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Utility of *Azolla* as a Superfood for Animals and Fish

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Abstract: *A small aquatic fern, Azolla (Salviniaceae), has been widely researched as a possible low-cost feed source due to its high growth rate and relatively high protein levels. It is capable of accumulating protein without external sources of nitrogen, in part because of its symbiotic relationship with the nitrogen-fixing cyanobacterium Anabaena azollae, which has led to its being investigated as an alternative to traditional feed components like soybean meal and fishmeal. Crude protein is reported as ranging between 19 to 30 percent of dry matter with some variance depending on conditions of growth and species. The present review is a compilation of the existing literature on the application of Azolla in livestock and aquaculture systems, including cattle, poultry, pigs, and a variety of fish. Instead of discussing Azolla as a universal solution, the discussion is dedicated to the areas where it can be effective and where the limitations can be revealed. Feeding trials indicate that it is most effective as a partial supplement, rather than a total replacement and results vary greatly depending on processing, inclusion levels and target species. Azelolla has a hard time being ignored by its economic and environmental appeal. It is relatively easy to manufacture, it does not have to compete with arable land, and can be incorporated into wastewater-based systems. Simultaneously, these benefits are accompanied by practical limitations, such as low dry matter content, difficulties in handling, and the existence of anti-nutritional factors which need processing. All in all, Azolla seems to be a valuable yet context-related feed resource. It will continue to play a minor role especially in smallholder and integrated farming systems. More research is required to understand the best levels of inclusion, standardization of processing procedures, and economic feasibility over the long term under the field conditions.*

Keywords: *Azolla*, Superfood, Fish, environment, livestock, aquasystems etc.

I. INTRODUCTION

The need of protein based on animals has been steadily growing over the last few decades, and this has put an increasing pressure on the feed regimes that underlie livestock and aquaculture production. The traditional feed components like soybean meal and fishmeal continue to prevail but their shortcomings are increasingly evident. Prices are unstable, supply chain is lumpy and when it comes to fishmeal, the reliance on marine resources brings ecological issues that cannot be overlooked.

This scenario has led to an interest in other sources of feed especially those that can be locally produced with fewer external inputs. But all alternatives do not do as well as they do in controlled situations. Others seem promising in laboratory conditions but cannot be scaled, and others have poor-quality nutritional value or handling problems. In this more general and a bit spotty search, Azolla has come back into the limelight as a candidate to look at more closely.

Azolla is not something new. It has long been used in Southeast Asia, particularly in rice production systems in Vietnam and China, primarily because of its nitrogen-fixing property. Its utilization as a feed source is more recent and has only been taken seriously since the late twentieth century. Adoption outside some areas is still small even today, with increasing evidence supporting it. This makes a valid question. In case the evidence is as good as it usually seems, then why has the uptake been so slow? (Lumpkin & Plucknett, 1980).

One of the answers is in the way Azolla is commonly provided. Paper wise it has an attractive profile. It is fast growing and in good circumstances the biomass can be doubled in a few days. It does not need arable land and it can be found at the surface of still or slow-flowing water. This fixes nitrogen in the atmosphere through its symbiotic relationship with Anabaena azollae and builds protein, but without the need to use synthetic sources of nitrogen (Watanabe, 1982). Its

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dry matter has also vitamins, pigments and minerals which assist in the nutritional value of animals. Other than feed applications, Azolla has also been explored as an organic compost and green manure in the production of medicinal plants with an improvement in chlorophyll content, dry matter yield, and soil-plant associations recorded (Agnihotri et al., 2007; Agnihotri and Mohan, 2012 a; Agnihotri and Mohan, 2012 b).

These benefits exist, but they are not uniformly distributed across systems. Temperature and availability of nutrients are important factors in growth. The processing of high amounts of fresh biomass is not necessarily feasible. The nutritional composition is dependent on the conditions of cultivation and the levels of inclusion in animal feeds cannot be pushed forever. That is, Azolla operates within some parameters and these parameters are not necessarily well delineated in the literature.

This is a more grounded review. The question is not, is Azolla making a broadly promising offer, but where it fits within the current feed systems. The discussion unites the existing information about its nutritional composition and compares its application in various animal species (cattle, poultry, pigs, and fish). It also takes into account the economic and environmental background where Azolla is probably to be utilized, especially the smallholder and integrated farming systems.

It is not intended to make Azolla a substitute to traditional feeds but to learn its value as a supplement. That is a big difference. It predetermines the way the evidence at hand is to be read, and whether Azolla is able to transition to experimental interest to a regular use.

II. BOTANICAL AND BIOLOGICAL OVERVIEW

The genus Azolla comprises small free-floating aquatic ferns, which are found primarily in tropical and subtropical areas. About seven species are generally known, such as Azolla pinnata, Azolla filiculoides, Azolla caroliniana and Azolla microphylla. Though native to warmer areas, the plant has been introduced to some temperate areas, both as a result of agricultural use and by accident. In others, it is even said to be invasive due to its capability of forming thick surface mats on fresh water bodies (Van Hove and Lejeune, 2002).

At a glance, Azolla is not a great plant physically. Single fronds are small, typically 1 to 2.5 centimeters in size and interlock to form an unbroken layer over the surface of the water. This type of structure enables it to encompass ponds and slow-moving bodies of water within a short time, which is one of the reasons why it is effective and in some ways a problem.

The more significant aspect is not what we see on the exterior but what happens on the interior which is the structure of the leaves. The leaves have lobules that have a hole in which the cyanobacterium Anabaena azollae is located. This correlation is not by chance. It is a stable, vertically transmitted symbiosis, i.e., the microorganism is transmitted between one generation of Azolla and the next and does not usually occur outside of this association. This interaction converts the atmospheric nitrogen into ammonia through the nitrogenase activity which is then absorbed by the plant into its metabolic pathways (Watanabe, 1982; Van Hove & Lejeune, 2002).

Agronomically, this fixation capacity is the key to the value of Azolla. In optimum environments, the Azolla-Anabaena system is capable of removing large quantities of nitrogen, and it is frequently cited in the 40 to 120 kilograms per hectare per season (Lumpkin and Plucknett, 1980; Okoronkwo et al., 1989). Although it has been conventionally addressed in connection with rice production, the same process has caused it to have a relatively high protein concentration when viewed as a feed source.

Environmental conditions have great effects on growth characteristics. Optimum growth of Azolla is at 20 C to 30 C, and biomass can be doubled in two to three days. Beyond this, the growth decreases exponentially. Cold (lower than 10 o C) or hot (greater than 40 o C) conditions can greatly retard growth (Watanabe, 1982). The availability of light is also a factor. Full sunlight is typical, but it can be partially shaded.

Another factor that is critical is water quality. Azolla is able to develop in a slightly acidic to neutral habitat, and it usually develops in a range of 5.5 to 7.0. Phosphorus is one of the nutrients that tend to be limiting. Modest phosphate supplementation, in most cultivation systems, results in apparent improvements in biomass production. This reliance is occasionally ignored in simplistic accounts of Azolla as a low-input crop, but in the real world, nutrient management remains a factor.

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Collectively, these biological characteristics account to the attractiveness as well as the limitation of Azolla. It is good at all the right conditions due to its rapid growth and fixation of nitrogen, but it is conditional. Performance can rapidly change in response to changes in temperature, nutrient availability, or water quality. Consequently, its behaviour in controlled contexts do not necessarily directly apply to field ones.

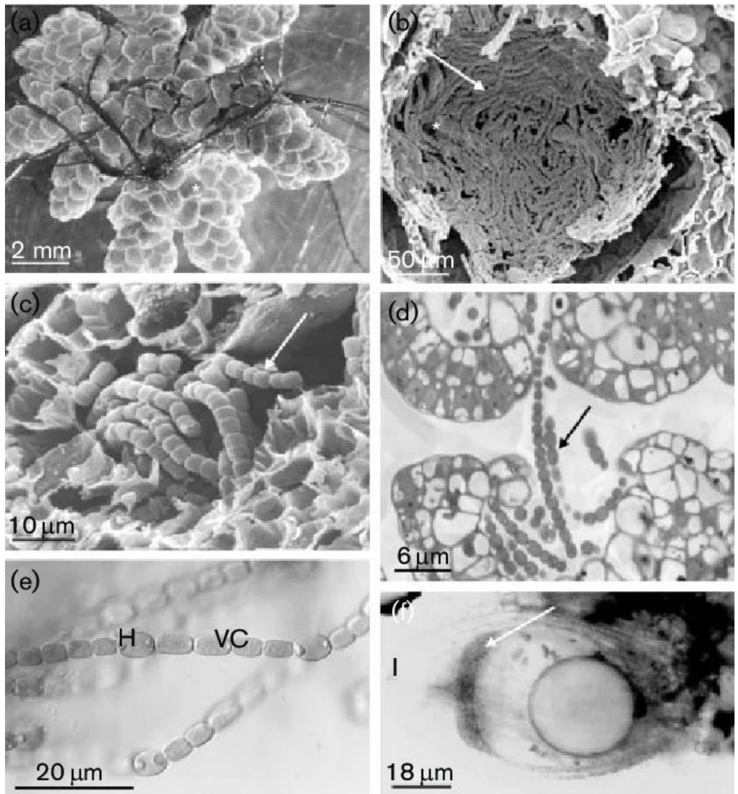

Figure 1. Symbiotic association between *Azolla* and *Anabaena azollae* showing nitrogen fixation within leaf cavities.

III. NUTRITIONAL COMPOSITION

The nutritional composition of Azolla has been studied in numerous studies and although the precise numbers vary based on the species, growing conditions and harvest stage, there are a few patterns that are similar. Crude protein content ranges between 19-30 on a dry matter basis, though in controlled situations, it is reported to be as high as 35 (Basak et al., 2002; Shilpashree et al., 2017). This places Azolla in the same category as the many leguminous forages and even higher than most of the grasses utilized in the feeding of animals.

That notwithstanding, protein content is not a sole determinant of the quality of feed. Its usefulness is finally determined by the amino acid profile, especially in non-ruminant diets. Azolla is doing quite well in this respect. The missing lysine is also included in significant quantities, and other necessary amino acids like threonine, leucine, isoleucine, and valine are also reflected (Sanginga & Van Hove, 1989). Methionine is also relatively lower, as is characteristic of vegetarian protein sources. Practically, this implies that Azolla is a better supplement as opposed to an independent source of protein particularly in monogastric animals.

In addition to protein, Azolla is a source of various micronutrients. It is a source of beta-carotene and other carotenoids, which are precursors to vitamin A and pigmentation, especially in poultry. Mineral composition is also prominent. There are amounts of calcium, phosphorus, iron, zinc, and manganese that facilitates supplementary feeding. By way of illustration, the minerals in Azolla caroliniana have been reported as potassium: approximately 3.89, calcium: approximately 1.89, phosphorus: approximately 0.42 and iron: approximately 0.1456, all on a dry matter basis. The values are generally comparable with other nutrient-rich forages, but it can be expected that variation among samples is possible.

The fiber generally is between 9 percent and 16 percent of dry matter. This is moderate and can be generally controlled in ruminants, although it puts a limit on the amount of inclusion in poultry and fish diets. Ether extracts are not very high, averaging between 3 to 5 percent and as a result, its role as an energy source is limited. In the majority of feeding regimes, Azolla is used as a protein and micronutrient supplement rather than a direct energy source (Leterme et al., 2010).

The presence of anti-nutritional factors is one of the factors that make its application challenging. Certain phenolics, trypsin inhibitors and tannins have been detected, especially in fresh material. These may decrease the digestibility of protein and at extreme levels of inclusion, feed consumption. Nonetheless, the magnitude of this issue relies on processing to a great extent. Sun drying, fermentation, or short-duration cooking have been demonstrated to bring these compounds to lower, more acceptable levels, and thus make the material more fit to be fed on.

In general, the Azolla composition allows it to be considered as a supplementary feed ingredient as opposed to a total substitute of the conventional feeds. Its advantages are evident, especially in the protein and micronutrient levels, but with limitations that should be addressed. Two variables that cannot be overlooked between the laboratory analysis and practical use are variability in composition and the requirement of processing.

Nutrients	Percentage Composition
Moisture content	83.84
Crude protein	28.92
Ether extract	6.31
Crude fibre	6.92
Ash	4.81
Nitrogen free extract	31.44

Figure 2. Proximate nutritional composition of *Azolla* on a dry matter basis.

IV. UTILITY IN LIVESTOCK FEEDING

Cattle and Buffalo

The quantity of green fodder is seasonal, especially in dry periods in most tropical production systems. This has been investigated in regards to Azolla as an additional feed to dairy cows and buffalo primarily due to its ability to be grown in the region with relatively low input levels. Trials of feeding in India and other areas have demonstrated most feeding trials by feeding fresh Azolla (approximately 1 to 2 kilograms per animal per day) in combination with a more traditional roughage diet.

The results reported are mostly favourable, but not impressive. Some studies have reported increased yields of milk, though the more reliable impact is a shift in milk composition, with the increase in protein and fat levels when Azolla is used to substitute a portion of concentrate feed (Kumar et al., 2020; Rawat et al., 2015). Partially replacing concentrate feed with Azolla meal has also been demonstrated in controlled trials to keep milk production unchanged while lowering feed costs, which in many cases is more pertinent to small-scale farmers.

The figures of digestibility indicate that Azolla protein is fairly accessible to ruminants, and in vitro estimates usually lie within a range of between 65% and 75%(Parashuramulu et al., 2013). This puts it in an acceptable range of supplementary feeding, but fails to compete with more sophisticated concentrate feeds. In general, all evidence is directed in one way. Azolla is best used as a partial replacement and is lower cost of feed instead of an input that will raise production substantially.

Poultry

More mixed results have been gained through the poultry feeding trials thus making this area a little less clear. The nutritional information of Azolla indicates that it would fare well especially in terms of its protein content and carotenoids. In layer diets, 5-20 percent inclusions of dried Azolla have been linked to positive effects on egg production, eggshell quality and yolk pigmentation (Alalade and Iyayi, 2006). The pigmentation effect is particularly apparent and is practically useful in markets where the darker the yolk colour the better.

Broiler performance on the other hand is not as stable. Other studies have found similar growth rates to soy diets with low inclusion levels, typically to the 10% range. Depression of growth is more prevalent beyond this stage. This is

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closely associated with the content of fiber and the existence of anti-nutritional factors that are left over especially in cases where the material has not been properly processed (Basak et al., 2002).

What comes out of these tests is not a single recommendation but a range. A small amount of the dietary protein sources in poultry can be substituted with properly processed Azolla, but only to an extent. High levels of inclusion are likely to lower performance instead of enhancing it. Middle inclusion with appropriate processing seems to be the most valid in practice.

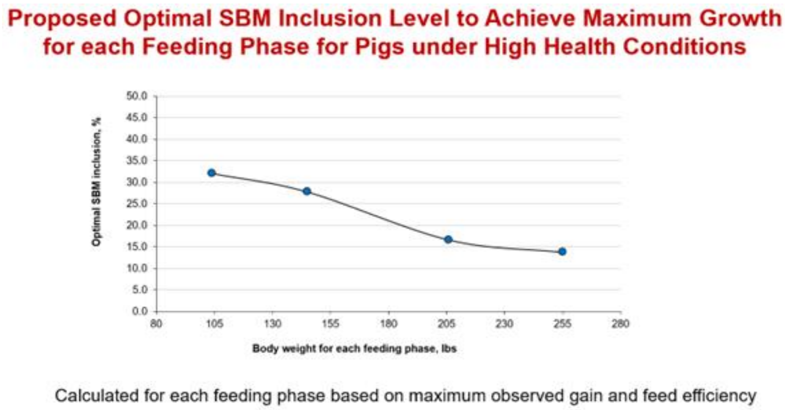

Figure 3. Conceptual relationship between *Azolla* inclusion level and growth performance in animal and fish diets.

Pigs and Small Ruminants

Studies on Azolla in pig feed are smaller yet still suggestive of its possible use as a supplement protein source. Fresh Azolla has been utilized with the normal diets to supplement nitrogen levels and there has been partial replacement of soybean-proteins without significant adverse impacts on growth or health (Becerra et al., 1990). Meanwhile, the data available is not as stable and detailed as that of poultry or cattle research, which complicates the possibility of making definite conclusions.

Azolla is generally better accepted and digested in small ruminants like goats and sheep. Its fiber content is more effectively adapted by the rumen microbial system, and limits some of the constraints observed in monogastric animals. Research has shown increased weight gain in body weight and feed ratio with the addition of Azolla at moderate concentrations generally ranging between 9 percent to 12 percent of the dry matter intake. Under these circumstances comparisons with conventional legume fodder indicate that its feeding value is generally similar.

The trend is fairly evident across these species. Azolla is helpful, though primarily, it is a supplement that cannot replace feeding systems, but can be incorporated into them. It is worth it because it reduces costs and partially replaces, rather than providing uniformly better production results.

V. UTILITY IN AQUACULTURE

It appears simple to use Azolla in aquaculture. Substitute part of fishmeal with rapidly-growing vegetarian protein, save money, and boost sustainability. Practically it is not as clean as that.

Whether fish can eat Azolla is not the major limitation. Many species can. The question lies on the extent to which they will be able to bear before performance starts to drift. The protein content of Azolla is frequently discussed, yet its lower calorie content, fiber, and the remaining anti-nutritional compounds silently impose limitations that are seldom pointed out during the preliminary discussions.

This can be observed when one looks across feeding trials as opposed to individual studies. Moderate inclusion is likely to be effective. Growth is maintained, there is no serious decline in feed ratio, and in some instances there are slight improvements. However, when levels of inclusion increase, scores begin to differ. There are systems that uphold performance. Others have definite decreases. The trend is neither arbitrary, nor even.

Tilapia normally copes with Azolla as compared to most species, which is in line with its wider ability to exploit plant diets. Carp species are more constrained in their responses especially when the inclusion levels go beyond a certain point. Rohu and related species are intermediate and their results are largely dependent on diet formulation and processing. These are not unexpected differences but they do restrict the extent to which results can be generalized.

Processing is not so minor as it may seem. Dried meal and fermented versions of Azolla do not work the same. Poor processing is likely to increase the adverse impacts of fiber and anti-nutritional. This is one of the reasons why the same level of inclusion may lead to various results in different studies.

It is also inclined to concentrate on growth measures only, and this presents an incomplete view. The importance of Azolla in pond systems is not limited to direct feeding. It therefore can absorb surplus nutrients, and help regulate water quality, when grown in fish ponds, or in their surroundings. This is a feature that is frequently considered as a side effect of the feature yet in certain systems it can also be a significant feature. Nonetheless, the method of production and feeding in this manner adds another risk factor. The quality of water is a determinant of feed quality, and the connection is not necessarily regulated in practice.

The evidence, as a whole, is not indicative of an optimal inclusion level. It indicates a range that operates under certain conditions. The majority of systems seem to have a moderate inclusion range without significant performance degradation, though the error margin decreases as the extent of substitution grows. Beyond this range, the results are more unpredictable and species-based, processing-based, and management-based (Datta, 2011).

In this regard, Azolla is more of an adaptable input, as opposed to a dependable substitute. It has the capability of decreasing reliance on traditional feed ingredients, although it does not eliminate reliance completely. This difference is particularly important when the controlled trials are no longer applicable to actual production conditions.

VI. ECONOMIC AND ENVIRONMENTAL BENEFITS

Under good conditions, a small Azolla growing area of approximately 10 square meters can yield approximately 500 to 700 grams of fresh biomass per day. That is humble at a glance. Practically, it is sufficient to counter an apparent fraction of feed expenses in small systems, especially in the case of backyard poultry or a small number of livestock.

Here the majority of discussions cease. Low cost, low land use, high growth. True, all, incomplete.

Azolla has an economic worth not only in its cheap production capabilities but in how it can fit into current farm practices. New biomass is low in dry matter with a range of 5-7%. This implies that huge amounts are to be harvested, transported and fed per day to provide a significant nutritional value. This is feasible in smallholder systems that have access to labor. It becomes very inefficient in a larger or more mechanized operation. This is what allows Azolla to grow easily and complicates it to scale.

Cost cutting is a reality but not absolute. A 10-15 percent reduction in the amount of concentrate food used can reduce the cost of inputs in poultry systems, and the same has been reported in other livestock environments. These savings will however be based on regular production and appropriate incorporation into feeding programs. The advantage is rapidly diminished by disruptions in supply or low-quality biomass (Agnihotri, 2019)).

Azolla is commonly promoted as a perfect solution in terms of the environmental issue. It does not need arable land, fixes atmospheric nitrogen and can be grown in water bodies that otherwise would be lying idle. Its land and water footprint is substantially less than that of conventional crop feeds like soybean. Its usefulness in agriculture does not limit itself to the use of its feeds, with applications of Azolla composts and manure based on green manure also demonstrating positive outcomes on medicinal plant production systems (Agnihotri, 2011; Agnihotri, 2019).They constitute valuable benefits, particularly in resource-intensive environments.

Simultaneously, the environmental argument is even simplified in some cases. The growth of Azolla in wastewater or high-nutrient effluents is often mentioned as a twofold system that generates feed and cleanses wastewater. Technically this is accurate but it creates a reliance on water quality which cannot be overlooked. In case of any contaminant like heavy metals or pathogens, the contaminant may be deposited in the biomass and transferred via the food chain. This risk is manageable in controlled systems. In casual or loosely controlled arrangements, it is an actual issue.

Another scale question that is likely to be in the background is the scale question. It works well in localized, integrated systems in which production and use are tightly coupled. Its benefits are not so obvious in large, industrial feed chains where consistency, storage, and transport are more significant than raw cost of production. Structural benefits still favour conventional feed ingredients in those contexts.

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This does not weaken the case of Azolla but it makes it narrow. Its greatest contribution is in the smallholder and semi-integrated systems where the feed can be produced and consumed in the same cycle. In this context, it also helps to reduce costs as well as recycle nutrients especially when associated with livestock or aquaculture wastes.

In this light Azolla is not a universal solution to feed sustainability. It is a locally effective tool, which works under certain conditions. It is the understanding of the fact that boundary is what enables its benefits to be effectively utilized instead of exaggerated.

VII. LIMITATIONS AND CHALLENGES

These drawbacks of Azolla are usually recognized but not necessarily weighted equally to its benefits. This asymmetry is important, as the majority of the practical challenges arise not what Azolla is, but rather how it reacts in real situations.

Among the more stubborn ones is the existence of anti-nutritional factors. Fresh Azolla has been found to contain tannins, phenolic compounds and trypsin inhibitors and its impact is not trivial. The effect might be insignificant at low levels of inclusion. With higher inclusion, though, declines in palatability and protein utilization are more evident. Much of this can be dealt with by processing, but it adds a new step which is not always consistently used in practice.

Another limitation that is likely to be given less consideration is the low dry matter content of the plant. Fresh Azolla usually has a low dry matter (5%-7%). This is translated to huge amounts required to be processed on a daily basis to provide significant quantities of nutrients. The amount that is needed may soon be impractical when Azolla represents a significant part of feed in the case of a single dairy animal. Drying provides a solution, however time, space and added cost is necessary in certain cases(EI-Sayed, 1992).

Production is further complicated by environmental sensitivity. Growth rates are highly correlated to temperature, light and nutrient availability. Beyond optimum conditions, productivity diminishes drastically. In colder climates or seasonal changes, it becomes challenging to have a steady supply. This variability is usually undervalued when Azolla is offered as a year-round feed option.

Another factor that cannot be overlooked is contamination risk. Azolla is often grown on nutrient-enriched water, such as livestock or aquaculture wastewater. Although this promotes quick expansion, this also opens the chances of the establishment of high metals, pathogens, or any other unwanted substances. When they are in the cultivation medium, they may find their way into the feed chain. This risk has to be handled through monitoring and control mechanisms that are not necessarily present, especially in informal systems.

Limitations in the existing evidence base also exist. A high number of studies are done under controlled conditions with a reasonably small sample. Findings are usually reported in the short-term and the variations in the treatments or dietary combinations complicate comparing them. This leads to varying recommended inclusion levels, in some cases greatly, among studies. This does not nullify the findings but it implies that the conclusions should be applied with care when used beyond experimental environments.

All these limitations do not make Azolla unhelpful, but they set its limits. It is effective when its processing, cultivation, and levels of inclusions are carefully managed. In the absence of that, the same attributes that make it appealing could as well be sources of inconsistency.

VIII. FUTURE PROSPECTS

Possibility does not require starting work on Azolla in the future. The fundamental possibility is already evident. The more pertinent question is whether this potential can be converted to regular use, beyond controlled circumstances.

Strain selection is one of the directions that remains popular. Various species and strains of Azolla differ in protein content, growth rate and environmental tolerances. This variability indicates that it can be improved by means of selection instead of depending on a single and broad-based profile. There are already studies that have demonstrated that the capacity of nitrogen fixation varies greatly among different strains and this in turn impacts on protein accumulation (Okoronkwo et al., 1989). Nonetheless, the transfer of the isolated high-performing strains to stable field performance is an independent issue (Roy et al., 2016).

Another focus of incremental improvements that may have a disproportionate effect is processing. Most of the existing restrictions, especially those of anti-nutritional factors and digestibility, are not natural to the plant as it is but to the way it is utilized. More standardized and reproducible processing procedures may minimize differences in feeding performance. It is not a challenge to find effective techniques, but to make them replicable in various production environments.

The ability to be integrated into circular farming systems is commonly shown as one of the main advantages of Azolla. In addition to livestock and aquaculture, Azolla-based organic compost application in medicinal and horticultural crops may also be part of the future integrated system as proposed by previous investigations on the cultivation of safedmusli and the sarpagandha (Agnihotri and Mohan, 2012a; Agnihotri and Mohan, 2012 b).The reasoning is simple. Waste streams rich in nutrients promote Azolla growth and the biomass obtained is used as feed. This can be used to enhance resource efficiency and waste management in well-managed systems. But such systems require that there is control on inputs especially the water quality to be successful. And without it the very integration which renders the system efficient may be used to create risks (Rathore et al., 2013).

The trend of decreasing the use of fishmeal in aquaculture still opens up room to alternative sources of protein. Azolla can help in this transition especially when it can be added to processed feed formulations and not just used in fresh form. This would enhance storage, handling and consistency. Currently this is more of a guideline rather than an established practice.

Extension and adoption-oriented work also have a part. Reintroduction of Azolla in the livestock and aquaculture setting may be more viable in areas where Azolla has historical familiarity (particularly in rice-based systems), than the introduction of completely new technologies in feeds. The technical demands of cultivation are not high, and regular use remains to be based on the training, demonstration, and localization (Magouz et al.,2020). In the future, stabilizing existing applications is the primary challenge, not finding new applications. Azolla is already in a number of niches. The growth of its use will be based on minimizing variability, enhancing handling and processing, and matching its use to the limitations of actual production systems. Without this it is likely to have a future of limited use to small scale or experimental use, but not on a large scale.

IX. CONCLUSION

Azolla is in a peculiar segment with regard to alternative feed resources. It's a little bit experimental and not really there. There is a significant amount of evidence to support its use, and its use is not even across the board. This disconnect between knowledge and practice constitutes a great deal of its present-day importance.

The common thread here is the same; in livestock and aquaculture systems. Azolla has consistent performance at medium inclusion levels, especially as a supplementary feed to decrease reliance upon more costly feed ingredients. It helps to add protein, micronutrients, and in some instances helps enhance product quality. Meanwhile, its production impact is usually marginal, rather than revolutionary.

The restrictions are no different, either. It's limited in use due to lower dry matter content, variable nutritional content, environmental sensitivity and correct processing. These do not diminish its value, but its ability to be a simple substitute for normal feeds is not optimal in most systems.

As is apparent, allowing the use of Azolla is best used as an integrated intervention rather than a single intervention. It is well suited in smallholder and integrated farming systems where production and use are more closely tied and reducing costs and recycling resources are important as production maximization. It loses its benefits out of these conditions.

Going forward, consistency will be more important than finding new uses. Rather than simply establishing more benefits, more uniform cultivation techniques, improved processing and more similar field data will help increase usage.

So in that sense, Azolla doesn't need redefining. It needs to have the boundaries set up better. Where it works and where it doesn't is what will be the deciding factor on whether it continues to be a niche technology or a mainstay technology for management feeding.

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