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REVIEW ARTICLE

A Review on Potential Livestock Feed: *Azolla*

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Abstract

Azolla is a floating fern also known as duck weed is belongs to the family *Salviniaceae*. *Azolla* is a good source of protein and contains almost all essential amino acids and minerals such as iron, calcium, magnesium, potassium, phosphorus, manganese etc. apart from appreciable quantities of β-carotene (vitamin A precursor) and vitamin B12. *Azolla* is considered to be the most promising because of the ease of cultivation, high productivity and good nutritive value. For that, cultural practices, seasonal availability and manure requirements need to be established for more production. Thus, *Azolla* appears to be a potential source of nutrients and has a considerably high feeding value to the animals. Moreover, this is a strong case for more systematic research on long duration feeding trials with *Azolla*. A review of some nutritional experiments with *Azolla* as a cattle feed is described.

Keywords: *Azolla*, Chemical composition, Livestock feeds, Nutrition.

1. Introduction

Azolla is a small floating fern also known as duck weed is genus of seven species of aquatic ferns belongs to the family *Salviniaceae*. *Azolla* grows in waterways in dense patches, which can look like a green or red carpet. Generally it grows in stagnated water, streams, canals, ponds etc. where water is present for longer period under sunlight or shade of tree is widely distributed throughout the India (Masoodi and Khan, 2012). Roots of *Azolla* plants remain suspended in water. Shape of *Azolla* is triangular with 1.5-3 cm length and 1-3 cm breadth. *Azolla* grows with blue green algae *Anabaena azollae*. Symbiotic relationship exists between *Azolla* and algae (Becking, 1979; Reynaud and Franche, 1987; Aber *et al*., 2016). Some strains of *Azolla* can fix as much as 2-3 kg of nitrogen/ha/day. *Azolla* provides carbon and favorable environment for growth of blue green algae which fixes and assimilates the atmospheric nitrogen and decomposes it by enzymatic activity and further converted into soluble ammonia (Van Hove, 1989). The use of *Azolla* also increases organic matter and potassium contents of the soil (Bhuvaneshwari and Singh, 2015). This symbiotic relationship makes *Azolla* rich in protein content. *Azolla* is promising plant having good nutritive contents and easy to cultivate (Lumpkin, 1984; Kathirvelan *et al*., 2015) and above all cost of production is very low. In vermi-composting *Azolla* can also be used for feeding to the earthworms. Due to easy cultivation and high biomass yield, *Azolla* can be an ideal feed substitute for cattle, buffalo, sheep, goat, pigs, poultry and fish (Becerra *et al*., 1995; Hossiny *et al.*, 2008; Indira *et al.*, 2009; Leterme *et al*., 2010). Apart from animal feed, *Azolla* is also used as a bio-fertilizer for paddy cultivation, in poultry and fish feed, as a mosquito repellent and bio-scavenger as it takes away all heavy metals (Moore, 1969; Cassani, 1981; Lumpkin, 1984; Van Hove, 1989; Pabby *et al.*, 2004; Bhuvaneshwari and Singh, 2012; Bhuvaneshwari, 2012). In fact, it is being used in some Asian countries like China, Thailand, Korea, Vietnam and the Philippines, as a bio-fertilizer (Prasanna *et al.*, 2008). However, in India its cultivation is limited to the southern part of country, but recently gaining adoption in other parts of the country. *Azolla* enhances the growth of rice as it releases the plant growth regulators and vitamins (Bhuvaneshwari and Kumar, 2013). Being bio-fertilizer it can substitute for chemical fertilizers to certain extent and increases the nutrient utilization efficiency which increases the crop yield as well as quality of produce (Pabby *et al.*, 2004; Bhuvaneshwari and Singh, 2012). *Azolla* helps to reduce the evaporation rate from rice field.

Azolla contains around 23-27 % crude protein and 10 % carbohydrates on a dry weight basis (Pullin and Almazan 1983; Cherryl *et al.*, 2014; Kathirvelan *et al.*, 2015). Apart from this Pillai *et al*. (2002) reported that *Azolla* contain probiotics and biopolymers.

Literature suggests that *Azolla* has the potential to be a source of nutrients due to its considerably high feeding value.

2. Taxonomy

Class	Pteridophyta
Order	Salvinales
Family	*Azolla*ceae/*Salviniaceae*
Genus	*Azolla*
Sub Genus	Eu-*Azolla*

3. Cultivation of *Azolla*

a) Small ponds of 320 meter size should be made in low land field.
b) Add sufficient water and 10-15 cm standing water should be there in the ponds.
c) Culture of green *Azolla* 50-200 g/sqm along with single super phosphate (20 kg/ha) as a phosphorus source should be mixed and release into the pond containing water level of 15 cm.
d) Rapid multiplication of *Azolla* plants forms a green color mat just like carpet in the ponds within 14-21 days.
e) This green mat then can be harvested and released in the rice field or can be used after through washing and drying as an animal feed.
f) This *Azolla* can be used as a bio-fertilizer by converting it into compost.
g) During hot season (summer) *Azolla* can be harvested at regular interval of 21 days.
h) However, during winter season growth rate of *Azolla* plant slow down due to moisture stress and low temperature. Therefore, *Azolla* should be harvested after 30 days of interval during this season.

4. Environmental Conditions that Required for Higher Yield of *Azolla*

Some favorable conditions should be there for proper growth of *Azolla* that should be otherwise made available so that prolific growth can be achieved. Water should always be there in pond for multiplication of the *Azolla* branches. Maintenance of pure culture free from contamination is essential for higher yield. *Azolla* should be harvested regularly to avoid overcrowding in pond. Temperature is an important factor for good growth. Mean temperature of 25-35ºC is most favorable for maximum growth. This optimum environmental temperature should be maintained within this range by using green nets. The *Azolla* pond should be covered with a plastic sheet in cold seasons so as to reduce the impact of cold weather. Places with direct and adequate sunlight should be preferred. A shady place should be preferred where sunlight is extreme. *Azolla* plants require sunlight but prefer to grow slightly in acidic pH of soil at 5.3-5.8 in shade. *Azolla* require phosphorus for their regular growth and propagation in acidic soil. Apart from phosphorus suitable nutrients such as cow dung slurry, micronutrients should be supplemented at frequent intervals.

5. Benefits of *Azolla*

There are numerous benefits of *Azolla* which are useful to the aquatic environment in many ways. Some of the benefits are as:

a) Low input cost.
b) This is easy to grow in wild and also can grow under controlled condition at farm.
c) Within short period of time it can easily be produced a large quantity as green manure required in both *Kharif* as well as *Rabi* season.
d) It can fix atmospheric nitrogen and CO_2 to form carbohydrates and ammonia, respectively, and after decomposition it adds available nitrogen for crop uptake and organic carbon content to the soil.
e) The oxygen released due to oxygenic photosynthesis, helps the respiration of root system of the crops as well as other soil microorganisms.
f) It makes Zn, Fe and Mn to soluble form and incorporates to the crops such as paddy.
g) *Azolla* suppresses tender weeds such as *Chara* (water fern) and *Nitella* (stonewort) in a paddy field.
h) *Azolla* releases plant growth regulators and vitamins which enhance the growth of the rice plant.
i) A potential bio-fertilizer *Azolla* can be substituted for chemical nitrogenous fertilizers to a certain extent (20 kg/ha) and it increases the crop yield and quality and thus reduced cost of production.
j) It increases the utilization efficiency of chemical fertilizers, if any used.
k) It reduces evaporation rate from the irrigated rice field.
l) It is a food source for waterfowl, fish, shrimp, insects, worms, snails, crustaceans etc. and provides habitat to them.
m) Mats of *Azolla* can actually discourage blue-green algal blooms. They restrict the penetration of sunlight into the water, which is essential for algal growth and take up nutrients from the water, limiting the availability of this food source for the algae.

n) The mats of *Azolla* acts as a biological mosquito control, preventing mosquito larvae surfacing for air.
o) The presence of *Azolla* can also restrict the growth of exotic aquatic plants, including *Salvinia* and water hyacinth by limiting the availability of nutrients to these plants.

6. *Azolla* Have Detrimental Effects?

Actually the presence of *Azolla* in water way is beneficial. However, in certain circumstances where water bodies are rich in nutrients, prolific growth of *Azolla* may be a problem. It may be possible that thick, complete coverings of water surface by *Azolla* can cause de-oxygenation of the water. This can affect presence of fish and other aquatic plants and the decay of the latter can lead to a strong odour. However, situations like this are rare because coverage of the water surface by the *Azolla* needs to be almost total for it to have a negative impact on the ecosystem which seldom happens.

7. *Azolla* and Soil Health

a) Basal application on green *Azolla* manure @ 10-12 t/ha increases soil nitrogen by 50-60 kg/ha and reduces 30-35 kg of nitrogenous fertilizer requirement of rice crop thus reduces cost of cultivation.
b) Release of green *Azolla* twice as dual cropping in rice crop @ 500 kg/ha enriches soil nitrogen by 50 kg/ha and reduces N requirement by 20-30 kg/ha.
c) Increases rice yield by 20 to 30 %.
d) Rice varieties like DR-92, RCPL-1-87-8, Mendri, H.-2850 and Manipuri produced more than 30 q/ha rice yield when grown with *Azolla* as dual cropping under natural soil fertility.
e) Under low land condition a thick *Azolla* mat does not allow the weeds to grow in rice field thus, *Azolla* suppresses the weed growth and creates congenial condition for increased rice production.
f) *Azolla* reduces evaporation from water surface and increases water use efficiency in rice.
g) Dry *Azolla* flakes can be used as poultry feed and green *Azolla* is also a good feed for fish and ruminants.

8. Chemical Composition

Azolla is high producing aquatic plant containing 20-37 % protein (Fujiwara *et al.*, 1947; Singh, 1980; Subudhi and Singh, 1977; Singh and Subudhi, 78; Sreemannaryana *et al.*, 1993; Van Hove, 1989; Kumar *et al.*, 2012; Kathirvelan *et al.*, 2015). However, the digestible protein of the *Azolla* is 56.6 % (Tamany *et al.*, 1992; Kumar *et al.*, 2012) which limits the inclusion of higher level of *Azolla* in poultry diets. The chemical score index showed the potential of *Azolla* meal as a good source of protein. *Azolla* contains 0.47-0.53 % leucine and lysine, 0.11-0.17 % methionine, 0.53-0.55 % threonine, 0.14-0.15 % tryptophan. Apart from this arginine and valine are the predominant essential amino acids while tryptophan and the sulphur-containing amino acids were deficient (Alalade and Iyayi, 2006; Leterme *et al.*, 2009). *Azolla* contains 0.8-6.7 % crude fat (Fujiwara *et al.*, 1947; Subudhi and Singh, 1977; Buckingham *et al.*, 1978; Querubin *et al.*, 1986a, b; Sreemannaryana *et al.*, 1993; Ali and Lesson, 1995), out of which 13-27 % are reported to have polyunsaturated fatty acids (PUFA), omega 3 and omega 6 fatty acids which are classed as an essential fatty acids. Crude fibre in *Azolla* is 14-16 % (Querubin *et al.*, 1986b; *Basack et al.*, 2002; Cherryl *et al.*, 2014) and 46-62 % NDF. Nitrogen free extract in *Azolla* is reported to be 31 % (Bhuyan *et al.*, 1998; Ali and Leeson, 1995; Querubin *et al.*, 1986a, b; Basak *et al.*, 2002). Ash content is 15-16 % (Buckingham *et al.*, 1978; Basak *et al.*, 2002). Lower acid detergent fibre (ADF) and neutral detergent fibre (NDF) in *Azolla* indicate a better efficiency of utilization by non-ruminant animals. The concentrations of calcium, phosphorus, potassium and magnesium were 1.16, 1.29, 1.25 and 0.25 %, respectively, while those of sodium, manganese, iron, copper and zinc were 23.79, 174.42, 755.73, 16.74 and 87.59 ppm, respectively. *Azolla* also contains 3.4-3.5 % sugar, 6.5 % starch, 0.34-0.55 % chlorophyll and iron content is 0.26 % on dry matter basis. Apart from a good source of plant proteins, fresh *Azolla* is good a source of pro-vitamin A, β-carotenes (Lejeune *et al.*, 2000; Kathirvelan *et al.*, 2015). *Azolla* can be ranked among carotene rich plants as it is rich in carotene content which ranged from 300-600 ppm. A gross energy value of 2039 kcal/kg is present in *Azolla*. Nutrients composition present in different *Azolla* species (on dry mater basis) are given in table 1. Comparison in terms of dry matter (%), metabolisable energy (MJ), crude protein (%) and neutral detergent fibre is presented in table 2.

A major advantage of water plants is that they are higher in protein than most of the high yielding tropical forages (Gaffer, 1981). Once cultivated, *Azolla* is double in its weight within 8-10 days and can produce 300-350 tonne of protein in one acre of pond in a year (Table 3).

Due to its nutritional composition it can be an excellent substitute for costly protein ingredients for livestock feeding. Faster rate of fermentation and high-

Table 1: Nutrients composition of different *Azolla* species (Kathirvelan *et al.*, 2015)

Nutritional Content	*A. caroliniana*	*A. microphylla*	*A. pinnata*
Crude protein (%)	23.07	23.69	17.59
Crude fiber (%)	13.19	15.02	16.54
Total Ash (%)	29.17	28.71	25.28
Calcium (%)	2.07	2.07	1.67
Phosphors (%)	0.59	0.77	0.46
Iron (%)	0.269	0.249	0.231
Manganese (%)	0.238	0.274	0.205
Sodium (%)	1.240	0.488	0.777
Potassium (%)	2.44	4.93	2.19
Copper (ppm)	16.37	17.55	15.90
Zinc (ppm)	64.51	71.75	46.77
Magnesium (ppm)	0.15	0.173	0.155
Moisture (%)	5	5	5

Table 2: Comparison of different feeds with *Azolla*

Sr. No.	Feed	Dry matter (%)	Metabolisable energy (MJ)	Crude protein (%)	Neutral detergent fibre (%)
1	Canola meal	90	12.0	38	20
2	Wheat grain	90	12.7	12	12
3	Lucerne hay	88	10.0	23	44
4	Summer pasture	20	10.0	23	44
5	Quality pasture	15	11.0	22	39
6	*Azolla*	5.7	9.0	18.4	46

Table 3: Relative biomass production and protein content of different fodders

Sr. No.	Name of fodder	Annual Production of biomass (MT/ha)	Dry matter content (MT/ha)	Protein content (%)
1	Hybrid Napier (CO-3)	250	50	4
2	Kolakattao grass	40	8	0.8
3	Lucerne (*Medicago sativa*)	80	16	3.2
4	Cowpea (*Vigna sinensis*)	35	7	1.4
5	Subabul (*Leucaena leucocephala*)	80	16	3.2
6	Sorghum (*Sorghum vulgare*)	40	3.2	0.6
7	*Azolla*	1000	80	24

er *in vitro* digestibility of *Azolla* is reported as compared to alkali treated straw (Juul-Nielsen, 1981). Higher digestibility is attributed to the digestible cellulose present in *Azolla* which is important starting substrate of cellulose degrading bacteria. Moreover, mixing *Azolla* with some agricultural by-products such as rice bran (Aban, 1989) and the use of fermentable by-products such as yeasts or the addition of purified enzymes can improve ingestion and digestibility. *Azolla* alone may not be accepted by animals, but when combined with other ingredients such as ground nut cake, soybean meal, rice straw etc. animals may be adopted after some time. A short review of some water plants in animal feeding (Dolberg *et al.*, 1981) also - suggests the utility of these plants for livestock feeding. Water plants are very useful in combinations with poor quality feeds. Combinations improve the nutritional value. However, the feeding trials are of short period and the results need to be confirmed with feeding trials over longer periods of time. For all the water plants, standard culture practices, seasonal availability and manure requirements need to be established.

9. *Azolla* and Ruminants

In southern India, farmers' having insufficient lands for fodder production thus they have started cultivating *Azolla* as cost of production is low with better output. Dairy farmers in South Kerala and

Kanyakumari, have also started adopting this low-cost production technology and it is believed that this technology will be taken-up more widely by dairy farmers, in particular those with insufficient land for fodder production (Pillai *et al.,* 2005). *Azolla* increases the milk yield in cattle and feed conversion ratio. Reduced intake, increased digestibility and more body weight gain was reported in crossbred heifers (Singh, 1980). Use of *Azolla* as a feed substitute nearly saved 20-25 % of cost feeding for concentrate mixtures.

10. *Azolla* and Non-Ruminants

Azolla as a feed resource for fish, swine and poultry had been tested with encouraging results (Castillo *et al.,* 1981; Alcantara and Querubin, 1985; Ara *et al.,* 2015). Inclusion of water plants at low levels in poultry diets have shown better performance when they supply part of the total protein or when included as a source of pigment for egg yolk and broiler skin (Maurice *et al.,* 1984). *Azolla* is a potential feed ingredient for chickens (Singh and Subudhi, 1978; Lumpkin, 1984). Studies in India as early as in 1978 concluded that fresh *Azolla* could replace 20 % of commercial feed in diets of growing chickens (Singh and Subudhi, 1978). Water plants do not accumulate any plant secondary compounds due to their growth pattern and habit. Therefore, water plants such as *Azolla* have greater prospects as a protein substitute for non-ruminants as compared to the tree leaves which contents one or more anti-nutritional factors. *Azolla* tested clear for organophosphates and organochlorides. *Azolla* plant also tested clear of mycotoxin activity in a fresh as well as in one week old sample. So *Azolla* can be efficiently used as a feed for non-ruminants. *Azolla* is a good source of minerals and essential amino acids for pigs but reported to be low in digestible energy for growing pigs (Leterme *et al.,* 2009). However it can be used as partial replacement of protein source for growing-fattening pigs (Becerra *et al.,* 1995). Recently Ara *et al.* (2015) indicated that *Azolla* at 5 % inclusion level in broiler chicken ration is highly economical.

Reasonable cost and availability of quality feed is a key to successful poultry farming. Chickens and ducks can be raised successfully on diet containing *Azolla*. In USA, *Azolla* has been used as a wildfowl feed from long time. In China it is used as a duck feed. In Vietnam it is reported to be used as feed for domestic fowl (Kha and Thuyet, 1970). No mortality in birds is reported during experimentation on broilers fed *Azolla* meal (Basak *et al.,* 2002). Reports indicate that *Azolla* does not have any deleterious effect on broilers (Castillo *et al.,* 1981; Basak *et al.,* 2002). Low digestibility of *Azolla* may make unfit as the sole source of feed for poultry birds (Buckingham *et al.,* 1978; Khatun, 1996) but it can be used in combination of other feed ingredients such as rice bran, wheat bran, maize etc. It is reported to have a potential as a feedstuff for egg type chicks and no mortality was observed in layers fed on *Azolla pinnata* (Alalade and Iyayi, 2006). Carcass characteristics of broiler chicken fed *Azolla* based diets showed non-significant difference in the percentage of cut-up parts of birds (Dhumal *et al.,* 2009; Ara *et al.,* 2015). Cambel (1984) reported the better results at 10 and 15 % of replacement by *Azolla* on growth performance of the broilers. Addition of *Azolla* does not affect feed consumption in broiler ration (Castillo *et al.,* 1981; Querubin *et al.,* 1986a; Sreemannryana *et al.,* 1993; Bhuyan *et al.,* 1998; Alalade and Iyayi, 2006).

In layers egg production is increased while in broilers body weight is improved fed on *Azolla* supplemented diets. *Azolla* meal reported to have no deleterious effect on palatability in broilers (Paulraj and Kutty, 1984; Basak *et al.,* 2002; Sithara and Kamalaveni, 2008). Improved performance of broilers was reported when *Azolla* meal was added at the rate of 5 % dry matter which is established as a safe. Nutrient digestibility of crude protein, crude fibre and crude fat were not influenced by the level of *Azolla* in broiler ration and broilers are reported to digest the crude fibre readily (Alcantara and Querubin, 1985).

Azolla can replace 20 % of CP of soybeans in diets of ducks without any adverse effect on growth and health. Feed conversion ratio was also better and net profit was reported to be highest in *Azolla* fed ducks (Becerra *et al.,* 1995). Becerra *et al.* (1995) further concluded that fresh *Azolla* can partially replace whole soybeans up to a level of about 20 % of the total crude protein in diets of fattening ducks based on sugar cane juice, without any problems and no adverse effects on growth rate or health. Cost of feed per kg gain was lowest and net profit per bird highest for this treatment. However, at levels of replacement above this, rate of gain and feed conversion efficiency were significantly poorer.

All strains of *Azolla* reported to have a well balanced of essential amino acids and high quality protein cultivated under good conditions (Table 1). These are good for the duck farming. No obvious health problems or deficiency symptoms were observed in ducks indicating that the *Azolla* was supplying essential nutrients (Becerra *et al.,* 1995). This suggests that *Azolla* supply vitamins as well as minerals to the ducks and chickens which are of added advantage as in rural areas as mineral mixtures are rarely used or is expensive to be used in diet. Fresh *Azolla* at the rate of 0, 20, 30 and 40 % replacement of traditional paddy rice-snail-shrimp does not compromise the production

efficiency in egg and meat producing ducks (Escobin, 1987). Previous reports by Beckingham *et al.* (1978), Tamany *et al.* (1992) and Basak *et al.* (2002) have implicated high levels of ADF and lignin as the main factor limiting the efficient utilization of *Azolla* meal by non-ruminant animals. The trend of the growth rate did corroborate previous observations. Querubin *et al*. (1986) and Basak *et al*. (2002) recorded the highest weight gain in birds on diet containing 5 % *Azolla* meal while Cambel (1984) found better result using 10 and 15 % *Azolla* meal. Variations observed in weight gain at different levels of *Azolla* meal could be attributed to differences in the strain and nutrient composition of *Azolla* used and the type and physiological state of the experimental animals used. However, feed intake was significantly affected on the 10 and 15 % *Azolla* meal.

Fish require diets relatively higher in protein than those of commercially cultured animals. As protein represents the most expensive component in a formulated diet, it is considerable of practical importance to determine the optimum level that will support maximum growth and survival. As *Azolla* contains optimum protein and essential amino acids it is a better food option for the fish. In aquaculture, ammonia and nitrite are toxic to fish at relatively low levels (10 mg/L) and can cause decreased performance of fish at levels as low as 1-10 mg/L (Spotte, 1979). As *Azolla* fixes nitrogen thus it seems to be good substitute in fish food. Similar to other water plants, aspartic acid and glutamic acid are the most concentrated amino acids in *Azolla*. *Azolla* and other water plants are generally deficient in sulphur amino acids and lysine. *Azolla* is richer in cystine than other water plants thus can be a better source of lysine (Fiogbe *et al.,* 2004) and better food supplement for fish. The least expensive diet containing 45 % *Azolla* also exhibited growth and can be used as a complementary diet for *tilapia* in fertilized ponds (Fiogbe *et al.,* 2004). *Azolla* as a substitute for defatted soybean meal in diets of juvenile black tiger shrimp (*Penaeus monodon*) has been reported with encouraging results (Sudaryono, 2006).

On the contrary, some studies with fish indicate the poor growth when higher levels of *Azolla* are incorporated which is attributed to the excesses or deficiencies of amino acids (Fiogbe *et al.,* 2004). Imbalance or inadequate levels essential amino acids causes reduced food intake and growth. Deficiencies of one or more amino acids are known to limit protein synthesis, growth or both. Grass carp (*Ctenopharyngodon idella*) fingerlings accepted well finely chopped *Azolla caroliniana*. Improved weight gain and more net gain for grass carp production is reported. The significant increase in absorption rate in the experimental fish may be due to the adequate levels of indispensable amino acids (Sithara and Kamalaveni, 2008). Grass carp and common carp recorded a weight gain of 174 and 35.8 g/fish, respectively, and utilized *Azolla* nitrogen to the extent of 30 % (Ayyappan, 1992). Therefore, these studies indicate that *Azolla* can be incorporated in the feed of omnivorous plantophagous *tilapia* in extensive system to reduce feed cost significantly. Moreover mixing *Azolla* with some agricultural by-products such as wheat bran and rice bran can improve the digestibility and feed quality (Sithara and Kamalaveni, 2008). Favorable results were reported with *Azolla* replacing upto 45 % of control diets fed to young *Oreochromis niloticus* grown in a re-circulating system (Fiogbe *et al.*, 2004). Young Nile *tilapia* utilized *Azolla* more efficiently than adults. Studies with fish showed that growth was higher in the conventional feeds as compared with the *Azolla* based diets. Fish died or negative growth was recorded when fed exclusively with fresh *Azolla*. Therefore, *Azolla* should always be fed either in combination or limited amount of diet.

11. *Azolla* and Agriculture

Azolla has been used for centuries as green manure in rice fields. Atmospheric nitrogen is fixed and converted to ammonia which is made available as soluble nitrogen for paddy. In Asian countries, *Azolla* is the most commonly used as green manure for rice crop due to its high growth rate, nitrogen fixing capacity and ability to scavenge nutrients from soil and water (Bhuvaneshwari and Singh, 2015). Now due to more awareness and with scientific evidences, use of chemical fertilizers is showing declining trend. Consequently, being cheaper and easy to cultivate, *Azolla* is getting popular as a bio-fertilizer. *Azolla* in near future will be the bio-fertilizer of choice. This supplements the nitrogen to the crop for production and growth and maintains the soil fertility. The results of several studies indicate that rice-fish-*Azolla* integration increased the yield of both rice and fish compared to rice-fish culture alone. The likely reasons for the increase in rice yield are improved soil fertility resulting from the increased production of fish faeces, decrease need for inorganic fertilizers and pesticides and reduced weed growth and decrease in incidence of pests and improvement of soil fertility. Fish yields increase through the direct consumption of *Azolla*. However, the adoption of integrated farming (rice-fish-*Azolla*) depends on the attitude and capacity of the farmers, the capacity of support services, including the *Azolla* inoculums availability and the overall economic feasibility of the system.

Apart from used as feed ingredients, *Azolla* can be used to treat waste water. As the capability of nitrogen fixation by *Azolla*, the efficient removal of phosphorus would be expected even after N is consumed. *Azolla* in outdoor batch cultures actively absorbed nutrients from the secondary treated effluent of waste water.

12. Conclusion

Azolla has a potential as a promising and economical feed for different species of animals. Combination of *Azolla* with some agricultural by-products such as wheat bran and rice bran can improve the digestibility and feed quality and thus production performance of animals. *Azolla* has been used for centuries in agriculture field. Available literature indicates that *Azolla* is an economic and efficient feed supplement for different species of animals, containing substantial amounts of protein, amino acids, vitamins and minerals which significantly reduce the cost of feeding. Thus, *Azolla* has future as a potential feed ingredient for various types of animals.

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