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The Prospect of Duckweed in Pig Nutrition: A Review

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Abstract

The demand for meat and its products has always exceeded supply. To match the ever-increasing demand, more animal products should be produced. Pig production could be a livestock enterprise of choice since pigs grow rapidly and are ready for marketing in a short time. With the escalating costs of feeds, it is worthwhile to use cheaper alternatives such as duckweed. Duckweed has a potential for full utilisation in the nutrition of the different classes of pigs. Researches have been conducted with different classes of pigs. The aim of this review is to consolidate work that has been conducted on duckweed in the nutrition of all classes of pigs, giving recommendations where necessary. In addition, areas requiring research have also been highlighted.

Keywords: biomass, digestibility, *Limne*, piglets

1. Introduction

Demand for animal products, especially in developing countries, is likely to rise significantly as a result of population growth, urbanization, and rising incomes in the face of relatively low levels of consumption at present (Nonhebel & Kastner, 2011). Consequently, changing climatic conditions are envisaged to lead to veld and crop reduction culminating to in reduction in quantity and quality of meat and meat products (Nardone et al., 2010). It is under such a situation that some invaluable plants are required to feed livestock. Duckweed is one appropriate candidate of such plants. It is an aquatic monocotyledonous plant that is adapted to a wide range of ecological conditions and this makes it to be globally distributed (Landolt, 1986; Leng et al., 1995). Albeit, the plant can be scarce in areas with extremes of precipitation, as well as where temperatures can be as low as 0 ºC, it is highly productive. It grows in thick blanket-like mats on still, nutrient-rich, fresh and slightly brackish waters thus the plant serves as nutrient pump; reducing eutrophication and providing oxygen (Azeez & Sabbar, 2012; Singh et al., 2012). It can also be used to restore derelict ponds (Lottermoser & Ashley, 2011). Furthermore, because of its favourable nutritional profile and its relatively easy propagation, it is widely used to feed livestock such as pigs (Hassan & Edwards, 1992).

Pigs have a high reproductive rate, having at least 2½ farrowings per annum (Chiba, 2010). They are easy to manage and have a fast growth rate although they have a voracious appetite and would need a lot of water for good sanitation purposes (Chiba, 2010). Combining pig productivity and use of duckweed for feeding purposes will allow this animal species to provide the much needed animal protein through meat and meat products to many nations. It should, however, be acknowledged that this livestock species has limited acceptance but it still serves well the purposes of providing nutritious animal protein to those who accept its white meat and meat products (Chiba, 2010). It is, therefore, pertinent to conduct studies that deal with alternative feed sources, such as the duckweed, in a way to enhance the productivity of pigs. The simplicity of the establishment of duckweed, its excellent growth habit, minimal carbon footprint, less land use competition with food crops coupled with other advantages could allow the plant to be deployed in different localities of the world.

2. The Characteristics of Duckweed

Duckweed belongs to the botanical family Lemnaceae (which originated from the Greek word “*Limne*” meaning pond). Duckweed is near-ubiquitous (Leng et al., 1995) but absent in the Polar Regions and deserts, easy to establish and can be produced with minimum costs (Armstrong, 2011). It is a small (1 to 15 mm) floating monocotyledonous aquatic plant that consists of five genera which are *Lemna, Spirodera, Wolfia, Wolfiella* and *Landoltia* (Table 1: Rusoff et al., 1980; Armstrong, 2011) that comprise about 40 species (Skillicorn et al., 1993;

Les et al., 2002). The most commonly available species belong to the three genera *Lemna*, *Spirodela* and *Wolffia*. *Lemna* is the largest genera while *Wolffiella* species scarcely exist. Duckweed has the distinction of being the smallest angiosperm in the world (Zhao et al., 2012). The plant is identified by the presence of only one root for each small green ovoid frond. Duckweed is capable of both sexual and asexual reproduction, overwintering by producing seeds or turions (Les et al., 2002).

Table 1. Classification of selected species of the family Lemnaceae (Source: Armstrong, 2011)

Lemna	***Spirodela***	***Wolffia***	***Wolffiela***	***Landoltia***
L. gibba	*S. biperforata*	*W. microsopia*	*W. oblonga*	*L. punctata*
L. japonica	*S. intemediata*	*W. australiana*	*W. rotunda*	
L. minor	*S. oligorrhiza*	*W. neglecta*	*W.caudate*	
	S. polyrhiza	*W. Columbiana*		
	S. punctata			

The plant preferentially takes up ammonium, while secreting hydrogen ions, thus creating a reduced-pH environment at the water surface. This low-pH environment is of importance since it reduces ammonia emission to the atmosphere (Chaiprapat et al., 2003) in the context of global warming. Duckweed has a longer growing period than most other plants. In some areas with warm climates, duckweed can grow in all seasons. In addition, the plant has a greater rate of nutrient uptake when compared to other aquatic macrophytes. The growth pattern of duckweed follows a logarithmic fashion (Oron et al., 1986; Wang et al., 2014) doubling in 2 to 7 days (Ge et al., 2012; Okomoda et al., 2012). The yields for the plant can vary from 7.9 (Amali et al., 1999) up to even 55 tonnes (Oron, 1994) per annum per hectare depending on the species, climatic conditions, available surface area, amount of nutrients and management (Ge et al., 2012). Duckweed requires quiescent or slow flowing water. It forms dense floating mats in atrophic ditches and ponds (Driever et al., 2005) containing brackish water. Such characteristics of the duckweed together with its capability to adapt to a wide range of agro-ecological zones, makes it better withstand the effects of climate change compared with other crops and plant species. Besides knowledge on the characteristics aforementioned, it is crucial to have knowledge on the nutritive value of this plant.

3. The Nutritive Value of Duckweed

The nutrient content of duckweed is more related to the medium in which the plant grows than on the duckweed species *per se* (Hassan & Edwards, 1992). The duckweed plant has no central root system so absorption of nutrients is through the whole plant resulting in direct assimilation of organic molecules through the entire plant. The high growth rate is, therefore, due to the non-structural but metabolically active tissue (Ice & Couch, 1987).

The water content of duckweed (92 to 95%) (Yilmaz et al., 1994; Samnang, 1999; Negesse et al., 2009) has an effect on the cost of handling, transportation and drying, especially if the duckweed is to be moved from the site of production. The drying might be accomplished through sun drying (Akter et al., 2011) oven drying (Haustein et al., 1994), par-boiling, pressing or forced air drying (Effiong & Sanni, 2009). Although it is slow, air drying is the most ideal. Furthermore, value addition to the harvested duckweed plant is paramount. More so, sundried duckweed has been observed in storage for 13 years without any sign of fungal growth and nutrient loss (Mbagwu, 2001) and it has been attributed to the presence of a wax coat on the upper surface of plants which acts as a barrier for fungal growth.

Duckweed has a high protein content of 9 to 20% in nutrient poor media and 24 to 41% in nutrient rich media (Ge et al., 2012; Mwale & Rumosa Gwaze, 2013). The nitrogen levels in the healthy plant are comparable to those in commercial fertilizers; thus, the biomass could also be utilized as a fertilizer supplement (Mbagwu & Adeniji, 1988). Its protein has a well balanced amino acid profile. As shown in Table 2, duckweed is generally rich in leucine, threonine, valine, phenylalanine and lysine (Rusoff et al., 1980). The methionine and lysine levels, which are essential amino acids, are higher than the levels found in most plant proteins. According to Journey et al. (1991), the concentration levels of methionine and lysine closely resemble that of animal protein. In addition, duckweed contains minerals and vitamins that are essential for the normal functioning of the body (Men et al., 1996). The lipid content is lower (1.8 to 2.5%) in duckweed species grown in nutrient-poor water, and generally higher and varying between 3 and 7% for duckweed grown in nutrient rich water (Kesaano, 2011).

Effiong and Sanni (2009) established a decreased mold infestation in duckweed (*Lemna pausciscostata*) and incorporated pelleted fish feeds also highlights its value addition potential with great application in feed storage. Generally, duckweed has low fibre content (5%) (Kesaano, 2011); however, higher figures have been reported for duckweed plants growing in nutrient rich water. Duckweed can tolerate high nutrient stress and appears to be more resistant to pests and diseases than other aquatic plants (Khang, 2003). Regardless of the attributes that the plant exhibits, it is affected by some environmental conditions.

Table 2. The amino acid composition of various duckweed species (Rusoff et al., 1980)

Amino acid (%)	**Plant species**			
	L. gibba	***S. polyrhiza***	***S. punctata***	***Wolffia Columbiana***
Threonine	3.2	3.45	3.31	2.55
Serine	2.61	2.80	2.83	2.28
Proline	2.93	3.28	2.95	2.41
Glycine	3.79	3.95	3.93	2.04
Alanine	4.59	4.48	4.79	3.75
Valine	4.96	4.4	4.71	3.49
Methionine	0.83	0.83	1.07	0.87
Leucine	7.15	6.85	6.88	5.83
Lysine	4.13	4.3	4.26	3.37

4. Environmental Factors that Influence the Growth of Duckweed

Despite the resilience duckweed exhibits, the plant is affected by several environmental factors. The plant is unable to survive in unsheltered water bodies and fast moving water (greater than 0.3m/sec) (Leng et al., 1995). Several studies indicated that wind or movement lead to reduced growth (Edwards et al., 1992; Willet, 2005). At pHs near 9.3, phosphorus will precipitate with calcium and this can result in mineral deficiency leading to slow growth of the plant. Duckweed prefers ammonium (NH_4) to ammonia (NH_3), and growth decreases when NH_3 levels exceed the levels for NH_4 or when pH exceeds 9.25 (Culley et al., 1981; Al-Nozaily, 2001). The "desirable" exponential growth can quickly lead to aging and decomposition, thereby requiring efficient harvesting. Alaerts et al. (1996) harvested approximately 4.5 mg (dry)/m^2·day, Willet (2005) harvested 50% after the biomass had doubled the starting density, while Edwards et al. (1992) harvested every 2-15 days depending on whether it was the dry (warm) or wet (cool) season. Growth rate decreases as biomass accumulates to the point that fronds start overlapping each other (Al-Nozaily, 2001); and this decreases with nutrient depletion (Chaiprapat et al., 2005). Culley et al. (1981) reported that up to 50% of the nitrogen and phosphorus in the biomass gets released with an interval of more than 20 days between harvests. Continuous harvesting prevents overcrowding, biomass death, and release of nutrients back into the water system (Al-Nozaily, 2001; Nhapi, 2004). However, availability of labour for harvesting the plant might be a limiting factor.

Water temperature has also been proven to have an effect on growth of duckweed. Biomass starts depleting at temperatures below 17 °C, and completely disappeared below 5 °C (Zimmo et al., 2002). Growth rate also decreased due to competition between species. *Wolffia* out-competed *Lemna* species in terms of growth rate but however due to *Wolffia*'s smaller size in nature compared to *Lemna* species *Wolffia* yielded less biomass (Edwards, 2005). Aphids and fungi living atop duckweed mats in some instances were associated with reduced growth as well (Zimmo et al., 2004). Besides the nutritional profile of the plant, its economic importance is also fundamental in the plant's analysis.

5. The Economic Importance of Duckweed

Duckweed has widely been recommended as an appropriate weed for waste water treatment due to its ability to hyper accumulate various nutrients and toxic metals (Zimmo et al., 2004; Kaur et al., 2010; Azeez & Sabbar, 2012; Bouali et al., 2012; Khellaf & Zerdaoui, 2012; Mohedano et al., 2012; Singh et al., 2012). The presence of some tannins and phytic acid in duckweed meal has earned this weed a place in the preservation of feed against spoilage by fungi (Bairagi et al., 2002; Effiong & Sanni, 2009). Duckweed has also proved that it is a novel source for bio-ethanol production (Xu et al., 2011; Chen et al., 2012; Ge et al., 2012; Muradov et al., 2014). In addition, duckweed (the *Wolffia* species) has been used as a vegetable in Indochinese Peninsular for many generations (Bhanthumnavin & Mcgarry, 1971). Moreover, duckweed has been used in the production of insulin, pharmaceuticals and other valuable compounds. Of great importance to the farmer and animal nutritionist is the potential of duckweed to provide livestock with feed and that it subsequently has been used in feeding several livestock species (Ahammed et al., 2000; Khandaker et al., 2007; Saroeun et al., 2010). This review, however, focuses on the importance of this plant in pig nutrition.

6. Use of Duckweed in Pig Nutrition

Pigs lack the ability to synthesize lysine and methionine, yet these amino acids are essential for metabolism in livestock (McDonald et al., 2010). These amino acids can be obtained from conventional sources. It is the cost, however, that is deterrent to the full utilisation of such sources. It is, therefore, imperative to employ cheaper sources of the required amino acids. In this instance, duckweed contains a wide array of amino acids such as lysine and methionine (Men et al., 1997) which are essential to the nutrition of pigs. Limited research has been conducted on the use of duckweed as feed for pigs (Leng et al., 1995; Men et al., 1996; Rodriguez & Preston, 1996; 1997; Nguyen Van Lai, 1998; Gutierrez et al., 2001; Dung et al., 2002; Ly et al., 2002). Apart from the favourable amino acid composition, other characteristics such as enrichment in mineral content, Vitamin A and dry matter yield make duckweed plants appropriate ingredients for pig feeds meant for different classes of pigs.

6.1 Use of Duckweed in Diets Meant for Piglets

Since piglets grow fast, it is imperative to supply them with a feed that contains nutrients that are able to support such a fast growth rate. Moss (1999) placed piglets (from 0 to 10 days old) on 4 diets; 44% CP soyabean meal, 20% replacement of soyabean meal with duckweed, 40% replacement of soyabean meal with duckweed and 60% replacement of soyabean meal with duckweed as the supplementary protein. The author observed a significant difference between the 40 and the 60% duckweed diets on one hand and the control diets on the other hand for average daily gain. No difference existed between the control and the diet that contained duckweed at an inclusion level of 20%. The poorest feed efficiency was observed for the 60% treatment whilst the highest was observed for the 40% duckweed treatment. This could be attributed to the fact that, depending on the nutritional profile of the duckweed species that was used, at low inclusion levels, the effects of duckweed is insignificant while at higher (60%) levels anti-nutritional factors could be hampering the efficient use of duckweed. However, research on the anti-nutritional factors of duckweed species that are predominantly used as pig feed is paramount to substantiate this assertion. In addition, evaluation of the toxicity levels of these anti-nutritional factors is crucial. The inclusion level of 40% duckweed seems ideal in countering the adverse effects associated with the use of duckweed thereby paving way for the efficient utilisation of the plant. More research should, however, be conducted on piglets of different genotypes using different varieties of duckweed before conclusive results are recommended.

Nguyen van Lai (1998) indicated that indigenous piglets found duckweed to be palatable compared to the low intake by Large White piglets. The study proved that Mong Cai (indigenous pigs of Vietnam origin) piglets grew faster than Large White piglets (average daily gain of 200 g/d versus 87 g/d). This was attributed to a higher protein intake by Mong Cai piglets (48.2 g/d) compared to intake by Large White piglets (27.9 g/d). The higher growth rate in the Mong Cai piglets was attributed to the higher protein intake which meant higher proportion of duckweed intake compared to that by Large White pigs. The study showed that there was some interaction between nutrition and genotype. These findings indicated that apart from the factors of palatability and acceptability of feed by the piglets, their duckweed intake and hence growth and development was also influenced by their genetic make-up. It is essential then to conduct studies that determine the effects of genetics on the growth and performance of piglets of various genotypes fed on duckweed. This is crucial in the determination of the ideal inclusion level for each genotype for appreciable growth and development of piglets to porker stage. Studies should also include the effect of the different duckweed species on different piglet genotypes.

Rodriguez and Preston (1996) reported that when fresh duckweed (CP of 30%) was fed to Mong Cai and Large White piglets as the only supplement to sugar cane juice, the apparent digestibility of the diet DM was 90 and 67% for the two breeds, respectively. Protein digestibility at this level of duckweed was 73%. Nguyen van Lai and Rodriguez (1998) reported that piglets reflected a higher apparent digestibility of N of the diet when duckweed was the protein source (67.3%) as compared with cassava leaves (58.9%) reflecting differences in the concentration of the cell wall material as the small floating water plant has much less need to built-in structural support. Du Thang Hang (1998) further confirmed this when the author indicated that the crude fibre concentration in the dry matter of ensiled cassava leaves was twice as high as in duckweed (15.3 versus 8.3%). The authors attributed the higher digestibility of duckweed-based diet to the lower cell wall material of duckweed compared to that of the cassava leaves. The high digestibility of duckweed material was also confirmed by Rodriguez and Preston (1996) who reported that N balance increased linearly with increasing duckweed in the diet for pigs. The authors partly credited that to an appropriate amino acid balance of the duckweed protein (Hillman & Culley, 1978). Not only is duckweed crucial in piglets diets but in mature pigs as well.

6.2 Use of Duckweed in Diets Meant for Growing and Mature Pigs

Duckweed has not only been used in piglet nutrition but for mature pigs as well. A high DM digestibility (75%) for fresh *Lemna* leaves has been reported by Nguyen van Lai and Preston (2001). Moss (1999) indicated that with weaners, duckweed showed digestibility of nutrients: DM (84 and 82% for 40 and 60% duckweed, respectively), CP (82 and 80% for the 40 and 60% duckweed), and P (69 and 63% for 40 and 60% duckweed). Such high digestibility figures are suitable for feed that is meant for growing pigs. It is important to pay attention to the nutritional profile of the duckweed to be used as feed for the pigs. Haustein et al. (1992) proved that using low protein/high fibre duckweed at an inclusion level of 0, 5 and 10% resulted in a reduction in live-weight of pigs as the level of inclusion of duckweed increased (Table 3). This is because pigs, as monogastric animals, they are not efficient in digesting fibre compared with ruminant animals. Research by Haustein et al. (1992) with a low protein /high fibre duckweed meal (23% N and 7.5% fibre DM) showed that replacing conventional protein sources in diets for growing pigs reduced production and increased feed required per unit growth. This indicates that the *Lemna* meal used may have been relatively mature since it was low in protein and high in fibre. The authors also speculated that there might have been a high level of oxalate in the duckweed or accumulation of heavy metals or toxins since the duckweed was harvested from a lake. The study indicated that good performance will not be realised if poor quality duckweed is used. It, therefore, implies that it is imperative to consider the source and nutritional profile of the duckweed and to analyse for any potential hazardous substances in the duckweed if anticipated before feeding the pigs.

Van et al. (1996) proved that a diet of ensiled cassava root with 25% of the protein provided by fresh duckweed can totally replace rice by-products and protein meal in diets for fattening pigs with no reduction in growth rate or conversion rate and with leaner carcasses. This is crucial in mitigating the effects of pigs competing with humans for grain crops such as maize and rice. Other findings have indicated that fresh duckweed used to replace all the soyabean for Mong Cai pigs fed ensiled cassava roots or sugar cane juice (Du et al., 1997; Nguyen van Lai & Rodriguez, 1998) led to improved performance. The improved performance of pigs fed duckweed was attributed to the high ileal apparent digestibility of organic matter (81.7%), crude protein (73.2%) and ether extract (59.8%) of the plant (Du et al., 2009).

Table 3. The live-weight of pigs with *Lemna* at different inclusion levels (Haustein et al., 1992)

Time (d)	Level of *Lemna* meal in diet (%)		
	0	5	10
	------------------------Live-weight in kg---------------------		
1	6.9	6.8	6.8
10	9.4	9.2	9.1
20	13.4	11.9	11.2
30	17.4	14.6	13.2
40	23.8	19.5	17.2
Live-weight gain (g/d)	423	320	260

In a study by Rodriguez and Preston (1996) the authors fed unconventional diets containing duckweed to three pig genotypes (Mong Cai, Large White and Mong Cai X LW), Mong Cai pigs and the crosses utilised the duckweed efficiently. According to these authors as the proportion of the N intake for duckweed increased, 50% of the N in duckweed consumed was stored in the tissues. These authors suggested that the protein of the duckweed plants is readily utilised and has a higher biological value than meals such as those prepared from cassava leaves which are often fed to pigs in the developing countries. The study indicated that duckweed could be well utilised by mature, native pigs. Prior to the establishment of full utilisation of this plant, more research should be conducted using different breeds and different classes such as boars and pregnant sows.

In their study, Rodriguez and Preston (1996) reported that the N retained as a percentage of N intake (41%) and of digested N (57%) was superior to those reported for cassava meal (1.2% for N intake and -0.31% of digested

N). In their comparison of acceptance of duckweed by Large White and Mong Cai pigs, Rodriguez and Preston (1996) reported that Large White pigs could only consume the duckweed plant when sugar cane had been added to the plant because they had not been exposed to duckweed earlier in life whilst Mong Cai pigs had no problems in consuming the duckweed material without sugar cane added to it. A study is required where breeds are exposed to the same feed earlier in life to ascertain if there are pig breed effects on acceptance of duckweed as feed. In their findings, Gutierrez et al. (2001) reported that although pigs fed duckweed consumed more feed and grew faster, the duckweed diet was not digested as efficiently as sorghum/soyabean meal control diet when duckweed was included at 10% of the diet. The authors attributed this to the high level of fibre (2.3%) in the duckweed that was used. It implies that the nutritional profile of duckweed should be established and necessary adjustments be made before using it. Research findings have also indicated the importance of duckweed in the improvement of reproductive parameters in pigs.

6.3 Duckweed as Feed for Breeding Pigs

Since breeding pigs have a higher requirement of nutrients than other classes it is mandatory that a nutrient dense diet be supplied. However, such diets are costly. This, therefore, calls for utilisation of feeds such as duckweed. Van et al. (1996) reported a reduction in fat deposition, an improved reproductive performance and decreased economic costs when duckweed was included in diets meant for breeding pigs. This was confirmed by Men et al. (1996) who reported that replacement of 50% of a conventional protein source (fish meal and soyabean meal) with fresh duckweed in the diets of breeding sows led to larger litter sizes, improved rates of survival and heavier litter weights. A study was conducted by Men et al. (1997) where pregnant sows were placed on four protein supplements; 50% fish meal, 50% soyabean meal (at a rate of 150 g or 200 g/d for treatments without duckweed) and, 75 and 100 g/d for the treatments with duckweed. Findings from this study indicated no significant difference between diets with and those without duckweed on litter size at birth (8.81 for those with duckweed and 7.44 for those without duckweed), litter size at 21 d (7.56 versus 5.94) and litter size at 42 day (7.56 for those with duckweed and 5.81 for those without duckweed). However, for the same experiment, the litter weight at birth was higher for those fed duckweed (8.23 kg) compared to those that had access to feed that did not have duckweed (6.7 kg). With no difference in litter size between pigs fed duckweed and those fed diets that did not contain duckweed and a higher litter weight for duckweed, it is worthwhile using duckweed as feed for breeding pigs. These authors concluded that replacing half the conventional protein sources (soyabean and fish meal) with fresh duckweed can improve the reproductive performance of sows. They attributed the improved performance to a wide spectrum of amino acids and a high concentration of major and minor minerals, carotene and other pigments such as xanthophylls (Men et al., 1997). With the low cost invested in establishing and harvesting duckweed compared to purchase or formulation of the conventional diets, it therefore is worthwhile using duckweed.

7. Further Research

The simplicity of the establishment of duckweed, its excellent growth habit, minimal carbon footprint, less land use competition with food crops coupled with its other advantages should secure duckweed's deployment in different localities of the world (Zhao et al., 2012). It is important to develop a system to use the freshly harvested duckweed on pigs in liquid form in the grower finisher unit. Other forms of duckweed for other livestock classes merit investigation. One form which might be investigated is the use of fresh duckweed as this might go a long way in reducing drying, transportation and storage costs.

Duckweed has been postulated by Eid et al. (1992) and Marten et al. (1996) as a plant with insecticidal properties against the larval stages of mosquitoes. This is another area that requires investigation because if the insecticidal properties are sufficient to control mosquito populations, duckweed will have a positive effect on the health of people residing in mosquito infested areas, especially in those areas where conventional methods of controlling mosquitoes are not feasible. Concerted efforts in research will lead to a renaissance of this excellent novel plant which is highly likely to have a positive impact in sustainable development. Institutions such as the Chengdu institute of Biology (CIB), a Chinese Academy of Science, should be applauded for the effort they are exerting towards research on duckweed i.e. 30 researchers have been tasked to study various aspects relating to duckweed.

8. Practical Considerations

Integrated farming could be advocated for wherein for instance pig waste is used to fertilise duckweed fields and gardens. Such integrated systems may include use of pig production excreta to fertilise ponds where duckweed and fish are, duckweed harvested and fed to pigs or any other livestock species. This paves way for possibilities such as using dairy excreta to fertilise duckweed which is then fed to chickens and pigs. Such integrated systems are aimed at reducing (or even preventing) loss of nutrients from a farming system (Preston & Murguetio, 1992). However, cross contamination and hence diseases manifestation should be guarded against.

Most of the village ponds are constructed without proper planning in terms of location, layout and drainage system. Ponds located in the middle of the inhabited area of the village are difficult to drain and have little scope of alterations required for developing duckweed based bio-remediation models. However, ponds at the outskirts of the village are easy to manage as their nutrient rich water can be utilized for irrigating the adjoining agricultural fields. Hence, for full scale commercial utilization of duckweed based bio-remediation models, construction of village ponds is required to be well planned with respect to location, layout and drainage facility. State governments should be encouraged to promote duckweed based bio-remediating models for village ponds through educating people and introducing some rural welfare schemes integrated with village ponds for employment and income generation purposes.

9. Conclusion

The duckweed plant is of paramount importance as a feed source for pigs. This serves to meet the demand for meat and meat products to the ever-increasing human populace. The plant has several attributes that include easy establishment, adaptation to a wide range of agro-ecological zones, minimal carbon footprint and high in nutrient composition thereby making it ideal for feeding pigs at various stages of growth. Advocating for the use of duckweed as feed for pigs is critical; however, studies need to be conducted to verify the ideal duckweed species for various genotypes of pigs. Potential of feeding fresh duckweed and testing for the presence of harmful substances before feeding the pigs is crucial.

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