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Inulin in poultry production

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Since 2006, when the European Union imposed a total ban on the use of antibiotic growth promoters, scientific interest has focused on natural feed additives that might be positive to both production performance and animal health. Inulin is a prebiotic, which occurs naturally in many plants as a storage material. The specific structure of inulin underlies the fact that it is not digested by the host digestive enzymes. Unchanged, the prebiotic reaches the large intestine, where it undergoes fermentation and becomes a substrate for some strains of healthy bacteria. Current literature contains information on the effects of inulin on broiler performance and laying performance of hens. It may be concluded from data available that inulin is beneficial in the production of poultry meat and eggs. Inulin may improve feed intake and conversion, stimulate weight gains, strengthen the skeletal system, improve carcass yields and the production and quality of eggs. However, reports on the subject are scarce, and the results they present vary substantially. The mode of action of inulin appears to be complex, multidirectional and is not yet fully understood. The ambiguous character of inulin may result from the fact that its effectiveness in poultry nutrition depends on a number of factors. Despite these unresolved issues, the positive properties of inulin may be of benefit to the poultry industry.

Keywords: inulin; prebiotic; performance; egg quality; meat quality

Introduction

All commercial breeding programs are focused on maximising production parameters, such as growth rate, feed conversion and, depending on the production type, meat or laying performance. Proper nutrition of the birds is the key factor to reach the goal. Since the EU enforced the ban on antibiotic growth promoters, the incidence of gastrointestinal tract diseases has increased substantially. Consequently, new feed components to control disease have been urgently sought. Also, higher nutritional awareness in consumers and an increasing popularity for healthy lifestyles make scientific interest focus on natural substances as antibiotic alternatives, including prebiotics (Verdonk *et al.*, 2005; Przeniosło-Siwczyńska *et al.*, 2006; Lessire and Etienne, 2007; Hejdysz *et al.*, 2012; Kowalczyk *et al.*, 2012; Dankowiakowska *et al.*, 2013).

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Prebiotics are a term to refer to some oligosaccharides or polysaccharides that pass the gastrointestinal tract without being digested or absorbed. They are beneficial effects on the host result from the selective stimulation of growth and/or activity of members of the gut microbiota (Kowalczyk *et al.*, 2012; Dankowiakowska *et al.*, 2013).

One of the most effective prebiotics is inulin (Świątkiewicz and Koreleski, 2007), which occurs naturally in many plants as a storage material. Chemically, inulin is a carbohydrate, a mixture of oligomers and polymers. Industrial scale production technologies use the roots of chicory (*Cichorium intybus*) and tubers of Jerusalem artichoke (*Heliantus tuberosus*) as the sources of inulin (Niness, 1999; Wierzejska and Szponar, 2003; Górecka *et al.*, 2009). The following review was aimed to provide detailed information on the effects of inulin on the performance traits of poultry.

Poultry meat production

Meat production is based on young, highly productive meat birds characterised by high body weight gains, good feed conversion, quick feather growth, conformation and high carcass yields. Traits such as feed intake and FCR affect the profitability of meat poultry production. Some authors, who used mainly corn and soybean meal-based feeds, however, have denied that inulin has any effect on feed intake and conversion (Rehman *et al.*, 2007; 2008; Ortiz *et al.*, 2009; Alzueta *et al.*, 2010; Hu *et al.*, 2010; Rebolé *et al.*, 2010; Velasco *et al.*, 2010; Świątkiewicz *et al.*, 2011; Elrayeh and Yildiz, 2012; Nabizadeh, 2012b). Others, using similar feeds, on the other hand, suggest that inulin is a beneficial additive, so conclusions on using inulin are conflicting. Yusrizal and Chen (2003) demonstrated that inulin improved feed intake and FCR in female broiler chickens. Józefiak *et al.* (2008) observed that an addition of 3 g/kg inulin in feed had a positive effect on FCR in broilers from the first day to slaughter at 42 days. Park and Park (2011) found that feed intake was even better if microencapsulated inulin (MCI) was used. These authors demonstrated that the parameters of feed consumption were best in the group receiving 0.25 g/kg MCI in feed. In another study, Nabizadeh (2012a) showed that supplemental inulin had a significant effect on feed consumption as calculated for the entire period of the experiment (42 days) when 10 g/kg inulin was added to feed, although FCR improved regardless of whether the addition of inulin was 10 g/kg or 5 g/kg.

Finally body weight is one of the most important traits of meat poultry. Those authors who used mainly corn and soybean meal demonstrated that inulin did not significantly affect weight gains in broilers (Rehman *et al.*, 2007; 2008; Ortiz *et al.*, 2009; Alzueta *et al.*, 2010; Kucukersan *et al.*, 2011; Świątkiewicz *et al.*, 2011; Elrayeh and Yildiz, 2012). On the other hand, according to authors who used similar feeds, there are indications that this prebiotic was positive in terms of body weight. Yusrizal and Chen (2003) observed that inulin addition (10 g/kg of feed) gave a 10% increase in the body weight of female broiler chickens. Van Leeuwen *et al.* (2006) reported that 10 and 20 g/kg inulin positively affected weight gains in broilers. Similar results were seen by Nabizadeh (2012b). In another report, Park and Park (2011) found that body weight increased in chickens fed with MCI (0.2 and 0.25 g/kg of feed), as compared with birds fed a negative control diet or with the antibiotic Avilamycin (0.08 g/kg), over the entire period of the experiment (0-35 days). Inulin as MCI used at a dose of 0.2 g/kg of feed was considered the optimum MCI concentration in the diet of broiler chickens.

Adding 10 or 20 g/kg inulin, Rebolé *et al.* (2010) demonstrated that the effect of the prebiotic was larger within the early period of life (7-21 days). The effect was observed until the end of the experiment when inulin supplementation was 10 g/kg in a soybean

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meal-wheat-barley-based feed. Velasco *et al.* (2010) noted that an addition of inulin resulted in a non-significant body weight increase. The authors stated that 5 g/kg inulin had a stronger effect on poultry body weight gains compared to 10 g/kg, suggesting that the positive impact on inulin on weight gains may depend on the dose. It should be stressed, however, that the positive effect of inulin is observed only up to certain level and further increases did not have any further effect. Therefore, when using inulin, it is important to pay attention to the proper inclusion level in the feed. Moreover, body weight as well as any other production parameters is subject to a number of genetic and environmental factors that should be taken into account when interpreting the results of particular feeding trials, as these can influence outcome.

An elevated incidence of skeletal abnormalities may sometimes be the case in the intensive poultry production systems. Such disorders lead to disabilities, particularly in heavy and fast-growing broilers. This in turn contributes to significant economic losses and has a negative impact on animal welfare (Julian, 2005; Waldenstedt, 2006; Dibner *et al.*, 2007; Świątkiewicz *et al.*, 2011).

A study conducted by Chen and Chen (2004) indicated that birds fed diets containing the prebiotic (10 g/kg feed) had a significantly higher tibia total ash, Ca, P and Na. The same authors analysed the levels of Mg, K, Cu, Zn and Fe, and found no significant differences. This suggested that inulin may promote the mineral absorption of Ca and P in particular. Similar conclusions have been drawn by Ortiz *et al.* (2009). These authors observed increased levels of tibia content of ash and Ca; however, they did not found any linkage between this and the morphology. Thus, the authors suggested that the increased absorption of calcium and microminerals has a positive effect on the mineralisation of the bone. Others have obtained different results, with no significant differences in terms of biochemical and morphometric parameters of tibiae and femora (Świątkiewicz *et al.*, 2010b; 2011).

The research carried out so far demonstrates that inulin used in the nutrition of intensively managed poultry flocks may improve bone mineralisation. It should be stressed, however, that the studies in this field were relatively recent, and it may be stated that there is not enough data yet to formulate clear conclusions.

Slaughter characteristics are another important parameter in the production of meat poultry. It can involve several indicators, but one of the most important is the carcass yield, which may include the weight of giblets. The complete evaluation of the carcass involves dissection of all parts and calculation of the percentage content of muscle, skin, fat and bone in relation to either eviscerated carcass weight or live weight.

Ortiz *et al.* (2009) and Kucukersan *et al.* (2011) applied various inulin concentrations (5, 10, 15 or 20 g/kg of feed), but failed to demonstrate its effect on carcass yields in broiler chickens. Likewise, Świątkiewicz *et al.* (2011) observed that the weight of carcass, breast, abdominal fat and liver did not change as a result of inulin supplementation.

Yusrizal and Chen (2003) noted that supplemental inulin gave a significant increase in carcass yields in male broiler chickens. Park and Park (2011) stated that carcass weight and meat yield from the carcass were higher in groups fed inulin in diets. The authors noted a positive effect of inulin in relation to breast and thigh meat weight. In liver and gizzard, no weight differences were found between the treatment groups, although abdominal fat content was much lower in the group with inulin supplementation. Abdominal fat in groups receiving MCI at levels of 0.2 and 0.25 g/kg feed was lower by 19.08 and 21.97%, respectively, when compared to the control group, and by 20.5 and 23.3%, respectively, when compared with the group treated with an antibiotic. The decrease in abdominal fat content was supported by other data from Yusrizal and

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Chen (2003) and Elrayeh and Yildiz (2012). This decrease is important for the poultry industry, since the fat in the abdominal region represents a post-slaughter waste. The fact that accumulation of abdominal fat is reduced in birds fed supplemented diets may result from a decreased amount of lipids transferred to the abdomen, the decrease being due to an inulin-induced reduction in the blood fat level (Velasco *et al.*, 2010).

Egg production

In laying hens, little research has been conducted on dietary inulin supplementation, however from what is available, it can be concluded from available sources that the prebiotic improves the desirable traits of laying hens.

Park and Park (2012) reported that laying production, egg weight and feed consumption increased in groups treated with a higher level of inulin (0.25 and 0.30 g/kg of feed), as compared with the control and a group treated with a lower level, 0.20g inulin/kg of feed. Chen *et al.* (2005b) demonstrated that an addition of 10 g inulin per kg feed increased egg production by approximately 11% and improved FCR. However, supplementation did not affect the weight of eggs or internal protein quality. This was in agreement with various other researchers, e.g. data from Hu *et al.* (2010), who also did not observe any effects of inulin on the weight of the eggs or Haugh units. Hartini *et al.* (2003), who studied ISA Brown hens, demonstrated that 2 g/kg inulin in a wheat-based feed did not affect egg production, and similar results were reported by Świątkiewicz *et al.* (2010a).

Inulin, which influences lipid and cholesterol metabolism, has been shown to improve egg quality. Chen *et al.* (2005a) studied the effect of 10 g/kg inulin in feed and observed a reduction in yolk cholesterol by 16.4% and concentration in the whole egg dropped by 22.4%. However, there was no difference among the control and prebiotic group with respect to the yolk weight. Similar effects were observed by Hu *et al.* (2010), who added inulin in various doses (1, 5, 10, 15 and 20 g/kg feed) and showed that cholesterol concentration in the egg decreased linearly with dietary inulin dose. Park and Park (2012) demonstrated that an addition of varied amounts of MCI significantly reduced egg cholesterol, from 5.7% to 8.5%, depending on dose in the feed.

Cholesterol accumulates in the tissues and eggs of birds and reduced blood cholesterol is reflected in its lower content in the eggs, which Chen *et al.* (2005a) measured in yolk and whole eggs. However, Yildiz *et al.* (2006), who fed laying hens with inulin-rich Jerusalem artichoke, found no effect on egg production or yolk cholesterol content.

The profitability of egg production on commercial farms and in breeding flocks largely depends on the eggshell quality. Durability against damage is essential in terms of possible microbial contamination and saleability. The process of eggshell mineralisation requires large amounts of calcium and other macro- and microminerals from the diet and tissue reserves. Therefore, the optimal intake of dietary minerals is one of the main issues in the production of high-yielding laying hens (Świątkiewicz *et al.*, 2010a; 2010c), and bone data has shown that inulin may affect mineral uptake. Chen and Chen (2004) observed that an addition of inulin (10 g/kg of feed) significantly increased the strength of the eggshell as early as in the first week of its application. By the second week there was a significant increase in the total eggshell mass by 4.4%. In an experiment on laying hens fed with a limited amount of Ca and P in the diet, Świątkiewicz *et al.* (2010a) demonstrated a positive impact of the prebiotic on eggshell quality, particularly at age 46, 58 and 70 weeks. They found that inulin may have a positive effect on eggshell quality in older, highly productive hens, in which the

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incidence of cracked eggshells can exceed 20% (Nys, 2001). However, Hu *et al.* (2010) reported that inulin had no effect on the eggshell strength or thickness.

Besides hen age, eggshell quality may also be influenced by dietary flaws, housing conditions and diseases of laying hens. The impact of inulin on eggshell quality may be associated with positive effects on utilisation of feed minerals. Reduction of intestinal pH represents a factor affecting this process, and prebiotics can reduce pH in the lower part of the colon. A low pH leads to an increase of Ca solubility, which enhances passive absorption (Samanta *et al.*, 2013) making more Ca available for eggshell formation.

Conclusions

As a feed supplement, inulin may improve feed consumption and intake, stimulate body weight gains, strengthen the skeletal system, improve slaughter performance, as well as egg production and quality. The mechanism of inulin impact is complex, multidirectional and not fully understood. The ambiguous character of inulin may result from the fact that its effectiveness in poultry nutrition depends on a number of factors. Variables such as the prebiotic origin, inulin content in the feed, type of feed, bird age, sex, house hygiene and maintenance and environmental stress may affect the response to inulin supplementation in feed. Prebiotic supplementation of livestock feeds is a relatively new concept. Despite a number of still unresolved issues, the available data on the positive aspects of inulin are promising for the poultry industry. Further in-depth research on the impact of inulin on the traits that are important for meat and egg production are necessary to fully exploit its positive effects.

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