Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 08, pp.36069-36079, August, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

ALGAE (*SPIRULINA PLATENSIS*) AND DUCKWEED (*LEMNA GIBBA SP*) PROTEINACEOUS AQUATIC BIO-MASS AS FEED SUPPLEMENTS IN LIVESTOCK AND POULTRY RATIONS-A REVIEW

***Ramaprasad, J. and Chala Merera Erge**

Animal Science Department, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia

ARTICLE INFO

Article History:
Received 16th May, 2016
Received in revised form
23rd June, 2016
Accepted 13th July, 2016
Published online 20th August, 2016

Key words:

Algae,
Duckweed,
Feed supplement,
Livestock,
Poultry,
Rations.

ABSTRACT

With the high costs of the conventional protein supplements required in producing more quantities meat and its products to meet the escalating demand by the ever increasing human population, it is imperative that other cheaper affordable protein sources should be explored. Such protein rich bio-mass are aquatic plants such as algae (*Spirulina platensis)* and duckweed (*Lemna gibba sp*). This paper focuses on attributes and challenges in researches associated with the use of these plants which make it a special contender as protein source in livestock and poultry rations. Algae and duckweed are excellent sources of quality proteins, carbohydrates, essential fatty acids, pigments and vitamins and can form food source for human and animals. At present they are being used as food-web to marine species. They are grown to reduce chemical load and to absorb heavy metals in sewage ponds and are used as raw materials for pharmacy, cosmetic, food and feed industry and also to produce bio-diesel on small scale. Even though, there are some challenges and impediments in utilising these marine sources, they have great potential as feed supplements and can solve scarcity and affordability of protein sources in livestock and poultry rations, when they are produced at affordable costs on large scale. Algae have been used as food source to human and animals due to its excellent nutritional profile. There are very few investigations to utilise algae in ruminant rations due to its large requirements to conduct animal trials. Several research works has been conducted to utilise algae in layer and poultry rations which imparts intense orange yellow colour to egg yolk and meat. There are few investigations on duckweed inclusion as partial/full substitution either wet/dry form in cattle, sheep and goats. Duckweed has been extensively tested in layer and broiler birds and also in other poultry including ducks and quails. Results indicated that, it should be fed in relatively small amounts either fresh or dried form. It is of paramount important that the optimum level of inclusion of duckweed as protein sources should be tested widely to obtain their economic benefits. It is imperative to conduct more research on the development of high productive strains, their growth requirements, their production on large scale, processing techniques employed to reduce moisture content and to eliminate antinutritional factors inherently present in them, before advocating them as protein replacement feed resources in the rations of livestock and poultry.

Citation: Ramaprasad, J. and Chala Merera Erge, 2016. "Algae (*Spirulina platensis*) and duckweed (*Lemna gibba sp*) Proteinaceous aquatic bio-mass as feed supplements in livestock and poultry rations-a review", *International Journal of Current Research*, 8, (08), 36069-36079.

INTRODUCTION

World human population is expected to increase from 6.7 billion in 2006 to over 9 billion (with 1.7 billion from Sub Sahara Africa) by 2050 (Anonymous,1997; UN Population Division,2007), the demand for meat and meat products will also escalate to match the ever increasing human population. It is imperative to maximise the livestock and poultry production. The feed resource- base for feeding livestock and poultry is shrinking and economic feed resources has become scarce and unaffordable (Teguia and Fon Fru, 2007). It is expected that other protein sources which are cheap and easily affordable should be explored. In this regard, a protenaceous aquatic resource such as algae and duckweed has great potential to address the feed shortage problem by reducing the competition between the animals and human beings. Therefore, recovering and recycling of these nutrient resources makes sense both ecologically and economically. Generally algae (*Spirulina platensis*) and duckweed (*Lemna gibba sp*) are suitable for both human animal consumption and are rich in proteins, carbohydrates, essential fatty acids, pigments vitamins and antioxidants, have great potential as feed supplements (Landlot

****Corresponding author: Ramaprasad, J.***
Animal Science Department, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, Ethiopia.

and Kandeler, 1987) These aquatic plants are of considerable interest for pharmacy, cosmetic, feed and food industries and also potential raw materials for bio-fuels such as bio-diesel, ethanol, kerosene etc. They are efficient in producing bio-mass than any common crops such as soy, palm trees etc, because they do not require growth and maintenance of root or stem or leaf structure or arable land and can grow anywhere, where there is sufficient sunlight and water. The blue green algae (*Spirulina platensis*) have been used as food source for human and animals for many years, because of its excellent nutritional profile, high catotenoid and antioxidant content. They are relatively high in protein (55-65%) and contain all essential amino acids (Anusuya Devi *et al..,* 1981). The available energy has determined to be 2.5-3.29Kcal g^{-1} and Phosphorus availability is 41 % (Lorenz, 2003). Algae is an excellent source of nutrients and provides a superior natural source of catotenoid that are effective into give yellow colour to egg yolk (Zahroojian *et al.*, 2013). The yellow colour of broiler skin and shanks as well as of egg yolk is the most important characteristic that can be influenced by feeding algae. At present in many international markets microalgae catotenoid are in competition with synthetic form of pigments (Spolaore *et al.*, 2006). Although the synthetic forms are expensive than the natural products, microalgae catotenoid have the advantage of supplying natural isomers in their natural ratio (Olaizola, 2003). The plants of family *lemnacae*, colloquially known as duckweed, have been used in human and animal diets for hundreds of years (Leng, 1999). They consists of two sub-families (Lemnidea and Wolffoideae), with four genera (*Spirodella, Lemna, Wolffia and Wolffina*). Generally duck weed plant species are rich in invaluable nutrients (Landlot and Kandeler., 1987 :Mwale, and Gwaze., 2013). There are about more than 40 species of duckweed plants available worldwide and contains the world's smallest species of flowering plants (Les *et al.*, 2002). Their most striking qualities are capacity to explore reproduction and an almost lack of filamentous material (Goopy and Murray, 2003). The plant is rich in both in macro and micro elements such as calcium and chlorine and has a protein content that ranges between 6.8 and 45 %DM (Landlot and Kandeler, 1987). Duckweed species are small floating aquatic plants found worldwide and often seen growing in thick, blanket like mats on still or slow moving nutrient rich fresh or brackish waters. They are monocotyledons of the botanical family *lemnaceae* and are higher plants or macrophytes. They have been identified as being ideally suited to nutrient reclamation and water cleansing and as protein rich bio-mass feed supplement for animals (Culley and Epps, 1973: Hillman and Culley, 1978). Unfortunately, the vast majority of research on these aquatic plants in the area of high producing species, their growth requirements is fragmentary, looking only at one or two aspect of the growth, physiology or nutritive value. But potential of these resources should be explored to the fullest extent. This paper reviews current knowledge of research conducted on these aquatic resources arising from number of endeavours to develop into frame work to exploit these resources fully in future animal feeding practices on large scale.

Environmental requirements and production of algae and duckweed plants

Small and quick growing algae are important source for a bio-based economy. They have been the basis for the marine food web for millions of years and several species of algae are found in every imaginable water body. If they are produced on large scale, they can contribute to a high quality protein source, but must be produced at a cost comparable to existing supplements. Algae produce essential polyunsaturated fatty acids (PUFA), EPA and DHA. There are thousands of different algae species but handful is cultured for commercial production. At present algae production takes place on a relatively small scale with high production costs. Algaecom has developed a production system to farm algae on large scale with in controlled settings at affordable costs. The use of residual streams such as carbon dioxide rich flue gas and waste heat is used. The technology Algaecom, photo-bioreactors are flexible and have a plug and play character which has been field tested . It uses waste heat and carbon dioxide from glue gases which are residual streams from industry, horticulture or agriculture. In addition they can also be produced using algae – XL bags which are closed photo- bioreactors, which make optimal use of sunlight (Algae/Duckweed innovation (ADI) project, 2015). In Delfziijl, first Algaecom pilot project for large scale production of algae was started in 5 hectares in the Walden sea area by Algaecom project. At present the company, Algaecom has developed a suitable production method to culture aquatic crops on agriculture scale. This takes place in novel algae XL bags that can set up modularly and are easily scalable, with a simple heating technique the bags are kept worm and there by extended productive system, with in our climate. Algaecom produces algae by culturing algae strain, grow in a algae XL bags using carbon dioxide, sunlight and nutrients, finally harvested wet/dry. High quality algae are obtained by this process.

In recent years duckweed species have received much research attention because of their potential to remove mineral contamination from waste waters emanating from sewage works, intensive animal industries like tannery or from intensive irrigated crop products (Leng *et al.*,1995). They have to be managed, protected and maintained at an optimum density by judicious and regular harvesting practices and fertilised to balance nutrient concentrations in water to obtain optimal growth rates. When effectively managed duckweeds can yield 10-30 ton DM/ha/year containing 43% crude protein and a highly digestible dry matter. The habitat and environment requirements of duckweed vary between species, but all share need for sheltered still water. Duckweeds are found all around the world (Rusoff *et al.*, 1980; Landlot and Kandeler, 1987: Xu, 2011) except waterless deserts and permanently frozen areas like Arctic and Antarctic regions (Greenway *et al..,* 2007). They are tiny free floating green vascular fresh water plants grown fresh or sometimes brackish water plants with a frond that is few centimetres 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; Mwale and Gwaze., 2013). Duckweed plants grow very fast and can flourish for long, if their nutritional and environmental requirements are met (Iqbal, 1999; Al-Nozaily *et al.*, 2000; Caicedo *et al.*, 2000; Cheng *et al.*, 2002; Cayuela *et al.*, 2007: Lasfar *et al.*, 2007). Most species of duckweed reproduce by vegetative propagation and are characterised by rapid clonal growth. The plants cluster in colonies and form green mats on the surface of the water. It is very common for floating mats of duck weeds to consist of more than one species. Duckweeds have the ability to reinvigorate when blown by wind to nutrient rich sites (Rusoff *et al*., 1980; Hasan *et al*., 2009). Luxurious growth often occurs through active extraction of nutrients in sheltered small ponds, ditches or swamps where there are rich sources of nutrients making plants highly nutritious (Willet, 2005; Khellaf and Zerdaoui, 2010). Optimum Temperature required for control growth of duck weeds lies between 17.5-30^0C. Duckweeds have range of tolerance for pH and survive well from 5-9 (Hasan *et al*., 2009). Duckweeds can grow in water of any depth but they cannot grow in fast moving water (>0.3m/sec) or water unsheltered from wind (Leng *et al..,*1995; Hasan *et al*., 2009). Duck weeds are highly productive plants can double their bio-mass in 16 h to 2 days under optimum nutrient availability, sunlight and water temperature (Cross, 1994; Rusoff *et al.*, 1980) Reported yields varied widely ranging from 9-38 tons DM/ha/year, depending upon species selected, climatic conditions and nutrient supply in water (Hasan *et al*., 2009). Though duckweeds can be easily established, farming requires daily attention and frequent harvesting to ensure optimum productivity. Any waste organic material like animal manure, kitchen waste night soil from villages that is easily degradable and has a sufficiently high nutrient content like N, K and P can be used for duck weed cultivation. They have a high mineral absorption capacity and can tolerate high organic loading and are thus being used to process waste waters and to remove contaminants of heavy metals from it (Leng *et al*., 1995).

Uses of algae and duckweed plants

Algae provide food for many pond creatures; they produce oxygen and small pond animals sheltering amongst it. The blue green algae have been used for many years as a food source for human and animals due to its excellent nutritional profiles. About 30 % of the current world algal production is utilised for animal feed applications and over 50 % of the current world production of *artrospira* species are used as feed supplements (Spolaore *et al*., 2006; Zahroojian *et al*., 2013). Different studies have been conducted on the use of algae in poultry rations and other animals (Anderson *et al*., 1991; Toyomizu *et al*., 2001: Venkatesh Kumar *et al*., 2009; Zahroojian *et al*., 2013). Duckweed plants are mainly used to reduce chemical load of facultative sewage ponds during waste water treatment (Vajpayee *et al*., 1995; Willet, 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 duck weed in control of fungal growth in stored feed has been established (Effiang and Sanni, 2009). Preliminary research indicated that duckweed plants may be used to produce bio-fuel ethanol (Cheng and Stomp, 2009). The greatest potential of duckweed lies in its ability to produce large protein rich aquatic bio-mass which can be included in livestock and poultry rations. It is thus can solve the problem scarcity and affordability of livestock supplements. Several research studies have been conducted to establish the suitability of duck weed plant in feeding different species of livestock and poultry (Haustein *et al*., 1994; Nolan *et al*., 1997; Samnang, 1999; Men et al., 2001; Ngamsaeng *et al.*, 2004; Ansal *et al*., 2010; Chantiratikul *et al*., 2010; Mwale and Gwaze, 2013). However, there are some challenges that might encounter when using these aquatic plants.

Problems and challenges associated with establishment and use of algae and duckweed plants

Sometimes pea-soup coloured ponds are caused by the tiny green planktonic algae in the water. This problem, along with filamentous algae and duckweed is due to many nutrients in the water especially nitrates and phosphates. Most of the times nutrient pollution due to many causes may occur due to excess seepage of fertilizers applied in the field or runoff from urban surfaces such as roads sand pavements. Moderate amounts of algae and duck weed should not be a cause for concern but when they are in abundance, making the water cloudy or forming thick surface, which can blocks out Sunlight to submerged plants. Surface cover of duckweeds can also prevent exchange of gases with the air so that the underlying water can become de-oxygenated and noxious to many aquatic animals. Although the fast growth rate of duckweed species is desirable, if it forms thick mat which covers the water resulting in the limiting of further growth of the plant. This may reduce the essential amino acid contents of tryptophan and methionine, there by requiring supplementation when plant is included in diets of animals (Rusoff *et al*., 1980; Men *et al*., 2001b). When, different types of duckweed species which contain antinutritional factors like large quantities of oxalic acid, their intake in poultry may be limited due to off taste (Landlot and Kandeler, 1987; Goopy and Murray, 2003). There are numerous impediments to these plants being incorporated into livestock and poultry rations. Large variations in growth in response to nutrients and climate apparent nutritional factors concerns about the sequestration of heavy metals and possible transfer of pathogens raise questions about the safety of these plants. Farmers are to be careful when feeding duckweed to livestock since its nutrient composition varies from one species to other. Duckweeds can readily absorb heavy metals such as cadmium, selenium and copper (Zayed *et al*., 1998). The high water content (92-96%) of the duckweed plant results in high costs of the drying the plant (Pedraza *et al*., 1965; Khanum *et al*., 2005). Drying, especially to levels where it can be preserved represent a major cost in terms of labour or energy. Best solution seems to be to utilise it on site. In addition, there are some dangers associated with the growth of duckweed to the people like workers due to pathogens emanating from the duckweed plant and from waste water. To reduce the risk of infection, the pond workers should wear protective clothing. It is also crucial to educate the concerned people associated with improper handling of these plants, to enable the farmers to enjoy full benefits of the nutritive value of duckweed.

Composition and nutritive value of algae and duckweed

The blue green algae (*Spirulina platensis*) has an excellent nutritional profile, such as high catotenoid content, relatively high protein content (55-65%) and contains all essential amino acids (Anusuya Devi *et al*., 1981). The available energy has been determined to be 2.5-3.9 Kcal g^{-1} and phosphorus availability is 41 %(Lorenz, unpublished data, 2003, available at: http://www. Cyanotech.com/pdfs/sspbul53.pdf). *Spirulina* is an excellent source of nutrition and provides a superior natural source of catotenoid. Chemical composition of *Spirulina platensis* is summarised in Table-I.

Table I. Chemical Composition of *Spirulina platensis* [a]

General composition	%	Phytopigments	Mg100 gr^{-1}
Protein	55-69	Total carotenoids	400-500
Carbohydrates	15-25	Carotenes	160-260
Fats(Lipids)	5-6	Xanthophyll	170-240
Minerals	6-9	Chlorophyll	1300-1700
moisture	2.5-4.5	Phycocyanin	15000-19000

[a] http://www.parrynutraceuticals.com/organic-Spirulina.aspx o http;/www.parrynutraceuticals.com/PDF/SPIRULINA tablet spec sheet.pdf

The duckweed plant is composed of non-structural, metabolically active tissue; most photosynthesis is devoted to the production of protein and nucleic acids, making duckweeds very high in nutritional value, typically rich in protein and mineral. The chemical composition of duck weeds varies considerably due to the age of the plant, environmental temperature, and nutrient aqueous environment (Hasan *et al*., 2009). The crude protein content of the duckweeds ranges from 7 to 45 %, depending on the nitrogen availability (Culley *et al*., 1981). Under optimal conditions duckweed contains considerable protein, fat and minerals. Duckweeds grown on effluents from agriculture and municipal waste lagoons can have a protein content as high as 30-40 % (Hillman *et al*., 1973; Rusoff *et al*., 1977; Rusoff *et al*., 1978). On the other hand, the protein content of duckweeds obtained from natural waters has been reported to range from 7 to 20%DM (Bhanthumnavian *et al*., 1971). Duckweeds contains 7to 10% crude fibre on dry matter basis. Duckweeds have a highly variable mineral content (upto.30%DM). They may contain relatively larger amounts of potassium and calcium (Leng *et al*., 1995). Duck weeds have high concentration of pigments and Xanthophylls that make this makes the plant valuable supplement for livestock, especially poultry when these pigments can contribute deep orange yellow colour to skin, shank and egg yolk. Carotene content reported in the literature are in the 600-1000mg/Kg range (Dewanji, 1993; Mwale and Gwaze, 2013). Table-2 shows the nutritional profile of duckweed reported by several authors as they investigated the potential of duckweed as a feed for livestock.

Duckweed species have been proven to be high in amino acids that are required for the growth of poultry. Johnson (1988) reported 1,1.3% lysine content in duckweed whilst Rusoff *et al*. (1980) reported varied lysine content from 3.37to 4.3%. In addition the duckweed plant has a high concentration of pigments and xanthophylls that makes this plant a valuable supplement for livestock (Mbagw and Adeniji, 1988; Nolan *et al*., 1997; Negesse *et al*., 2009). Chinh *et al*. (1995) reported a carotene content of 801.6mg/Kg DM, whilst Men *et al*. (2001a) reported a level of 1025mg/Kg DM. Duckweed plant contains 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 of 16.66(Negesse *et al*., 2009). Since duckweed plant contains more SCFA, this can be used as preservative for preventing food deterioration and extending shelf life of perishable food ingredients.

Uses of algae and duckweed in livestock feeds

There is very little research work conducted about the use of *spirulina* as a feed supplements in ruminants, because of the large requirement to conduct animal trials. However, Grinstead *et al*. (2000) studied the effect of *spirulina platensis* on growth performance of weanling pigs. There has been few investigations into using aquatic plants to feed ruminants, which may be due to the large amounts of material needed (Leng,, 1999). Duckweeds grown on nutrient rich waters have the potential to be of high nutritional value particularly for the young and lactating ruminants. Preliminary observations suggest that they might form the basis of a supplement to diets based on mature biomass such as crop residues, mature grass or pasture. Even the high water content, softening the straw, let alone nutrients they provide would facilitate the use of straw by ruminants. In ruminants, microbial activity in the rumen which can alter the availability of nutrients from duckweed has to be taken into account when it is consumed and digested. Ruminants are generally fed mature biomass such as straw which are deficient in a range of minerals and ammonia for efficient fermentative digestion of the straw in the rumen and in addition for maximum efficiency of feed utilization they require supplements containing proteins that escape the rumen environment to be digested in the intestines, with ruminants, therefore, it is necessary to describe the nutritional role that is required of the duckweed before assessing its feed value for ruminants.

Table 2. Chemical composition of duckweed

DM(%)	CP(%)	EE(%)	CF(%)	Ash (%)	Reference
3.3	3.6	4.5	10.7	8.5	Pedraja *et al*. (1996)
4.5	26.3	3.2	11	15.9	Becerra *et al*. (1995)
4.7	38.6	8.6	18.7	19.9	Men *et al*. (19950
--	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 Dhavan. (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)

DM; Dry matter, CF: Crude fibre, CP: Crude protein, EE: Ether extract

There are contradictory reports about the duckweed protein degradability: some authors found duckweed protein to be highly degradable (Huque *et al*., 1996), while others found much lower values such as 50-60% (Damry *et al*., 2001) and described duckweed as a valuable source of proteins for ruminants. Fresh or dried duckweed has been fed to cattle, sheep and goats, provided that is only part of the diet. In several cases, full substitution resulted in lower performance. In table 3 duck weed as potential supplement to ruminant diets has been summarised based on the available research work conducted around the world. Huque *et al*. (1996) has concluded that the daily intake of duckweed is well accepted by cattle up to 10% of their live weight. It was found that the feed was highly digestible and the protein was ruminally degradable. Damry *et al*. (2001) studied the effects of these different nitrogenous substances on wool growth in Merino sheep and found that duckweed compares favourably and well accepted in both fresh and dried form and comparable to other concentrates like cottonseed meal.

There have been few trials on the use of duckweed for pig feeding. Leng, (1999) has suggested that feeding low levels of a poor quality (23%CP) duckweed led to pronounced in the rate of weight gain in weanling pigs, but using low levels of supplementation along with soy bean meal tended to show no difference in growth rates, compared to pigs fed on iso-nitrogenous SBM only diet. In Cuba, the inclusion of 10% duckweed (*Lemna gibba*) in the diets of growing pigs resulted in decreased digestibility but did not affect performance and energy digestibility (Gutierrez *et al*., 2001). Dried duckweed could be introduced in pig diets in Vietnam up to 30%, resulting in relatively high organic matter digestibility (88%) in the diets (Du Thanh Hang *et al.,* 2009).

Uses of algae and duckweed as feed supplement in poultry rations

The algae (*Spirulina Platensis*) is rich in proteins (55-65%), carbohydrates and fats. Algae contains all essential amino

Table 3. Research work conducted using duckweed as supplement to ruminant rations

Animal type	Duckweed sp	Trial	Results	Reference
Bulls, 317 Kg	*Spirodella sp* With *Lemna sp. Wolfia sp*	Straw, fresh grass and mixed duckweed as concentrate containing 28%,	Eaten by cattle at 10% LW.DM	Huque *et al.* (1996)
Holstein heifers 150-300Kg	*Spirodelapolyrhiza, Landoltia Wolfia sp, Lemna sp*	Fresh duckweed and maize silage fed at 2;1 (DM) for 28 days	Higher daily gain than for the control(900g/d vs 450g/d)	Rusoff *et al*. (1978)
Crossbred Ewes, 40Kg	*Lemna sp Spirodela sp*	Napier grass supplemented with 200-300 g/d of sundried duckweed	No effect on DM intake, oestrous parameters and pregnancy rate	Zetina et al. (2012)
West african dwarf sheep 10-18Kg	*Lemna Gibba*	Soybean diet with 0,50, or 100% dried duckweed	Economical and sustainable at 50%,level	Belewu *et al*. (2009)
Merino sheep	*Landoltia punctata*	Oaten chaff supplemented with fresh (1Kg/d) or Sundried (50-100 g/d) duckweed	Readily ingested the duckweed Diet had no effect on wool measures	Damry *et al.* (2001)
West African dwarf goats	*Spirodella polyrhiza*	Duckweed offered *ad libitum* fresh or dried with or without Guinea grass	Well accepted in fresh or dried form Intake maximum at 205 fresh duckweed (440g/d) and decreased at 40% inclusion rate	Babayemi *et al*. (2006)

Table 4. Levels of inclusion of duckweed in diets meant for broiler chickens

Duckweed level as a proportion of protein used in experiment	Optimum inclusion level	Reference
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 experiment		
0.10,20,and 30%	10%	Kusina et al. (1999).
	30%	Olurunfemi et al. (2006)

Table 5. Summary of research work conducted with broilers using duckweed species

Country	Duckweed sp	Trial	Results	Reference
Peru	*Lemna gibba*	15-25% dry duck weed in the diet	25% duckweed resulted in a significant decrease in feed consumption but weight gains are similar with control at 15%.	Haustein *et al.* (1988)
India	*Lemna minor*	Diets with 0,4,8 and 12% duckweed meal *ad lbitum*	Bodyweight, intake, feed, protein and energy efficiency and profitability declined as proportion of DWM increased	Kabir *et al.* (2005)
India	*Lemna minor*	Fish meal (12%) fully replaced with combinations of duckweed and soybean meal	Full replacement is not recommended as it reduced feed efficiency intake, weight gain and profitability	Islam *et al.* (1997)
India	*Lemna perpusilla*	Control diet partially replaced either with fresh duckweed or 7% of dry duckweed	No effect on intake, weight gain, feed conversion ratio and carcass traits but inclusion of fresh or dried duckweed reduced the feed cost	Khatun *et al.* (2004)

acids and also contains essential Omega-3 and Omega-6 fatty acids and have been the basis for marine food web for many years (Anusuya Devi *et al*., 1981). In poultry rations algae can be used safely up to a level of 5-10% as partial replacement for conventional proteins (Spolaore *et al*., 2006). Prolonged feeding of algae at higher levels may produce adverse effects. *Spirulina* is an excellent source of nutrients and provides a superior natural source of catotenoid that are extremely effective in colouring egg yolks (Lorenz, 2003).The yellow colour broiler skin and shanks are the most important characteristic that can be influenced by feeding algae. In many international markets microalgae catotenoid are in competition with the synthetic form of pigments (Spolaore *et al.,* 2006). Though, synthetic form of catotenoid are expensive than the natural sources, microalgae catotenoid have the advantage of supplying natural isomers in their natural form (Olaizola, 2003). In fact, 30% of the current world production of algae is sold for animal feed applications and over 50% of the current production of *Arthrospira* is used as feed supplement (Spolaore *et al*., 2006). Different studies have been conducted on the application of algae in poultry rations (Anderson et al., 1991; Gouveia *et al*., 1996; Toyomizu *et al*., 2001; Zahroojian *et al*., 2013). In an experiment to study the effect of marine algae (*Spirulina Platensis*) on egg quality and production performance of laying hens, it has been observed that *spirulina* can be included at 2.0-2.5 % in the diets to produce aesthetically pleasing yolk colour without affecting performance Zahroojian *et al*. (2013). Due to their high protein content, duckweeds have been tested extensively in domestic birds as source of high quality protein. Duckweeds are also a valuable source of pigments for meat and egg production (Mwale and Gwaze., 2013). Results in commercial broilers shoed that duck weeds should be fed in relatively limited amounts, as high inclusion rates tend to decrease performance, particularly in young chicken because cannot consume enough due to their bulkiness and off taste (Mwale and Gwaze, 2013). Least cost ration trial showed that dried *Lemna paucicostata* was cost effective when included at 29.5 % level in broiler diets (Olorunfemi, 2006). The high carotene content of duckweed has been shown to deepen the yellow colour of the broiler meat and skin (Mwale and Gwaze., 2013). Reported values for metabolizable energy are rather low (< 7 MJ/Kg) for duckweed. Feed costs account for as high as 60%-70% of the total costs of broiler production, it is therefore imperative to explore cheaper feed resources to get maximum profit with minimum costs. The potential nutritional value of duck weed in broiler chickens has been recognised (Haustein *et al*., 1990, 1994; Samnag, 1999). This plant has been used to replace protein sources such as sesame oil cake (Ahammad *et al*., 2003) and fish meal Effiong *et al*., 2009) at graded levels.

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 -4, 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 and off taste (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 4) 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 4). 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. More so, some species of the duckweed plant are highly palatable thereby stimulating the birds to eat more (Men *et al*., 2001a).

Un palatability 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. In table-5 the performance of broilers fed duckweed species at different levels in the contemporary literature is summarised.

Table 6. Summary of research work done with duckweed in small holder chickens

Country	Duckweed sp	Trial	Results	Reference
Vietnam	*Lemna minor*	Fresh duckweed *ad libitum* with basal diet of maize and protein supplement (16%CP)	With increase of duckweed weight gain and feed conversion decreased, as chicken unable to eat enough fresh duckweed	Du Thanh Hang, (2013)
Cambodia	*Lemna minor*	Fresh taro leaves, duckweed and water spinach offered 4-5 times a day with broken rice	Duckweed was preferred followed, water spinach and taro leaves Intake of duckweed was 61-116 g/day	Kong Saroeun *et al*. (2010)
Vietnam	*Lemna minor*	Basal diet of different protein content (18-22%) with or without fresh duck weed *ad libitum*	Access to fresh duckweed increased feed intake and growth rates	Kong Sarouen *et al*. (2010)
Vietnam	*Lemna minor*	Broken rice with roasted Soybean partially or fully replaced with fresh duckweed *ad libitum*	Weight gain and FCR improved with duckweed optimum at 755 substitution. 100% substitution showed highest profits. Skin had a deeper orange yellow colour	Nguyen and Ogle, (2002)
Vietnam	*Lemna minor*	Diet based on % soybeans and scavenging daily	Good results under village conditions	Nguyen *et al*. (2004)

Table 7. Summary of research work done in laying hens with duckweed

Country	Duckweed sp	Trial	Results	Reference
USA	*Spirodela Polyrrhiza*	Diet containing 12.6 % *spirodella* meal	It can be fed at 12.6% inclusion no impact, enhancing Omega-3 fatty acid in eggs	Anderson *et al*. (2011)
Peru	*Lemna gibba*	Dried duckweed at 0,15, 25 and 40% inclusion rate	Optimum level was 15% and higher pigmentation in egg yolk	Haustien et al. (1988)
Vietnam	*Lemna minor*	Broken rice with roasted soybean partially or fully replaced with fresh duckweed *ad libitum*	Egg production, egg quality and FCR were highest at 75% 100% level highest profits	Nguyen *et al*. (2004)

Duckweed has been tested as supplementary feed in small holder (village) chicken production, with variable results. 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 (Mwale and Gwale, 2013). Research work conducted using duckweed in smallholder chicken is summarised in the Table-6. Work with laying hens using duckweed has been more limited but has been encouraging. Duckweed (*Lemna gibba*) was investigated as a partial substitute for layer mash (160 g CP/Kg) by Slippers et al. (1999). Duckweed feeding had no significant effect on body weight, production of damaged eggs and shell thickness (P>0.05),but significantly improved total egg production and yolk colour intensity (p>0.05), at lowest cost due to saving on use of duckweed in layer mash in Table-7 research work conducted with duckweed in laying hens is summarised.

Duckweeds are natural feeds for ducks (Cross, 1994) and there have been numerous trials concerning the use of duckweed in duck farming. The results of feeding fresh or dried duckweed on performance, skin colour, egg colour has been generally positive in ducks and quails.

Further research required

It is imperative to conduct more research on aquatic plants before they can be fully recommended. The most important aspect that should be taken into consideration is the economics of drying, including the methods or 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. The drying methods should not diminish the levels of carotene and xanthophylls from algae and duckweed. A possibility of packaging these plants into pellets and crumbles should also be considered. 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 poultry. Development of aquatic plant 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 broilers. 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 these aquatic plants could become a significant source of vitamin A and other pigments (Ansal et al., 2010). It is worth seeking ways of extracting these nutrients before packaging them and placing them on the market.

Systematic investigation of growth and plant quality attributes in relation to environment needs to be established to explore the economic value of these crops for animal feeding.

Conclusion

Research work conducted so far showed that these aquatic plants have a place in the nutrition of livestock and poultry. They can grow very fast and are highly nutritious especially in protein and minerals. Particular attention, however, has to be paid to the nutritional profile of the algae and duckweed used, so that lack of other nutrients in the plant can be augmented by other sources. In addition, the optimum inclusion level of these plants should not be exceeded, if optimum performance is preferred. Research on any elements that might be detrimental to chickens feeding is paramount important, before feeding algae and duckweed so as to explore full benefit from using these plants as a protein source. More research, however, is required to include aquatic plants such as algae and duckweed species, to determine their inclusion levels in livestock and poultry that can be adopted in future.

REFERENCES

Agae and duckweed innovation (AD I) innovation project, 2015.

Ahammad MU, Swapon MSR, Yeasmin T, Rahman MS, Ali MS 2003. Replacement of sesame oil cake by duckweed (*Lemna minor*) in broiler diet. *Pak. J. Biol. Sci*., 6(16):1450-1453.

Al-Nozaily F, Alaerts G, Veenstra S 2000. Performance of duckweed covered sewage lagoons-II. Nitrogen and phosphorus balance and plant productivity. *Water Res*., 34:2734-2741

Anderson, D.W, Tang, C. and Ross, E. 1991. The Xanthophylls of Spirulina and Their effects on Egg Yolk Pigmentation. *Pout.Sci*.,79:115-119

Andeson, K.E., Lowman, Z., Stomp, A.M. and Chang, J. 2011. Duckweed as a feed ingredient in laying hen diets and its effect on production and compostion of eggs. *Int.J.Poult.Sci*., 10(1):4-7

Anonymous 1997. Communication from the Commission to the council and the European parliament commission European Commission Brussels p. 20.

Ansal MD, Dhawan A 2007. *Spirodela* for low cost carp feed

Ansal MD, Dhawan A, Kaur VI 2010. Duckweed based bioremediation of village ponds: An ecologically and economically viable integrated approach for rural development through aquaculture. Livest. Res. Rural Dev. 22, Article # 129. Retrieved Feb 3, 2013, from http://www.lrrd.org/lrrd22/7/ansa22129.htm.

Anusuya Devi, M., Subbulakshmi, G., Madhavi Devi, K Venkataram, L.V. 1981. Studies on the Proteins of Mass cultivated, Blue green Algae(Spirulina platensis). *J.Agric.Food Chem*., 29:522-525

Babayemi, O.J., Bamicole, M.A and Omojola, A.B. 2006. Evaluation of the nutritive value and free intake of two aquatic (Nephrolepsis biserrata and Spirodela polyrhiza) by Weat African Dwarf Goats. Trop.Subtrop. Agroecosys.6(1):15-21

Becerra M, Ogle B, Preston TR 1995. Effect of replacing whole boiled soybeans with duckweed (*Lemna* sp) in the diets of growing ducks. Livest. Res. Rural Dev.7(2). Retrieved October 15, 2012 from http://www.fao.org/ag/aga/agap/frg/LRRD/LRRD7/3/8.HTM.

Belewu, M.A. Folajimi, F. and Olarewaju, K.D. 2009. Effect of replacing soybean meal with duckweed (Lemna Gibba) meal on intake and digestibility coefficients in sheep. *J.Agric. Biotech.Ecol*., 2(2):138-143

Bhanthumnavin, K. and McGarry, M.G. 1971.Wolffia arrhizaas a possible source of inexpensive source of protein. *Nature*, 232-494

Bouali M, Zrafi I, Mouna F, Bakhrouf A 2012. Pilot study of constructed wetlands for tertiary wastewater treatment using duckweed and immobilized microalgae. *Afr. J. Microbiol. Res*., 6(31):6066-6074.

Bunchasak C 2010. Effect of Replacement of Protein from Soybean Meal with Protein from Wolffia Meal [*Wolffia globosa* (L). Wimm.] on Performance and Egg Production in Laying Hens. *Int. J. Chickens Sci*., 9(3):283-287.

Caicedo, van der Steen NP, Arce O, Gijzen HJ 2000. Effect of total ammonium nitrogen concentration and pH on growth rates of duckweed (*Spirodela polyrrhiza*). *Wat. Sci. Tech*., 15:3829-3835.

Cayuela ML, Millner P, Slovin J, Roig A 2007. Duckweed (*Lemna gibba*) growth inhibition bioassay for evaluating the toxicity of olive mill waste before and during composting. *Chemosphere*, 68:19851991.

Chang, S.M., Yang, C.C and Suung, S.C. 1977. The cultivation and the nutritive value of Lemnaecae. *Bull. Inst..Chem.Academ.Sci*., 19-30

Chantiratikul AO, Chinrasri P, Chantiratikul A, Sangdee U, Maneechote, Chara J, Pedraza G, Conde N 1999. The productive water decontamination system: A tool for protecting water resources in the tropics. Livest. Res. Rural Dev. 11(1). http://www.cipav.org.co/lrrd/lrrd11/1/cha111.htm.

Cheng J, Ben A, Bergmann BA, Classen JJ, Stomp AM, Howard JW 2002. Nutrient recovery from swine lagoon water by *Spirodela punctata*. *Bioresour. Technol*., 81(1):81-85.

Cheng JJ, Stomp AM 2009. Growing duckweed to recover nutrients from wastewater and for production of fuel ethanol and animal feed. *Clean,* 37(1):17-26.

Chinh BV, Oanh BT, Ha NN, Viet TQ, Khang DT, Tinh NT 1995. Composition and Nutritive Values of Animal Feeds in Vietnam. Agricultural Publishing House

Cross, J.W. 1994. Duckweed as a primary feedstock for acqa culture,in:charms of duckweed:Missouri botanical gardens

Culley, D.D. and E.A. Epps 1973. Use of duck weeds for waste Treatment and Animal feed. *J. WaterPol.Cont..Fed*., 45:337-347.

Culley, D.D.Jr., Rejmankova, E., Kvet, J. and Frye. J.B. 1981. Production, chemical qulity and use of duckweeds (Lemnacae aquaculture and, waste management and animal feeds. *J.World Maricult.Soc*., 12;27-49

Damry, J.V.Nolan, R.E. Bell and Thomson E.S 2001. Duckweed as a Protein Source for Fine-Wool Merino Sheep:Its edibility and effects on Wool Yield and charecteristics. *Asian- Aust.J.Anim.Sci*., 14(4):507-514

Dewanji A 1993. Amino acid composition of leaf protein extracted from some aquatic weeds. *J. Agric. Food Chem*., 41:1232-1236.

Du Thanh H, Linh Nguyen Quang, Everts H, Beynen AC 2009. Ileal and total tract digestibility in growing pigs fed cassava root meal and rice bran with inclusion of cassava leaves, sweed potato vine, duckweed and stylosanthes foliage. Livest. Res. Rural Dev. 21:Article #12.Retrieved September 23, 2012, from http://www.lrrd.org/lrrd21/1/ hang21012.htm

Du Thanh Hang, 2013. Effect of offering fresh duckweed (lemna minor) to chickens fed restricted levels of maize meal and concentratesin confinement. *Livest.Res.Rural Dev*., 25(6):101.

Effiong BN, Sanni A, Fakunle JO 2009. Effect of partial replacement of fish meal with duckweed (*Lemna pauciscostata*) meal on the growth performance of *Heterobranchus longifilis* fingerlings. *Rep. Opin*., 1(3):76-81.

Effiong BN, Sanni, A 2009. Effect of Duckweed meal on the rate of mold infestation in stored pelleted fish feed. *Rep. Opin*., 1(2):26-31.

El-Shafai SA, Nasr FA, El-Gohary FA, van der Steen NP, Gijzen HJ 2006. Toxicity of heavy metals to duckweed-based water treatment ponds with different depth: Management of Environmental Quality. *Int. J*., 17(3):313-322.

Formulation. Abstract In: 8th Asian Fisheries Forum, Kochi, India, 2023 November, p. 164.

Gijzen HJ, Khondker M 1997. An overview of the ecology, physiology, cultivation and application of duckweed. Inception Report. Annex 1. Literature Review. Duckweed Research Report (DWRP), Dhaka, Bangladesh, p. 53.

Goopy JP, Murray PJ 2003. A review on the role of duckweed in nutrient reclamation and as a source of animal feed. Asian-Aust. *J. Anim. Sci*., 16:297-305.

Gouveia, L. Veloso., Reis A., Fernandes, H.Novias, J. and Empis, J. 1996. Chlorella Vulgaris used to colour Egg *Yolk.J.Sci.Food Agric*.,70:167-172

Greenway M, Jenkins G, Polson C 2007. Macrophyte zonation in stormwater wetlands: Getting it right! A case study from subtropical Australia. *Water Sci. Technol*., 56(3):223-231

Grinstead, G.S., Tokach, M.D., Dritz, S.S., Good band, R.D. and Nelson, T.L. 2000. Effects of Spirulina pltensis In growth performance of weaning pigs. *Anim.Feed Sci.Tech*., 83237-247.

Guierrez, K., Sangines, L., Perez, F. and Martinez, L. 2001. Stidies on the potential of the aquatic plant lemna gibba for pigs Cuban *J.Agric.Sci*., 35(4):343-344

Hasan, M.R. and Chakrabarthi, R. 2009. Use of algae and aquatic macrophytes as feed in small –scale aqua culture: A Review. FAO Feed and Aqua Technical Paper.531. FAO. Rome, Italy

Haustein AT, Gillman RH, Skillicorn PW, Guevara V, Diaz F, Vergara V, Gastanaduy A, Gilman JB 1992. Compensatory growth in broiler chicks fed on *Lemna gibba*. *Br. J. Nutr*., 68:329-335

Haustein AT, Gillman RH, Skillicorn PW, Hannan H, Dias F, Guevana V, Vergara V, Gastanaduy A, Gillman JB 1994. Performance of broiler chickens fed diets containing duckweed (*Lemnagibba*). *J. Agric. Sci*., 122(2):288-289.

Haustein AT, Gillman RH, Skillicorn PW, Vergara V, Guevara V, Gastanaduy A 1988. Duckweed, a useful strategy for feeding chickens: Performance of layers fed with sewage-grown Lemnaceae species. *Chickens Sci*., 69:1835-1844.

Haustein AT, Gilman RH, Skillicorn PW, Vergara V, Guevara V, Gastanaduy A 1990. Duckweed, a useful strategy for feeding chickens: Performance of layers fed with sewage-grown Lemnaceae species. *Chickens Sci*., 69(11):1835-1844.

Hillman, W.S. and Culley, DD 1978. The use of s of Duckweed. *Amer.Science*, 66:442-452

Hlophe SN, and Moyo NAG 2011. The Effect of Different Plant Diets on the Growth Performance, Gastric Evacuation Rate and Carcass Composition of *Tilapia rendalli. Asian J. Anim. Vet. Adv*., 6:10011009

Huque, K.S, Chowdhury, S.A. and Kibria, S.S 1996. Study on the potentiality of Duckweeds as a feed for Cattle. *Asian-Aus J. Anim.Sci*., 9 (2):133-137.

Iqbal S. 1999. Duckweed Aquaculture: Potentials, Possibilities and Limitations for combined Waste water Treatment and Animal Feed Production in Developing Countries. SUNDEC Report No. 6/99. Switzerland.

Islam, K.M.S., Shahjalal, Tareque, A.M.M. and Howlider, M.A.R. 1997. Complete replacement of dietary fish meal by duckweed, soybean meal on the performance of Broilers, *Asian-Aus.J.Anim.Sci*., 10 (6):629-634

Johnson J 1998. Livestock Waste Management and Policy through the Utilization of Aquatic Feedstuffs. Texas Technology University, Lubbock, TX.

Kabir J, Islam MA, Ahammad MU, Howlider MAR 2005. Use of duckweed *(Lemna minor)* in the diet of broiler. *Indian J. Anim. Res*., 39:31-35.

Kalita P, Mukhopadhyay PK, Mukherjee AK 2008. Supplementation of four non-conventional aquatic weeds to the basal diet of *Catla catla* and *Cirrhinus mrigala* fingerlings: Effect on growth, protein utilization and body composition of fish. *Acta Ichthyologica Et Piscatoria*., 38(1):21-27.

Khandaker T, Khan MJ, Shahjalal M, Rahman MM 2007. Use of duckweed as a protein source feed Item in the diet of semiscavenging jinding layer ducks. *J. Chickens Sci*., 44:314-321.

Khanum J, Chwalibog A, Huque KS 2005. Study on digestibility and feeding systems of duckweed in growing ducks. Livest. Res. Rural Dev. 17, Article #50 Retrieved October 15, 2012 from http://www.lrrd.org/lrrd17/5/ khan17050.htm.

Khatun, M.J. Chowdhury, S.A. Salaluddin. M. and Khan M.K.I. 2004. Effect of dietary inclusion of fresh or dry duckweed on the performance of broilers. *Indian J. Anim.Sci*., 74(7)780-782

Khellaf N, Zardoui M 2010. Growth, Photosynthesis and Respiratory Response to Copper in *Lemna Minor*: A Potential Use of Duckweed in Biomonitoring. *Iran. J. Environ. Health Sci. Eng*., 7(4):299-306.

Kong Saoeuen, Ogle, B., Preston, T.R. and Khiy Borin 2010. Feed selection and growth performance of local chicken offered carbohydrate sources in fresh and dried form supplemented with protein rich forages. *Livest. Res. Rural Dev*., 22912):225

Kusina J, Mutisi C, Govere W, Mhona R, Murenga K, Ndamba J. 1999. Evaluation of Duckweed (*Lemna minor*) as a feed ingredient in the finisher diets of broiler chickens. *J. Appl. Sci. South Afr*., 5(1):25-34.

Landolt E, Kandeler R 1987. Biosystematics investigations in the family of Duckweeds (Lamnaceae). Veroff. Geobot. Institute. ETH. Zurich, 2:42-43.

Lasfar S, Monette F, Millette L, Azzouz A 2007. "Intrinsic growth rate: A new approach to evaluate the effects of temperature, photoperiod and phosphorus-nitrogen concentrations on duckweed growth under controlled eutrophication." *Water Res*., 41(1):2333-2340.

Leng RA 1999. Duckweed: A tiny aquatic plant with enormous potential for agriculture and environment. Animal Production and Health Division, University of Tropical Agriculture Foundation, PhnomPenh(Combodia). FAORome(Italy),p.http://www.fao.org/ag/AGAinfo/resources/documents/DW/Dw2.htm.

Leng RA, Stambolie JH, Bell R 1995. Duckweed - A potential highprotein feed resource for domestic animals and fish. Livest. Res. Rural Dev. 7: Article # 1 Retrieved September 20, 2012, from http://www.lrrd.cipav.org.co/lrrd7/1/3.htm.

Les DH, Crawford DJ, Landolt E, Gabel JD, Kimball RT. 2002. Phylogeny and systematics of Lemnaceae, the duckweed family. Syst. Bot. 27:221-240.

Lorenz, R.T. 2003. A Review on Spirulina and Haehatococcus algae Meal as Carotenoid and Vitamin Supplement for Poulry. Available at: http://www.cyanotech.com/pdfs/spbul53.pdf.

Mbagwu IG, Adeniji HA 1988. The nutritional content of duckweed (*Lemna pauciscostata* Hegelm) in the Kainji Lake area, Nigeria. Aquat. Bot. 29:357-366.

Men BX, Ogle B, Lindberg JE 2001a. Use of Studies on the potential of the aquatic plant *Lemna gibba* for pig feeding. *Cuban J. Agric. Sci*., 35:343-348.

Men BX, Ogle B, Lindberg JE 2001b. Use of Duckweed as a Protein Supplement for Growing Ducks. *Anim. Sci*., 14(12):1741-1746.

Men BX, Ogle B, Preston TR 1995. Use of duckweed (*Lemna* spp) as replacement for soya bean meal in basal diet of broken rice for fattening ducks. Livest. Res. Rural Dev. 7: Article # 3 Retrieved August 23, 20102, from http://www.lrrd.org/lrrd7/3/2.htm.

Men BX, Ogle B, Preston TR 1996. Duckweed (*Lemna* spp) as replacement for roasted soya beans in diets of broken rice for fattening ducks on a small scale farm in the Mekong delta. Livest. Res. RuralDev.8:Article # 3, from http://www.cipav.org.co/lrrd8/3/men831.

Mwale, M. and Gwaze, F.R. 2013. Charecteristics of Duckweed and its Potential as Feed Source for Chickens reared on Meat Production: A Review. Academic Journals: 8(18),689-697. ISSN 1992-2248@2013 Academic Journals. http://www. Academic journals.org/sre

Nayyef MA. and Sabbar AA. 2012. Efficiency of Duckweed (*Lemnaminor* L.) in Phytotreatment of Wastewater Pollutants from Basrah Oil Refinery. *J.Appl.Phytotechnol. Environ.Sanit*., 1(4):163-172.

Negesse T, Makkar HPS, Becker K 2009. Nutritive value of some nonconventional feed resources of Ethiopia determined by chemical analyses and an *in vitro* gas method. *Anim. Feed Sci. Technol*., 154(3-4):204-217.

Ngamsaeng A, Thy S, Preston TR 2004. Duckweed (*Lemna minor*) and water spinach (*Ipomoea aquatica*) as protein supplements for ducks fed broken rice as the basal diet. Livest. Res. Rural Dev.16:Article# 16. Retrieved February 3, 2013, from http://www.lrrd.org/lrrd16/3/amo16016.htm.

Nguyen Thi Kim Khang and Ogle, B. 2004. Effects of duckweed on the performance of local hens Livest. *Res.Rural Dev*., 16 (8);article 57

Nguyen Thi Kim Khang and Ogle, B. 2004. Effects of replacing roasted soya bean meal by broken rice and duckweed on performance of growing Tau Vang Chicken s confined on-station and scavenging on farm. *Livest.Res.Rural Dev*., 16 (8):56

Nolan JV, Bell RE, Thomson E, Bremner D, Ball W 1997. Duckweed (*Spirodela punctate*) as a protein and pigment source in diets for layers. *Proc. Aust. Poult. Sci. Sym*., 9:166-170.

Ojewola GS, Okoye FC, Ukoha OA 2005. Comparative utilization of three animal protein sources by broiler chickens. *Int. J. Poult. Sci*., 4970:462-467.

Olaizola, M. 2003.Commertial Development of Microalgal Biotechnology from test tube to the Marine Marketplace. *Biomolecul.Engne*., 20:459-466

Olorunfemi TOS, Aderibigbe FM, Alese BK, Fasakin EA 2006. Utilization of Duckweed *(Lemna paucicostata)* in Least-cost Feed Formulation for Broiler Starter: A Linear Programming Analysis. *Inf. Technol. J*., 5:166-171.

Pedraza G, Conde N, Chara J 1996. Evaluacion de un sistema de descontaminacion de agues a traves de la producccion de organismos y plantas acuaticas. Report CIPAV, Cali, p. 106.

Rodriguez L, Preston TR 1999. Observations on scavenging Local (indigenous) and Tam Hoang (exotic) chickens given free access (when confined at night) to duckweed (Lemnaceae) offered alone or mixed with rice bran. Livest. Res. Rural Dev. 11: Article # 1, Retrieved June 28, 2012, from www.cipav.org.co/lrrd/lrrd11/1/lyl111.htm

Rusoff LL, Blakeney EW, Culley DD 1980. Duckweeds (*Lemnaceae*): A potential source of protein and amino acids. *J. Agric. Food Chem*., 28:848-850.

Rusoff, L.L,, Gantt., D.T. Williams, D.M., and Gholson J.H 1977. Duckweed A potential feed stuff for cattle. J. Dairy Sci. 60 (Suppl) 161.

Rusoff, L.L., Zerinque, S.P. Achacoso, A.S. and Culley, D.D.JR. 1978. Feeding value of duckweed *J.Dairy Sci*., 61 (Supplment.1)18

Samnang, H. 1999. Duckweed versus ground soya beans as supplement for scavenging native chickens in an integrated farming system. *Livest. Res. Rural Dev*., 11: Article # 1, Retrieved July 23, 2012 from http://ftp.sunet.se/wmirror/www.cipav.org.co/lrrd/lrrd11/1/sam111.htm

Saroeun K, Ogle B, Preston TR, Borin K. 2010. Feed selection and growth performance of local chickens offered different carbohydrate sources in fresh and dried form supplemented with protein-rich forages. *Livest. Res. Rural Dev*., 22: Article # 225.Retrieved April 3, 2012, from http://www.lrrd.org/lrrd22/12/saro22225.htm.

Shi W, Wang L, Rousseau DP, Lens PN 2010. Removal of estrone, 17alpha-ethinylestradiol, and 17 beta-estradiol in algae and duckweed-based wastewater treatment systems. *Environ. Sci. Pollut. Res. Int*., 17(4):824-33.

Singh D, Tiwari A, Gupta R 2012. Phytoremediation of lead from wastewater using aquatic plants. *J. Agric. Technol*., 8(1):1-11.

Skillicorn, P., Spira, W. and Journey W 1993. Duckweed Aqaculture a New Aquatic Farming System for Developig Countries The World Bank Washington DC

Slippers, S.C., Sarah Hugues-Games and Foli, J.A. 1999. Values of Duckweed (Lemna sp) as a Feed Supplement for Laying Hens. *Proc. Aust.Poult.Sci.Sym*., 11, 1-10.

Spolaore, P., Jonniua Casan, C., Duran, E. and Isambert, T. 2006) Commetrial Applications of Microalgae,. *J.Biosci.Bioeng.*, 101:87-96

Tavares F de A, Lapolli FR, Roubach R, Jungles MK, Fracalossi DM, De Moraes AM 2010. Use of Domestic effluent through duckweeds and red tilapia farming in integrated system. *Pan-Am. J. Aquat. Sci*., 5(1):1-10.

Tavares F de A, Roudrigues JSR, Fracalossi DM, Esquivel J, Roubach R. 2008. Dried duckweed and commercial feed promote adequate growth performance of tilapia fingerlings. *Biotemas*., 21(3):91-97.

Teguia A, Fon Fru S 2007. The growth performances of broiler chickens as affected by diets containing common bean (*Phaseolus vulgaris*) treated by different methods. *Trop. Anim. Health Prod*., 39:405-410.

Toyomozu, M., Sato, K., Taroda, H., Kato, T. and Akiba, Y. 2001. Effects of Dietary Spirulina on meat Colour in Muscle of Broiler Chickens. *Br. Poultr.Sci*., 42:197-202

United Nations population Division 2007. World Population Will Increase by 2.5 Billion by 2050; People Over 60 to Increase by more than 1 Billion. Department of Public Information, News and Media Division, New York Press Release.

Vajpayee P, Rai UN, Sinha S, Tripathi RD, Chandra P 1995. Bioremediation of tannery effluent by aquatic macrophytes. *Bull. Environ. Contam. Toxicol*., 55 (4):546-553.

Venkatesh Kumar, R., Jumar, D. and Dhami, S S. 2009. Effect of Blue Green Micro Algae (Spirulina) on Cocoon Qualitative parameters of Silk worm *ARPN J Agric.Biologi.Sci*., 4:50-53

Willett, D. 2005. Duckweed-based wastewater treatment systems: Design aspects and integrated reuse options for Queensland conditions. Queensland Department of Primary Industries and Fisheries. DP & F Publication's Brisbane, p.24.http://www.dcm.nt.gov.au/__data/assets/file/0015/431 43/14e.pdf.

Xu, J. and Genxiang S. 2011. Growing duckweed in swine wastewater for nutrient recovery and biomass production. *Bioresour. Technol*., 102:848-853.

Yilmaz E, Akurt I, Gunal G 2004. Use of duckweed, *Lemna minor*, as a protein feedstuff in practical diets for common carp, *Cyprinus carpio,* fry. *Turk. J. Fish. Aquat. Sci*., 4:105-109.

Zahroojian, N., Moravej, H, and Shivazad, M. 2001. Comparison of Marine Algae (Spiruluna platensis) and Synthetic Pigments in enhancing Egg Yolk Colour of Laying Hens. *Br.Poult.Sci*., 52:584-588

Zahroojian, N., Moravej, H. and Shivazad, M. 2013. Effects of Dietary Marine Algae (Spiruluna platensis) on Egg Quality and Production Performance of Laying Hens. *J.AGR.Tech*., 15:1353-1360

Zayed A 1998. Phytoaccumulation of trace elements by wetland plants. I. Duckweed. J. Environ. Qual. 27:715-21.

Zetina-Crdoba, P., Ortega-Cerilla, M.E., Torres-Esqueda, M.T.S., Herrera-Haro, J.G., OrJImmerez, E., Reta-Mendiola and Villoba-Arroniz, J. 2012. Reproductive resposonse of ewes fed with Taiwan hay (*pennisatum purpurium Schum*) supplemented with duckweed (*Lemna sp and Spirodella sp*). *Asian-Aus.J.Anim.Sci*., 25(8):1117-1123.

****