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In ovo Feeding Technology for Optimization of Incubation and Hatching in Broiler Chickens[#]

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ABSTRACT

This paper provided a brief account of the need of in ovo feeding technology for efficient incubation and hatching as driven by the current and projected poultry production figures. After substantial laboratory experiments in the early 1980s, in ovo vaccination technology became applicable in the commercial broiler hatcheries. The scientific theories that enabled the use of in ovo vaccination facilitated the process of injecting the various nutrient composition into broiler eggs/embryo (in ovo feeding) considering the injection site and the stage of embryonic development. Some studies of in ovo feeding have found scientifically positive effects on incubation properties but they remain insufficient at the commercial level thus, the adoption of the application is very slow compared to other embryo management techniques. Therefore, continuous studies on the best nutrient compositions, combinations, and concentrations are required for the commercial use of in ovo feeding technology.

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Introduction

In the last 50 years, the global poultry industry has grown over 5 times and owns over 24 billion poultry assets. The global meat production reached approximately 125 million tons in 2018 compared to 101 million tons in 2011 (FAOSTAT, 2018), and chicken meat constitutes over 88 percent of the global poultry meat yield. On the other hand, world per capita consumption of poultry meat increased to 15. 9 kg in 2018 from 14.9 kg in 2011. Per capita consumption of poultry meat is the highest compared to other animal-derived foods (FAO, 2018), and this is associated with its fastest growth rate over the last five decades. The per capita poultry meat consumption and broiler production values in Turkey were 21 kg and 2,138,000 tons respectively (TÜİK, 2019). Earlier studies reported that the demand for poultry meat is projected to increase by 121% due to population growth of 9.6 billion people in the next 3 decades coupled with many other factors (Alexandratos and Bruisma, 2012). It was emphasized that with factors such as urbanization, the decreasing costs of feeds, etc, the global poultry production is expected to grow 20 times (Mottet and Tempio, 2017), and recently, a slow increase of 17% in global poultry meat production is projected between 2018-2028 as a result of rising feed costs and global per capita poultry meat consumption rates will rise to 40 kgs by 2028 (OECD-FAO, 2018). In Turkey, both per capita consumption of poultry meat and broiler production have been projected at 30.75 kg and 3.534.000 tons respectively with a population of 93.4 million by 2025 (BESD-BİR, 2012). All the above reports drive to the importance of optimum incubation and hatching as a vital way of meeting the present and future demands for poultry meat. It is increasingly appreciated that incubation performance is directly linked to the chick quality, the cost of chicks, and post-hatch yield. In ovo feeding application is one of the embryo management application aimed at improving incubation performances. On top of summarizing the current and future state of the world and Turkey poultry industry, this paper provided a brief account of the efficient incubation of chicken eggs and discussed in ovo feeding technology as a means for optimizing incubation and hatching.

The Need for Efficient Incubation

Bergoug et al. (2013) reviewed pre-incubation factors (egg quality, breeder age, egg storage time and conditions, etc), and incubation conditions (temperature, humidity, ventilation, and carbon dioxide levels) that affect the optimization of incubation and hatching operation, thus chick quality. Furthermore, at hatchery important relationships include; (1) chick weight, chick length, and live slaughter weight; 1 g increment in chick hatch weight is associated with approximately 10 g increase in live slaughter weight that is generally reflected in production as 5-6 thousand tons/year/country. Also, the average chick length ranges between 17- 20 cm, and an increase from 17 cm to 20 cm, chick weight increases from 39 g to 49 g, and slaughter weight from 2330 g to 2470 g (Wolanski et al., 2006), and (2), the relationship between egg weight and the chick; chick weight is 68- 70% of egg weight, with an acceptable egg weight (56.7 g) but, 56.7 g ± 2.4 g = (± 18 g) to slaughter weight (Wolanski et al., 2007). The above relationships are vital to efficient incubation and post-incubation performances. In the chicken industry, chick losses as a result of embryonic mortalities and deformed chicks are still significant although researchers are continuously working on optimizing incubation and chick quality. Generally, any application that ensures a 1% improvement in incubation efficiency results in an increased number of broiler chicks per year from millions of broiler breeder eggs that are incubated for meat production in a particular country. Currently, many hatchery studies focusing on embryo management uses techniques including; in ovo vaccination (commercially accepted), and based on the number of available publications, epigenetic adaptation and thermal manipulation (Saleh et al., 2020; Nyuiadzi et al., 2020; Basaki et al., 2020; Tarkhan et al., 2020) and in ovo lighting (Tainika and Bayraktar, 2020) have been consistently tested while the spread of in ovo feeding is very slow (Kadam et al., 2013), and its insufficient studies have inconsistent findings.

In ovo Feeding: An Embryo Management Application Needed in the Hatchery

The phases of embryonic development include; differentiation, growth, and maturation, and during growth, all organs and systems of the embryo must obtain their shapes before they mature. In the maturation stage, organs and systems that are maturing (i) perform some physiological functions, and (ii) ensure the integration of physiological and endocrinal controlling systems (Bellairs and Osmond, 2005; Boerjan, 2010). Starting from the last quarter of embryo development till 1-week post-hatch is a defined critical period, and it is suggested that any application in the critical stage directly affects the survivability of chicks and post-hatch performance because basic embryonic functions mature in a way that adapts to environmental variations (Boerjan, 2010), and in ovo technology is one application that can be used to support the developing embryo in the critical period as reviewed by Kadam et al. (2013) and Peebles (2018). Though the adoption of in ovo feeding has been very slow, the application is suggested to have the potential to improve chick quality and minimize post-hatch losses during the critical period. This is through (i) Prevention of physiological limitations, (ii) Improvement of intestinal functionality, and (iii) Meeting the nutritional requirements of the embryo due to physiological and metabolic changes during the last stage of incubation (Uni and Ferket, 2003; Uni and Ferket., 2004; Kadam et al., 2013). These benefits are linked to the biological function of the administered nutrients coupled with injection site and time, nutrient dosage, etc (Peebles, 2018; Saeed et al., 2019).

For example, in an earlier study, when Tako et al. (2004) injected carbohydrate (CHO) and β-hydroxy-β-methylbutyrate (HMB) separately or in combination at 17.5 day of incubation (doi) via the amniotic fluid, the intestinal villus width and surface area were increased in all in ovo feeding (IOF) treatments at day (d) 2 post-hatch, and at d 3, the surface area of an average villus increased by 45% for (HMB) treatment, 33% for (CHO & CHO + HMB) treatments. Similarly, administration of CHO & HMB on the same doi and injection site increased chick hatch weight, liver glycogen content, and breast muscle weight by 5-6%, 2-5 times, and 6-8% respectively (Uni et al., 2005). On the other hand, Zhai et al. (2011) suggested that (IOF) of carbohydrate solutions at 18.5 doi in the amnion of broiler embryos should be in lower volumes for better results. IOF of a polyamine (putrescine) in varying concentrations (0.05, 0.1, 0.15, and 0.2%) at 17 doi in the amnion of broiler embryos led to a decrease in their percentage residual yolk compared with the non treated animals, hatchability was inversely proportional to the concentration of putrescine, and the percentage of the breast increased with increased concentration of putrescine. However, the authors recommended that the concentration of putrescine should not exceed 0.1% for the IOF application (Goes et al., 2020). IOF of varying doses of arginine (11 and 22 mg) at 14 doi in the FUNAAB-Alpha eggs decreased hatchability 88.4 and 91.1% respectively versus 92.9% of the noninjected group but both concentrations enhanced the establishment of duodenal villi of the injected chickens (Odutayo et al., 2020). IOF of vitamin B_{12} (20 and 40 μg) at 13 doi and (20 μg) at 15 doi in amnion of Ross broiler embryos significantly decreased hatchability compared to nontreated and distilled water treated groups (Teymouri et al., 2020). IOF of different LAB–nano-Se concentrations (10, 20, and 30 μg/embryo) significantly increased the hatchability ($p < 0 .05$) compared to normal saline (77.9%) and noninjected (77.1%) groups, and the effect of LAB–nano-Se on hatchability was concentration-dependent with 30 μg treated group having the highest percentage (94.9%) (El-Deep et al., 2020). Effect of IOF of hydroxyapatite nanoparticles (HA-NP) in varying doses (50, 100, and 500 μg/ml colloids) at 1 doi on chicken embryo development was evaluated by Matuszewski et al. (2020). The authors found that embryos treated with HA-NP showed normal growth and development, and IOF of HA-NP did not impact hatchability and body weight. In a study, when Bojarski et al. (2020) inoculated Hexavalent chromium (Cr (VI)) in different doses at 5 doi in the air cell of broiler chicken eggs, they observed that the effect of chromium on hatchability of chicks was dose-dependent. While higher Cr (VI) concentration from 25 to 250 µg per egg significantly reduced hatchability, lower doses (1.56 and 2.5 µg per egg) insignificantly increased hatchability. The effect of IOF of different levels of a commercial canthaxanthin product (CCX) comprising lignosulphonate, corn starch, canthaxanthin, dextrin (yellow), and ethoxyquin on incubation traits, chick quality, and broiler performance was investigated by Araújo et al. (2020). In the study, levels of CCX: 0.0, 0.35, 0.45, 0.55, and 0.65 mg/0.5 mL of sterilized and distilled water were injected into the chicken embryos at 17.5 doi. They observed that IOF of CCX significantly decreased hatchability ($P < 0.05$) and resulted in a longer hatching window ($P < 0.05$) as compared with the noninjected group.

Conclusions

Due to this great potential, fast adoption of approaches and methods such as in ovo feeding in the hatchery sector can provide significant gains not only scientifically but also economically. Research should continue to find the best possible nutrient combinations and concentrations to obtain consistent results with in ovo feeding application.

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