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Review Article

Application of micro algae in poultry nutrition; a review

Puja Thapa

Tribhuvan University, Institute of Agriculture and Animal Science
Prithu Technical College, Deukhuri, Dang, Nepal
Correspondence: pujathapa532@gmail.com,
ORCID: https://orcid.org/0000-0002-6922-0656
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ABSTRACT

In this review, we unveil the the use of microalgae as a feed ingredient in poultry nutrition. Microalgae are small-sized algae, unicellular, photosynthetic aquatic plants which have been studied as a natural marine resource for a number of economically applications, including animal feed. They are introduced to poultry diets mainly as a rich source of n-3 long chain polyunsaturated fatty acids, including eicosapentaenoic acid (EPA, 20:5 n-3) and docosahexaenoic acid (DHA, 22:6 n-3), but they can also serve as a protein, microelement, vitamin and antioxidants source, as well as a pigmentation agent for skin and egg yolks. The majority of experiments have shown that microalgae, mainly Spirulina and Chlorella sourced as a defatted biomass from biofuel production, can be successfully used as a feed ingredient in poultry nutrition. They can have beneficial effects on meat and egg quality, through an increased concentration of n-3 polyunsaturated fatty acids and carotenoids, and in regards to performance indices and immune function. Positive results were obtained when fresh microalgae biomass was used to replace antibiotic growth promoters in poultry diets. Because of their chemical composition, microalgae can be efficiently used in poultry nutrition to enhance the pigmentation and nutritional value of meat and eggs, as well as partial replacement of conventional dietary protein sources.

Keywords: Poultry, carotenoids, egg and meat quality, microalgae

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INTRODUCTION

Poultry plays a major role in developing countries. Poultry are most important in increasing income and gave high quality of proteins in the diets of rural people whose traditional foods are rich in carbohydrate (Mengesha, 2013). Chicken meat is healthier than others; it has high desirable monounsaturated fatty acids (FAO, 2010) and contains low total fat. Poultry are known for increased protein production and income for smallholder farmers (Muchenje *et al.*, 2001). Consumption of poultry and fish has not been found to be associated with increased risk of cancers (Pisulewski, 2005). Feed in poultry represent the major price of production. Another problem faced by the poultry consumer is chemical residue derived from supplement

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component fed to broiler to fasten its growth that can trigger many diseases for consumer (Salvia *et al.,* 2014). People are interested in evaluating alternative feed resources as substitutes for maize, soybean meal and animal proteins. Algae provide an alternative to the traditional sources (Schiavone *et al.,* 2007). They are considered the most important food supplement of the 21st century as a source of proteins, lipids, polysaccharides, minerals, vitamins and enzymes (Rimber, 2007). Becker (2004) and David (2001) reported that algae are a good source of fat and water soluble vitamins and pigments, such as chlorophyll. Microalgae, which are defined as microscopic algae, are unicellular, photosynthetic organisms which grow in salt or fresh water. As a rich source of nutrients and biologically active substances, including protein, amino acids, n-3 long chain polyunsaturated fatty acids (LCPUFA n-3), microelements, vitamins, antioxidants, and carotenoids, they have a long history of application as a food for humans (Belay *et al.,* 1996). Algae upto a level of 5-10% can be used safely as partial substitution for conventional proteins in poultry feeding (Spolaore *et al.,* 2006). Components of Chlorella vulgaris affected animals' performance, health, reproduction and the egg quality (Arakawa *et al.,* 1960).

There are two main types of algae: the macroalgae (seaweeds), which occupy the littoral zone and can be of very large size, and the small-sized microalgae, which are found in benthic and littoral habitats as well as throughout the ocean as phytoplankton (Hasan *et al.,* 2009). There are about 10,000 species of seaweeds (Guiry, 2014), but only a few of them are of interest in animal feeding. Seaweeds have a highly variable composition, which depends on the species, time of collection and habitat, together with external conditions such as water temperature, light intensity and nutrient concentration in water. All of these factors markedly influence the content of protein, amino acids, mineral, lipid and fiber in seaweed (Misurcova, 2012). The total protein content varies between different seaweed strains and is rather low in brown seaweed (10–24% of dry weight),whereas higher protein contents are observed in green and red seaweed species (up to 44% of dry weight) (Holdt & Kraan, 2011). In a recent review on the importance of seaweeds for poultry feeding, Makkar *et al.* (2016) surmised that when compared to soya bean meal (SBM), seaweeds are deficient in most indispensable amino acids except the sulphur-containing amino acids. In recent years, raw and processed seaweeds have been fed to poultry and other animals, as sources of protein (Gongnet *et al.,* 2001) or to enhance the product quality, particularly the level of polyunsaturated fatty acids and pigmentation (Zheng *et al.,* 2012; Swiatkiewicz *et al.,* 2015; Ao *et al.,* 2015). Selenium is a vital trace mineral for poultry that increase burse, thymus weight and increase immunity against coccidiosis in broilers (Hussain *et al.,* 2004) and chlorella is rich in selenium.

The increasing demand for human protein food sources has resulted in a need for new feed materials which provide a safe source of nutrients for poultry and livestock. Several feeding experiments have demonstrated that microalgae of different species can be successfully included into poultry diets, for example as a defatted biomass byproduct from biofuel production, and can have a beneficial influence on birds' health, performance, and the quality of meat and eggs. Recent studies show, the important thing in poultry industry, where microalga biomass was efficiently used in the production of eggs containing health-promoting lipids, i.e. eggs enriched with health promoting long-chain n-3 polyunsaturated fatty acids (LCPUFAs n-3). Microalgae are cultivated for the production of whole biomass

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and valuable substances such as nutraceuticals, carotenoids, phycocyanin and PUFAs, which are utilized in the food and feed industry. The traditional method of enriching eggs with LCPUFAs n-3 is to incorporate linseed or fish oil into the layer diet; however, this latter method is limited by the high demand for marine products and the risk of their contamination with heavy metals (Wu *et al.*, 2012). For this reason the use of some microalgae species, for instance *Nannochloropsis gaditana*, *Schizochytrium limacinum*, *Phaeodactylum tricornutum*, and *Isochrysis galbana*, in poultry nutrition could be of interest not only as a source of nutrients, but also as an alternative way of enriching of eggs with LCPUFAs n-3. The objective of this review is to discuss the results of current poultry studies where the effects of poultry feeding with microalgae have been examined.

Efficacy of microalgae biomass in poultry nutrition

Spirulina

The blue-green algae (*Spirulina*) is cultivated worldwide for use in the food and feed industries. Because of their prokaryotic cell type, these microalgae is sometimes called cyanobacteria and can be classified into two species: *Spirulina platensis* and *S. maxima*. Dried *Spirulina* biomass has a high nutritional value for human and animals as it contains about 60-70% protein, as well as being a good source of essential fatty acids, vitamins and minerals (Khan *et al.*, 2005). *Spirulina* is a rich source of carotenoids and contains around 6,000 mg total xanthophyll and 7,000 mg total carotenoids/kg in freeze-dried biomass (Anderson *et al.*, 1991). The study by Muhling *et al.* (2005) has shown a high concentration of gamma-linolenic acid in *Spirulina* biomass, which is an essential polyunsaturated fatty acid (12.9-29.4% total fatty acids). The results of the experiments on *Spirulina* inclusion use in broiler diets are summarized in Table 1. Evans *et al.* (2015) showed that dried full-fat *Spirulina* algae had an energy value equal to 90% the energy of corn (2839 kcal TMEn/ kg), as well as containing a high level of crude protein (76%) and essential amino acids. It is generally accepted to be a good source of protein, essential amino acids (1.30-2.75% of dry matter for methionine and 2.60-4.63% of dry matter for lysine), minerals, essential fatty acids (include gamma-linolenic acid), and antioxidant pigments (Holman & Malau-Aduli, 2012). They also reported that up to 16% of dried algae can be incorporated into a broiler starter diet without any negative effects on the performance of chicks. Similar results were obtained in work by Ross & Dominy (1990) who found no significant differences in performance of broilers fed a diet containing 1.5, 3, 6 or 12% dehydrated *Spirulina* in feed. They concluded that *Spirulina* at up to 12% of the diet may be substituted for other protein sources in broiler diets with good growth and FCR. Toyomizu *et al.* (2001) reported no difference in growth performance of broilers fed with or without 4 or 8% of *Spirulina* biomass in the diet. However, the yellowness of muscles, skin, fat and liver increased with an increasing dietary level of microalgae, being more attractive for consumers in certain markets. Hence, dietary *Spirulina* is useful for the manipulation of chicken meat color, especially as the range where the fillets produced by feeding *Spirulina* do not fall under the extremes of either dark or light meat (Toyomizu *et al.*, 2001). Similar results were reported by Venkataraman *et al.* (1994) who demonstrated no effect of dried *Spirulina* (included at 14 or 17% in the diet) as a replacement for dietary fish meal or groundnut cake protein on performance, dressing percentage and histopathology in the various organs of broiler. However, they found a more intensive meat color in the case of birds fed algal-supplemented diets. In contrast to the above

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authors, Shanmugapriya *et al.* (2015) recently observed improved body weight gain (BWG), feed conversion ratio (FCR) and villus length in broilers fed a diet containing *Spirulina* biomass. Mariey *et al.* (2014) reported that a low dietary level of *Spirulina* biomass (0.02 or 0.03%) not only improved performance in broilers, but also increased dressing percentage, meat color score, weight of lymphoid organs, improved blood morphology and decreased relative abdominal fat weight, blood cholesterol, triglycerides and total lipids. Inclusion of *Spirulina* in layer diets has also been shown to reduce total cholesterol content of eggs while increasing omega-3 fatty acid levels (Sujatha & Narahari, 2011).

Table 1: Results of selected studies on the effects of Spirulina inclusion into poultry diets.

Dietary concentration of algae	Animals, duration of the study and studied characteristics	Results	References
4 or 8%	Broiler chickens, 21-37 days, Performance and pigmentation of the muscles	No effect of Spirulina on performance and relative weights of internal organs. Pigmentation (yellowness) of muscles, skin, fat, and liver increased with an increasing dietary level of Spirulina	Toyomizu *et al.* (2001)
6, 11, 16, or 21%	Broiler chickens, 1-21 days, Performance, content of digestible amino acids in the diet.	Dietary levels up to 16% algae resulted in a similar performance as in control group. The positive effect of algae inclusion on the digestible methionine content in the diet	Evans *et al.* (2015)
0.5, 1.0, or 1.5%	Broiler chickens, 1-21 days, Performance indices histological measurements	A positive effect of 1% Spirulina on BWG, FCR, and villus length	Shanmugapriya *et al.* (2015)
1.5, 2.0, 2.5%	Laying hens, 63-67 week. Laying performance yolk colour	Spirulina increased yolk colour without an effect on egg performance	Zahroojian *et al.* (2011)
1.5, 2.0, or 2.5%	Laying hens, 63-67 week Performance, egg quality, yolk cholesterol content	No significant effect of Spirulina on studied indices, except yolk colour, which was increased by dietary algae addition	Zahroojian *et al.* (2013)

The results of several trials have shown that *Spirulina* can be used to enhance the immune function of birds. Quereshi *et al.* (1996) reported that broiler chicks fed diets containing 1% *Spirulina* had increased phytohaemagglutinin-mediated lymphocyte proliferation and phagocytic activity of macrophages compared to control treatment. Raju *et al.* (2005) found that dietary Spirulina (0.05% in feed) can partially alleviate the negative effects of aflatoxin on weight of immune organs and BWG in broilers. Mariey *et al.* (2012) reported improved

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egg production, hatchability and yolk colour when laying hens were fed a diet with a low level of *Spirulina* inclusion (0.10.2%). Ross *et al.* (1994) found that no negative effect of dietary *Spirulina* on final body weight. However, Kaoud (2012) found that body weight gain and body weight had increased significant ($p<0.05$) by the diet provided with *Spirulina platensis*. Kharde *et al.* (2012) who reported that feed conversion ratio significantly ($p<0.05$) improved by dietary inclusion of *Spirulina platensis* as compared to control. Gruzauskas *et al.* (2004) cleared that *Spirulina* has improved absorption of minerals. The chicks which drink watering algae perhaps has tolerate immunology due to be good health groups. That is congruent to Bennett & Stephens (2006) reported that functions of bursa are half of the birds' immune system and the size of the bursa reflects the birds overall health status. Baojiang (1994) reported that *Spirulina* polysaccharide (as a type of algae) acts similarly to phycocayanin. It improves the immune system's ability to detect and destroy foreign microbes or eliminate toxins.

A study with Japanese quail by Ross & Dominy (1990) evaluated the effect of *Spirulina* included at 1.5, 3.0, 6.0, or 12.0% in the diet on growth performance, egg production and quality. The authors observed no significant differences due to the dietary microalgae level, except for increased yolk color and fertility in birds fed with *Spirulina*, and concluded that up to 12% of *Spirulina* biomass could be included into diets. The results of the study with growing quail (aged 15-35 days) showed no negative effects in growth performance and meat quality when included in levels up to 4% of *Spirulina* in feed (Cheong *et al.,* 2015).

Chlorella

Chlorella, a unicellular, freshwater green microalgae used mainly for human food and biofuel production, has been studied in several animal experiments as a potential source of high quality protein (approximately 60%), essential amino acids, vitamins, minerals, and antioxidants. *Chlorella* biomass is a very good source of carotenoids, as it contains 1.2-1.3% of total pigments in dry mass (Batista *et al.*, 2013). As indicated by Kotrbacek *et al.* (2015), these microalgae is too expensive to be used as protein material for animals, however, due to the content of many bioactive substances, even a low, economically acceptable dietary level of Chlorella biomass may beneficially affect animal performance. Alga can be grown in Kuhl medium (Kuhl, 1962) for 15 days under light and dark natural days at 25±1°C. The growth of alga can be measured by optical density using Unico UV-2000 spectrophotometer (Wetherell, 1961), Chlorophyll a, b and carotenoids pigments (Hamouda *et al.*, 2016) total carbohydrate content (Krishnaveni *et al.,* 1984) total soluble proteins (Lowry *et al.*, 1951) and lipids (EI-Sheekh & Hamouda, 2016). The total phenolic content (TPC) of green alga *Chlorella vulgaris* can be determined by the Folin-Ciocalteu method (Singleton & Rossi, 1965), the antioxidant activity could be determined according to Al-Saman *et al.* (2015). Diets were formulated to cover all recommended nutrient requirements according to broiler nutrition guide (NRC, 1994). A very early study with chickens (Combs, 1952) demonstrated that dried *Chlorella*, included into the diet at 10% could serve as a rich source of certain nutrients, i.e. carotene, riboflavin and vitamin B12. Grau & Klein (1957) reported that *Chlorella* biomass grown in sewage was a rich source of protein and xanthophyll pigments, and levels up to 20% in the diet was well tolerated by chicks. Similarly, Lipstein & Hurwitz (1983) found that *Chlorella* was a suitable protein supplement in broiler diets and, used at 5 or 10% dietary

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level, had no adverse effect on growth performance. Kang *et al.* (2013) studied the effects of the replacement of antibiotic growth promoter with different forms of *Chlorella* on performance, immune indices and the intestinal microfloral population. They found that *Chlorella* in its fresh liquid form included at a 1% dietary level beneficially affected BWG, some immune characteristics (e.g. number of white blood cells and lymphocytes, plasma IgA, IgM, and IgG concentrations) and the intestinal production of *Lactobacillus* bacteria. Such an effect of dietary *Chlorella* appears to be based on multiple components, and the fibre fraction, among others including a polysaccharide named immurella, glycoprotein, and peptides contained in *Chlorella*, stimulate the immune response of birds (Kang *et al.*, 2013). Likewise, Kotrbacek *et al.* (1994) found that broilers fed a diet with 0.5% *Chlorella* significantly increased the phagocytic activity of leucocytes and lymphatic tissue development. Rezvani *et al.* (2012) observed a numeric increase in response to phytohemagglutinin, which was accompanied by improved FCR in broilers fed supplementary *Chlorella*. In a recent trial on a *Chlorella* by-product in diets for layers, Kim & Kang (2015) reported a linear improvement in feed intake and hen-day egg production when the product was fed at up to 75 g/kg diet. Eggshell thickness and strength were not affected. Supplementation of poultry diets with *Chlorella vulgaris* has been shown to increase microbial diversity in the digestive tract, especially in the ceca (Janczyk *et al.*, 2009).

A beneficial influence of feeding *Chlorella* on laying performance, egg quality, and caecal lactic bacteria population was observed by Zheng *et al.* (2012). Skrivan *et al.* (2008) reported that Se-enriched *Chlorella* was a more efficient source of Se than sodium selenite as, despite equal doses of Se supplementation, a higher Se content was found in eggs from hens fed diet supplemented with *Chlorella*. Englmaierova *et al.* (2013) showed that supplementing layers with *Chlorella* not only increased the concentration of lutein and zeaxanthin, but also improved FCR, shell quality, and the oxidative stability of yolk lipids of fresh and stored eggs. Moradi Kor *et al.* (2016) showed that *Chlorella* microalgae at high levels had positive effects on the serum contents of triglycerides, cholesterol, LDL and the serum content of HDL. It seems that *Chlorella* alga had hypolipidemic impacts and related to lipid metabolism. May be most important substance in *Chlorella* is β-1, 3-glucan, which is an active free radical scavenger and a reducer of blood lipids (Grima *et al.*, 2003).

An improvement in lipid profile may be a result of chemical composition of *Chlorella* microalgae. As mentioned before, biochemical and physiological events correlated with hyperthermia can potentially stimulate reactive oxygen species (ROS) production (Azad *et al.*, 2010). Harsini *et al.* (2012) showed that antioxidants play main action in protecting cells from ROS by decreasing free radicals and inhibiting the peroxidation of lipids. In human study Tsuchida *et al.* (2003) indicated that a hypolipidemic effect of *Chlorella* in hypertensive patients. It is reported that *C. vulgaris* contains carotenoids (Kay, 1991), which are well-known as coloring agents in skin pigmentation. In general, poultry skin pigmentation (i.e., yellowness) can be increased by feeding natural or synthetic pigments such as carotenoids in diets (Castaneda *et al.*, 2005).

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Table 2: Results of selected studies on the effects of Chlorella inclusion to poultry diets.

Dietary concentration of algae	Animals, duration of the study and studied characteristics	Results	References
Selenium enriched chlorella added in the amount supplying 0.3mg Se/kg of the diet	Broiler chickens, 1-42days, Performance, Se concentration and activity of glutathione peroxidase in meat, oxidative stability of meat lipids	Positive effect of algae on BWG, Se content and glutathione peroxidase activity in breast meat. Decreased oxidation of stored breast meat of birds fed a diet with Se-enriched Chlorella	Dlouha *et al.* (2008)
1%, to replace antibiotic growth promoter (dried powder, or fresh liquid Chlorella)	Broiler chickens, 1-28 days, Performance, immune indices, intestinal bacteria population	Fresh liquid Chlorella positively affected BWG, the immune characteristics and Lactobacillus bacteria count in the intestine	Kang *et al.* (2013)
1 or 2%	Laying hens, 56-63 week, Egg quality, yolk carotenoids content blood triacylglycerol and cholesterol level	Chlorella increased yolk carotenoids, lutein, β-carotene and zeaxanthin content and yolk color score. It decreased FI and yolk weight in hens fed a diet with 2% of Chlorella	Kotrbacek *et al.* (2013)
1% (conventional or lutein-fortified. Chlorella) (Exp 1), 0.1 or 0.2% lutein-fortified Chlorella in the diet (Exp. 2)	Laying hens, 70-72 week (Exp. 1), 60-62 week of age (Exp. 2). Performance, egg quality, lutein content in the body of hens and eggs	1% conventional or lutein-fortified Chlorella improved egg production, yolk color and lutein content in the serum, liver and growing oocytes. 0.2% of lutein- fortified Chlorella increased egg weight, yolk color and lutein content in eggs	An *et al.* (2014)

According to the study by Park *et al.* (2005), the quality of edible meat can be determined by pH, which is associated with water retention capacity and color. Indeed, they also observed that the pH and water holding capacity of the breast meat increased as *C. vulgaris* increased in diet. The findings by Pratt *et al.* (1944) who reported that chlorellin, the active component in *Chlorella*, has an antibiotic effect, and by Amaro *et al.* (2011) who reported that methanol extracts of *C. vulgaris* lowered E. coli and Salmonella. Earlier, intact C. vulgaris was known to have low protein digestibility, which was mainly attributed to the presence of rigid cell walls (Shelef & Soeder, 1980).

Other microalgae species

The results of an early study by Lipstein & Hurwitz (1981) showed that the microalgae *Micractinium* could be a useful protein source for broilers, and supplementing up to a 6% in the diet had no negative effect on growth performance. However, chickens fed a higher inclusion level of these algae had decreased feed intake and BWG. The study by Austic *et al.*

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(2013) evaluated the effects of *Staurosira* incorporation into the broilers' diet, and the results indicated that *Staurosira* may be used to substitute 7.5% of soybean meal without any negative influence on performance or plasma and liver biomarkers, when an appropriate amino acids dietary level was maintained. The aim of the study by Waldenstedt *et al.* (2003) was to evaluate the efficacy of an increasing dietary level of *Haematococcus pluvalis* meal, used as an astaxanthin source, in broiler chickens infected with *Campylobacter jejuni*. The authors showed no influence of algal meal on performance, but tissue astaxanthin concentrations were significantly higher with increasing levels of dietary algae. Caecal *Campylobacter jejuni* populations was not affected by *Haematococcus pluvalis* inclusion, however a diet with 0.18% algal meal reduced caecal *Clostridium perfringens* counts. Yan & Kim (2013) showed that adding 0.1 or 0.2% *Schizochytrium* to the diet improved the fatty acid composition of breast meat lipids, without affecting BWG in broilers. The results of several experiments have shown that microalgae, as a rich source of LCPUFAs n-3, can be introduced into the diet of laying hens to produce functional foods, i.e. designer eggs with naturally increased LCPUFAs n-3 concentration. Poultry products enriched with n-3 long chain polyunsaturated fatty acids are good examples of a functional food, i.e. food that, in addition to possessing traditionally understood nutritional value, can beneficially affect the metabolic and health status of consumers, thus reducing the risk of various chronic lifestyle diseases (Pietras & Orczewska-Dudek, 2013; Yanovych *et al.*, 2013; Zdunczyk & Jankowski, 2013). Similarly, supplementation of layer diets with *Porphyridium* (a red microalga) has been shown to reduce cholesterol and increase the omega-3 content of eggs (Ginzberg *et al.*, 2000). For instance, Bruneel *et al*. (2013) reported an increased content of docosahexanoic acid (DHA) in egg yolks of hens fed a diet containing *Nannochloropsis gaditana* and suggested that this alga may be used as an alternative to current sources of LCPUFA n-3 for the production of DHA enriched eggs. A similar effect was seen on enhanced DHA yolk concentration through diet supplementation with the marine microalgae *Schizochytrium limacinum* (Rizzi *et al.*, 2009). What is important here is that the sensory characteristics of eggs enriched with LCPUFA n-3 by a addition of Schizochytrium were not altered (Parpinello *et al.*, 2006). The results of recent work by Park *et al*. (2015) have shown that the addition of *Schizochytrium* to layers' diet not only significantly improved the fatty acids profile of the yolks but also positively affected laying performance and egg quality. Lemahieu *et al*. (2013) compared the efficacy of four different algae species (*Phaeodactylum tricornutum, Nannochloropsis oculata, Isochrysis galbana* and *Chlorella fusca*) on the enrichment of egg yolks in LCPUFA n-3. They reported that the highest enrichment with PUFA n-3 as well as increased yolk colour was achieved with supplementation using *Phaeodactylum* or *Isochrysis,* and these two microalgae could be used as an alternative to current sources for the enrichment of eggs. Subsequent studies proved the suitability of *Isochrysis* as an LCPUFA n-3 source and showed that 2.4% dietary supplementation with *Isochrysis* lead to the highest LCPUFA n-3 enrichment in the yolk, and that this supplementation level should be considered as the optimal dose (Lemahieu *et al.*, 2014; 2015). Leng *et al.* (2014) showed no adverse effect of feeding layers with 7.5% defatted *Staurosira spp*. when used for partial replacement of soybean meal. However, higher dietary levels (15%) worsened egg performance, feed intake and FCR. These authors indicated that such a decrease in performance was likely to be due to the high ash and sodium chloride concentrations of the algae. The abundance of beneficial bacteria, including *Bifidobacterium*

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longum and *Streptococcus salivarius*, was increased while the prevalence of *Clostridium perfringens* was reduced in response to dietary supplementation with a combination of red seaweed products for layers (Kulshereshtha *et al.*, 2014). The results of a recent study by Ekmay *et al*. (2015) demonstrated that defatted *Desmodesmus* and *Staurosira spp.* could be used in laying hen diets at relatively high levels (up to 25% in the diet), as a source of well-digested dietary protein, without any negative effect on egg production.

A study with Muscovy ducks investigated the effects of diet supplementation with 0.5% microalgae *Crypthecodinium cohnii* (Schiavone *et al.,* 2007). They demonstrated the positive effect of this microalgae on the fatty acid profile in breast meat lipids, without affecting growth performances or slaughter traits, as well as chemical composition, color, pH, oxidative stability and sensory characteristics of the breast meat. An experiment with Japanese quail showed that diet supplementation with *Schizochytrium sp*. could be an effective way of bio-fortifying egg LCPUFA n-3 levels, as the yolks of birds fed a diet with 0.5% of this microalgae significantly increased DHA concentration, as well decreasing n-6/n-3 PUFA ratio and cholesterol content in yolk lipids (Gladkowski *et al.*, 2014; Trziszka *et al.*, 2014).

CONCLUSION

From the literature available, it can be concluded that, although chemical composition of different micro algal biomasses is diverse, many can be safely added to poultry diets. Several Spirulina, Chlorella and other microalgae species may be used to increase the pigmentation and nutritional value of meat and eggs for human consumption, e.g. to enhance these products with LCPUFA n-3 and carotenoids, as well as to partially replace conventional protein sources, mainly soybean meal.

Author contribution

The author, Puja Thapa alone contributes for all the preparation and publication of this article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this review article.

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