NOVEL FUNCTIONS OF MICROALGAL PHYTOCHEMICALS IN FEEDING BROILER CHICKS AND LAYING HENS

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INTRODUCTION

Over 9 billion chickens are slaughtered for meat and 79 billion eggs are produced in the United States alone every year, with a total value of $23 billion. With a strong increasing trend of these numbers, finding alternative or more sustainable feed sources than corn and soybean meal to raise these animals is rather urgent to avoid the competition with the fast-growing human population in consuming these staples. Because microalgae have become an attractive feedstock for the biofuel production [Pulz and Gross, 2004], our laboratory has conducted a series of experiments to determine the nutritional, health, and environmental values of defatted microalgae in replacing corn and soybean meal in diets for broiler chicks and laying hens and in enriching their meat and eggs with omega-3 fatty acids [Austic et al., 2013; Ekmay et al., 2014, 2015; Gatrell et al., 2014]. Equally important, microalgae are rich in phytochemicals including phenolics, flavonoids, and other bioactive compounds [He and Giusti, 2010]. One particular carotenoid, astaxanthin, has shown anti-oxidant effects at concentrations up to approximately 200 mg/kg in diets for broilers and layers [Kobayashi et al., 1997; Naguib, 2000; Takahashi et al., 2004; Waldenstedt et al., 2003; Walker et al., 2012].

The majority of poultry production in the U.S. is located in southern States. Broiler chicks and laying hens reared in production houses in these States are vulnerable to heat stress in the summer, with decreased performance and increased mortality. Heat stress has been shown to induce oxidative stress in birds. Dietary supplementation of anti-oxidants can alleviate heat stress. However, the potential of antioxidative phytochemicals derived from microalgae in protecting broilers and hens against heat stress has not been explored.

While phytochemicals show benefits in humans to prevent or treat various chronic diseases, these compounds such as astaxanthin are able to improve meat quality and to extend shelf life of chicken. Several studies have indicated that astaxanthin is readily absorbed and incorporated into tissues and(or) egg yolks [Benakmoum et al., 2013; Takahashi et al., 2004; Waldenstedt et al., 2003]. Because phytochemicals directly ingested by humans have low bio-availabilities, with only a small percentage to be absorbed through the small intestine [Holst and Williamson, 2008], the phytochemicals incorporated into the chicken or eggs may not only improve the physical and chemical properties of those products but also potentially serve as a more bioavailable source to humans.

EFFECTS OF MICROALGAL ASTAXANTHIN IN TISSUES AND EGGS OF LAYER HENS

Astaxanthin is a well-known antioxidant phytochemical that has limited bioavailability to humans. We conducted a study to determine if astaxanthin present in full and defatted microalgae was bioavailable to layer hens and affected antioxidant status of their tissues and eggs. A total of 50 White Leghorn Shavers (21-wk old) were divided into 5 groups (n = 10/group), caged individually in an environmentally-controlled room, and fed a corn-soybean meal basal diet supplemented with microalgal (*Haematococcus pluvialis*) astaxanthin (Heliae, Gibert, AZ) at 0, 10, 20, 40, and 80 mg/kg for 6 wk. Body weight, feed intake, and egg production and quality were recorded weekly. At the end of study, blood and eggs were collected from all hens and liver samples were collected from 6 hens/group for biochemical analysis. Data were analyzed by one-way ANOVA. Supplemental astaxanthin showed no effect on feed intake, body weight gain, egg production, and egg quality (component weights or shell thickness). Supplemental microalgal astaxanthin resulted in dose-dependent enrichments ($P < 0.05$) of astaxanthin and total carotenoids in the plasma, liver, and egg yolk of hens. The oxygen radical absorbance capacity was also enhanced ($P < 0.05$) in a dose-dependent fashion in the liver and egg yolk of hens. Meanwhile, total glutathione concentration and activities of glutathione peroxidase and glutathione reductase in the liver of hens were decreased ($P < 0.05$) by the high dose of astaxanthin (80 mg/kg) supplementation, compared with the control. While the color of egg yolk was changed ($P < 0.05$, more orange) by the astaxanthin supplementation, there were no major changes in the fatty acid profiles of egg yolk caused by the diet treatments. In conclusion, supplemental dietary microalgal astaxanthin seemed to be highly bioavailable to be digested and deposited in the plasma, liver, and eggs of hens and to improve their antioxidant status.

EFFECTS OF MICROALGAL ASTAXANTHIN IN TISSUES OF BROILER CHICKS

We conducted a similar experiment to determine if astaxanthin present in microalgae was bioavailable to broiler chicks and affected their growth performance, antioxidant status, and quality and fatty acid profiles of meat. A total of 240 (day-old) Cornish male broiler chicks were housed in an environmentally-controlled room (6 cages/treatment, 8 chicks/cage), and fed a corn-soybean meal basal diet supplemented with microalgal astaxanthin at 0, 10, 20, 40, and 80 mg/kg for 6 wk. Growth performance were recorded weekly. Blood samples were collected at wk 3 and 6 (2 chicks/cage) and liver, breast, and thigh samples were collected (2 chicks/cage) for biochemical and meat quality analysis. Data were analyzed by one-way ANOVA. Supplemental astaxanthin did not affect body weight gain or feed intake, but decreased ($P < 0.05$) gain/feed ratio. Plasma activities of alanine aminotransferase, alkaline phosphatase, and tartrate-resistant acid phosphatase, concentrations of inorganic P, and profiles of lipids at wk 3 or 6 remained largely unaffected by the diet treatments. There were dose-dependent elevations (linear or polynominal, R2 > 0.9, $P < 0.05$) of astaxanthin and total carotenoids in the plasma and three tissues with increasing dietary astaxanthin supplementation. Similar enhancements ($P < 0.05$) of oxygen radical

absorbance capacity in the tissues were also detected. In contrast, supplemental astaxanthin decreased ($P < 0.05$) glutathione concentrations and(or) glutathione peroxidases activities in the liver, breast, and(or) thigh. There were no consistent effects of diets on meat quality or fatty acid profiles of breast and thigh muscles except for the dose-dependent color changes of the appearance by supplemental astaxanthin. In conclusion, supplemental dietary microalgal astaxanthin was bioavailable to the broiler chicks and led to dose-dependent depositions of the phytochemical, improved redox status, and coordinated changes of the endogenous antioxidant defense in the plasma and(or) tissues.

SUMMARY

Supplemental dietary microalgal astaxanthin was bioavailable to both layer hens and broiler chicks and led to dose-dependent depositions of the phytochemical, improved redox status, and coordinated changes of the endogenous antioxidant defense in the plasma, tissues, and eggs. The detailed mechanism and health values of the astaxanthin-enriched eggs and chicken for human consumption are under active investigation.

ACKNOWLEDGEMENT

This study was supported in part by a DOE grant (DE-EE0007091), a Cornell University Hatch grant (NYC-127419), and Heliae Development (Gilbert, AZ). For further information, contact XL20@cornell.edu.

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