and wheat gluten. Fermented grain and wheat gluten act as an alternative protein rich ingredient in diet for *Penaeus vannamei* (Poveda and Emoroles, 2004).

Nutritive value of fermented seaweeds

Seaweeds contain high quantity of protein, minerals such as potassium, phosphorum, calcium and salt. Seaweeds are the cheapest protein sources available but their utilization is limited by the presence of crude fiber, which can be eliminated by fermentation. Single cell detritus prepared by fermentation of seaweeds is used as a hatchery diet (Uchida, et al., 1997). *Lactobacillus brevis* is suitable for fermentation of seaweeds. Lactic acid fermentation can be performed on seaweeds such as *Gracilaria* sp., *Ulva* sp., *Laminaria* sp, *Undaria pinnatifida*, Hypnea sp, *Chondrocanthus*, *Gelidium* sp. to improve their nutritive values and reduce the crude fibre content.

Nutritive value of fermented aquatic weeds

Aquatic plants contain substantial amount of protein and minerals. The presence of anti-nutritional factors restricts their use in animal feeds. Fermentation reduces the tannin, phytate, mimosine level in *Lemna polyrhiza*, *Leucaena leucocephala* (Bairagi, et al., 2004). Inclusion of fermented *Lemna* at 30% in the diet resulted in the best growth performance in Rohu fingerlings. Water hyacinth (*Eichornia crassipes*) is a freshwater macrophyte which forms dense vegetation in ponds. Water hyacinth has low protein and high fiber content which has been used as animal feed. Fermentation may reduce its fiber contents and improve its nutritive value for fish feed. Molasses fermented water hyacinth was efficiently utilized than raw water hyacinth in Nile tilapia (Elsayed, 2003).

Conclusion

Fermentation is an environmentally friendly process consumes less energy and produces less waste. It is a typical example of biodiversity put in to efficient usage that can be applied to a variety of different products. The fermentation process significantly improves nutritive value, acceptability, digestibility and eliminates anti-nutritional factors in plant based ingredients. This provides a promising future for sustainable aquaculture. Fermentation will help feed manufacturers to replace fish meal to certain levels and help in reducing the feed cost and thereby increasing the profitability of aquaculture systems.

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