Azolla – A potent unconventional feed and its effect of feeding on various livestock species – A Review

Ninad Bhatt, Nripendra Pratap Singh, Amit Kumar Singh, Diksha Kandpal, Pramod Chaudhary and Priyanka Patoliya

Abstract
India has the largest bovine population in the world and second in poultry population. This trend is increasing with time. Also the demand for animal food source is gaining momentum due to rapid urbanisation and rising population. These all things combined together have increased scope for livestock industry. But decreasing land availability has become a major concern now. It has reduced the availability of nutrient rich primary food source for livestock. Livestock is relying on poor food source that has made them less productive. Under this context, Azolla can be one of the best alternatives. It has ability to grow faster with the minimum production cost. Azolla is rich in protein along with minerals, vitamins, antioxidants that is contributing to better growth and production from livestock. Also, it can be used as a protein supplement in ruminants. Azolla can be grown in both tropical and temperate regions. It can grow in wetlands, lakes, ponds, ditches, swamps, dry temperate and tropical areas all over the world, in both tropical and temperate regions. It can grow in wetlands, ditches, swamps, dry temperate and tropical areas all over the world, and also in lakes and rivers where the water is not turbulent (Lumpkin and Plucknett, 1984) [26]. Azolla is a free-floating aquatic macrophyte consisting of a thin, branched, floating stem, carrying roots suspended in water, consisting of 28 per cent crude protein and with the capacity to be used as a protein supplement in ruminants (Ahirwar and Leela, 2012) [3]. The floating species typically do not depend on the depth of soil or water. Owing to rapid growth, aquatic macrophytes come to invade gaps and cause numerous problems so many researchers find them to be plagues. However, if we use their energy correctly, they can be used as animal feed. It has the capacity to absorb or hold metals, nutrients and other materials, making them a valuable resource for handling polluting water.

Azolla has a symbiotic association with Anabaena Azolla algae (nitrogen-fixing blue-green) (Lumpkin and Plucknett, 1982) [25]. In place of fixed atmospheric nitrogen and probably other new growth-promoting substances, the Azolla provides the colonies of Anabaena and Anabaena with nutrients and a shielded cavity which provides adequate nitrogen both for itself and for its host (Peters, 1978) [29]. Azolla has been used for several decades as a bio-fertilizer in Vietnam and Southern China to successfully increase rice production (Watanabe and Liu, 1992) [48]. Azolla is protein rich, and can be used as a source of plant protein and provitamins for animal nutrition (Lejeune et al., 2000) [23]. The nutritional value of Azolla is well known,
demonstrating that it is a good source of protein, almost all the important amino acids needed for animal nutrition (particularly lysine), and also provides macromolecules such as calcium, magnesium, potassium and vitamins such as vitamin A (beta-carotene precursor) and B12 (Leterme et al., 2009) [24]. Azolla can be used as an unusual protein supplement feed for many livestock including ruminants, chickens, pigs, and fish (Hossiney et al., 2008) [17]. Multiple scientists used it as a valuable complement to the ammunition. Azolla can be used as an ideal substitute for livestock, fish, pigs, and poultry feed (Pillai et al., 2002) [10]. Azolla can act as a valued green feed supplement for dairy cattle to improve efficiency in terms of production, milk, meat, etc., particularly where the availability of green fodder is limited (Chatterjee et al., 2013) [10].

**Azolla pinnata taxonomy**

**Kingdom:** Plantae **Division:** Pteridophyta  
**Class:** Pteridopsida **Order:** Salvinales  
**Family:** Azollaceae **Genus:** *Azolla*  
(Lumpkin and Plucknet, 1982) [25]

Azolla appears to be a long, circular and triangular one with base, stem and leaves. Leaf consists of two lobes, a chlorophyllous aerial dorsal lobe and a ventral lobe that is partly submerged in water. In each dorsal lobe there is a leaf canal, which holds the symbiotic Anabaena Azolla. The plant is super-efficient, with the ability to double its weight in 7 days. It can produce nine tons of protein per hectare of pond per year. In laboratory circumstances, Azolla has been reported to be able to nearly double biomass in less than two days and in favourable field conditions within 3-5 days and 5-10 days in normal field situations. It is very high in crude protein, minerals, chlorophyll vitamins and carotenoids and is a promising feed portion for animals (Lumpkin, 1984) [26] and broilers (Singh and Subudhi, 1978) [38]. Azolla that comprise of 20-35% protein, 10-15% mineral and 7-10% amino acids, bioactive substances and biopolymers based on dry weight basis. Azolla has relatively low carbohydrate content as well as oil content. However, Azolla can be quickly digested by livestock due to its high protein content and low lignin content.

**Cultivation practices of Azolla**

Pillai et al. (2002) [30] mentioned the cultivation of Azolla byNDARPEP system in artificial water tanks constructed from silpaulin sheets. As the first level a pit of 2 m x 2 m x 0.2 m was dug. The silpaulin sheet was spread and about 10 – 15 kg of sieved fertile soil was uniformly spread over the silpaulin sheet. Slurry consisting of 2 kg cow dung and 30 g of super phosphate in 10 liters of water was poured onto the pad. A mixture of 20 g of super phosphate and around 1 kg of cow dung should be added once every 5 days to keep the Azolla in a process of rapid multiplication. To make the water level reach around 10 cm more water was dumped. Around 0.5-1 kg of new and pure Azolla culture was inoculated in the pit. Azolla will expand rapidly, filling the pit within 10-15 days. After that, about 500-600 g of Azolla can be harvested every day.

Bhatt et al. (2020) [9] performed the NDRI method of Azolla cultivation. Here first, a rectangular pit of size 10*4 feet (L*B) and 90 cm depth was prepared. Then the pits were covered with the silpaulin sheets and surface of the pit was made uniform. The edges of the sheets were fixed with bricks and muds. Afterward the pit was covered with 25 -30 kg of fine sieved fertile soil mixed with carbofuran @1% of total weight of soil and spread uniformly over the surface. Then the water was transferred into the pit up to the height of 25 – 30 cm. Slurry of cow dung (1-2 day old) about 6-7 kg was prepared and poured into the pit. SSP was spread @ 20-25 gm over each tank. Any foreign root and unwanted material over the surface is removed with the help of wire-mesh. Finally the pure fresh Azolla culture is inoculated @ 300-400 gm/m² over the surface. To maintain a faster growth, cow slurry (1-2 kg) and SSP of about 10 gm was poured at every 10th day gap. 25 to 30% of the water was to be replaced with fresh water once in every 15 days to prevent nitrogen build up in the pit. The pit was covered with the long plastic polythene sheet during the night time and was removed every morning around 9 am. This method helped a lot for Azolla growth and prevented it from cold stress and dew. Below is the plate representing the Azolla pinnata cultivation –

![Azolla pinnata cultivation](https://example.com/azolla_pinnata_cultivation)

**Important precautions to be considered during Azolla cultivation** –

- A place away from direct sunlight must be chosen that is preferably a shady area.
- Temperature is an important factor for good growth. Mean temperature of 25-35°C is most favourable for maximum growth.
- The level of the pit must be uniform from the ground as well as side in order to maintain the similar water level throughout the pit.
- Azolla bio mass @ 300-360 gm / sq. mt must be removed daily to prevent over-crowding and favouring the faster growth.
- A suitable insecticide such as neem oil must be poured to prevent pest growth.
- SSP is the most critical mixture and must be supplied @ 10-20 gm over each tank at gap of 10th day.
- An average of about 25 to 30% of the water has to be replaced with fresh water once in every 15 days to prevent excess nitrogen production in the pit
- Any foreign root and unwanted material must be removed on a regular basis

**Advantages of Azolla farming**

- It has capacity to double its biomass within a short period of time and produce green manure throughout the year.
- Azolla can be an effective bio fertilizer in rice cultivation. Azolla’s fast proliferation rate and fast decomposition ability has become a significant key consideration for use in rice fields as a green manure cum bio fertilizer (Wang et al., 1991).
- Cohn and Renlund, (1953) [12], Jain et al. (1989) [20] and Saxena (1995) [35] have found that Azolla and Lamna minor mixture have ability to sufficiently purify highly polluted effluent by biosorption of heavy metals. Salman et al. (2012) have found the Azolla fíliculoides ability in the removal of Ni and Cu from wastewaters.
**Chemical composition of Azolla pinnata**

All the samples were chemically analysed for the crude protein (CP), crude fibre (CF), total ash (TA), ether extract (EE) and moisture according to methods of Association of Official Analytical Chemists (AOAC, 2005) [8].

<table>
<thead>
<tr>
<th>Components</th>
<th>Azolla pinnata</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM %</td>
<td>9.95±0.03</td>
</tr>
<tr>
<td>OM (% DM)</td>
<td>79.7±0.18</td>
</tr>
<tr>
<td>NDF (% DM)</td>
<td>44.28±0.18</td>
</tr>
<tr>
<td>ADF (% DM)</td>
<td>39.4±0.06</td>
</tr>
<tr>
<td>CP (% DM)</td>
<td>26.5±0.08</td>
</tr>
<tr>
<td>EE (% DM)</td>
<td>3.9±0.13</td>
</tr>
<tr>
<td>TA (% DM)</td>
<td>20.3±0.28</td>
</tr>
</tbody>
</table>

(Bhatt et al., 2020) [9]

**Mineral profiling of Azolla pinnata (on percent DMB)**

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Percentage</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>1.51</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>2.41</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>2170</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>1100</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>6.1</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>2.01</td>
<td></td>
</tr>
</tbody>
</table>

(Bhatt et al., 2020) [9]

**Effect of Azolla feeding in ruminants**

Tamang et al., (1993) [43] performed a growth trial on Blackbengal kids and found that sun-dried Azolla can be incorporated into the diet of kids up to 20 percent of the concentrate mixture without adverse effect. Indira et al., (2009) [18] carried out growth studies using Azolla meal as a feed supplement in buffalo calves and found significantly higher daily gain in Azolla feed groups. Also the feed conversion efficiency in experimental diet was significantly (P<0.01) higher. Wadhwani et al., (2010) [45] performed a weaner lamb test to evaluate the dietary efficiency of Azolla feeding and found greater dry matter and protein consumption with no adverse effect on carcass characteristics in the treatment groups. Sritivas et al., (2012) [36] studied the impact of Azolla meal on Osamanabadi kids at different concentrations viz; T1 (control), T2 (15% concentrate replaced with Azolla meal), T3 (25% concentrate replaced with Azolla meal) and found that dry matter intake per kid was greater in T2 (0.35 kg) followed by T1 and T3 (0.34 and 0.33 kg) groups respectively. Rawat et al., (2015) [31] performed experiment using Azolla (Azolla pinnata) into sixty crossbred cows and reported a substantial rise in milk production by 11.85 percent in Azolla feed groups. Adake (2015) [2] researched on goat kids with the following feeding patterns that is T1 (Grazing+ 100% concentrate), T2 (Grazing+ 80% concentrate + 20% Azolla) and T3 (Grazing + 70% concentrate+ 30% Azolla) and found that the average daily weight gain (ADG) of goat kids was 0.10, 0.23 and 0.25 kg respectively in T1, T2 and T3 groups. Ahmed et al., (2016) [4] conducted feeding trial on Corriedale sheep by dividing them into 5 equal groups viz, T1, T2, T3, T4 and T5. Here, he replaced 0, 6, 12, 18 and 24% Azolla by 0, 25, 50, 75 and 100% linseed cake respectively. Highest body weight was noted in group T1, and there was no noticeable difference in group T2, but there was a significant difference in group T3, T4, and T5. T2 group had shown a significant difference with T5 group, but no important difference in the final body weight was observed with other groups. Das et al., (2017) [14] researched on Jalauni lambs in order to evaluate the impact of azolla meal as a substitute for mustard cake protein on nutrient basis. The average DM1 in groups T1, T2 and T3 was 3.90, 3.77 and 3.49 percent of the live BW. Digestibility of DM and OM was similar in T1 (61.43% and 64.98%) and T2 (59.91% and 62.97%), but greater (P<0.05) than in T3 (51.57% and 56.51%). Bhatt et al., (2020) [9] conducted the experiment on Sahiwal female calves distributed into three groups (T0, T1 and T2) for 90 days. The animals in (T0) group were fed as per ICAR 2013 feeding standards, while (T1) and (T2) group were fed by replacing 15%, 30% protein content of concentrate with Azolla pinnata on DM basis respectively. The average daily live-weight gain (ADG) was higher in T2 (.456±.01kg/d) than in T1 (.431 ±0.01 g/d) and least in T0 (.411±.02) and the difference was statistically significant (P<0.05).
Effect of Azolla feeding in non-ruminants

Subudhi and Singh, (1978) [49] conducted experiment on White Leghorn females by providing commercial poultry meal and fresh Azolla on a dry matter basis in an experiment in India at concentrations of 5, 12.5, or 16 percent. The animals getting the 5% Azolla diet grew quicker than the control group and those receiving the 12.5% Azolla diet grew only mildly slower, although development levels were considerably lower at 16% incorporation. Duran (1994) [40] used fresh palm oil as the source of power in pig fattening diets and Azolla filiculoides as a replacement for soybean meal and discovered that Azolla’s optimum substitution levels in growing and fattening cows were 10 percent and 20 percent. Duc Ach (1997) [15] revealed that adding the fresh Azolla to the pig diets at the rate of 1-4 kg lower the feed expense by 40%.

Accodji et al., (2009) [1] discovered that when fresh Azolla in the diet was fed at 15, 30 and 45 percent level, the one with 15% level had the greatest output and the lowest feed costs. Due to the nutrient imbalance associated with feeding a high-moisture and bulky product, Azolla feeding at 30 and 45 percent was harmful to productivity and feeding effectiveness. Parthasarathy et al., (2002) [28] indicated considerably enhanced dietary FCR, energy efficiency, dressing percentage and total expense, when sesame meal was replaced by 5 percent Azolla meal. Anil et al (2014) [8] reported that sun dried Azolla can be included up to 5% level in quail diet as an unconventional feed resource to reduce cost of production. Abou-Zeid et al., (2001) [40] concluded that in female mating rabbits, when 25% of soybean meal protein was replaced by protein from sun-dried Azolla, it sustained feed conversion, weaning litter size and female weight, as well as economic performance, but reduced conception rate, birth litter size and milk production. Pillai et al., (2002) [40] revealed that birds with 75% of standard feed and 12.5% Azolla weighed nearly the same as birds with 100% regular feed. Birds receiving ordinary feed with 5 percent additional in the form of Azolla grew quicker than birds receiving 100 percent feed alone, as well as 10–12 percent boost in complete body weight. Dried Azolla was discovered to be secure for poultry efficiency at 5 percent. Sabra et al., (2006) [32] conducted a study in rabbits and gave them diets containing 0 to 36 percent dried Azolla, and found that maturing rabbits can be fed securely rations containing 24 percent dried Azolla hay with positive impacts on most production characteristics. Ambade et al., (2010) [5] performed a survey on biochemical modifications in protein, carbohydrate and lipid concentrations in the tissues of the liver and muscles after feeding Azolla. The experimental animals showed a significant rise in protein content in different tissues confirmed that the protein conversion percentage is very high in-group diet-fed azolla. Sujatha et al., (2013) [42] revealed that there was no adverse effect on hen-day egg production and other performance parameters when the new Azolla @ 200 g / d was added to the indigenous laying ducks but resulted in reduced feed consumption and greater egg yolk colour score. The addition of Azolla proved to be profitable owing to feed cost savings.

Sudaryono, (2006) [41] performed a feeding experiment on black tiger shrimps and found that Azolla meal protein can substitute up to 100 percent of soybean meal protein in practical nutrition without negative effects. Naghshli et al. (2014) [27] researched the impact on broiler chicks performance and carcass features of varying levels of Azolla meal (Azolla pinnata). Results stated that chickens fed diets comprising 5% Azolla powder (P<0.01) considerably enhanced daily weight gain and feed conversion percentage in all rearing phases between treatments relative to other diets. So the lowest consumption of feed, the largest weight gain and the smallest conversion ratio of feed is associated with diets comprising 5% Azolla.

Anil et al (2014) [8] reported that sun dried Azolla can be included up to 5% level in quail diet as an unconventional feed resource to reduce cost of production. Sireesha et al., (2017) [39] conducted research on white New Zealand rabbits and randomly divided them into three groups: T1 feed with (0 percent Azolla), T2 feed with (10 percent Azolla) and T3 with (20 percent Azolla). At the end of the experiment, the average weight gain of T2 group rabbits was higher than those of T1 group and T3 group respectively. In T2, the ADG was higher than in T1 and T3. Rabbits in the T2 group showed higher FCR over groups T1 and T3.

Economics of Azolla feeding in different livestock

Shital et al., (2012) [33] confirmed that Rs. 40.49, 39.27 and 81.68 were found to be the total cost per kg live weight gain for T1, T2 and T3 groups respectively. Therefore, the use of Azolla meal is relatively profitable when it includes up to 15% of the total concentrate in Osmanabadi kids. Cherryl et al., (2013) [13] explored the Azolla production economics and its impact on swine feeding costs. The calculated ration cost per day was Rs. 24.50, 22.55 and 20.75 for G1, G2 and G3 groups during the growing phase and Rs. 26.39, 24.45 and 22.90 respectively for F1, F2 and F3 groups during the finishing phase and the difference between groups was significant (P<0.01). The ration price per kg increase for G1, G2 and G3 was respectively Rs. 68.06, 64.42 and 59.28, and likewise Rs. 75.40, 71.91 and 65.42 respectively for F1, F2 and F3, and the variations between the organizations were significant (P<0.05).

Adake (2015) [2] found that cost of whole feed per goat kid was Rs. 265.23, Rs. 217.35 and Rs. 193.91 in treatment groups T1 (Grazing + 100 percent concentrate), T2 (Grazing + 80 percent concentrate + 20 percent Azolla) and T3 (Grazing + 70 percent concentrate + 30 percent Azolla) for the experimental period of 63 days. The feeding cost / day / goat price in T3 group was lowest as compared to T2 and T1 showing that the greater quantity of Azolla used in feeding goat kids reduced feeding costs. The feeding price was lowest in T3, which can be useful to goat owners by having greater monitoring yields owing to greater growth rate.

Ahmed et al., (2016) [4] revealed that the maximum feeding price per kg gain was observed in group T2 and had significant difference with group T3, group T4 and group T5 but not group T1 (control) in sheep’s. There was also no significant difference between the T3, T4 and T5 groups, but significantly higher feeding costs per kg gain was observed in the T3, T4 and T5 groups than the T1 (control) group. Jadhav (2016) [19] calculated feed costs per heifer cow per day in the treatment group T1, T2 and T3 respectively as Rs. 34.31, Rs. 34.40 and Rs. 21.95. The price of feeding / day / heifer was lowest in T3 compared to T2 and T1 stated that reduced concentrate combination used in crossbred heifer feeding with Azolla meal reduces feeding costs. As feeding costs are smaller in T3, which can be very useful to heifer owner.

Conclusion

Thus due to increasing population and reducing land coverage area; Azolla can act as a best alternative to meet the quantity...
and nutritional demand of livestock. Azolla can play a great role in feeding various varieties of livestock like swine, bovine, poultry, rabbit, goat, etc. It can be one of the best alternative source of green manure and protein supplement for livestock. It could act as cheapest source of protein for livestock owners especially the poor marginal farmers and can help them to raise their income. Azolla can be combined with some of the agricultural by-product such as rice bran, concentrate that can improve the digestibility, quality and hence production performance of animals. Available literature have proved that that Azolla is an economic and efficient feed supplement for different species of animals, containing definite amounts of protein, amino acids, vitamins and minerals which significantly reduce the cost of feeding and enhance production performance.

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