Food Chemistry 151 (2014) 86–92

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Soybean meal enriched with microelements by biosorption – A new biological feed supplement for laying hens. Part I. Performance and egg traits

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ARTICLE INFO

Article history:
Received 8 April 2013
Received in revised form 13 September 2013
Accepted 4 November 2013
Available online 14 November 2013

Keywords:
Egg trait
Organoleptic parameter
Feed conversion
Haugh unit
Laying hen

ABSTRACT

The aim of the study was to evaluate the effect of soybean meal enriched with Cu(II), Zn(II), Fe(II) and Cr(III) by biosorption on egg traits (egg weight, eggshell strength, eggshell thickness, yolk colour, albumen height) and performance of laying hens. Also, the effect of increased microelement doses in biological form on egg quality parameters and hens performance was investigated. A consumer questionnaire was undertaken to evaluate the organoleptic parameters of the eggs.

Generally, our study showed that in the groups fed with the new biological supplement, egg quality parameters improved, including eggshell strength, eggshell thickness, albumen height and yolk colour. The biological form of microelements also improved the feed conversion rate, especially in the group fed with a biological form of Cr(III). Moreover, the new supplement improved organoleptic parameters of the eggs, in comparison to the inorganic form of microelements as well as to chelate. Enriched soybean meal could constitute an alternative for currently used feed additives with microelements.

1. Introduction

Animals living in their natural habitat, by instinct, search for foods that cover the requirement of an organism for all its nutrients, including microelements. Under extreme circumstances of micronutrient deficiency, this search leads to geophagy, which is the consumption of clays rich in minerals (Wilson, 2003). In modern intense breeding, the intake of micronutrients by farm animals from natural sources is reduced. Free-range breeding, which is an integral part of organic farming, constitutes a negligibly small percentage of animal production, i.e. less than 1% share for cattle and 0.5% for pigs (European Commission, 2010; Von Borell & Sørensen, 2004).

The vast majority of farmers provide animals with a complete diet, which comprises exclusively of compound feeds. Although these commercially blended feedstuffs usually contain all of the necessary nutrients, the quality of these products varies, as well as the bioavailability of particular ingredients. Of special interest are microelements, whose presence in animal diet is indispensable for both the proper growth of an organism and health maintenance (Brisibe et al., 2009; Haenlein & Anke, 2011). Many micronutrients are active in enzyme and hormone systems. Zinc, chromium, manganese and copper are especially required nutrients for enzyme function. A deficiency or excess of a specific nutrient could be the cause of nutritional, toxic or metabolic disorders (Julian, 2005). The mere provision of micronutrients in compound feed is not sufficient, because the bioavailability of microelements in the digestion tract should be taken into account (Fuquay, Fox, & McSweeney, 2011) as well as antinutritional factors, such as the presence of phytic acid in cereals, which chelate mineral cations and proteins, forming insoluble complexes, which leads to reduced bioavailability of trace minerals (Siddhuraju, Makkar, & Becker, 2002). The most commonly used supplements providing microelements in feeds are inorganic salts (i.e. copper(II) sulfate pentahydrate, zinc(II) sulfate heptahydrate), due to their low price. However, their use has many drawbacks, the most important being a very low bioavailability, sometimes as low as a few percent (Fairweather-Tait, 1999). Other microelemental supplements for farm animals are chelates. Their bioavailability reaches up to 100%, but their use is limited by their high price, which is often ten times higher than price of inorganic salts. Consequently, their use is economically unattractive for both breeders and feed producers (Chojnacka, 2010).

A new biological supplement for livestock was developed by our team. A natural biomass, edible for animals, can be enriched with microelements by biosorption and by that innovative feed

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http://dx.doi.org/10.1016/j.foodchem.2013.11.023

additives can be obtained (Chojnacka, 2006, 2008; Michalak & Michalak & Chojnacka, 2009; Michalak, Zielinska, Chojnacka, & Matula, 2007; Saeid, Chojnacka, Korczyński, Korniewicz, & Dobrzański, 2012; Witkowska, Chojnacka, & Zielińska, 2011; Zielińska & Chojnacka, 2009; Chojnacka, 2008). In this process, the non-living biomass is suspended in a solution containing microelement ions. Alkali metal and alkaline earth metal ions, naturally bound with the cell, are released to the solution, while microelement ions take their place on the surface of the biomass.

For laying hens, the most important microelements are manganese, zinc, iron, copper, iodine and selenium (Smulikowska & Rutkowski, 2005). Many researchers clearly indicate that supplementation of feed with these microelements is indispensable (Dobrzański, Korczyński, Chojnacka, Górecki, & Opaliński, 2008; Ferguson, Leeson, Julian, & Summers, 1978; Opaliński et al., 2012). For example, Leeson and Caston (2008) showed that eggs from laying hens fed with a feed devoid of supplemental minerals (Cu, Mn, Zn) were smaller and weighed less in comparison with eggs from birds fed with a diet containing either inorganic or organic mineral supplements. The lack of microelements in laying hens diet may directly affect the quality of eggshell, because they are involved in the formation of both membrane and eggshell (Leach, 1976; Nys, Gautron, McKee, Garcia-Ruiz, & Hincke, 2001). Also, the lack of microelements can indirectly affect eggshell quality, because diseases caused by insufficient amounts of microelements in laying hens diet can affect the formation of the eggshell (Roberts, 2004).

The objective of the present work was to investigate the applicability of soybean meal enriched by biosorption with microelement ions as a feed supplement for laying hens. The effect of the preparation on egg traits (egg weight, eggshell strength, eggshell thickness, yolk colour and albumen height) was investigated. Also, the effect of increased microelement doses in biological form as well as chelate form on egg quality parameters and hens performance was investigated. The consumer questionnaire was undertaken to evaluate the organoleptic parameters of eggs.

2. Materials and methods

2.1. Biosorption experiments

Soybean meal was enriched separately with a given microelement by the biosorption process. The solutions of Zn(II), Cu(II), Fe(II) and Cr(III) were prepared by dissolving appropriate amounts of $ZnSO_4 \cdot 7H_2O$, $CuSO_4 \cdot 5H_2O$, $FeCl_2 \cdot 4H_2O$ and $Cr(NO_3)_3 \cdot 9H_2O$ (POCh S.A. Gliwice, Poland) in deionized water. The initial concentration of the ions in the solutions was 300 mg/l. The pH of the solutions was adjusted to 5.0 with 0.1 M HCl/NaOH solution (POCh S.A. Gliwice, Poland) and measured with pH meter equipped with an electrode (InLab413) with the compensation of temperature (Mettler-Toledo Seven Multi; Greifensee, Switzerland). Biosorption experiments were performed in a column reactor with a capacity of 4 l. The process was carried out at ambient temperature. The solution was pumped through the column from the top. The flow rate was 0.072 l/h. The saturation of the bed was determined by controlling the concentration of the microelement ions in the solution coming out from the column. The complete saturation of the bed was reached after 7 h. After the biosorption, the preparations were dried in air at 25 °C for 48 h. Samples of biomass were taken before and after the biosorption process to determine the content of the microelements in the soybean meal.

2.2. Feeding experiments

The feeding experiments with laying hens (30 week of age, Hy-Line Brown) were carried out on 180 birds kept in a 3-tier battery system (1.5 m^2/hen), in a room with a controlled climate and light regimen of 16L:8D. Birds were randomly divided into 6 groups: five experimental groups and one control group (C) (5 hens per group, 6 replicates (N)). The experimental groups were fed with the diet supplemented with enriched soybean meal (groups: Sm-Zn, Sm-Cu, Sm-Fe and Sm-Cr) and with chelate (Ch-Zn group). Although chromium is not currently added to feed as a supplement, one of the groups was fed with a diet supplemented with a biological form of chromium, because the further goal of our work was to fortificate eggs with microelements. Eggs fortified with chromium could be used as a supplement for humans as an alternative for the currently used chromium picolinate. The results of the mineral content of eggs will be presented in another paper (Part II). The design of the experiment is presented in Table 1. The division of laying hens to groups and the assigned diets is presented in Table 1a. Feed and water were available *ad libitum*. The composition of the basal diet (Tasomix Universal, Tasomix, Poland), which was formulated according to the nutrient recommendations for laying hens (Smulikowska, 2005), is presented in Table 1b. The feeding experiment was conducted over 12 weeks and was divided into three series (4 weeks each). However, all laying hens were fed with the basal diet containing an inorganic form of the investigated microelements for 2 weeks before the beginning of the feeding experiment.

During the experiment, the control group was fed with the basal diet, in which all of the supplemented microelements were provided in inorganic form. All five of the experimental groups were fed with the same basal diet, but for each group given the microelement in an inorganic form was eliminated on the production stage and substituted either by enriched soybean meal or by zinc chelate (Glystar Zn-16 forte, Arkop, Bukowno, Poland). In the case of the Sm-Cr group, soybean meal enriched with Cr(III) ions had been added to the unmodified basal diet, since no inorganic chromium salt was included in this composition.

In the control group the demand of laying hens for microelements was covered in 100%, in all three series (Table 1a). The microelement doses were established according to nutrition standards (Smulikowska, 2005). The demand for the given microelement in experimental groups was covered in 100%, 150% and 200% during Series I, II and III, respectively (Fig. 1), by enriched soybean meal (groups Sm-Zn, Sm-Cu, Sm-Fe and Sm-Cr) or by chelate (group Ch-Zn). The doses of the remaining microelements in inorganic form covered the demand to 100% in all series. This was to verify if increased doses of a given microelement in biological form affect the egg quality parameters and hens performance compared to standard feeding. The chelate group was created to compare the effects of the new biological supplement and organic chelate.

2.3. Sample collection and analysis

Hens were weighted individually at the beginning of the experiment and at the end of each series. Feed intake was recorded bi-weekly, and the number of laid eggs was recorded daily. Five randomly collected eggs from each cage (a single replicate) laid before the feeding experiment and during the last 2 days of each series were collected and analysed. For each measurement in every group the mean value was calculated for every cage, which gives six replicates for statistical analysis.

Each egg was weighed. Eggshell breaking strength was measured using an Egg Force Reader (Orka Food Technology Ltd, Herzliya, Israel). Eggshell thickness was measured on the egg equator at 3 points by a micrometer screw (0.001-mm micrometer IP 54, Wilson Wolpert, Maastricht, the Netherlands) and the average eggshell thickness was calculated for every egg. Yolk colour was visually estimated using a La Roche colour fan (Roche, Switzerland).