



## ASOCIACIÓN DE MÉDICOS VETERINARIOS ESPECIALISTAS EN AVES

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### Introduction

It is common for broiler producers to regard chicks hatched from a specific age of breeder flock as being more desirable than chicks from breeder flocks of other ages. Much of this bias comes from the well-proven relationships among broiler breeder age, egg size and chick size. Older hens lay larger eggs, which hatch into larger chicks, which are therefore deemed to be of better quality than the smaller chicks arising from younger hens which lay smaller eggs. However, older hens tend to produce fewer eggs with reduced hatchability, and so the chicks from the “optimal” breeder age for the broiler producer may not be the same as what is best for the value chain. For integrated companies, this balance becomes extremely important.

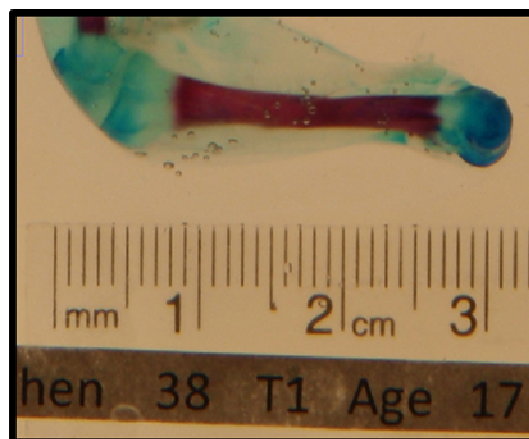
The initial idea behind this paper was the observation in our studies of some unexpected effects of broiler breeder age on hatchling bone development and early innate immune function. As we began to dig deeper into the literature, it became apparent that, although there may be some validity to the opinions regarding the effects of breeder flock age on broiler chick quality and productivity, there may be many opportunities to use nutrition, hatchery and broiler management to increase the overall quality of broiler chicks regardless of breeder flock age. Where discrepancies exist in chick quality due to breeder age, the poultry industry may be able to level the playing field through managing eggs and chicks from young breeders differently than those from older breeders.



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### Experimental design

The studies we conducted investigated the interaction of breeder age and maternal nutrition on specific aspects of embryo and chick physiology. First, we investigated the effects of antioxidant nutrients in the maternal diet on transfer of these nutrients to the egg, and subsequent effect on early innate immune function. At the same time, in different hens within the same facility, we investigated the effects of maternal trace mineral form (organic vs inorganic) on embryonic and early chick bone development. In both studies, fertile eggs were collected and hatched at early (~32 wk of age), mid (~46 wk of age) and late (58 wk of age) breeder ages. The main effects of maternal diet type are in preparation for publication elsewhere, so in this paper we will focus on the effects of breeder age on various aspects of hatching eggs, embryos and the hatchling. We measured early innate immune cell activity in blood (*ex vivo*) at 1 and 4 days of age by measuring the number of phagocytic cells that engulfed at least 1 *E. coli* bacterium, the number of bacteria engulfed per cell, and the ability of the immune cells to kill *E. coli*. To assess bone development, we collected femur and tibia samples from embryos at 10, 15, 17 and 20 days of incubation, as well as at hatch. Using staining techniques, we were able to differentiate between mineralized and un-mineralized portions of bone (Figure 1). By measuring the relative 2-dimensional areas of mineralized and un-mineralized portions of bone, we could assess the relative bone development. We also measured characteristics such as femur and tibia length, width and weight.



**Figure 1.** Tibia from an embryo at 17 days of incubation differentially stained for bone mineralization.



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We were interested in early innate immune function specifically because although there is some maternal transfer of immunoglobulins, the chick hatches with a poor ability to produce their own antibodies, thus making them more susceptible to pathogens (Bar-Shira et al., 2003). Antibody responses are part of the acquired immune system. However, although the chick hatches with an immature innate immune system, it is the first line of defense for pathogens (Wells et al. 1998), and is primarily responsible for protection against pathogens for which there has been no maternal transfer of antibodies. In our previous studies, we have found that maternal nutrition can increase the bactericidal activity of innate immune cells (Saunders-Blades and Korver, unpublished data). We were interested in trace mineral form because Cu, Mn and Zn influence development of the organic matrix of developing bone (Richards and Packard, 1996; Richards, 1997), and maternal nutrients are the only source of nutrients for the developing embryo.

### **Preliminary results and discussion**

As expected, we found that as chicks aged from 1 to 4 days, the innate immune system matured, in that there was a greater killing of *E. coli* at 4 days of age than at 1 day of age. Contrary to our expectations however, we found that as breeder hens aged, the ability of immune cells from the 1-d-old chicks to kill the bacteria declined substantially, from 55% killing for the young breeders to 12% and 3% in chicks from the mid and late breeder ages, respectively. Although a similar trend was observed for chicks at 4 days of age, it was not as pronounced. It is important to note that there are many mechanisms and cell types involved in protection of the chick against bacteria, but the marked decline in ability of the cells to kill the bacteria was surprising.

We found that thickness and length of the femur and tibia in embryos at 20 days of incubation tended to be greatest from embryos from the mid breeder age. Bone calcification (ratio of bone cartilage area to calcified bone area) was substantially higher for embryos from the mid breeder age than embryos from the early breeder age; differences in bone mineralization between chicks from mid and late breeder ages were less distinct. One of the most interesting things we observed was that, when controlled for chick weight (using chick weight as a covariate), bone development at hatch seemed to decline with breeder age.



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Femur weight at hatch declined significantly from early to mid, and from mid to late breeder ages. Tibia length was greatest in chicks from the mid age hens, and least in chicks from the late age hens. Based on the limited amount of literature in this area, these results were somewhat surprising, and indicated that some measures of bone development are limited in chicks from older hens.

Based on these preliminary results we began to consider the prevailing assumptions in the poultry industry regarding the perceptions of “chick quality”, and how this vague concept is more complex than “chick quality increases with breeder age”. When we started searching the literature, it became apparent that, although there are some definite aspects of chick quality that do appear to increase with breeder age, depending on the characteristic being considered, there are not uniform “improvements” taking place as hens get older. In addition, it became clear that there may be opportunities, through maternal nutrition and management, hatchery management, and early chick management to minimize the effects of breeder age by treating eggs and chicks from different-aged breeder flocks differently.

### **Breeder age effects on embryos**

- **Fertility & Hatchability**

A large body of literature over the years has shown that fertility is affected by is affected by broiler breeder age. In general, older flocks tend to have reduced fertility relative to the same flock at younger ages in broiler- (Elibol et al., 2002; Zakaria et al., 2005, Yilmaz-Dikmen and Sahan, 2009) and egg-type breeders (Tanure et al., 2009). When reading the literature, it is important to consider the age of the breeder flocks being compared, as Pedroso et al. (2005), found that as broiler breeders aged from the initial stages of egg production (25 to 27 wk of age), fertility increased. However, fertility did not increase between 32 and 37 weeks of age (Pedroso et al., 2005), between 32 and 41 wk of age (Joseph and Moran, 2005), or between 32 and 38 wk of age (O’Dea et al., 2004). Similarly, fertility and hatchability of ducks from young breeders were lower than for breeders at peak or post-peak production (Braun et al., 2002).



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As the breeder flock progresses past peak production, fertility tends to decline. Hocking and Bernard (2000) found that fertility in broiler breeders tended to increase to a peak at between 30 and 40 weeks of age, and then declines thereafter. As the egg production cycle progresses, egg production declines as clutch sequences become shorter, resulting in an increase in first-of-sequence eggs. First-of sequence eggs tend to have relatively low fertility (Robinson et al., 1991; Goerzen et al., 1996).

When taking into account the hatchability of fertile eggs, younger breeder flocks tend to have an advantage over older breeder flocks (Elibol et al., 2002; Elibol and Brake, 2006). Again, the definition of “older” and “younger” may vary among studies, and so some caution is necessary when interpreting results. Hatchability of fertile eggs was similar between breeder flock ages of 28 and 45 wk, but decreased at 65 wk (Yilmaz-Dikmen and Sahan, 2009). Hatchability is generally greatest during the middle stages of breeder egg production due to decreased shell thickness and increased porosity relative to eggs from younger hens (Peebles and Brake, 1987). The smaller size and thicker shell and shell membrane cuticle may impair the respiration of the embryo, lowering hatchability of eggs from younger breeders, whereas for eggs from older breeders, the high rate of heat production and a lower ventilation rate in the incubator may impair hatchability (Tona et al., 2001).

Although the increase and then decrease in hatchability of fertile eggs as hens age may have several causes, it appears that differences in embryonic mortality are an underlying factor (Tona et al., 2001). Hatchability was greatest at a breeder flock age of 42 wk, which corresponded with the lowest rate of absolute and early embryonic mortality, and malpositioned embryos (Tona et al., 2001). Very young (26 wk old) breeder hens had higher infertile, early dead and late dead eggs and embryos and lower hatch of fertile relative to older hens (28 and 30 wk) with a lower hatch of fertile in eggs from the youngest hens (Bruzual et al., 2000a). Early embryonic mortality was greater in eggs from young (32-35 wk) turkey hens, but pre-pip and percentage dead pips were greater in eggs from older (44-50 wk) turkey hens (Fairchild et al., 2002). Similarly, early embryonic mortality was found to be lower, and hatchability of fertile eggs higher in eggs from breeder hens aged 35 to 37 wk of age relative to those from 27 to 29 and 55 to 57 wk of age (Hocking and Bernard, 2000).



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Early embryonic mortality increased from 2.73% at 28 wk of breeder age to 8.93% at 65 wk of breeder age; mid and late embryonic mortality, and pipped embryonic mortality did not differ with age (Yilmaz-Dikmen and Sahan, 2009). Breeders at 59 wk of age had a greater rate of fertility than the same flock at 29 wk of age; hatch of fertile, embryonic death and percentage of cull chicks were not affected by breeder age (Ulmer-Franco et al., 2010).

Although changes in hatchability over time seem clear, interactions of breeder age with egg handling indicate that hatchery management may be able to influence the rate and extent of the decline. Increased turning frequency of eggs in the incubator resulted in a reduction in late-embryonic mortality in eggs from older hens (59 to 61 wk) as compared to younger hens (34 to 37 wk; Elibol and Brake, 2006). Hatching eggs are commonly stored prior to placement, both on-farm and in the hatchery. Increased turning during egg storage had a greater positive effect on eggs from an older flock that had reduced fertility than eggs from a younger flock, which tended to have increased fertility (Elibol et al., 2002).

In general, extended storage of eggs from older breeders has a greater negative influence on hatchability than eggs from younger hens (Lapao et al., 1999; Tona et al., 2004). The greater negative effect of egg storage on chick quality in older breeders may be due to a greater deterioration in internal egg quality (Tona et al., 2004). There is also an interaction of breeder hen age and egg storage on chick quality. Although egg storage had little effect on chick quality at hatch for younger breeders, the broilers hatching from stored eggs produced by younger breeders had reduced early growth rate relative to un-stored eggs from young broiler breeders (Tona et al., 2004). These results indicate that chick quality and the decline in hatchability may be managed by treating eggs from young breeder hens differently than those from older breeder hens.

- **Egg weight and egg components**

As breeder hens age, they tend to lay larger eggs (Viera and Moran, 1998a; Shaw et al., 2010; Peebles et al., 1999).



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Hatchling weight is highly correlated with egg weight (Wyatt et al., 1985; Shanawany, 1987; Suarez et al., 1997), meaning that hatchlings from older hens tend to be larger than those from younger hens (Applegate et al., 1998; Latour et al., 1998; Viera and Moran, 1998a; Weytjens et al., 1999; Bruzual et al., 2000a, Fairchild et al., 2001; Peebles et al., 2001a; Hudson et al., 2004; Tona et al., 2004; Pedroso et al., 2005; Yilmaz-Dikmen and Sahan, 2009). Much of this effect is likely due to increased body size and fat reserves of the hen, but decreased egg production may allow the hen to deposit more nutrients within each egg. Because eggs from older flocks tend to be larger, they may provide more total nutrients to the embryo for growth (Tullett and Deeming, 1982). However, when matched for egg size, hatchlings from older breeder hens still have increased weight at hatch relative to those from younger breeders (Wilson et al., 1991; Shanawany, 1985; O'Dea et al., 2004). Embryos from older breeder flocks may be more efficient at utilizing maternal nutrients, and older hens may be more efficient in depositing nutrients into the egg (O'Sullivan et al., 1991; Applegate and Lilburn, 1996; Suarez et al., 1997; Applegate et al., 1998; all in Braun et al., 2002). Although chicks hatching from eggs laid by 36-wk-old breeder hens had lower body weight (BW) they also had greater relative yolk sac -weight as compared to chicks hatched from 51-wk-old breeders (Latour et al., 1998), perhaps indicating a reduced utilization of yolk sac nutrients. Chick yield (chick weight as a percentage of egg weight) was similar in eggs from breeders at 27 wk and 62 wk of age (Viera and Moran, 1998), and from young (32 wk) breeder flock and and prime breeder flock (41 wk; Joseph and Moran, 2005). Since eggs from the older hens were larger, chick size was greater from the older hens.

The composition of the egg changes with breeder age. Yolk weight as a proportion of egg weight increased, and albumen weight as a percentage of egg weight decreased with breeder age (Suarez et al., 1997). Egg weight increased with hen age from 26 to 47 wk of age with concomitant increases in the yolk:albumen ratio (Peebles et al., 2000). Eggs laid by 50-wk-old breeders were heavier than those from 30-wk-old breeders; yolk weight relative to total egg weight was also greater for eggs from the older hens (Yadgary et al., 2010). Eggs from 29-wk-old broiler breeders had lower wet and dry yolk percentages and greater albumen percent relative to eggs laid by the same flock at 59 wk of age (Ulmer-Franco et al., 2010).

The effect of breeder hen age on eggshell quality is inconsistent in the literature.



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Several studies have found that eggshell characteristics such as weight (Joseph and Moran, 2005), conductance (Hamidu et al., 2007; Berrang et al., 1998), specific gravity and susceptibility to experimental *Salmonella* penetration (Berrang et al., 1998) are not affected by breeder age. However, a large number of other studies have shown eggshell quality traits to decrease with hen age, including eggshell weight (Peebles et al., 2001), thickness (Latour et al., 1998; Peebles and Brake, 1987), and egg specific gravity (Ulmer-Franco et al., 2010). Greater shell mineralization at younger breeder ages could result in lower egg weight loss during incubation (Peebles et al., 2001). The differences among studies in the effect of hen age on eggshell characteristics may be related to differences in experimental design or hen management during the studies.

- **Immune function**

There is limited information available regarding the effect of breeder age on chick immune function. At 66 d of age, poults from young breeders had greater haptoglobin (an acute phase protein) levels following a bacterial lipopolysaccharide (LPS) injection than poults from an older breeder flock (Schaefer et al., 2006), indicating a greater inflammatory response. In addition, poults from younger hens tended to have increased intestinal lymphocyte infiltration in response to LPS injection, (Schaefer et al., 2006). However, turkey hen age had no effect on production of antibodies to sheep red blood cells, cell-mediated immunity (cutaneous basophil hypersensitivity) or susceptibility to an air sac inoculation of *E. coli* in turkey poults (Siegel et al., 2006). Although there tends to be an overall negative relationship between growth rate and immunocompetence, the effect of hen age on immunocompetence of the chick depends on the trait being measured (Weytjens et al., 1999; Yalcin et al., 2005). The interaction of breeder hen age, chick growth rate and immune function may become a more important area of research, particularly considering worldwide changes in the use or legality of growth-promoting antibiotics.



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- **Embryo metabolism**

At oviposition, embryos from younger hens are less physiologically advanced and have lower metabolic rates for the first 2 days of incubation compared to embryos from older hens (Mather and Loughlin, 1979). Embryos from 38-wk-old hens produced more metabolic heat (based on eggshell temperatures) and CO<sub>2</sub> production (O'Dea et al., 2004) than chicks from 33 wk-old breeders. In addition, chicks from 38-wk-old breeders had lower liver glycogen than chicks from 33-wk-old breeders, indicating a greater glycogen requirement during hatching. The reduced liver glycogen content, increased CO<sub>2</sub> consumption suggest a higher metabolic rate during incubation, including during hatching (O'Dea et al., 2004). Embryos from peak (34 to 36 wk) and post-peak (40 wk) flocks had lower metabolic activity over the 21-d incubation period than embryos from younger or older flocks (Hamidu et al., 2007), suggesting that different incubation conditions may be required from eggs from breeder flocks of different ages. Older breeder flocks tend to lay larger eggs, and larger eggs have greater difficulty losing metabolic heat produced by the embryo in the late stages of incubation (Hulet et al., 2007). Embryonic temperature during the last 5 days of incubation can significantly influence post-hatch performance, and so effects of egg size and incubator conditions may influence the outcome of research into effects of breeder flock age and chick performance (Hulet et al., 2007). Incubation conditions in multi-stage setters and hatchers may not necessarily be adjusted to reflect the different needs of eggs from young and old breeder flocks (Tona et al., 2001).

As the embryo develops, demand for oxygen increases until the diffusion rate of oxygen through the shell is exceeded by demand, at which point the embryo becomes hypoxic and causes the embryo to use anaerobic metabolism (gluconeogenesis and glycolysis) to meet its energy demands (Christensen et al., 1999). Internal pipping occurs to increase oxygen supply, and the embryo begins to metabolize carbohydrates (glycogen) as an anaerobic source of energy (Pearce and Brown, 1971). When the duration between internal pipping and hatching is extended, increased amounts of hepatic glycogen must be used to supply the cardiac and skeletal muscles (Freeman, 1969). Successful hatching of poults from young hens may require the use of a greater proportion of the glycogen reserves of the poult during internal and external pipping at hatch, meaning that the poults may be more susceptible to subsequent environmental stressors, including bacterial challenges (Christensen et



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al., 1996). This is consistent with increased late embryo mortality in chickens (Reinhart and Hurnik, 1984) and turkeys (Tona et al., 2001; Christensen et al., 1996).

During the last week of embryonic development, the yolk sac is a major storage site for carbohydrate that will be used to provide energy to the embryo as hatch approaches (Yadgary et al., 2010); low glucose status can negatively affect hatching or chick performance (Hudson et al., 2004). When blood glucose is low, the liver converts lactate into glucose-6-phosphate and provides energy to demand organs such as the heart and skeletal muscles (Watford et al., 1981). Delayed access to high carbohydrate feed following hatch may increase the reliance on gluconeogenesis, and lead to ketosis and dehydration (Viera and Moran, 1999b ).

Proportionately more yolk is deposited in the egg with increasing turkey hen age, leading to increased yolk availability to support embryonic growth rate in the last week of incubation (Applegate and Lilburn 1996, 1998a). In addition, embryos from young breeders have reduced lipid mobilization from the yolk relative to older breeders (Noble et al., 1986, Yadgary et al., 2010; O'Sullivan et al., 1991; Noble et al., 1986). Up to embryonic d 15, absorption of yolk fat by the embryo was lower in embryos from young hens than in embryos from older hens (Yadgary et al., 2010). Chicks from older hens had greater yolk sac reserves than younger hens (Viera and Moran, 1998), and fat accumulation in chicks from 32-wk old breeders was lower than in chicks from 42- or 65-wk-old breeders, reflecting the smaller yolks in eggs from young breeders. This effect was independent of chick weight (Yalcin et al., 2008). Chicks from younger hens hatch with lower residual yolk sac weights (Yadgary et al., 2010; Hamidu et al., 2007), which may limit nutrient supply to the newly-hatched chick, particularly if there is a delay in access to feed. Young breeders have chicks with impaired lipid mobilization and lipoprotein transfer, resulting in impaired energy availability for development, resulting in lower first week chick viability (Latour et al., 1996b; Latour et al., 1998). Egg cholesterol content increased from 28 to 45 wk of age, and remained constant thereafter. There was a negative relationship between cholesterol level and hatchability of fertile eggs, and hatchability of total eggs (Yilmaz-Dikmen and Sahar, 2007).

Chicks from younger hens had less fat in the yolk sac to support immediate post-hatch nutritional requirements (Yadgary et al., 2010).





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Increased mortality of chicks from young breeders was due to reduced lipid mobilization and assimilation from the yolk (Noble et al., 1986). Chicks from a young flock had lower yolk-free BW and yolk sac reserves than chicks from the prime-aged flock; by 3 d of age, BW was still lower, but yolk sac weights were similar between flock ages (Joseph and Moran, 2005). The effect of breeder flock age continued to 8 d of age, but had disappeared by 16 d of age (Joseph and Moran, 2005). The amount of yolk nutrient reserves is often considered to have a direct effect on the performance of the chicks as broilers (Viera and Moran, 1999).

Not only is distribution of lipids in eggs from younger breeder flocks is different in than that of eggs from older breeders (Noble et al., 1986), but incubation conditions and age of breeder affect the fatty acid profile of the yolk (Peebles et al., 1998). In fresh eggs, total saturated fatty acids (SFA) were lower from 65-wk-old breeders than from 32- or 42-wk old breeders; total polyunsaturated fatty acids (PUFA) was lower from 32-wk-old breeders relative to those from 42- or 65-wk-old breeders. The ratio of saturated (SFA) to unsaturated fatty acids (UFA) was greater in eggs from 32-wk-old breeders than from 42 or 65-wk-old breeders (Yalcin et al., 2008). The differences in yolk fatty acid classes tended to be due to changes in specific fatty acid deposition with age, although maternal diet played a large role in the changes in egg fatty acids with breeder age (Latour et al., 1998). Myristic, palmitic stearic, oleic and palmitoleic acid levels in eggs have been reported by a number of investigators to decrease with hen age (Latour et al., 1998; Latour et al., 1998; Nielsen, 1998; Gardner 1997 ). Linoleic acid has been found to increase (Nielsen et al 1998; Burnham et al., 2001) or decrease (Yilmaz-Dikmen and Sahan, 2009) with hen age. The reduction in myristic and linoleic acids with breeder age were correlated with the reductions in fertility, hatchability and hatch of fertile observed with increasing hen age (Yilmaz-Dikmen and Sahan, 2009).

Embryos from old and young hens also appear to metabolize yolk fatty acids differently, since residual yolk sac SFA, monounsaturated (MUFA) and PUFA were similar among chicks from the various breeder flock ages (Yalcin et al., 2008). In 16-19 d embryos, stearic and arachidonic acid concentrations were increased, and myristic acid concentrations were decreased in 26-wk-old hens relative to 28- and 30-wk-old hens; linoleic and palmitic acid concentrations were greatest in the 30- and 28-wk-old breeders, respectively (Burnham et al., 2001).



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Incubator conditions interact with breeder hen age to influence fatty acid metabolism in embryos. High incubator temperature increased linolenic acid in residual yolk sacs in chicks from young breeders relative to normal incubator temperatures, but this effect was reversed in chicks from the oldest flock age (Yalcin et al, 2008). Docosahexaenoic acid (DHA) in residual yolk sacs was reduced in chicks from younger parents due to high incubator temperature, but was increased in chicks from older parents incubated at high temperatures (Yalcin et al., 2008). In spite of greater transport of linolenic acid uptake by the chick following high temperature incubation of eggs from older breeders, there appeared to be an impaired conversion of this fatty acid to DHA (Yalcin et al., 2008). Essential fatty acid depletion of hens reduced arachidonic and linoleic acids in the chicks, resulting in delayed hatch times and reduced growth rates (Menge et al., 1974). Overall, it appears that older breeders may require different diets than younger breeders in order to ensure the hen can provide sufficient levels of the various important fatty acids to the developing embryo.

- **Organ development**

Gut development (intestinal villus height and width) was greater for poults from older breeders than from younger breeders (Schaefer et al., 2006). However, differences in intestinal morphology between poults from young or old breeders decrease as the poults age (Applegate et al., 1999 in Schaefer et al., 2006). In the absence of feed, broilers from older breeders had greater intestinal development at 24 hr post-hatch than broilers from younger breeders; this difference disappeared if feed was provided (Maiorka et al, 2000).

Chicks hatched from eggs from 41 to 56-wk old breeders had greater heart/chick weight ratio than those hatched from 26 wk-old breeders (Barbosa et al., 2008). Heart glycogen and liver lactate was lowest in chicks from 65-wk-old hens, and relative heart weight and yolk sac weights were lowest in chicks from the 29-wk-old hens, indicating that underdeveloped supply organs may limit the growth of chicks from young hens (Hudson et al., 2004). Relative heart and yolk sac weights were lowest in chicks from young hens, indicating that nutrient supply to demand organs such as skeletal muscle may be limited in these chicks (Hudson et al., 2004).



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- **Hatch time**

Incubation time is usually measured as the average time to hatch among eggs in a hatcher; incubation length decreases as breeder hens age (Suarez et al., 1997). There was a negative correlation between egg weight and incubation time (Suarez et al., 1997), and when egg weight was held constant, incubation length decreased with increasing flock age (Burke, 1992; Christensen et al., 2000).

Ulmer-Franco et al. (2010) reported that eggs from 29 wk-old breeders pipped and hatched later than eggs from the same flock at 59 wk of age. However, relative to mid-cycle breeders, eggs from younger breeder hens tend to hatch in less time (Suarez et al., 1997; Hudson et al., 2004; Pedroso et al., 2005). Suarez et al., (1997) found a significant curvilinear response in hatch time to breeder age; the lowest hatch time was observed for hens near the middle of the cycle (41 and 47 wk of age) relative to the flock at 29 and 57 wk of age.

Under the same incubation conditions, late embryonic development occurs more slowly in eggs from young hens than in eggs from old hens (Christensen et al., 2001a; Applegate, 2002). Embryos from young flocks tend to have a longer hatching time, which can result in dehydration and death with extended length of time the chicks are held in the hatcher. A prime aged breeder flock produced more chicks that hatched early than a young flock, meaning a greater proportion of chicks from the prime flock spent a longer time in the hatcher prior to being removed. Increased length of time spent in the hatcher decreases chick body weight and yolk sac weight (Joseph and Moran, 2005).

Chick BW is affected by hatcher and setter humidity, and by time of removal from the hatcher, with lower chick body weights resulting from increased length of time in the hatcher following hatch (Reinhart and Hurnik, 1984). The rate of water loss during incubation can influence embryo development (Rahn and Ar, 1974) and hatchability (Lundy et al., 1969; Meir et al., 1984). The rate of water loss during incubation can be manipulated by altering relative humidity during incubation (Peebles et al., 1987; Tullett, 1990).



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Low incubator RH may reduce embryogenesis (Peebles et al., 2001a) and therefore result in poor post-hatch performance in chicks from young broiler breeders.

Extended holding in the hatcher can increase dehydration and reduce body weight (Wyatt et al., 1985; Wyatt et al., 1986). From 29 to 41 or 47 weeks of breeder age, incubation time decreased, leading to an increased time the chicks were out of the shell but in the hatcher and were therefore subject to loss of body moisture (dehydration; Suarez et al., 1997). When incubation time was manipulated by changing incubation temperatures, eggs from 33-wk-old turkey hens had increased hatchability at shorter incubation periods, but hens from 54-wk-old hens had greater hatchability at longer incubation periods (Christensen et al., 2001). It was recommended that smaller eggs, from younger turkey hens would benefit from increased incubator temperature in order to reduce the incubation period (Christensen et al., 2001). Incubator conditions could therefore be manipulated to increase hatchability of eggs from different aged breeder flocks (Tona et al., 2001). The increase in the use of single-stage, rather than multi-stage incubators by the poultry industry in many parts of the world may allow hatchery managers to optimize incubation conditions for eggs from different ages of breeder flocks.

### **Breeder age effects on chick quality**

- **Indices of chick quality**

An important concern for broiler producers is the quality of the chicks at placement in the barn. A common observation is that chicks from younger (eg. between 26 and 30 wk of age) breeder flocks are of lower quality than those from older breeders (McNaughton et al., 1978; Wyatt et al., 1985). In support of this, Viera and Moran, 1998 ) suggested that young breeders lay smaller eggs with increased albumen DM, lower yolk DM and a thicker shell than older breeders, which results in smaller chicks with less yolk sac reserves. At placement, chicks from older breeder hens were on average 8 g heavier than chicks from younger breeders; this resulted in an 80 g difference in final broiler body weight at 42 d of age (Vargas et al., 2009).



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However, although chicks hatched from young (39 wk) breeders weighed less than chicks from older (53 wk) breeders, the chicks from the younger breeders had greater chick quality scores (Willemsen et al., 2008). Chicks from the peak and post-peak breeder flock ages had the shortest chick length, but the longest shank length relative to other breeder ages (Hamidu et al., 2007). The proportion of lower quality chicks increases with breeder age (Boerjan, 2002); Tona et al., 2004 ), and older breeders (45 wk) produced a lower percentage of high quality chicks than younger breeders (35 wk; Tona et al., 2004).

- **Hatchling Growth rate**

Hatchlings from older breeders are believed to be of higher quality in terms of growth characteristics than those from younger breeder hens (Yannakopoulos and Tserveni-Gousi, 1987; Braun et al., 2002). The effects are particularly noticeable in studies that only report early production traits. Chicks from young (26 to 27 wk) broiler breeders had lower BW gain to 14 days of age than chicks from older (58 to 59 wk) broiler breeders (Fasina and Thanissery, 2011), and chicks from older breeders (60 to 61 wk) had greater growth rates to 16 d of age than chicks from younger breeders (26 to 27 wk; Shim et al., 2008). Turkey poults from 58-wk-old hens had increased BW and cumulative BW gain to 2 weeks of age relative to poults from 33-wk-old hens (Fairchild et al., 2001).

When the entire production cycle is taken into account, the effect of breeder age on the performance of meat-type birds becomes less clear. Some studies show a continued advantage in chick growth from older breeders. Broilers from hens at 29 wk of age weighed less at 21 d of age and at 41 d of age than broilers from the same flock at 59 wk (Ulmer Franco et al., 2010), and body weight gain from 21 to 35 d of age was greater for chicks from 60-wk-old breeders than chicks from 30-wk-old breeders (Vargas et al., 2009). Similarly, Hulet et al. (2007) found that broilers from an older breeder flock had greater BW and lower feed conversion ratios than chicks from younger flocks. Peebles et al (1999b) reported that at 43 d of age, BW of broilers from 51 wk-old breeders were greater than that of broilers from 63-wk-old breeders, which in turn were greater than that of broilers from 35-wk-old breeders.



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In spite of the previously-mentioned studies, a large number of researchers have also shown that the early production advantages enjoyed by chicks and poults from older breeders disappear by processing age. Although chicks from a young breeder flock were smaller at hatch and at 1 wk than chicks from a prime-aged breeder flock, by processing at 6 weeks there were no differences in body weight due to breeder age (Joseph and Moran, 2005). Turkey poults from younger breeders weighed less than poults from older breeders initially, by 63 d of age, the hen age effect had disappeared (Schaefer et al., 2006). Although the larger initial size of broiler chicks from older hens may convey an early performance advantage, in many cases the chicks from younger breeders are capable of increased growth rate later in production. Chicks from a 57-wk-old breeder flock had greater BW than chicks from a 29-wk-old breeder flock from hatch to 35 d of age, but the difference was not significant at 44 d of age (Hulet et al., 2007). Between 0 and 21 d of age, broilers from 35-wk-old hens had higher growth rates than chicks from 51- or 63- wk-old hens, but from 22 to 42 d of age, chicks from the 51-wk-old hens grew more quickly than chicks from the 35- or 63-wk-old hens (Peebles et al., 1999). Chicks from older breeders had heavier body weights from hatch to 14 d of age, but growth rate from 14 to 21 d of age was greater in broilers from young breeders; broiler body weights from 21 d to 42 d of age were similar between breeder flock ages (Tona et al., 2004). Finally, breeder age had no effect on final broiler BW when the initial weight was similar (Wyatt et al., 1985; Peebles et al., 2004; Tona et al., 2004).

Part of the variation in the effect of breeder flock age on performance of the chicks may be related to the variation in hatch time observed between eggs from young and old breeder flocks. As previously mentioned in this paper, eggs from older flocks tend to hatch sooner and result in chicks with greater yolk nutrient reserves than eggs from younger flocks. Broilers from older (60 wk) breeders grew more quickly from 21 to 35 d of age than younger (30 wk) breeders following a 12-hr delayed access to feed following hatch; when feed was provided immediately following hatch, this difference was not significant (Vargas et al., 2009). The lower yolk sac nutrient reserves at hatch typically found in chicks from younger hens may make them more susceptible than chicks from older hens to delayed access to feed.



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- **Bone growth**

Bone strength and mineralization are important considerations in meat-type poultry, as impaired skeletal development can result in pain, lameness, and ultimately reduced growth rate, culling, or mortality. In spite of this, relatively few studies have investigated the effect of breeder age on hatchling bone development. In addition, the conclusions drawn from these few studies are not consistent with one another. Bone density at hatch was greater for chicks from old hens relative to young hens (Yalcin et al., 2001), but there was no difference in breaking strength (Yalcin et al., 2001). Bone breaking strength was increased in chicks from 65-wk-old breeders relative to chicks from 25-wk-old breeders (Shaw et al., 2010). At hatch, breaking strength of the tibia in chicks from older hens had twice the breaking strength as compared to chicks from younger hens. This difference continued through 21 days of age, but the difference had disappeared by 28 days of age (Shaw et al., 2010). Maternal age effects on bone development at hatch varied among two commercial strains. Bone weight at hatch in chicks was not affected by strain in chicks from young (32 to 35 wk of age) hens, but there was a strain difference in chicks from old hens (56 to 58 wk of age; Yalcin et al., 2001). This was reflected in similar interactions for bone volume and ash content (Yalcin et al., 2001). Nelson et al. (1992) reported that maternal flock age did not affect incidence of tibial dyschondroplasia (TD), but Driver et al. (2006) and Shim et al. (2006) reported that the incidence of TD in broiler chicks decreased as breeder hens aged from 39 to 64 wk of age.

Chicks from young breeders had lower yolk sac P concentration than chicks from older breeders, which may increase the dietary requirement for P in chicks from young breeders (Viera and Moran, 1998). Chicks from young and old breeder hens may have different P requirements, and progeny from younger hens may be more susceptible to leg problems when fed P-deficient diets (Shim et al., 2008). Bone ash was higher in chicks from young breeders except when the chicks were fed a diet inducing P-deficiency rickets, in which case bone ash was greater from older breeders (Shim et al., 2006). Storage of eggs from young breeders for 10 days reduced rickets scores and incidence of P-deficiency rickets relative to chicks from un-stored eggs from the same flock (Shim et al., 2006). Storage of eggs from a young breeder flock decreased the incidence of P-deficiency rickets at 16 d of chick age, whereas egg storage increased the incidence of P-deficiency rickets in chicks from older breeders (Shim et al., 2008).



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There is little clarity in this area, and more well-designed studies must be done to determine the influence of breeder age on chick bone metabolism.

- **Broiler metabolism**

Breeder flock age influences the susceptibility or resistance to both heat and cold stress. Chicks from younger breeders may be more susceptible to cold stress, as rectal temperatures and plasma levels of  $T_3$  following cold exposure were reduced to a greater extent in chicks from young breeders than in chicks from old breeders (Weytjens et al., 1999). However, chicks from older breeders may be more susceptible to heat stress than chicks from younger breeders. Chicks from a young breeder flock were more resistant to heat stress, as rectal temperatures following heat stress were lower in chicks from young breeders than in chicks from old breeders (Weytjens et al., 1999). Incubating chicks from younger hens at higher temperatures may reduce the effects of heat stress on BW at slaughter; this effect was not observed for chicks from older breeders (Yalcin et al., 2005).

- **Carcass composition at processing**

Although larger hatching eggs are agreed to result in larger chicks, differences in yolk sac size, management, environment and disease can greatly affect final size at market age (Hulet et al., 2007). Relatively few studies of breeder hen age effects have carried the broilers through processing. Carcass yields at 43 d of age were greater in broilers from 63-wk old breeder hens than broilers from 35- or 51-wk-old breeder hens (Peebles et al, 1999b). There was a slight increase in carcass yield at 49 d of age in broilers from old hens relative to broilers from young hens (Viera and Moran, 1998a). Viera and Moran (1998a) found that at 49 d of age, abdominal fat as a proportion of broiler carcass weight was not affected by maternal age, however broilers from younger hens had less carcass fat at processing than those from the prime flock (Joseph and Moran, 2005). Although broilers from an older flock had greater BW and lower feed conversion ratios than chicks from younger flocks, but no significant differences in carcass characteristics were observed. (Hulet et al., 2007).



## ASOCIACIÓN DE MÉDICOS VETERINARIOS ESPECIALISTAS EN AVES

- **Mortality**

Effects of breeder flock age on mortality among studies has been inconsistent. (Hulet et al., 2007). Peebles et al. (1999) reported that mortality in broilers from 65-wk-old hens was greater than in broilers from 35- or 51-wk-old hens. However, most studies have found that mortality of broilers from young hens is higher than in broilers from older hens (Viera and Moran, 1998a; McNaughton et al., 1978). Poultry mortality rates were generally lower from older hens than younger hens; increasing poult dietary vitamin E supplementation resulted in a greater reduction in poult mortality for poults from young hens than from old hens (Siegel et al., 2006). Broilers from a 26-wk-old breeder flock had a higher mortality rate than broilers from a 36-wk-old breeder flock, perhaps due in part to a larger surface area to body weight ratio, making the smaller chicks more susceptible to dehydration (Wyatt et al., 1985). In a multi-year survey of the Dutch broiler industry, first week mortality of broiler chicks was 1.82% from 25-wk-old breeders, 1.02% for breeders between 38 and 44 wk, and 1.20% for 60-wk-old breeders (Yassin et al., 2009). The upward trend in mortality for chicks from older breeder hens could be due to poor healing of navels and subsequent yolk-sac infections (Yassin et al., 2009), as well as earlier hatch times leading to a risk of dehydration in the hatcher (Suarez et al., 1997). Ducks from young breeders grew more slowly, and had increased mortality relative to ducks from breeders at peak or post-peak production (Braun et al., 2002). It is interesting to note that, as discussed in section 5.1 of this paper, the proportion of lower-quality chicks is greater from old breeders than young breeders. Therefore, the apparent decrease in chick mortality with breeder age may actually reflect a removal of defective chicks at the hatchery, which may be more severely culled than chicks with an apparently greater proportion of good quality chicks from young breeder flocks.

### **Conclusions and implications**

From the information presented in this paper, it is clear that the influence of breeder age on the characteristics that are often used to determine chick “quality” is not a simple matter to discern. It is not universally true that chicks from young broiler breeders make “worse” broilers.



## ASOCIACIÓN DE MÉDICOS VETERINARIOS ESPECIALISTAS EN AVES

Under “standard” breeder, hatchery and broiler management conditions, many of the currently accepted assumptions about the effect of broiler breeder age on chick quality may hold true. However, if we can change the “standard” conditions to “optimal” based on hen, embryo and chick needs, we may be able to level the playing field. Single-stage incubation may allow hatchery managers to optimize setter and hatcher conditions based on egg size and breeder flock age, and different nutrition, management programs, hatchery conditions, storage etc. may be needed for hens, eggs from flocks of different ages.

When reading the literature, it is also important to look not only at the conclusions drawn by the authors, but also the experimental design. The following is a partial list of factors that may affect the outcome of the trial, and therefore the interpretation of the results:

- **Egg storage time** – for how long were the eggs stored before being incubated? Were the eggs put into the incubator stored for varying lengths of time? In many studies with small numbers of hens, eggs are stored until a sufficient number of eggs are obtained.
- **Definition of “younger” and “older”** – many studies compare breeder flock age over a rather short portion of the breeder’s life. There is nothing wrong with this approach, but be careful about assuming that “younger” and “older” actually mean “young” and “old” as opposed to “young” and “slightly less young”
- **Definition of chick quality** – there are many different means used to assess chick quality at hatch. An apparent increase in one index of chick quality may not necessarily reflect what is most important to the industry (which could be livability, growth rate, efficiency, processing yield, meat characteristics, and so on)
- **Egg size** – effects of breeder age on chick characteristics can often be explained simply on the basis of older hens producing larger eggs. However, there are physiological effects of breeder age that are independent of egg size.



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- **Loss of effect as chicks age** – many experiments are only carried out to the first few weeks of broiler age, and several studies show that effects of breeder age that are significant at a young broiler age may not be by the end of processing.
- **Replication – number of birds in the experiment** – breeder research is difficult to do. In many cases, small numbers of birds may be necessary to investigate in very fine detail various aspects of nutrition, metabolism, physiology, etc. However, small experiments may not allow conclusions to be drawn about some broiler breeder traits (egg production, hatchability, broiler traits, etc.).
- **Implications of post-hatch fasting** – depending on facilities, chicks from an experimental breeder farm may be placed in the experimental broiler barn much more quickly than would be possible in commercial practice.
- **Does the study look at the same breeder flock at different ages, or different breeder flocks at different ages at the same point in time?** Apparent differences due to hen age may in some cases be explained by differences in facilities, feed, environmental temperature etc. if looking at the same flock at two different points in time. However, if looking at different flocks at the same time, the source of the breeders (grand-parent flock age, for example), feeding and management between different facilities may confound the results.



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