

REVIEW

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# Azolla pinnata as unconventional feeds for ruminant feeding

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## Abstract

Due to the scarcity of concentrate and green fodder and its high prices in animal feeding, the quest for readily available and inexpensive alternative sources has become critical for breeders seeking to minimize the cost of animal production. Azolla is an invasive plant that grows faster in freshwater lakes, rivers, wetlands, and ditches in both temperate and tropical countries by a few precautionary steps with low production costs. It can modify biodiversity and aquatic ecosystems substantially. Azolla has a symbiotic relationship with the nitrogen-fixing blue-green alga *Anabaena azollae*, which increases the protein content of Azolla, making it one of the greatest alternative feed ingredients as a source of protein, with 25–30% protein, 7–10% amino acids, vitamins (Beta Carotene, vitamin A, vitamin B12), minerals (calcium, potassium, phosphorus, ferrous, magnesium, copper, etc.), and antioxidants. Several studies showed that Azolla can be fed to animals like cow, buffalo, sheep, goat and rabbit because it is easily digestible (because to its high protein and low lignin content), increases feed efficiency, average daily gain of animals, and milk production by 15–20%. Therefore, the present review was aimed to show the possibility of using Azolla as a source of alternative low-cost protein and its impact on animal efficiency.

**Keywords:** Azolla, Unconventional feed, Ruminant, Growth, Milk production

## Background

Azolla is an aquatic fern that belongs to the *Azollaceae* family and Azolla genus, its diameter varies from 2.5 to 15 cm (Lumpkin and Plucknett 1980). It can double its weight in 3–5 days, and from a starting weight of 1 ton/ha, it can reach 15–30 ton/ha in about 20 days (Khan 1983), also Anon (1985) estimated that one hectare of Azolla can provide protein equivalent to 790–1100 kg soybean grains in one month. The optimum temperature for growing Azolla is 18–28 °C with a pH of 4.5–7 (Kathirvelan et al. 2015). Azolla (*Azolla pinnata*) is a good alternative protein source that might also be used to provide rumen undegradable dietary nitrogen (Jayasuriya et al. 1988).

Azolla has a symbiotic relationship with the nitrogen-fixing blue-green alga *Anabaena azollae*, which increases

the protein content of Azolla and contains approximately all amino acids specially lysine, and pro-vitamins (Hossiny et al., 2008) and B12 (Leterme et al. 2010). Also, because azolla has a low lignin content, it is easily digested by livestock and can be utilized as a green feed supplement for dairy cattle (Prabina and Kumar 2010; Chatterjee et al. 2013).

According to Sanginga and Van Hove (1989), the chemical composition of Azolla varies depending on a variety of parameters, including soil chemical composition, ambient circumstances (such as light intensity, heat and humidity), and contamination.

## Main text

### Azolla cultivation

As described by Cherryl et al. (2014):

1. Making an even floor pit with dimensions of 5 × 4 × 0.3 m with the same level of corners to maintain a uniform water level.

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2. Put and uniformly Silpaulin sheets over the pits such are longer and broader than the pit and the outer edges of the sheets were good fixed.
3. Evenly spread 10–15 cm clear soft soil over the sheet.
4. Fill water in the pit to a three-fourth level and regular maintenance the same level of water.
5. Dissolve about 15 kg of fermented buffalo feces in 35 L of water and add the mixture evenly throughout the pit.
6. Dissolve about 30 g of superphosphate in 10 L of water and add it as a zigzag to the previous soil.
7. Five Kg of fresh and pure Azolla incubated in the pit and slowly sprinkled water over it.
8. Every 15 days the application of buffaloes feces, superphosphate and minerals was done to avoid nutrient deficiency and obtain continuous growth of Azolla.
9. If the pit is affected by pests or diseases must be clearing and a fresh inoculation of the pure culture of Azolla will be done.
10. Azolla multiplies rapidly and fills the pit within one week, so every week can harvest fully grown Azolla.
11. Sun dried the yield of Azolla for 2–3 days and packed in air tight bags and stored until use.

5. Need long photoperiods for high nitrogen-fixation potential.
6. Need more micro and macro elements.
7. Didn't need nitrogenous fertilizers but a low concentration of nitrate and ammonium promote the growth of Azolla.

#### Chemical composition of *Azolla pinnata*

The chemical composition of Azolla was analyzed according to the methods of AOAC (2005) and it differs according to several factors and is almost the same between different authors. Chemical analysis of Azolla as estimated by:

2.1. Samanta and Tamang (1995): 90.1% DM, 79.7% OM, 15.4% CP, 14.1% CF, 2.7% EE, 47.4% NFE, 20.4% Ash, 6.8% cellulose, 15.6% hemicellulose, 15.7% lignin, 16.0% silica, 0.35% phosphorus and 1.54% calcium.

2.2. Ahirwar and Leela (2012), Mathur et al. (2013): 8.7% DM, 16–28% CP, 20–30% CF, 3.1% EE, 35.40% NDF and 23.97% ADF, 8.5–11.7% cellulose and low content of carbohydrates being 34.9%, and considered a rich source



Sun-drying Azolla

#### *Azolla pinnata* cultivation factors for better growth (Kumar and Chander 2017)

1. Water is 7–11 cm deep is required and salinity of water adversely affects.
2. The pH of soils is 5.0–7.2.
3. Temperature 20–28 °C.
4. Relative humidity 65–80%.

of micronutrients, 0.44% phosphorus, 0.58% calcium, 17.15 ppm copper, 77.30 ppm zinc, 207.87 ppm manganese and 710.65 ppm iron.

2.3. Becerra et al. (1995): 4.5% EE and 3.5% by Ghodake et al. (2012).

2.4. Parthasarathy et al. (2001) and Ghodake et al. (2012): 24.91–27.22% CP.

2.5. Parashuramulu et al. (2013) who recorded that Azolla rich in trace minerals and has 21.37% CP, 1759 kcal ME/kg energy and has high metabolizable energy contents, in vitro DM and OM digestibility being 7.36 MJ/kg DM, 79.55% and 63.8%, respectively.

2.6. Cherryl et al. (2014): sundried Azolla 89.73% DM, 75.73% OM, 23.49% CP, 14.7% CF, 3.7% EE, 24.26% ash, 33.84% NFE, 0.26% phosphorus and 2.58% calcium.

2.7. Ahmed et al. (2016): 24.1% CP, 15.1% CF, 3.75% EE, 16.8% ash, 40.25% NFE, 0.47% phosphorus and 2.18% calcium

2.8. Anhita et al. (2016): 4.7% DM, 82.66% OM, 22.48% CP, 14.7% CF, 4.5% EE, 17.34% ash, 40.98% NFE, 54.85 NDF, 36.57 ADF, 24.05 ADL and minerals profile as ppm was 0.34 phosphorus, 1.64 calcium, 2.71 potassium, 9.1 copper, 2418 manganese, 325 zinc, 1569 iron, 8.11 cobalt, 5.06 chromium, 31 boron, 5.33 nickel, 8.1 lead, 1.2 cadmium.

2.9. Sihag et al. (2017): Azolla meal contains 22.93% DM, 11.63% CP, 2.8% EE, 15.59% ash, 47.03% NFE, 40.47% NDF, 32.55% ADF and 7.92% hemicellulose.

2.10. Bhatt et al. (2020): 9.95% DM, 79.70% OM, 26.50% CP, 3.90% EE, 44.28% NDF, 39.4% ADF and minerals profile was 2.41% potassium, 1.51% calcium, 2170 ppm manganese, 4.1 ppm copper, 230 ppm zinc, 1100 ppm iron, 7.1 ppm cobalt, 2.01 ppm chromium and 6.1 ppm nickel.

2.11. El-Fadel et al. (2020): Azolla meal contains 85.08% DM, 72.86% OM, 18.58% CP, 32.17% CF, 3.35% EE, 27.14% ash and 18.76% NFE.

## The effect of integrating Azolla into ruminant feed on

### Nutrient's digestibility and gain

Anon (1985) reported that feeding buffaloes on a rice straw diet incorporated with 45% Azolla enhanced the growth rate compared with that of a diet containing rice-straw alone. Azolla can be incorporated up to 20% of the concentrate mixture of goats without any adverse effect (Samanta and Tamang 1995). Also, replacing 30 or 50% of groundnut protein with Azolla meal in the diet of Nellore sheep or buffalo, respectively, improved DM digestibility, daily gain and feed efficiency (Indira et al. 2009).

Due to its high fiber content, azolla meal can be utilized as a replacement in the diet of Osman badi goats up to 15% of the concentrate mixture (Ghodake et al. 2012). In buffalo, there were no significant differences in nutrient digestibility when replaced 25% of protein of concentrate mixture by sun-dried Azolla (Kumar et al. 2012).

Replacement concentrate feed by 20 and 30% dried Azolla increased the average daily gain of goats by 56.5 and 60%, respectively (Adake 2015). Replacing 25% linseed cake by 6% Azolla in the diets of Corriedale

sheep increased body weight, DM digestibility and FCR (Ahmed et al. 2016).

The inclusion of 10% Azolla had 2.5 times higher weight gain as compared to reported on rearing lambs under semi-intensive system and reduced the feed cost by 22% compared to control diet without adverse effect on feed intake (Wadhvani et al. 2010). Das et al. (2017) reported that the optimal replacement of Azolla was 25% from mustard cake protein in the diet of Jalauni lambs without different effects on nutrients digestibility and utilization. Replacing the concentrate mixture of the diet of heifers at a 5% level by dried Azolla improved average daily gain (ADG) by 15.7% and feed conversion efficiency (FCE) by 20% (Roy et al. 2016). Average daily gain of white New Zealand rabbits fed diets containing 0, 10, and 20% Azolla, as a replacement of protein diet, was higher for 10% than 0 and 20% and the same trend with feed conversion ratio (FCR) was higher for 10% over 0 and 20% (Sireesha et al. 2017). Sihag et al. (2017) concluded that a concentrate mixture of goat's diets can be replaced with sundried Azolla up to 15% without any adverse effect with economic feeding. Also, there were no significant differences in DM intake, ADG, and feed efficiency of Mecheri lambs' groups when 10% protein of concentrate mixture was replaced by Azolla meal on a DM basis (Sankar et al. 2020).

Bhatt et al. (2020) reported that as DM basis replacement 15% protein content of concentrate with Azolla increased average daily gain of female calves. Sharma et al (2021) concluded that green Azolla improved the growth performance of male kids when supplemented by 150, 250, and 350 gm to concentrate diet such ADG increased by 21.13, 29.34, and 22.59% and FCR enhanced by 13.3, 17.38, and 12.82%, respectively, compared with 0 Azolla supplement, and from the results, the best green Azolla supplement was with 250 gm. Recently Varun Singh et al (2021) reported that supplemented dried Azolla up to 20% of DM intake enhanced carcass characteristics of lambs.

### Milk yield

Pillai et al. (2002) reported that replacing 15–20% commercial feed with dried Azolla did not influence milk yield but saved 20–25% of commercial feed. On the other hand, Pillai et al. (2005) found that incorporating 1.5–2 kg of fresh Azolla with regular feed/day in the diet of dairy cattle increased milk yield by 15% and saved 20–25% of commercial regular feeds.

In the diet of dairy cows, replacing 15–20% commercial feed with Azolla increased milk yield by 15–20%, this might be due to the low lignin and high protein content of Azolla (Gouri et al. 2012). Also, Azolla supplementation (2 kg/day) in the diets of crossbred bovine animals



increased milk yield and FCM by 11.2 and 12.5% and feed conversion efficiency as kg DMI / kg FCM yield (Chatterjee et al. 2013).

Incorporating 1.5–2 kg fresh Azolla in the diets of cows increased milk yield by 20.96% and in buffalo by 16.9% (Mathur et al. 2013). Khare et al. (2014) reported that the milk yield of lactating cows increased when the diet was supplemented with Azolla compared with the control group. Supplemented 1.5 kg fresh Azolla/buffalo/day with cottonseed cake increased milk production by 16.25% and enhanced animal health (Meena et al. 2017). Using Azolla in the diets of crossbred cows as a feed supplement (1 Azolla:1 concentrate) showed a significant increase in milk yield by 11.85% (Rawat et al. 2015), also (Kumar et al. 2020) recorded that fresh Azolla can be used as a feed supplement for dairy cows up to 1000 g per day which could increase the milk production by 7–13%.

## Conclusions

Available literature has reported that Azolla is an unconventional feed and cheapest source of protein can be incorporated in the diets of ruminant up to 20% which enhance nutrients digestibility and animal performance. Also, several studies found that fresh Azolla can be used as feed supplement up to 2 kg/day/animal or as replacement dried Azolla up to 20% from commercial feed for dairy cows and buffalo which saved 15–20% of commercial feeds and increased milk production from 7 to 20%. We may conclude that employing Azolla in animal feeding improve animal performance and save feeding costs.

## Abbreviations

DM: Dry matter; OM: Organic matter; CP: Crude protein; CF: Crude fiber; EE: Ether extract; NFE: Nitrogen free extract; ADG: Average daily gain; NDF: Neutral detergent fiber; ADF: Acid detergent fiber.

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## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

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## Competing interests

The authors declare that they have no competing interests.

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