Comparison of three hatching systems 1: Chick performance

Recent decades have been characterised by intensive genetic selection of broiler and layer chickens for enhanced growth rate and meat yield or intensified egg production, respectively. Besides feeding programme and nutrition efficacy, improvement of immunology, health, welfare, equipment and setting programmes have significantly influenced poultry production.

In this series of two articles we will examine objectively the current challenges facing poultry producers, focusing on chick welfare at the hatchery.

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One challenge faced by incubation manufacturers is to provide equipment that is capable of delivering the optimum environmental conditions for developing embryos as well as ensuring hatchlings are not subjected to physical and environmental stresses.

Another challenge is to provide the best conditions for newly hatched chicks to ensure that their residual yolk sacs are sufficient to sustain them without stress until they reach the farm.

This article will discuss the role of the yolk sac and the optimum time newly hatched chicks have before they should have to access to feed and water. We will also consider the implementation of a variety of hatching systems and their effect on chick performance, immunity, meat quality and chick welfare.

Our research will compare three hatching systems: (HH) traditional hatchery, (HO) hatchling with feed and (HF) on-farm hatching. The last two (alternative) systems had some benefits in improved initial chick body weight due to the provision of early accesses to feed and/or water to the newly hatched chicks.

To compare the merits of all three systems we should understand that chicks from traditional systems will have only relied on their residual yolk sac reserves to sustain them, whereas chicks from alternative hatchery systems will have been encouraged to feed soon after they have hatched and seemingly gaining an initial up-to four day 'advantage' over their traditional hatchery counterparts.

However, our research suggests that at slaughter age chicks reared from traditional systems did not differ in terms of final body weight (FCR). Moreover, chicks reared from the two alternative systems had a lower chick quality score, lower breast meat quality and reduction in welfare efficacy.

We compare the effect of both early access to feed/water and to the feed deprivation (traditional hatchery practice) on the chick's immunity organs. We also discuss the influence of the hatch window on chick performance and welfare.

The early feeding concept was developed decades ago to improve chick post-hatch performances. There are two original concepts of early feeding:

- Production performance:
To prevent delayed access to feed and water for the newly hatched chicks to enhance their body weight, growth rate, gut-health and immunity, and decrease first week mortality. Early feeding benefits have been approved however the discussion is ongoing on when is the most beneficial time for newly hatched chicks to access water and feed.
- Welfare:
The principle for the poultry industry is that chicks should have access to feed and water as soon as chicks hatch, moreover, regarding welfare, the Dutch, in 2018, revised a domestic law to ensure chicks should be able to access feed and water within 36 hours of hatch rather than the current 72 hours.

Traditionally, hatcheries are identified as installations that produce the maximum number of high-quality, healthy one-day-old chicks in a small area, using a minimum number of fertile eggs.

The objective of modern hatcheries is focused more especially for broiler chickens from the time of egg setting in the incubator up to slaughter age and involves egg handling, hatchery process, the quality of equipment, vaccination, transportation and other management aspects.

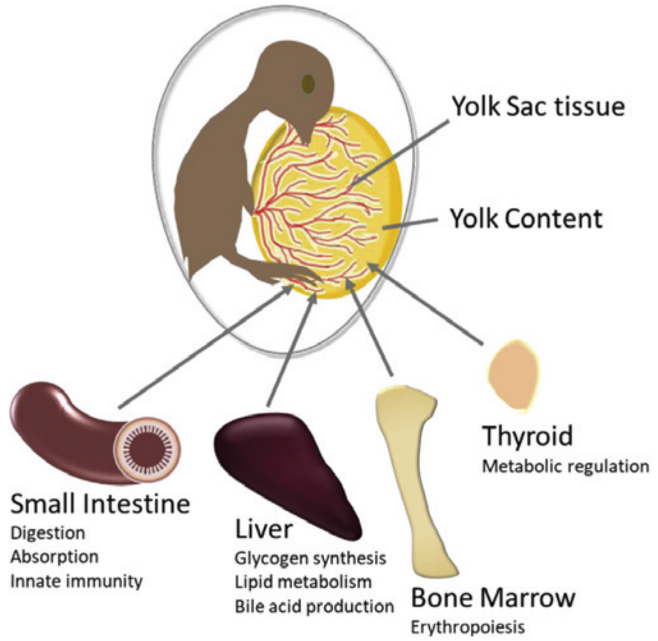

Fig. 1. A schematic diagram showing the multifunctional properties of the chick's yolk sac tissue. This provides the functions of the intestine, liver, bone marrow, and thyroid, while the organs of the embryo are developing and maturing.

Multifunction of the chick's yolk sac

Newly hatched chicks of all birds have a unique food strategy in their journey of development until they have access to exogenous feed – they have a yolk sac that contains important nutrients. This is different from all other domestic animals. The yolk sac is an internal food source for post-hatch chicks to sustain them over the first few days, post hatch.

During the last days of incubation the residual yolk is retracted into the body cavity as an extension of the intestine. Post hatch the residual yolk is the only nutrient source available to the chicken until exogenous feed is available. Naturally, chicks have a higher proportion of yolk sac which is specifically evolved to help these ground-feeding birds avoid predation by being able to synchronise the post hatch feeding process between all hatchlings.

Chickens use their residual yolk for sustenance during the first few day's post hatch. Development and maturation of the gastrointestinal tract and important immune related organs are delayed in chickens as they rely solely on their residual yolk having no feed and water available for a sustained period (often over 36 hours) between hatch and placement at the farm.

Fasting for a short time (less than 30 hours) shows a more rapid reduction in residual yolk size and indicates that valuable nutrients have been used for development.

Protein in the residual yolk is a vital source of antibodies. To be effective, it is important that maternal antibodies move from the residual yolk into the chick's bloodstream to improve the chick's immune system against pathogens.

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Wong and Uni (2021) reported that, before the development of fully functional organs, the embryonic chick must rely on the yolk sac tissue to provide all essential metabolic functions for the growth, development, and health of the developing embryo. Because the yolk sac tissue consists of three different cell layers and provides these functions, it is not just a membrane but a multifunctional organ.

The yolk sac tissue acts as:

- An immune organ by transporting maternal antibodies from the yolk and expressing the host defence peptide AvBD10.
- The intestine for digestion of proteins and polysaccharides and absorption of amino acids, monosaccharides, lipids, and minerals.
- The liver for storage of glycogen and expression of enzymes involved in glycogen synthesis and breakdown and glucogenesis, as well as the synthesis of plasma proteins.
- The bone marrow for both primitive and definitive erythropoiesis.
- The thyroid for synthesis of thyroid hormones that regulate metabolism.

The multiple functions of the yolk sac tissue are illustrated in Fig. 1. The transition of functionality from the yolk sac tissue to the maturing organs of the embryo occurs in a coordinated fashion during incubation. During incubation embryonic growth and development are dependent on nutrients deposited in the egg. The contents of the yolk can be transferred to the embryo in two ways: directly into the intestine via the yolk stalk or through the highly vascularised yolk sac membrane.

A higher metabolic rate during incubation would imply a lower residual yolk weight and possibly lower energy reserve for the hatchling. This might affect post-hatch development and performance.

- Residual yolk weight and the total solid amount of the residual yolk at hatch seem to be decreased in recent decades.
- Factors specially affecting residual yolk weight at hatch include egg size and incubation temperature, whereas breeder age has more influence on nutrient composition of the residual yolk.

There are two reasons for this:

- The embryonic phase has become a larger part of the total lifespan of a chicken.
- Due to the faster postnatal growth rate chickens should be prepared for that in the embryonic phase, meaning that organ development (for example, bone, muscles, heart) should be optimal at the moment of hatching.

During incubation embryos act mainly as poikilothermic, which means that their metabolic rate, yolk utilisation, and embryonic growth during incubation are temperature dependent.

Several studies examined the effects of incubation temperature on embryonic development and found that a higher (37.8°C) incubation temperature or EST from ED7 to hatch reduced embryonic development, which was demonstrated by shorter chicken length, lower chicken weight, lower yolk-free body mass (YFBM), and higher residual yolk weight at hatch.

The lower YFBM and higher residual yolk weight at hatch, due to a higher incubation temperature after ED7, is probably related to an imbalance between metabolic rate and oxygen availability. Based on the consistent literature about effects of incubation temperature on YFBM and residual yolk weight at hatch, it can be concluded that it appears plausible that part of the variation among studies related to embryonic yolk utilisation and residual yolk weight at hatch can be explained by incubation temperature and particularly when a higher incubation temperature than 37.8°C is applied in the last week of incubation.

The incubation temperature affects metabolic heat production (MHP) and yolk utilisation. There was a higher embryonic MHP in eggs that were incubated at a higher EST (38.9°C) during the second week of incubation than at a control EST of 37.8°C. This leads to higher metabolic rate, and as a result, more O_2 is needed. During the last week of incubation, the demand of O_2 exceeds the diffusion capacity of the eggshell pore system and the CAM, and as a consequence the metabolic rate is reduced.

The Importance of feed and water – access time

Chicks fed immediately and those food-deprived for 24 hours did not differ significantly in BW, whereas deprivation for 24 hours appears to be acceptable for growth and normal immunological performance.

However, this development has had negative effects on the immune system, there has been an increase in the incidence of metabolic disorders, such as ascites, and higher mortality probably due to reduced resistance to infectious diseases. The reduction in resistance to infectious pathogens constitutes a problem from a production as well as a welfare point of view.

There is a disturbance in the immune capacity of the broilers that have access to feed immediately after hatch. The significance of early post-hatch feeding (<24 hours) on faster utilisation of yolk sac nutrients, optimum development of intestines and organs culminating in better weight gain (>10.5%) of broilers at five weeks of age.

Lamot et al. 2014 summarised that, chicks seem to be able to compensate for a relatively short period of delayed feed access after hatch, (less than 24 hours), the differences in growth performance did not persist until 18 days of age. No effect of hatch moment on other organ size was found, including the residual yolk.

Although in this study the trend remained, the effect of hatch moment within the hatch window on long-term growth seems to disappear as the chick ages. Wang et al. (2018), reported that the increase of digestive enzyme activity in the small intestine promoted the absorption and utilisation of nutrients and increased the apparent metabolic rate of ether extract and crude protein, leading to higher average daily gain, average daily feed intake, and gain: feed.

This may be the reason why the appropriate start feeding time, which was from 24-30 hours, improved broiler performance. Moreover, it was not beneficial for newly hatched chicks to be exposed to exogenous feed as soon as possible. On the contrary, feeding untimely and prematurely could cause negative effects. They recommended that the appropriate time access to feed was from 24-30 hours post-hatch.

Also, Tambli et al. (2018) concluded that post-hatch feed deprival for the first 24 hours did not affect the growth performance at market age, but improved in vivo cellular immune response. However, feed withdrawal for 36 hours or beyond may affect the market weight of broilers.

Ozlu et al. (2020) reported that, feed and water deprivation for 28 hours or longer after hatching (28 hours) negatively affects the final BW but tends to improve the FCR at 35 days of age compared with chicks that receive feed immediately (two hours after hatching). When the feeding period was equalised in all groups, feed and water deprivation up to 40 hours under optimum conditions had no detrimental effect on final live performance.

These results suggest that the total feeding period is more critical for broiler performance than the time of post-hatch access to feed and water.

Short-term feed restriction (12-24 hours) can enhance the response of birds to a vaccination relative to fasted or ad lib. fed birds. Longer periods of restriction or fasting (up to 48-72 hours) can have deleterious effects on the immune response associated with increasing levels of corticosterone.

In contrast, Reicher et al. (2020) concluded that feeding upon hatch, compared to 24 hour delayed feeding, enhanced the small intestine maturation and functionality by increasing the quantities and proportions of proliferating and differentiated cells, thus expanding the digestive, absorptive, and secretive cell populations throughout the first 10 days post-hatch period.

Kang et al. 2019, studied the effects of early feeding time on growth performance, organ weight, blood biochemical, and leukocyte profile in post-hatch broiler chicks to 35 days of age. Feed intake was significantly higher for chicks that received early feeding within three hours, compared with those fed at 12, 24, 36, and 48 hours.

No significant differences were found for FCR for chicks subjected to different feeding regimens. Moreover, there are significant differences in body weight gain at seven and 21 days. But no significant differences at 35 days. The concentration of cholesterol, triglyceride, total protein, and AST was not significant by the early feeding time at 35 days.

Additionally, from 7-21 days, there was no significant difference in the leukocyte count, including white blood cells, neutrophils, lymphocytes, monocytes, eosinophils, and basophils.

At 35 days, the white blood cells, neutrophils, lymphocytes, monocytes, and basophils were no different in chicks that received early feeding. The villus height and crypt depth tended to be greater in chicks fed at 12 hours post hatch. However, the villus height and crypt depth were not statistically or significantly different in chicks that were fed early.

Effect of the hatch window on chick immune systems

The hatch window (HW), or the span of time from the hatch of the first chicks to the hatch of the last chicks, may range from 24-48 hours or more. Chicks that hatch earlier than others must wait longer periods of time before they receive access to feed and water.

There are many factors affecting the hatch window, for example breeder flock age, egg characteristics, egg weight, the length of egg storage, and temperature of egg storage and egg handling before incubation and sex of the embryo may all influence the HW. Female chicks hatch earlier than male chicks regardless of incubation system utilised (multistage or single-stage).

During egg incubation, variables such as temperature, humidity, ventilation and gas exchange, air velocity, egg turning, egg position, all

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have an effect on hatch times. Incubation temperatures and bandwidth will either prolong or accelerate embryo development and impact the HW.

Marquisha A. Pau, 2015, concluded that, the negative consequences of delayed feeding on commercial broiler chick growth performance are only evident during early growth. If chicks are fed nutrient deficient diets, then the effects of delayed feeding can have lasting effects on carcase characteristics and bone mineral concentration.

Effect of early post-hatch feeding

Paying special attention to young animal nutrition is important to achieve the full production capacity of birds and to ensure sustainable business for the producers. Day-old chicks are the final product of the hatchery industry and provide an important starting point for poultry production.

In commercial hatcheries, chicks do not typically emerge from their egg all at the same time, as there is a hatching window varying from 24-48 hours before a significant portion of the remaining eggs are hatched out. As the hatch period increases, the number of chicks that are without feed, and water increases for extended periods of time.

Additionally, further hatching practices, including the transfer of chicks to the farm, may often spend considerable time (48-72 H) without any access to feed and water for chicks. This delay in access to nutrients due to hatchery operations and procedures may limit the utilisation of the yolk sac and result in poor immunity in the newly hatched chick. During this first week post hatch, the avian immune system is immature and inefficient at protecting chicks from invading pathogens.

Hayashi et al. 2011, studied the effect of the hatch window on the presence of CD3+ cells in the lymphoid system of broilers from eggs of various weights laid by breeders of the same age. They reported that the numbers of CD3+ in the thymus had an influence on HW since longer time periods of residence inside the hatcher after hatch (+32h HW), resulted in fewer cells in such organs. In the spleen, a HW x egg weight interaction was seen, with an effect on CD3+ cell counts ($P<0.05$).

The primary lymphoid organs, such as the thymus and the bursa of Fabricius, start to develop during embryo life. The thymus, the site of development and maturation of T cells, has its own CD3, CD4 and CD8 marker cells during the embryo stage. After hatch, waves of migration of these cells occur towards secondary lymphoid organs, such as the spleen, which is still immature at hatch. This transport from the thymus to other organs may explain the findings in this study, since a decrease in the number of CD3+ cells in the thymus of birds with longer (+32 hours) hatch window was seen.

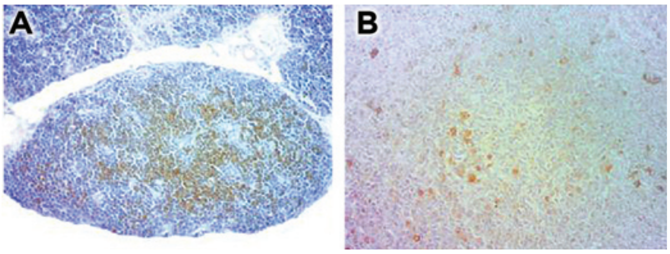

Photo micrograph of thymus (A) and spleen (B) for the identification of CD3+ cells by immunohistochemistry (40X).

When studying the body population of CD3+ cells, Mast and Goddeeris (1999) explained that the spleen provides the ideal micro-environment for the interaction of lymphoid and non-lymphoid cells, and it is mostly responsible for storing and transporting lymphocytes to the bloodstream and tissues.

The chicks hatching in the 32 to 16 hours prior to standard pull time (32 hours HW) showed no difference in the amounts of CD3+ cells in the spleen regarding egg weight, thus showing that in this period no difference exists in the transport of these cells to other tissues between chicks from either light or heavy eggs.

In the chicks that hatched near pull time (16 hours HW) from lightweight eggs, showed a higher number of CD3+ than those from heavy eggs, which once again suggests a higher efficiency in the transport of these cells from the spleen to other tissues. ■

References are available from the author on request