Scientific Papers. Series D. Animal Science. Vol. LXII, No. 2, 2019
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

BENEFICIAL USES OF CHROMIUM IN LAYING HENS NUTRITION: A REVIEW

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Abstract:

Research on various avian species has shown that supplementation of diets with various mineral elements can have favourable effects on production indices, production quality and bird health. In particular, chromium has proven to be an essential mineral, active biologically as a component of glucose tolerance factor, which enhances tissue sensitivity to insulin and glucose utilization. Clinical trials conducted in human patients diagnosed with Type II diabetes along with studies on production animals have led to the conclusion that chromium is beneficial to animals and people undergoing physical or metabolic stress. A brief analysis of chromium supplementation of avian species feed revealed more results of chromium supplementation in broiler nutrition compared to laying hens, which is why the present review was conducted to evaluate the results of using different chromium sources in laying hens. Summarizing the information from the scientific literature on the use of chromium in laying hens nutrition can highlight whether this nutritional strategy is useful or not for laying hens farmers.

***Key words**: laying hens, chromium supplementation, chromium sources, beneficial uses.*

INTRODUCTION

A plenty of studies supported the use of chromium supplementation in laying hens nutrition to improve the feed intake, growth performances, carcass quality, meat lipid profile and immune response (Sahin et al., 2001; Torki et al., 2014; Pogurschi, 2007; Uyanik et al., 2002; Ma et al., 2014; Du et al., 2005; Hanafy, 2011).

Plant feed ingredients commonly used in poultry diet contain small amounts of chromium and addition of this mineral may, therefore become a common micronutrient for animals in the future (Dikeman and Devine, 2004). Chromium deficiency cases in poultry are rare, the diet without chromium addition seem to be meeting their daily requirements. The NRC (1995, 1997) did not specify any recommendation of chromium in poultry diet. Chromium supplementation is required in difficult situations such heat stress, metabolic stress or fatigue. The first experimental data on chromium supplementation in the laying hens feed have been reported in 1970 by Hill and Matrone. Their studies support Cr supplementation in the laying hens diet to decreased the toxicity of dietary vanadium. The interest in the study of chromium and its supplementation in laying hens diets has increased considerably with the demonstration of its positive effect on egg quality. The first results for this purpose were reported by Jensen et al., in 1978. Data from different studies since then have been mixed. The influence of chromium supplementation on egg quality obtained from laying hens feed with different chromium sources have varied. The present review is a synthesis of the results reported in the literature on the forms of chromium administered, the doses and the optimal experimental periods for obtaining considerable effects in the growth of the laying hens. Several sources of chromium have been studied in poultry nutrition, but organic forms have proven to be more effective.

MATERIALS AND METHODS

This review consisted of a compressive analysis of the studies published in PUB Med between 1979 and present.
The search terms were: chromium and laying hens. For the two criteria used, the PUB Med database published a total of 21 published studies. The studies which included chickens (1) or quails (1) were excluded. Another study that did not refer to the proposed criteria but was listed in the database was also ruled out (this is the study of Choi et al., 1979, which used chromium oxide as marker to assess the phosphorus excretion of laying hens). Figure 1 shows the chromium sources used in feeding the laying hens in the published studies analysed.

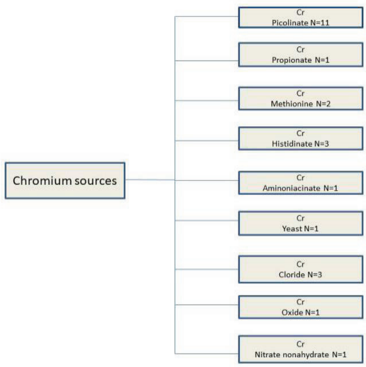

Figure 1. Chromium sources cited
Abbreviations: Cr-Chromium; N-number of studies cited chromium sources

Chromium doses, duration of the experimental periods, and the results obtained were also evaluated and analyzed (Table 1).

RESULTS AND DISCUSSIONS

Most studies used chromium picolinate (N = 11) while studies using inorganic chromium were very few and performed more than 2 decades ago (3-chromium cloride, 1- chromium oxide). Chromium histidinate (CrHis) was only used together with chromium picolinate (CrPic), the purpose of the research being to highlight the chromium source that led to the best results in production. Orhan et al. (2018) reported that the efficacy of Cr as Cr His was more notable than Cr as CrPic. At the same doses (1600 mg CrPic/kg of diet and 0,788 mg CrHis/kg of diet), at the same ages but when the laying hens were exposed to heat stress, both chromium sources were equally effective in alleviating performance variables under heat stress condition (Sahin et al., 2018). Moreover, Ozdemir et al. (2017) reported that the same doses and sources of chromium supported the relief and treatment of stress complications.
Comparing the bioavailability of organic and inorganic chromium forms associated with other mineral elements such asmanganese, zinc and copper, Yenice et al. (2015) reported a significant increase of Mn, Zn, Cu and Ca in the laying hens serum, when the minerals were administered in organic form. When the level of these elements was double in diet the Cr and Ca excretion was not affected. A combination of Mn (80 mg/kg diet), Zn (60 mg/kg diet), Cu (5 mg/kg diet) and Cr (0.15 mg/kgdiet), administrated in organic form showed a significant increase of egg content in Mn, Zn, Cu and Cr. In the eggshell only Zn and Cr concentration was notable.
The diet supplemented with the combination of chromium and vitamin C was also studied extensively by Mirfendereski and Jahanian (2015) and Torki et al. (2014). A combination of CrMet and acid ascorbic revealed beneficial effectsin terms of egg production and egg mass but when the CrMet was administered separately in the diet the egg production and feed conversion was improved (Mirfendereski and Jahanian, 2015).
The addition ofchromium propionate at 400 µg dose/kg diet has been found to improve egg production during the latter 4 weeks as reported Ma et al., 2014. At this dose, however, there was a decrease in the height of albumen, yolk color score and Haug unit. The addition of 600 µg chromium/kg diet as chromium propionate improve the shell thickness. The dose of 200 µg/kg diet only led to a 31% decrease in uric acid. A combination of CrPic and copper did not significantly affect egg production, egg weight, eggshell thickness and eggshell strength as Lien et al. reported in 2004. In previous investigation the same authors also showed the copper and chromium supplementation did not influence egg production (Lien et al., 1996; Chiou et al.,

1997). It was also reported a significant interaction between copper and chromium. Egg cholesterol was significant affected by copper in the sense of reducing that, while chromium supplements had no effect on this parameter. Very Low-Density Lipoprotein was significantly reduced when the laying hens were fed with diet supplemented with copper and chromium while High Density Lipoprotein was increased. The interaction between chromium and a microelement, this time zinc, has been studied by Onderci et al. in 2003. The reported results showed that diet supplemented with chromium or supplemented simultaneously with chromium and zinc increased significantly the digestibility of nutrients alleviating the negative effect of cold in laying hens. Reducing the effect of low temperature on the hens can also be done by supplementing the diet with chromium and vitamin C, as Sahin et al., reported in 2002a. The chromium source was chromium picolinate and the dose was 400 micrograms of Cr/kg diet. The authors did not specify the duration of the experimental period. Supplemental chromium and ascorbic acid increased serum vitamin C and E bud decreased malondialdehyde concentration (Sahin et al., 2002b).

Because of the growing interest in the use of chromium as a supplemental micronutrient in laying hens, Guerra et al., 2002 investigated whether high Cr(III) levels, fed in the form of chromium yeast (Cr-Y), chromium aminoniacinate (Cr-AN) or chromium chloride ($CrCl_3$), produces changes in the hepatic microsomal metabolism.

The activity of ECOD (anspecific marker of a number of CYPs-Cytochrome P-450) was significantly ($P<0.01$) reduced by $CrCl_3$ (~63% loss), Cr-Y (~35% loss) and Cr-AN (~54% loss). The diets supplemented with 50 ppm Cr/kg diet (different forms) administered to hens for a period of 28 days led to changes in the microsomal metabolism. The addition of half dose of chromium in diet (25 ppm/kg diet) did not change noticeably the microsomal metabolism. The doses of 50 ppm/kg diet (whatever the chromium source was) did not affect the egg production or egg quality.

Supplementing the diet with chromium and zinc, when the chromium dose was 400 micrograms CrPic/kg diet, has led to improved feed efficiency, egg production and even live weight of laying hens treated (Sahin et al., 2002). According to the authors serum glucose and cholesterol concentration decreased while protein concentration increased.

Table1. Doses, sources of chromium and duration of experimental period

Reference	Dietary Cr concentration/kg (source)	Duration of experimental period/Age
Witkowska et al., 2019	0,1g Enriched Soybean meal-Cr nitrate nonahydrate	12 wk/30 wk old hens
Orhan et al., 2018	1600 mg CrPic& 0,788 mg CrHis	12 wk
Zhang et al., 2018	0,4 mg and 0,6 mg CrPic	10 wk/23 wk old hens
Sahin N. et al., 2018	1600 mg CrPic& 0,788 mg CrHis	12 wk
Ozdemir et al., 2017	1600 mg CrPic& 0,788 mg CrHis	12 wk
Yenice et al., 2015	0,15 mg Cr oxide & 0,07 CrMet	16 wk
Mirfendereski et al., 2015	0, 500, 1000 ppb CrMet	12 wk
Torki et al., 2014	0, 200, 400 µg CrPic	8 wk
Ma et al., 2014	0, 200, 400, 600 µg CrProp	8 wk
Lien et al., 2004	0, 800, 1600 mc CrPic	28 days
Onderci et. al, 2003	0,4 mg CrPic	108 days
SahinK. et al., 2002a	400 µg CrPic	32 wk old hens
Sahin K. et al., 2002b	400 µg CrPic	32 wk old hens
Guerra et al,, 2002	25, 50 ppm CrY/25,50 ppm CrAN /25, 50 ppm $CrCl_3$	28 days
Sahin N. et al., 2002	400 µg CrPic	32 wk old hens
Sahin K. et al., 2001	100, 200, 400 µg CrPic	120 days/46 wk old hens
Ousterhout L.E. et al., 1981	20 ppm $CrCl_3$	10 days/50 wk
Maurice DV et al., 1979	10 µg/g $CrCl_3$	12 wk/40 wk old hens

Definitions of abbreviations used:CrProp-chromium propionate; CrMet-chromium methionine; CrPic-chromiumpicolinate; CrAN-chromium aminoniacinate; $CrCl_3$-chromium chloride; CrY-chromium yeast; CrHis-chromium histidinateWk-week

In the experiment conducted by Sahin et al., in 2001, 3 doses of chromium were used: 100, 200 and 400 µg CrPic respectively, but only the 200 µg CrPic dose has been shown to have positive influence on egg production. In this case the increase in chromium dose of diet also led to a linear increase in live weight.

The authors also reported a linear increase in insulin concentration in plasma while corticosterone concentration decreased linearly.

Zhang et al. (2018) stated that brown-egg laying hens diet supplemented for 10 weeks with 0.4 or 0.6 mg Cr/kg led to a significant reduction of serum glucose concentration and increased serum antibody titer against Newcastle disease. These doses of chromium (0.4 and 0.6 mg Cr/kg diet) have not been shown to have a positive influence on egg production performance and egg quality.

Researches to obtain eggs fortified with chromium but also with other microelements were carried out by Witkowska et al., in 2019. Eggs fortified with chromium could be used as a supplement for humans as an alternative for the currently used chromium picolinate (Witkowska et al., 2014).In the context in which the consumer has a skeptical attitude towards food additives (Zugravu et al., 2017), fortified products are a perfect alternative to reaching optimal levels of the various micronutrients essential for certain categories of population. The authors compared the results of basal diet to the results of a diet which include soybean meal enriched with Cr(III). The raw soybean meal from the basal diet had a chromium content of 0,022 mg/g and the soybean meal after biosorption had 20,588 mg/g. The soybean meal enriched with chromium did not significantly affect the weight of eggs. Statistically significant differences were observed between the control group and group with soybean meal enriched with chromium, where the egg shell strength was higher by 11.3% ($p=0.045$). Regarding the eggshell thickness, the authors reported a decrease after the first two series of the experiment but the differences were not statistically significant, however, compare to the control group the eggshell thickness was higher. A significant decrease in feed intake and feed conversion rate was observed after every series compare to the control group. These results may indicate that a biological form of chromium improved hens performances due to better feed conversion. After eating eggs obtained from laying hens fed with soybean meal enriched with chromium, the consumers indicated that eggs smelled more pleasantly.

Concluding, soybean meal enriched with chromium, influenced the content of chromium in the albumen, particularly due to the increased dosing. It is worth underlining that the chromium was accumulated primarily in the albumen, probably because chromium was supplemented in a form bound with protein.

Michalak et al. (2011) documented that the diet of laying hens supplemented with two marine macro algae enriched with chromium compare to the diet where chromium was included in inorganic salt favoured the increase in the content of chromium in yolk and albumen.

The study of Ousterhout et al. (1981) revealed that addition of 20 ppm chromium to laying hens diet had no detectible effect in preventing the albumen quality deterioration caused by vanadium. The effect of chromium supplementation on albumen quality is contrary to other report (Jensen and Maurice, 1980). The differences between the obtained results are caused by the experimental periods that had different duration (4 to 6 weeks at Jensen and Maurice's experiences and no 2 weeks at Ousterhout's experience). In order to show a protective effect, chromium should be administered for more than 10 days in the laying hen’s diet.

Contrary to recent studies (Du et al., 2005; Sahin et al., 2002a) where the hypolipidemic effect of diet supplemented with chromium has been shown in laying hens, Maurice and Jensen (1979) reported no significant effect of chromium on liver fat and incidence of liver hemorrhage. The data on egg production, egg weight or body weight reported in the mentioned study do not provide evidence to demonstrate the positive effect of dietary chromium supplementation for these parameters.

CONCLUSIONS

In conclusion, after a thorough review of trials relevant to the issue, there are many reasons to recommend supplementation of chromium in laying hens diet. The organic chromium sources have proven to be more effective than the inorganic forms. CrPic has been used in more than 10 researches. CrHis has been shown to be much more efficient compare to CrPic due to its higher bioavailability. Under heat stress, both sources had the same efficiency. When chromium was associated with various mineral elements, the production proved to be superior. The minerals in the organic forms associated with a chromium supplement in the laying hens diet led to significantly increased concentrations of these minerals in the egg. The chromium/vitamin C combination revealed beneficial effects in terms of egg production and egg mass. The egg shell thickness could be improved by adding 600 µg chromium propionate to laying hen's diet while 400 µg chromium propionate improve egg production. The chromium/copper combination in the laying hen's diet has been shown to have significant results on the cholesterol content of the egg. Changes in microsomal metabolism were observed in laying hens fed with chromium. The analysed studies have shown the beneficial effect of chromium on the feed efficiency, egg production and live weight. Recent research with laying hens has shown that supplemental chromium decreased serum glucose and cholesterol concentration. The evidences available indicates that supplemental dietary chromium can affect egg production, egg quality, well-being of poultry and even their metabolism. In order to be able to show the beneficial effects. The chromium should be introduced in the diet of laying hens for an experimental period of at least 8 weeks.

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