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IMPORTANCE OF AZOLLA AS A SUSTAINABLE FEED FOR LIVESTOCK AND POULTRY - A REVIEW

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ABSTRACT

India has the largest livestock population in the world. To meet the present and future demands of the growing human population certain new strategies are to be adapted to meet the input requirements for production of livestock and their by products. Though India stands first in the world in terms of milk production and bovine population, average production still needs to be improved; this may be due to low plane of nutrition due to insufficient availability of good quality fodder/feed. This has led to find alternate sources of good quality unconventional feed/fodder for efficient livestock production. The search for alternatives to concentrates/fodder/feed to different species of animals, a wonderful plant called azolla, which holds the promise of providing a sustainable feed for livestock. Since azolla contains most of the nutrients which are required for all classes of livestock including poultry and fish. The azolla can be fed to these animals without any adverse effects. Various studies revealed that feeding of azolla, in dairy cows increases milk production by 15 to 20 per cent. Feeding of azolla in poultry birds improves the weight of broiler chicken and increases the egg production in layers. Hence the azolla can be used as unconventional high potential feed resource for non-ruminants. Above all, for the best performance diets of pullet chicks can be formulated with inclusion of azolla up to 10 per cent. The azolla and salvinia are good sources of minerals and essential amino acids; their usage is limited in pig production due to their low digestible energy. Information obtained from different studies revealed that azolla has high nutrient and it is well accepted by sheep and goats. Azolla can be used as an ideal source of feed for cattle, sheep, goats, pigs, rabbits and fish as an alternate source to a concentrate / feed / fodder to improve the production status of the animals.

Key words: Azolla, Feed, Production, Livestock, Composition.

India has a large livestock population, regarded by some as an asset provided in plenty by nature, and by others as a burden. Since 1971, when 'poverty eradication' became the main theme of development planning, livestock development has been recognised by the Indian Government as an important tool for poverty alleviation while funding support was provided for development and research programmes. However, the focus of the programmes has been on improving production of livestock commodities for income generation, applying the western model and assuming that ideal conditions would be provided.

The demand for milk and meat in India is creating new potential in the profitability of animal husbandry as an occupation. Yet, at the same time, there is a substantial decline in fodder availability. The area under forest and grassland is decreasing as is the amount of various crop residues available for feed, largely due to the introduction of high yielding dwarf varieties. The shortage of fodder is therefore compensated with commercial feed, resulting in increased costs in meat and milk production. Moreover, as commercial feed is mixed

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with urea and other artificial milk boosters, it has a negative effect on the quality of milk and the health of the livestock.

The search for alternatives to concentrates led us to a wonderful plant azolla, which holds the promise of providing a sustainable feed for livestock. Azolla is a floating fern and belongs to the family of Azollaceae (DeFrank, 1995). Azolla hosts symbiotic blue green algae, Anabaena azollae, which is responsible for the fixation and assimilation of atmospheric nitrogen. Azolla, in turn, provides the carbon source and favorable environment for the growth and development of the algae. It is this unique symbiotic relationship that makes azolla, a wonderful plant with high protein content (Kamalasanana Pillai *et al*, 2002). The dairy became main occupation in rural area because of agriculture is receding. Since growing demand for meat and milk, the animal husbandry became profitable income source for rural poor. Cultivation of Dwarf crops and decrease in forest and graze lands resulted sustainable decline in fodder production. Azolla is a floating fern in shallow water. Azolla is very rich in proteins, essential amino acids, vitamins (A, B12, Beta carotene) and growth promoter intermediaries and minerals (calcium, phosphorus, potassium, ferrous, copper, magnesium etc.,) (Pascal Letermea *et al,* 2010). Azolla on dry weight basis is constituted of 25.35 per cent protein content, 10.15 per cent amino acids, bio active substances and bio polymers. Carbohydrate and oil content are very low in Azolla. Azolla can be easily digestible by the livestock, owing to its high protein and low lignin content. Milk yield increases by 15 to 20 per cent. 15 to 20 per cent commercial feed is replaced by azolla. Azolla feeding does not affect the milk production, improves quality of milk and health and longevity of livestock. Feeding Azolla to poultry birds improves the weight of the broiler chicken and increases the egg production of layers. Azolla can be fed to sheep, goat, pig and rabbits as feed substitute (Kamalasanana Pillai *et al*, 2002; Satish and Usturge, 2009 and Kololgi *et al*, 2009).

Amino acid analyses show lysine, methionine and histadine are probably limiting, although the protein content is as high 13% on a dry weight basis. No growth inhibitors or toxins were found in experiments with rats. Used as feed for ducks, pigs and fish. The dairy farmers are dependent on commercial feeds. The commercial feeds are mixed with urea and artificial milk booster. This might have an effect on the quality of milk produced and longevity of the animal. This may in-turn leads to cancer and coronary ailments in human beings. Usage of commercial feed is not economical and declines income. Azolla is the most economic and efficient feed substitute for livestock (Kamalasanana *et al,* 2002; Satish and Usturge, 2009 and Kololgi *et al*, 2009).

METHODS

Figure 1: Azolla plant with roots in the water.

AZOLLA PRODUCITON: The normal appearance of azolla plant is shown in Figure 1. The average of N-fixation of azolla ranges from 0.4 kg to as much as 2.9 kg N/ha/day when grown together with rice plants (Badayos 1989). Uses: nitrogen-fixing green manure, weed suppression, feed for ducks, pigs, chickens and fish, compost, potential for human consumption (Lumpkin and Plucknett, 1980). The total nitrogen and amino acid composition of seven Azolla strains were compared at four different growth phases. Total nitrogen content of the individual strains ranged from 2.6% to 5.7% of dry matter and was not significantly influenced by growth phase or population density. The concentration of the sixteen amino acids determined was maximal during the linear growth stage and specific differences occurred among Azolla strains. All Azolla strains contained a similar proportion of essential (55%) and non-essential (45%) amino acids. Leucine, lysine, arginine and phenylanine+tyrosine were the predominant

essential amino acids whereas the sulfur containing amino acids (methionine and cystine) were present in smaller amounts (Sanginga, and Van Hove, 1989).

Methodology of Azolla production: The cultivation of azolla is shown in Figure 2. The comparison of biomass production potential of azolla and other species is shown in Table 1. A water body is made, preferably under the shade of a tree, with the help of a silpauline sheet. Silpauline is a polythene tarpaulin which is resistant to the ultra violet radiation in sunlight. A pit of the size of 2 m x 2m x 0.2 m is dug as a first step. The pit is covered with plastic gunnies to prevent the roots of the near by trees piercing the silpauline sheet. Spread the silpauline sheet over the plastic gunnies. About 10 – 15 kgs of sieved fertile soil is uniformly spread over the silpauline sheet. Slurry made of 2 kg cow dung and 30 gms of super phosphate in 10 liters of water is poured into the sheet. More water is poured to make water level to reach about 10 cm. About 500 gms - 1 kg of fresh and pure culture of Azolla is inoculated in the pit. Azolla will rapidly grow and fill the pit within 10 – 15 days. About 500 – 600 gms of Azolla can be harvested daily thereafter. A mixture of 20 gms of super phosphate and about 1 kg of cow dung should be added once in 5 days to keep the Azolla in rapid multiplication. Micro nutrient mix containing trace element is added weekly intervals to enhance mineral content of Azolla. In this method the cost of production of Azolla is less than 65 ps/pit. A farmer can harvest up to 750 tonnes of Azolla from one acre. The bed would have to be wet and in the shade." (Anonym 2004)

Figure 2: Cultivation of Azolla.

PRECAUTIONS: A shady place, preferably under a tree with sufficient sunlight should be chosen for the Azolla production unit. A place of direct sunlight should be avoided. All corners of the pit should be of the same level so that the water level can be maintained uniformly. Azolla bio mass @ 399 – 350 gm / sq. mt should be removed daily to avoid over crowding and for keeping the fern at rapid multiplication. Suitable nutrients should be supplied as and when, nutrient deficiency is noticed. Plant protection measures against pests and disease should be taken as and when required. About 5 kg bed soil should be replaced with fresh soil, once in 30 days to avoid nitrogen build up and prevent micro-nutrient deficiency. Twenty five to 30 per cent water also needs to be replaced with fresh water once in 10 days to prevent nitrogen build up in the bed. Replacement of water and soil should be followed by fresh inoculation of Azolla at least once in six months. A fresh bed has to be prepared and inoculated with pure culture of Azolla when contaminated by pest and diseases

Nutrient content and its impact on growth: Azolla is an aquatic pteridophyte that forms a permanent, hereditary symbiosis with a nitrogen-fixing, heterocyst-forming cyanobacterium, Anabaena azollae. The Azolla–A, azollae symbiosis is the only known mutualistic symbiosis between a pteridophyte and a diazotrophic prokaryote. This association has gained attention in recent decades because of its potential use as an alternative to chemical nitrogen fertilisers and as feed for animals (van Hove and Lejeune, 2002). More extensive reviews have appeared elsewhere (Lumpkin and Plucknett 1982; van Hove 1989; Braun-Howland and Nierzwicki-Bauer 1990; Lejeune *et al,* 1999).

The Natural Resources Development Project (NARDEP), Vivekananda Kendra, carried out trials in Tamil Nadu and Kerala using azolla as a feed substitute. The trials on dairy animals showed an overall increase of milk yield of about 15 percent when 1.5 - 2 kg of azolla per day was combined with regular feed. The increase in the quantity of the milk produced was higher than could be expected based on the nutrient content of azolla alone. Hence, it is assumed that it is not only the nutrients, but also other components, like carotinoids, bio-polymers, probiotics etc., that contribute to the overall increase

in the production of milk. Feeding azolla to poultry improves the weight of broiler chickens and increases the egg production of layers. Azolla can also be fed to sheep, goats, pigs and rabbits. In China, cultivation of azolla along with paddy and fish is said to have increased the rice production by 20 percent and fish production by 30 percent (Kamalasanana Pillai *et al*, 2002).

BODY OF THE REVIEW

The chemical composition of azolla such as protein, fiber, minerals, vitamins and amino acid contents is presented in Table 2 and 3.

Azolla in dairy cows: Many researchers (Khutan, *et al,* 1999, Satish and Usturge, 2009 and Tamang and Samanta, 1993) have identified many un-conventional feed and fodder to maintain the milk production particularly in off season. All the time supplementation of good quality protein in milch animal is always challengeable. Supplementation of protein to ruminants always increases the cost of milk production. This is a good source of minerals and vitamins (Table 2) . Azolla contains 25-35 percent protein on dry weight basis. It is rich in essential amino acids, minerals, vitamins and carotenoids. The rare combination of high nutritive value and rapid biomass production make Azolla a potential and effective feed substitute for livestock's (Kamalasanana Pillai *et al,* 2002). Azolla should be harvested with a plastic tray having holes of 1 cm2 mesh size to drain the water. Azolla should be washed to get rid of the cow dung smell. Washing also helps in separating the small plantlets which drain out of the tray. The plantlets along with water in the bucket can be poured back into the original bed. When introducing azolla as feed, the fresh azolla should be mixed with commercial feed in 1:1 ratio to feed livestock. According to Dr Subramaniam, mentioned in the The Hindu (2004), two micro ponds (each measuring 9 x 6 ft) of feed, per cow, per day was sufficient to increase the milk yield by 30 per cent. "The protein content in the milk is also enriched," he added. When asked if Azolla alone would be sufficient to feed the livestock, he said that it could only complement and supplement the normal feed. "Only 10 per cent of the body weight of any animal is given in the form of feed and forage," he said. After a fortnight of feeding on azolla mixed with concentrate, livestock may be fed with azolla without added concentrate (Kamalasanana *et al*, 2002).

Fresh azolla thus collected can be mixed with commercial feed in the ratio 1:1 or given directly to livestock. It was found that the milk production in cattle increased by 10-12 per cent when they were fed with azolla and there was 20-25 per cent savings on buying commercial feeds. Milk composition is a very important determinant of milk value and therefore of total farm revenue. It is a well established statement milk composition is affected by quantity of forage in the ration and diet quality (Baghel, 2007). Kololgi *et al* (2009) conducted experiment in lactating buffaloes and fed @ 2 kg / animal/day by replacing 25% concentrate. It has been found that there was 10% increase in milk yield and 0.5% Fat and SNF in milk by feeding Azolla. There was saving of Rs. 6/ animal/day due to 25% replacement of concentrate by Azolla and additional earning of Rs. 9/animal/day due to increase in quantity and quality of milk. Similarly, Dinesan, 2007 and Biradar, 2007 also reported that "Feeding azolla has improved the milk production and quality of the milk from in dairy animals.

Azolla in sheep and goats: Trivedi, *et al* (2005) reported that both conventional and non-conventional creep mixtures were equally effective for enhancement of pre-weaning lamb. Azolla, could safely be used for economical raising of the lambs to improve growth as a source of non- conventional creep mixtures. A small aquatic fern is distributed throughout the tropical, subtropical and temperate fresh water ecosystems. In the present study sun-dried azolla was evaluated for feeding of Black Bengal goats. Forty Black Bengal male kids (5.43 - 7.15 kg body weight) were randomly distributed to 4 equal groups and fed standard kid grower rations containing sun-dried azolla at 0, 10, 20 and 50 % levels replacing concentrate mixture on equi-weight basis. The concentrate mixture composed of maize, 50 ; groundnut cake, 15 ; rice polish, 16 ; wheat bran, 16 ; mineral mixture, 2 ; salt, 1 ; and vitamin A, B2 and D3, 0.30 part respectively. The kids were offered 150 g concentrate mixture in the morning followed by paragrass ad lib. Growth study was carried out for 90 days and at the end a metabolic trial was conducted. On termination of growth study, carcass characteristics were also studied in the

Table 1: Comparison of biomass and protein content of azolla with different fodder species (tones/hactare) (Kamalasanana Pillai *et al,* 2002).

Fodder	Annual production of biomass	Dry matter content	Protein content
Hybrid Napier	250	50	4
Lucerne	80	16	3.2
Cowpea	35	7	1.4
Sorghum	40	3.2	0.6
Azolla	730	56	20

different groups of animals. The chemical composition of sun-dried azolla on dry matter basis showed that it contains dry matter, 90.1 % ; organic matter, 79.7 % ; crude protein, 15.4 % ; crude fibre, 14.1 % ; ether extract, 2.7 % ; nitrogen free extract, 47.4 % ; total ash, 20.4 % ; hemicellulose, 15.6 % ; cellulose, 6.8 % ; lignin, 17.5 % ; silica, 16.0 % ; calcium, 1.54 ; phosphorus, 0.35. Kids fed with 50 % azolla showed profuse diarrhoea and became sick. This group was discarded. The dry matter consumption, feed efficiency and body weight gain in different groups were comparable, indicating that azolla was palatable. Significantly ($P<0.05$) lower NFE and cellulose digestibilities were observed in 20 % replacement. Nitrogen, calcium and phosphorus balances were positive in all groups. Carcass characteristics of different groups of animals were also comparable. The DCP and TDN values of sun-dried azolla were 8.7 and 51.8 % respectively. These findings indicated that dried azolla can be incorporated up to 20 % of the concentrate mixture of kids without any adverse effect (Samanta and Tamang, 1995).

Aquatic plants are a potential as forage in countries with rivers, streams, brooks, oasis, swamps and dams. The crude protein of the aquatic fern decreases in matured plant. Such lowered crude protein at advanced age had also been noticed in other aquatic plants (Bagnall *et al*, 1973). The chemical composition, forage acceptability and N-balance of aquatic fern (AF) and duckweed (DW) were studied using West African dwarf goats. Effect of rainy and dry seasons in AF was not noticed for DM, CP, EE, CF, ash and gross energy. Crude protein content however, was highest in leaf (12.76%) but least (4.35%) in the stem and this was contrary for CF content. Young AF was richer in CP (10.45%) but lower in DM (20.35%), EE (1.37%), CF (26.96%) and ash (6.96%) than the matured AF. The results showed that aquatic fern and duckweed are potential sources of nutrients in West African dwarf goats (Babayemi, *et al*, 2006, Devendra, 1985). Information obtained from this study suggests that aquatic fern and duckweed are high in nutrient and are well acceptable by goats. African Feed Resources Network (AFRNETA) on Sustainable Feed Production and Utilization for Smallholder Livestock Enterprises in Sub-saharan Africa (Babayemi, *et al*, 2006 and Becerra Maricel, 1991).

Azolla in poultry: For poultry, azolla can be fed to layers as well as broilers (Gerpacio and Pascual, 1981). Poultry industry as one of the most profitable business of agriculture provides nutritious meats and eggs for human consumption within the shortest possible time. However, availability of quality feed at a reasonable cost is a key to successful poultry operation (Basak *et al,* 2002). FAO program focuses on increasing the feed base production systems to locally available feed resources in developing countries (Sansoucy, 1993). In addition, for livestock production systems to be sustainable it should be based on the resources available in the country and likewise there should be a balance between crop and livestock, so that these activities are complementary and if possible synergistic (Preston and Murgueitio, 1987). Aquatic plant species, because of their growth habit, appear not to accumulate secondary plant compounds and therefore offer a greater potential than tree leaves as a source of protein for mono-gastric animals (Bacerra *et al*, 1995). Of these species, the water fern Azolla, which grows in association with the blue-green algae Anabaena azollae, a nitrogen fixing organism, is perhaps the most promising from the point of view of ease of cultivation, productivity and nutritive value(Lumpkin and Plucknette, 1982). The use of Azolla as a feed resource for fish, swine and poultry had been tested with favourable results (Castillo *et al*, 1983; Alcantara

Table: 2 Chemical composition of azolla meal (AZM) (Alade and Lyayi, 2006)

Sl No.	Nutrient	% DM
1	Crude protein	21.4
2	Crude fibre	12.7
3	Ether extract	2.7
4	Ash	16.2
5	NFE	47.0
Cell wall fraction		
1	Neutral detergent fibre	36.88
2	Acid detergent fibre	47.08
3	Hemicellulose	10.20
4	Cellulose	12.76
5	Lignin	28.24
Minerals		
1	Calcium	1.16
2	Total phosphorus	1.29
3	Potassium	1.25
4	Magnessium	0.35
Trace minerals ppmDM		
1	Manganese	174.42
2	Zinc	87.59
3	Copper	16.74
4	Iron	755.73
5	Sodium	23.79

and Querubin, 1985). Besides, the inclusion of aquatic plants at low levels in poultry diets have shown better performance.

Chicks fed diet containing 15% AZM had the lowest growth rate, however, the value was not significantly different from others. The poorer growth rate A.O.A.C., 1990. Official method of analysis, Association of birds on 15% AZM diets could be attributed to the lower feed intake and consequently a reduced metabolizable energy intake. It has been reported that birds on high-energy diets consume more metabolizable energy thus resulting in a significant increase in body weight gain (Brue and Latshaw, 1985). Previous reports by Basak *et al* (2002), Tamany *et al* (1992) and Bukingham *et al* (1978) have implicated high levels of ADF and lignin as the main factor limiting the efficient utilization of AZM by monogastric animals. The trend of the growth rate did corroborate previous observations. Basak *et al* (2002) and Querubin *et al*. (1986) recorded the highest weight gain in birds on diet containing 5% AZM while Cambel (1984) found better result using 10 and 15% AZM. Variations observed in 29-24. weight gain at different levels of AZM could be attributed to differences in the strain and nutrient composition of Azolla used; and the type and physiological state of the experimental animal used. Feed intake was significantly affected on the 10 and 15% AZM dietary treatments. This observation parallel previous report by Bhuyan *et al* (1998), Castillo *et al* (1983) and Basak *et al* (2002) that inclusion of AZM in broiler diet did not affect feed consumption. However, Bacerra *et al* (1995) explained the decrease in dry matter intake as the inability of the birds to eat more of the bulky AZM-based diets. Lower feed conversion ratio (FCR) of the AZM-based diets compared with the control suggests a benefit from the AZM supplementation. Bacerra *et al* (1995) in studies with growing ducks observed that growth rate was linearly related to protein intake. The correlation was found to be stronger with total protein (Azolla + soybean protein) compared with soybean protein (Maricel Becerra *et al,* 1995). No mortality was recorded in all the treatments. Thus indicating that AZM had no deleterious effect on pullet chicks.

Azolla in pigs: Twenty desi pigs were randomly distributed into four groups of five pigs each and fed with iso-nitrogenous concentrate mixture replaced with sun-dried Azolla at 0, 10, 20 and 30% levels. Body weight gain and feed intake were recorded fortnightly during the 90-day growth trial period to determine the growth rate and feed efficiency. The average body weight gain ranged from 11.20 to 13.10 kg. The weight gain of pigs fed with 10% Azolla was 10% more but the differences among the groups were non-significant. The highest level of dietary Azolla decreased feed efficiency significantly. It is concluded that Azolla can be incorporated up to 30% in the ration of desi pigs without any considerable adverse effect on growth (Parthasarathy, 2006).

Aquatic plant species, because of their growth habit, appear not to accumulate secondary plant compounds and therefore offer perhaps a greater potential than trees as a source of protein for mono-gastric animals. Of these species the water fern Azolla filiculoides, which grows in association with the blue-green alga Anabaena azollae, is perhaps the most promising from the point of view of ease of cultivation, productivity and nutritive value (Lumpkin and Plucknett 1982; Lumpkin *et al,* 1980; Van Hove and López 1983). There were significant differences ($P = 0.01$) among groups of pigs receiving the experimental treatments during the growth phase.

Table 3: Amino acid composition of azolla meal (Alalade and Lyayi, 2006, Froidmont-gortz, 1998).

Sl. No.	Amino acids	% DM	g /100g protein	Chemical score (%)
1	Lysine	0.98	4.58	130.9
2	Methionine	0.34	1.59	45.4
3	Cystine	0.18	0.84	24
4	Threonine	0.87	4.07	116.3
5	Tryptophan	0.39	1.82	52
6	Arginine	1.15	5.37	153.4
7	Isoleucine	0.93	4.35	124.3
8	Leucine	1.65	7.71	220.3
9	Phenylalanine	1.01	4.72	134.9
10	Tyrosine	0.68	3.18	90.9
11	Glycine	1.00	4.60	131.4
12	Serine	0.90	4.21	120.3
13	Valine	1.18	5.51	157.4

Performance decreased as the amount of Azolla in the diet increased. These effects were reversed in the fininishing phase when there was a strong tendency (P = 0.2) for the pigs fed azolla to grow faster than on the control treatment. The final result was that there were no differences in growth rate (P = 0.80) among treatment groups for the total period of the trial. The information obtained has served to stimulate interest in the growing and use of Azolla as a protein supplement (Maricel Becerra,*et al,* 1990). A possible imbalance of amino acids due to inclusion of Azolla would not appear to be the problem, since Azolla protein appears to have a better amino acid profile than soybean mean such that the combination of the two more closely resembles the balance required by the growing pig according to the recent studies of Wang and Fuller (1989). The water fern Azolla (Azolla spp) has been used successfully as a partial replacement for soybean in pig fattening diets based on sugar cane juice (Alvaro Ocampo Durán, 1994).

A digestibility study in 60 kg pigs was carried out with diets containing maize, soybean meal, minerals and 0, 125 or 250 g AF/kg diet. The weight and length of the digestive organs was also measured. According to Pascal Leterme *et al,* (2010) the presence of AF decreased the faecal digestibility of crude protein, NDF and gross energy of the diet (P<0.001). AF intake did not affect the gastrointestinal tract, with the exception of an increase in the length and weight of the colon of pigs fed 250 g AF/kg diet (P<0.01). Aquatic plant species, because of their growth habit, appear not to accumulate secondary plant compounds and therefore offer perhaps a greater potential than trees as a source of protein for mono-gastric animals. Of these species the water fern Azolla filiculoides, which grows in association with the blue-green alga Anabaena azollae, is perhaps the most promising from the point of view of ease of cultivation, productivity and nutritive value (Lumpkin and Plucknett 1982; Van Hove and López 1983).

Azolla in rabbits: Nutrition is by far the most important environmental influence on animal growth and development before and after birth (Widdowson and Lister, 1991). Sreemannaryana *et al,* (1993)) stressed that young and rapidly growing non-ruminant animals are the most important experimental animals because they are sensitive to small differences in diets and dietary components that are relatively easy to measure as growth and intake responses.

Rabbit needs ration with high fiber content. The fiber content of Azolla microphylla is relatively high (Dwi Retno *et al*, 2008). Therefore, beside as protein source, Azolla microphylla could also be used as fiber source at the same time in rabbit's ration. As herbivorous animal, rabbit is capable in utilizing nutrient in the ration through cecotrophy (Rahardjo *et al,* 1990, Rahardjo 2005). Several researches havebeen done especially on the utilization of Azolla microphylla as protein source in rabbit ration. It was used by mixing it with other fiber source feedstuffs like tofu, and rice bran. Fresh production and protein content of Azolla microphylla was high, therefore it could be used as non-conventional protein source in rabbit ration. Utilization of Azolla microphylla in

rabbit ration was better when mix with high fiber feedstuffs. Ration with azolla as the main feedstuff was palatable and did not affect diarrhea in young rabbit or kits. However, it caused abortion when fed to pregnant rabbit (Lejune *et al,* 1999). The ration with azolla as the main feedstuff was palatable, no feed left so that the cages were dry and good for rabbit's health (Dwi Retno *et al*, 2008).

According to Dwi Retno *et al* (2008), azolla could be used to replace green bean in local rabbit's ration as high as 2.5, 5.0, 7.5, and 10% showed no differences in daily weight gain 11.64, 9.29, 8.71, and 6.85 g/head/day and carcass percentage 49.69, 52.28, 54.07, and 50.69%. Lestari et al (1997) mentioned that utilization of Azolla microphylla as natural lysine source in the form of protein concentrated leaf meal (PCLM) in rabbit ration. The slaughter weight was higher in rabbit fed with PCLM as compare to those fed without PCLM (1330 g vs 1103 g). Body weight and carcass percentage in rabbit fed with PCLM compare to those without PCLM in their ration such as 594 g (48.3%) compared to 491g (44.9%), respectively. With such high protein levels and high in trace minerals, Azolla microphyla may be considered a rich nutrition source of feed for livestock. The azolla was high also in fiber content. Furthermore, lignin and silica were quite high, which are indigestible to both ruminant and non-ruminant animals (Querubin *et al.* 1989). However, it is not recommended as pure feed since it lacks three essential amino acids (lysine, methionine and histidine). It can be mixed with rice bran, corn bran, or other feedstuff as ration. Most rations with 20-25% azolla have given succesful results (Quebral 1989).

Azolla in fish: An aquatic fern, Azolla microphylla (strain 175 MI, Catholic University of Louvain, Belgium), a natural source of protein, was used in this study to produce low-cost feeds for the omnivorous–phytoplanktonophagous tilapia, Oreochromis niloticus L. Fish were grown in a recirculating system and fed with six different diets in triplicate groups. Diets were formulated with approximately similar total protein, ranging from 27.25 to 27.52% dry weight (dw), gross energy content ranging from 85.1 to 96.5 MJ kg"1 dw, and with different levels of dry meal Azolla (0, 15, 20 30 40, 45% diet dw). All diet levels with incorporated Azolla meal exhibited weight gain, thus it can be assumed that Azolla in good combination with local products can be used to promote fish culture development. The Azolla-free diet and the diet containing 15% Azolla produced the same growth performance (Fiogbé *et al.* 2004). However, the least expensive diet containing 45% Azolla also exhibited growth and can be used as a complementary diet for tilapia raised in fertilized ponds.

CONCLUSION

Azolla can be used as an ideal feed for cattle, fish, pigs and poultry, and also is of value as a bio-fertilizer for wetland paddy. It is popular and cultivated widely in other countries like China, Vietnam, and the Philippines, but has yet to be taken up in India, in a big way. Dairy farmers in South Kerala, Kanyakumari and Northern parts of Karnataka have started to take up the low cost production technology and we hope that the azolla technology will be taken up more widely by dairy farmers, in particular those who have too little land for fodder production. Based on the results of the study, it could be concluded that AZM as an unconventional feed resource has a potential for use in diets for non-ruminant animals. Above all, for the best performance, diets of pullet chicks can be formulated with the inclusion of AZM up to 10 per cent. Azolla and Salvinia are good sources of minerals and essential amino acids but their interest is limited in pig production by their low digestible energy and protein content.

Since azolla contains more of cell wall fractions, animals can be supplemented with cellulolytic enzymes preparations to get the better performance and productivity of animals. Up to 15 to 20 per cent of azolla can be included in the diet of dairy cows as replacement to concentrate. However, further studies need to carried out to assess the utilization of azolla

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