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Review

Characteristics of duckweed and its potential as feed source for chickens reared for meat production: A review

Marizvikuru Mwale[1]* and Francisca Rumosa Gwaze[2]

[1]Institute for Rural Development, University of Venda, Private Bag X5050, Thohoyandou 0950, South Africa.
[2]Lovedale Public Further Education and Training (PFET) College, Private Bag X1303, Alice 5700, South Africa.

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With the high cost of the conventional protein required in producing meat and its products to meet demand by the ever-increasing population, it is imperative that other cheaper alternatives be explored. One such protein source is duckweed. This paper focuses on the attributes that duckweed has which make it a special contender as a protein source for chickens. The paper also focuses on the challenges associated with the use of this plant as an ingredient in chicken feeds. In addition, discussion on other researches that have been conducted regarding using the plant in feeding chickens is provided. Furthermore, the manuscript highlights areas that researchers need to focus on before duckweed can be widely accepted as a feed source or feed ingredient. Researchers seem to agree that in the growers and finisher stage contribution from duckweed as protein should not exceed 6%. More research, however, is required, probably per duckweed specie, to determine the inclusion levels that can be adopted for the starter diets for meat producing chickens.

Key words: Animal feed resource, carcass quality, chickens, duckweed plant, growth performance, inclusion level.

INTRODUCTION

With the world population expected to increase from 6.7 billion in 2006 to over 9 billion (with 1.7 billion from Sub-Saharan Africa) by 2050 (Anonymous, 1997; UN Population Division, 2007), the demand for meat and meat products to match the ever increasing population will also escalate. Regarding that the feed resource-base for livestock is shrinking and that the cost of protein to feed non-ruminant animals has become unaffordable (Teguia and Fon Fru, 2007), it is imperative that other protein sources which are cheap and easy to establish be explored. In this regard, duckweed has a potential to address the feed shortage problem by reducing competition between chickens and human beings. Therefore, recovering this valuable nutrient resource and recycling it makes sense both ecologically and economically (Ansal et al., 2010). Generally duckweed is suitable for both human and animal consumption and is rich in invaluable nutrients (Landolt and Kandeler, 1987). There are about 40 species of duckweed plant species worldwide and the major ones are of the genus *Lemna, Wolffia, Wolffiella* and *Spirodella* (Les et al., 2002). The plant is rich in both macro and micro-elements such as

*Corresponding author. Email: mukudzeishe@yahoo.com. Tel: +27 15 962 8681. Fax: +27 15 962 8859.

calcium and chlorine and has a protein content that ranges between 6.8 and 45.0% DM (Landolt and Kandeler, 1987). The successful establishment of this plant requires an understanding of its environmental requirements.

ENVIRONMENTAL REQUIREMENTS OF DUCKWEED PLANTS

Duckweed species are found throughout the world (Rusoff et al., 1980; Landolt and Kandeler, 1987; Xu, 2011) except waterless deserts and permanently frozen areas (Leng et al., 1995), with most species inhabiting the tropical and subtropical areas (Greenway et al., 2007). Duckweed plants are small, green, fragile freshwater plants with a frond that is few centimeters wide and a short root which is usually less than 1 cm long (Becerra et al., 1995; Ahammad et al., 2003; Olorunfemi et al., 2006). If their nutritional and environmental requirements are met, duckweed plants grow very fast and can flourish for long (Iqbal, 1999; Al-Nozaily et al., 2000; Caicedo et al., 2000; Cheng et al., 2002; Cayuela et al., 2007; Lasfar et al., 2007). Duckweed plants can easily be established since they have the ability to reinvigorate when blown by wind to nutrient-rich sites. Luxurious growth often occurs through active extraction of nutrients in sheltered small ponds, ditches or swamps where there are rich sources of nutrients, making the plant highly nutritious (Willett, 2005; Khellaf and Zerdaoui, 2010). Such characteristics have made the duckweed a useful plant in various ways.

USES OF DUCKWEED PLANTS

Duckweed plants are mainly used to reduce chemical load of facultative sewage ponds during waste water treatment (Vajpayee et al., 1995; Willett, 2005; El-Shafai et al., 2006; Shi et al., 2010; Bouali et al., 2012; Nayyef and Sabbar, 2012; Singh et al., 2012). The potential use of duckweed in the control of fungal growth in stored feed has also been established (Effiong and Sanni, 2009). In addition, preliminary research has indicated that duckweed plants may be used to produce ethanol (Cheng and Stomp, 2009). The plant's greatest potential, however, lies in its ability to produce large protein-rich biomass which can be used to feed livestock. It, therefore, implies that duckweed can reduce the problem of farmland scarcity for the production of animal feeds. Several studies have been conducted to establish the suitability of this plant in feeding different species of livestock (Haustein et al., 1994; Nolan et al., 1997; Samnang 1999; Men et al., 2001a; Ngamsaeng et al., 2004; Ansal et al., 2010; Chantiratikul et al., 2010). It is important, however, to note that some challenges might be encountered when using duckweed.

CHALLENGES ASSOCIATED WITH ESTABLISHMENT AND USE OF DUCKWEED PLANTS

Although the fast growth rate of duckweed is desirable, it is important to comprehend that once the plant has formed a mat, the body of the water is covered resulting in the limiting of further growth of the plant. This calls for continuous harvesting in a situation where labour might be limiting. In addition, although the nutritional profile of duckweed has given it a place in the nutrition of livestock, tryptophane and methionine exist in minute quantities (0.3 to 3% of the total protein) (Rusoff et al., 1980; Landesman et al., 2001; Men et al., 2001b) thereby requiring supplementation when the plant is used. Moreso, the different types of duckweed species have variant nutritional profile and anti-nutritional factors also depending on the growth media. Linked to this, duckweed species such as *Spirodella* and *Lemna* have large quantities of oxalic acid and, therefore their intake by chickens might be limited because of the off taste (Landolt and Kandeler, 1987; Goopy and Murray, 2003). A phytate, condensed tannins and total phenolics level of 3.2, 0.2 and 28%, respectively have been reported for the duckweed plant used by Negesse et al. (2009). Elevated levels of calcium in the medium in which the duckweed is grown favours the formation of calcium oxalate. This undesirable situation can be countered by placing the duckweed in a low-calcium medium for a relatively short period (Franceschi, 1989).

Farmers need to be careful when feeding livestock using duckweed since its nutrient composition differs from one species to the other. Duckweed species of high protein content should be utilized since low protein quality duckweed impacts are negative on the performance of livestock. Furthermore, since duckweed species, such as *Lemna minor,* can readily take up heavy metals such as cadmium, selenium and copper (Zayed et al., 1998), it is important to monitor these metals in the waste water used as the medium of growth for the plants. The high water content (92 to 96 %) of the duckweed plant (Pedraza et al., 1996; Khanum et al., 2005) translates to high costs of drying the plant. It is crucial to note that the metabolism of the plant can come to a halt if the temperatures are low. This entails that farmers who intend to establish duckweed plants should not be surprised when growth becomes minimal under such conditions. Apart from such challenges that can be addressed relatively easily, there are dangers that are associated with the growing of duckweed.

People who are at high risk of pathogens emanating from the waste water are the pond workers, those who

Table 1. Nutritive value of duckweed.

DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	Reference
3.3	36	4.5	10.7	8.5	Pedraza et al. (1996)
4.5	26.3	3.2	11	15.9	Becerra et al. (1995)
4.7	38.6	8.6	18.7	19.0	Men et al. (1995)
-	39.4	9.9	2.8	4.1	Chara et al., (1999)
-	38.1	11.4	2.7	6.0	Chara et al., (1999)
8.0	37.7	3.3	8.7	3.8	Du Thanh Hang et al. (2009)
-	38.8	3.8	13.2	16.0	Tavares et al. (2008)
-	45.0	4.0	9.0	14.0	Leng et al. (1995)
-	30.5	2.0	17.0	9.5	Ansal and Dhawan (2007)
-	20.8	5.0	10.0	25.0	Kalita et al. (2008)
-	38.0	3.0	16.17	14.6	Tavares et al. (2010)
4.6	25.2	4.7	9.4	14.1	Rusoff et al. (1980)
4.8	36.5	14.1	11.0	17.1	Rusoff et al. (1980)
7.9	40.2	7.9	12.3	14.0	Khanum et al. (2005)
7.0	39.1	7.7	12.3	14.7	Khanum et al. (2005)
6.7	27.4	4.2	10.0	12.3	Hlophe and Moyo (2011)

CF: Crude fat, CP: Crude protein, DM: Dry matter, EE: Ether extract.

reside near the pond and those who will consume the livestock that will be fed on such duckweed. To reduce the risk of infection by pathogens, the pond workers should wear protective clothing such as overalls, boots and gloves when working in the pond. In addition, the pond design should allow the workers to work from an embankment, so that they do not get into the pond. Furthermore, workers can use floating platforms made from bamboo poles or boats for harvesting. Those who live near the pond, especially children, must be barred from playing or swimming in the pond. For those that might contract the infection from the livestock fed such duckweed, it will be worthwhile to avoid consuming the intestines, washing the meat thoroughly using safe water and cooking it thoroughly (Goopy and Murray, 2003). It also is crucial to conduct workshops to educate concerned people about the dangers associated with improper conduct pertaining to farming with duckweed. This enables the farmers to enjoy the full benefit of the nutritive value of duckweed.

NUTRITIVE VALUE OF DUCKWEED

The potential of using duckweed as a feed for chickens is based on the high protein content and fast accumulation of biomass of this plant compared to other terrestrial plants. The high nutritive value of duckweed emanates from the non-structural metabolically active makeup of the plant. Table 1 shows the nutritional profile reported by several authors as they investigated the potential of duckweed as a feed for livestock. The minute dry matter yield (Table 1), however, is compensated for by the high growth rate of the plant whilst the low crude fibre makes the plant to be easily digested by chickens. Pedraza et al. (1996) reported a mineral content of 8.5% of the dry matter whilst Becerra et al. (1995) established a higher ash content in duckweed compared to that of boiled soyabean (15.9% versus 5.1%). Men et al. (1996) reported even higher ash content in duckweed (19%) compared to roasted soyabean (5.6%).

A phosphorus content of 0.5% of the dry matter content of the plant has been reported by several authors (Becerra et al., 1995; Men et al., 1995; 1996). However, considering that phytates have been discovered in some duckweed, it is paramount for farmers to use phytase as an additive so that it can hydrolyse phytate phosphorus thereby enhancing the bioavailability of phosphorus to the chickens (Maguire et al., 2004; Pillai et al., 2009). Becerra et al. (1995) reported a higher calcium content in duckweed compared to soyabean (1.1 versus 0.4% of DM) whilst Men et al. (1995; 1996) found a higher calcium content in duckweed compared to soyabean (0.7 versus 0.2% of DM). These findings indicate that duckweed is a better source of minerals compared to soyabean, but however, the levels vary with the nutrients of the medium in which the plant is growing as well as the species of the duckweed plant.

However, chicken farmers using duckweed as feed are encouraged to establish whether the mineral content in the duckweed matches the requirements of the stock and act accordingly as incorrect levels might be detrimental to

Table 2. Variation of amino acid content in percentage (%) of some plants and duckweed species.

Type of amino acid	Plant specie			
	Azolla	*Lemna*	*Pistia*	*Alfalfa*
	Amino acid value in percentage (%)			
Lysine	6.1	5.9	7.0	6.7
Histidine	2.3	2.7	2.9	2.5
Serine	5.3	5.4	4.8	4.3
Proline	4.7	4.5	5.0	4.8
Glycine	5.8	5.6	5.7	5.3
Alanine	7.0	7.1	6.3	6.0
Valine	6.8	6.4	6.7	6.8
Methionine	1.2	1.4	1.1	2.3
Leucine	9.4	9.6	9.6	8.9

Dewanji (1993).

the health or development of the birds. For example, calcium levels exceeding the recommended values in diets meant for broilers (Mohammad et al., 2010) will lead to unavailability of other minerals resulting in limitations on growth and development. In addition Rath et al. (2000) reported that adolescent meat-type poultry and cage layers exhibit a high incidence of bone problems that include bone weakness, deformity, breakage, and infection and osteoporosis-related mortalities. The authors further highlighted that the tibia from 5-week-old chicks were strong but brittle because of low collagen crosslinks and high mineral content. The associated problems consequently lead to economic and welfare issues. In line with Nolan et al. (1997), considering the detrimental effects of high mineral content in duckweed to chickens and in the light that some duckweed species usually constitute high mineral content, it is worthwhile to evaluate the mineral profile of the plant first before formulation of diets.

Oron et al. (1985) in their study reported that crude protein value that is as high as 48% for a feed ingredient, with very little input invested in producing it, will go a long way in enhancing profits of the enterprises concerned. Based on the values provided in Table 1, the average CP content for duckweed is 34.9%, and the range is 20.8 to 45% (Leng et al., 1995; Kalita et al., 2008). The variation in the CP content (Table 1) of the duckweed has been attributed to the different species and management. Roots less than 10 mm in length indicate higher protein content than roots more than 10 mm in length since root length is an indicator of pond conditions (Ansal et al., 2010). Linked to this, poorer conditions result in longer roots as the plants search for more nutrients. The protein content of duckweed responds rapidly to the availability of nutrients in the aquatic environment (Leng et al., 1995). It is not the high protein content *per se* that makes duckweed a potential feed source, but the array of amino acids that make up the duckweed proteins, in addition to other invaluable minerals contained therein by the plant. Duckweed species have been proven to be high in amino acids that are required for the growth of chickens.

Table 2 shows the distribution of various amino acids, in different species of duckweed. Johnson (1998) reported 1.13% lysine content in duckweed whilst Rusoff et al. (1980) established that as CP varied from 37.5 to 44.7%, lysine content varied from 3.37 ± 0.43 to 4.30 ± 0.43%. Higher values of lysine have been reported elsewhere [5.9% by Dewanji (1993) and 10.9% by Yilmaz et al. (2004). In a duckweed feed that contained 27.4% CP, the methionine content was 0.35% whilst Yimlaz et al. (2004) obtained a value of 0.2% for the mineral. Since the levels of the sulphur containing amino acids is variable, it is imperative to determine the value of the duckweed to be used and supplement if necessary.

In addition to the favourable array of amino acids, the duckweed plant has a high concentration of pigments and xanthophylls that make this plant a valuable supplement for livestock (Mbagwu and Adeniji, 1988; Nolan et al., 1997; Negesse et al., 2009), especially chickens. Chinh et al. (1995) reported a carotene content of 801.6 mg/kg DM whilst Men et al. (2001) reported a level of 1 025 mg/kg DM.

The duckweed plant, therefore, becomes economically important due to high costs of conventional pigment supplements, especially in chicken diets (Haustein et al., 1988). Furthermore, the fat that the duckweed plant contains has favourable fatty acids (SCFA) such as C2 (11%), C3 (3.1%), C4 (1.4%) and C5 (0.4%) with a total short chain fatty acids (SCFA) of 16.6% (Negesse et al., 2009). This gives this plant a place in chicken nutrition. Just like organic acids that are utilized as food additives and preservatives for preventing food deterioration and extending the shelf life of perishable food ingredients, SCFA are used to control microbial contamination and dissemination of foodborne pathogens in preharvest and postharvest food production and processing (Ricke, 2003). According to van Immerseel et al. (2004), SCFA are widely used as feed additives in poultry for the control of pathogenic bacteria, such as *Salmonella enteritidis*. Researches that have been conducted on duckweed indicate that this plant can be included in chicken feeds to enhance the performance of chickens.

USE OF DUCKWEED IN BROILER CHICKEN FEEDS

Feed costs account for as high as 60 to 70% of the total of broiler chicken production whilst protein accounts for 15% of this cost (Ojewola et al., 2005). It is therefore imperative to explore cheaper feed to get maximum

Table 3. Levels of inclusion of duckweed in diets meant for broiler chickens.

Duckweed level as a proportion of	Optimal inclusion level	Author
Protein used in the experiments		
0, 3, 6 and 9%	6	Ahammad et al. (2003)
0, 4, 8 and 12%	Between 4 and 8%	Kabir et al. (2005)
	5	Haustein et al. (1994)
Whole diet used in the experiments		
0, 10, 20 and 30	10	Kusina et al. (1999)
	30	Olorunfemi et al. (2006)

returns with minimum costs. The potential nutritional value of duckweed in broiler chickens has been recognized (Haustein et al., 1990, 1994; Samnang, 1999). The duckweed plant has been postulated to offer a solution to the feeding of broiler chickens (Abdulayef, 1969; Ahammed et al., 2003; Khandaker et al., 2007). This plant has been used to replace protein sources such as sesame oil cake (Ahammad et al., 2003) and fishmeal (Effiong et al., 2009) at graded levels. In this regard, it is important to determine how important duckweed is in the nutrition of broiler chickens.

In a study by Ahammad et al. (2003), the live-weight of broiler birds that were placed on diets with duckweed protein inclusion levels as shown in Table 3, with the other source of protein as sesame oil, were similar across the treatments up to 21 days of age but differed significantly at 28, 35 and 42 days of age. The authors observed that the live-weights increased linearly for the 3 and 6% duckweed inclusion diets whilst a decline was observed for the diet with 9% duckweed. These authors concluded that partial replacement of sesame oil cake (SOC) with duckweed is possible with increased growth performance of the broiler birds. These results concurred with observations by Haustein et al. (1994) who established that live-weights were significantly higher in broilers that were fed a diet containing 5% level of duckweed compared to other treatments with higher and those with lower inclusion levels. These authors attributed growth depression of birds with duckweed levels beyond 6% to the fact that the birds were unable to consume sufficient duckweed, due to its bulkiness and high moisture content (Haustein et al., 1994; Ahammad et al., 2003).

The results obtained by Haustein et al. (1994) and Ahammad et al. (2003) are further confirmed by Kabir et al. (2005) who conducted a study in which they used 4 iso-nitrogenous and iso-calorific diets (as indicated in Table 3) up to 42 days of age. The study revealed that body weight linearly declined as the proportion of DWM increased in the diet. Ahammad et al. (2003) reported that the decrease in production cost and increase in profitability per broiler as duckweed level was increased in the diet is an indication of lower cost of duckweed (0.12 US$/kg) in comparison with that of SOC (0.29 US$/kg). These authors concluded that a diet containing 3% SOC and 6% duckweed instead of 9% SOC may increase performance and profitability whilst full replacement may not be advisable. These authors confirm that performance of broiler chickens increases as the inclusion level increases up to 6%, after which a reduction in performance will be observed. Kabir et al. (2005) further observed that parallel to the decline in body weights, were reduction in the following parameters; feed intake, feed and protein efficiency, energy efficiency and profitability. This might indicate that the optimum level of inclusion of duckweed was between 4 and 8%. It is important, however, to appreciate that other authors have focused on the level of inclusion of duckweed in the whole diet, not as a fraction of the protein in the diet (Table 3).

Kusina et al. (1999) reported that inclusion of duckweed in broiler finisher diets at 10% level did not compromise growth performance and carcass quality of broiler chickens. Olorunfemi et al. (2006) showed that utilisation of diet containing duckweed (*Lemna paucicostata*) at approximately 30% is cost effective and may reduce the cost of feed by about 21% thereby improving profitability in broiler finisher production. There is, however, need to combine the two approaches in experiments. Studies on the type of duckweed species and breed of chickens offered feed containing a particular duckweed species need to be conducted. In addition, despite the fact that it is cost effective and beneficial to use duckweed in diets of chickens either as a protein source replacement or as inclusion in the diet, establishing the extent of palatability of the poultry meat fed with duckweed warrants investigation.

The improved performance with inclusion level of duckweed up to the limit might be ascribed to the relatively high levels of essential amino acids, especially lysine, methionine and threonine (Leng, 1999) compared to other plant proteins. In addition, duckweed also provides vitamins, especially Vitamin A which is essential for growth and reproduction. Furthermore, the high carotene content of duckweed has been shown to deepen the yellow colour of the broiler meat and skin.

Moreso, some species of the duckweed plant are highly palatable thereby stimulating the birds to eat more (Men et al., 2001a). Unpalatability is usually associated with the genera *Lemna* and *Spirodela* that may contain high amounts of calcium oxalate which might limit their intake (Gijzen and Khondker, 1997).

It is however, important to note that although duckweed induces superior weight gains when it replaces up to 6% of the protein in the finisher diets for broiler chickens, studies have demonstrated that the growth of young broiler chickens may be retarded by increasing levels of dehydrated duckweed meal in the diet (Hausten et al., 1992, 1994). This might be ascribed to the fact that young birds are unable to consume sufficient duckweed due to its bulkiness and low DM content. This implies that duckweed should be used sparingly when feeding young broiler birds. Apart from feeding duckweed to broiler chickens, it is also important to evaluate the effect of this feed source on the performance of village chickens.

USE OF DUCKWEED IN VILLAGE CHICKEN PRODUCTION

Poverty, hunger and malnutrition are common among smallholder families in developing countries with the village chicken farming playing a significant role in mitigating the discourse (Alders et al., 2009). The nourishment of the village chickens depends on the feed available in the village. Due to its appreciable nutritional profile, duckweed could be used to augment village chicken feeds. Several studies (Samnang, 1999; Khang and Ogle, 2004; Saroeun et al., 2010) have evaluated the performance of village chickens when placed on diets containing duckweed. In a 70 day trial conducted by Samnang (1999), intake of village chickens increased steadily with time (with an average of 36 ± 0.35 (SE) g/day) for duckweed when the birds were kept on station. In the village, however, the native chickens' duckweed intake was constant (49 ± 0.22 g/day) over the entire feeding period. This author observed that, soyabean-supplemented chickens grew faster than those that were on the duckweed diet when raised on station; whereas on farm, chickens supplemented with duckweed outperformed those fed ground soyabean. This could be that when chickens are taken for on-station experimentation, they take long to adjust to feeding on duckweed, compared to soyabean which they at times are supplemented with. More adaptation period and graded level of inclusion of duckweed could be explored in order for the chickens to benefit from the nutritious plant, duckweed.

On the other hand, if the study is conducted on farm, very little adjustment is done to the chickens and they also benefit from several sources of feed available at their dwelling places. The same author also reported that chickens consumed half the duckweed offered giving them a protein intake (originating from duckweed) of about 1 g/day in comparison with 10 g/day for those birds that were placed on soyabean supplement. This could be that the duckweed offered had a bitter test hence it affected feed intake. The nutritional profile of the duckweed as well as the appropriate inclusion levels need to be verified.

Saroeun et al. (2010) established that Sampov, an indigenous chicken breed had a daily feed intake of 3.9, 2.0 and 0.02 g of duckweed (29.2% CP), water spinach (24.0% CP) and taro leaves (25.2% CP), respectively. These findings indicate that even small amounts of duckweed in the diet could yield extremely greater performance. In a separate study, Khang and Ogle (2004) reported that a total DM intake and live-weight gain of village chickens showed a curvilinear relationship with the proportion of dietary protein derived from duckweed. In another study by Rodriguez and Preston (1999), exotic (*Tam Hoang*) birds from China consumed less duckweed than local chickens under semi-scavenging conditions, a situation that might be attributed to the aggressiveness and the effect of natural selection pressure on indigenous birds scavenging in tropical ecosystems that favour traits reflected in the ability to consume protein-rich vegetative matter (Rodriguez and Preston, 1999) in searching for feed than the exotic birds. The authors concluded that the optimum inclusion level for duckweed was 20% for feeding the indigenous breed, the *Tau Vang* birds. Intake of duckweed is influenced by the quantity of nutrients in the plant as well as the bitter taste of some of the species of the plant due to the level of tannins and/or toxins that might be present in the plant. Therefore, it is important to test for the nutritional profile, toxicity as well as the anti-nutritional factors that might be present in duckweed and corrective measures taken before feeding the chickens.

Samnang (1999) established that for both on station and on farm village enterprises, the profits were highest for the birds supplemented with duckweed and lowest for those supplemented with ground soyabean. The author concluded that offering small amounts of fresh duckweed (30 to 40 g/day) to native chickens will lead to an improvement in the growth rate if they are also offered broken rice, if both supplements are given when the birds are confined at night. Increased duckweed consumption has been linked to increased profit margin (Samnang, 1999). This concurs with Khang and Ogle (2004) who reported on a reduced cost when a duckweed-based diet was used compared with 100% soyabean. Meat from birds that were on the duckweed diet had a deep yellow colour compared to the birds placed on the control (no duckweed), thereby creating the need to investigate the effect of duckweed plant on other meat quality properties.

In addition, given that duckweed usually grows in waste water, it is paramount to investigate the safety of meat and meat products of chickens fed on duckweed. The attributes of duckweed have calls for consideration of more research work.

FURTHER RESEARCH

It is imperative to conduct more research on duckweed before its use can be fully recommended. The most important aspect that should be taken into consideration is the economics of drying, including the methods and techniques such as drying in the shade, sun drying or air drying. Solar drying as well as simultaneous drying are alternative options that are worth exploring. In addition, the drying methods that could be recommended should not diminish the levels of carotene and xanthophylls from the duckweed. A possibility of packaging this plant into pellets and crumbles should also be considered. Studies on this issue could validate reports by authors such as Tavares et al. (2010) who proposed that 8 weeks after drying duckweed and keeping it in plastic bags at 4°C can make a safe and good feed for livestock. Researchers should also focus on compounding complete rations that have duckweed as an ingredient. Further studies should be conducted on the use of fermented duckweed and duckweed silage in chickens. Research on the effect of feeding duckweed on compensatory growth may also be worthwhile conducting.

Scientists are also compelled to focus on screening for duckweed species with less fibre and low moisture content. In addition, development of duckweed strains with low contents of anti-nutritional factors, including phytates, and those that are more tolerant to variation in conditions such as pH and temperature by way of recombinant technology can go a long way in improving the nutrition of meat producing chickens. Researches towards the understanding of circumstances which favour one species of duckweed over another also merit investigation. The high concentrations of beta carotene and xanthophyll suggest that duckweed could become a significant source of vitamin A and other pigments (Ansal et al., 2010). This indicates that it is worth seeking ways of extracting these nutrients before packaging them and placing them on the market.

PRACTICAL CONSIDERATION

Village ponds receive waste from livestock that visit them which not only pollutes the water affecting its productivity but also causes nuisance for the villagers due to foul smell. It, therefore, is vital to reclaim and manage these water bodies to their optimum productivity status through some suitable scientific interventions which are not only economically viable but easy enough to be adopted by the resource limited rural populace (Ansal et al., 2010).

Communities should be encouraged to come together and work towards the establishment of duckweed. The community is also compelled to work hand in hand with scientists who should provide them with the required technical guidance and advice for seeking financial assistance. State government and other relevant stakeholders should also come on board and promote duckweed based rural models through educating the people and introducing some rural welfare schemes integrated with village ponds for employment and income generation (Ansal et al., 2010).

CONCLUSIONS

Researches showed that duckweed could have a place in the nutrition of chickens. The plant grows very fast and is highly nutritious especially in protein and minerals. Particular attention, however, has to be paid to the nutritional profile of the duckweed being used so that lack of other nutrients in the plant can be augmented by other sources. In addition, the optimum inclusion level of the plant should not be exceeded if optimum performance is preferred. Research on any elements that might be detrimental to chickens feeding is paramount before feeding duckweed so as to fully benefit from using the plant as a protein source. Researchers seem to agree that in the growers and finisher stage contribution from duckweed as protein should not exceed 6%. More research, however, is required, probably per duckweed specie, to determine the inclusion levels that can be adopted for starter, growers and finisher diets for meat producing chickens.

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