Recent developments and future prospects for using azolla as animal feed in livestock and poultry

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Abstract

Azolla is a small, free-floating water fern with a global distribution. Azolla can be used as a feedstock because it is high in proteins, fatty acids, amino acids and vitamins. Protein content in azolla species is in a range of 21–26%, dry matter, while fatty acids ranged from 41% to 66% dry matter. Azolla is rich in various classes of active compounds such as phenolic content, caffeoylquinic acid derivatives, tannins, and carotene. Azolla has been shown to improve the growth rate of animals, depending on the percent of inclusion in animal's diet. The most common species of azolla used as animals' feedstock is *Azolla pinnata*. The impact of azolla as a feed ingredient in the food production system on the environment has been addressed, including greenhouse gas emissions, carbon footprint, low land requirements, and amino acid-enriched feedstuffs.

Introduction

As the global population grows, so does human food consumption, resulting in increased food demand. This increasing demand has led farmers to meet high trade for animal ingredient for livestock, poultry, and fish nutrition industries. According to United Nations (2019), the global population is rising by 2 billion persons in the next 30 years, from the current 7.7 billion to 9.7 billion in 2050. There are several reports that global food production is needed to be doubled by 2050 (Ray et al., 2013; Fròna et al., 2019). Food production through agricultural industries is expected to increase by approximately 60% in the next 40 years so that the population around the world can be supplied with food in an appropriate quantity and quality (Fròna et al., 2019).

Soybeans and maize are the most common protein sources used by animal producers across the world (Dei, 2011; Park et al., 2017). Azolla is a type of aquatic fern and is native to the tropics and subtropics and warm temperate region of Africa, Asia, and the Americas (Costa, 2009). It forms

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a one-of-a-kind symbiotic relationship with filamentous cyanobacteria like *Nostoc* and *Anabaena*, which then act as nitrogen fixers (Brouwer et al., 2017). These aquatic macrophytes, azolla can normally be found in natural water habitats such as lakes, paddy fields, freshwater pond areas, slow-moving rivers or irrigation channels (Rascio and La Rocca, 2013). Furthermore, in the paddy field, azolla is grown either as a monocrop or as an intercrop and incorporated into the mud or soil to increase soil humus and nutrient content (Roy et al., 2016, Roy et al., 2016). Azolla is believed to be a promising prospective feed ingredient that can assist farmers in achieving sustainability, which is characterized as being both economically and environmentally viable (Kollah et al., 2015), feed ingredient that do not compete with a human food source (Schader et al., 2015), and low land requirement (Tallentire et al., 2018).

Characteristics of Azolla

Azolla is a sporophyte plant having a rhizome, which is horizontal (0.5–7 cm in diameter) and densely arranged branches and overlapping leaves (Yadav et al., 2020). Azolla have a symbiotic relationship with the blue-green algae *Anabaena azollae* (Pereira, 2018). This symbiotic relationship is unique because it involved the associations of two organisms, which are azolla (the aquatic fern) and anabaena (cyanobacteria). This aquatic fern supplies nutrients

Production and harvesting of azolla

The cultivation of azolla needs soil, water, and a pond (Utomo et al., 2019). Water is the most critical requirement for azolla cultivation (Azab et al., 2020). In order to make azolla grow continuously, 10% of the azolla is harvested from perfect and optimum development conditions, leaving only a small quantity of open area on the pond (Aziz, 2012). Brouwer et al. (2018), emphasises the importance of continuous harvesting whereby, *A. filiculoides* cultures equilibrated at roughly 1000 kg ha $^{-1}$

Nutritive value of azolla

The nutritional value of alternative feedstock from azolla needs to be fully understood in order to declare the good quality of this source as an animal feedstock.

Phytochemical analysis in azolla revealed the presence of antioxidant derivatives through caffeoylquinic acid derivatives, which has been reported in *Azolla mexicana* (Qian et al., 2020) and in *Azolla imbricata* (Wu et al., 2019) (Table 3). According to Jiang et al. (2017), caffeoylquinic acid, are the main antioxidant derivative in plant extraction, it helps in treating hyperuricemia and acute gouty arthritis in mice. Another important derivative that can be found in azolla is phenolic compounds

Factors influence the nutritional content in azolla

Azolla is an alternative resource for meeting current demand in the livestock, poultry, and fish nutrition industries, where improvement and mass production are the first steps toward meeting the growing need in a sustainable manner. Thus, requires continuous mass production, which is not yet common in azolla for large-scale cultivation (Brouwer et al., 2018).

The environmental condition for cultivating azolla has been a great influence factor related to its growth performance.

Application of azolla as animal feed

Azolla has traditionally been used as an animal feed in Vietnam in 1979 and China in 1980, and currently extensively been used in many other countries (Shiomi and Kitoh, 2001). *A. pinnata* was found to be the most species studied, and it was also the most extensively used for animal feed (Das et al., 2018). Azolla has been utilised in a range of species, and various studies have shown that azolla has a good influence on growth performance depending on concentration (Kumar et al., 2020; Samad et al)

Sustainability status of Azolla as a feed ingredient

According to Ritchie and Roser (2020), there are a variety of factors that lead to global environmental problems caused by food production, including greenhouse gas emissions, agricultural land use, freshwater use, eutrophication, and endangered species biodiversity. According to Trans et al. (2020), azolla is known to be one of the novel sustainable feed ingredients due to its high composition of valuable compounds.

Conclusion

The most common azolla species as an animal feed are *A. pinnata*. Azolla dietary inclusion levels of less than 15% in poultry, 5% in broiler chicken, and less than 25% in fish nutrition are recommended. A variety of other parameters, including animal species and azolla concentration as feed ingredients, seem to have influenced azolla efficiency. Overall, depending on the proportion of inclusion used, azolla is a promising candidate for animal feed ingredients that contribute to a healthy food.