CONSERVING AND MONITORING SHELL EGG QUALITY

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I. INTRODUCTION

The goal of all producers is to make a better product. In the shell egg industry, this translates to producing a higher quality egg. Egg quality can be defined in many ways. The American consumer demands a clean and sound egg that looks appealing when cracked into a skillet. The shell egg producer could define egg quality in terms of being relatively free of defects which would result in a downgrade. There are many factors that can affect egg quality. Lambrou (1986) stated that breeding, nutrition, environment and management along with egg handling, grading, storage, packaging, and transport effect egg quality. Therefore, when attempting to enhance egg quality, a producer must consider both production and processing factors.

II. GENETICS

The poultry industry utilises genetic selection to attain desirable economic and consumer traits in products. Genetic selection can also assist in disease resistance, habitat adaptability and other factors. One of the benefits of poultry, compared to other agricultural commodities, is the short period of time between generations and the ability to produce multiple offspring in a single generation.

Several papers have examined the differences in closed, random-bred laying stocks and commercial breeds. Anderson et al. (2004) reported significant changes in egg shape, weight and surface area amongst the strains studied. They did not report any significant differences in percent shell weight, shell thickness or specific gravity. Another study found an increase in egg weight from the later to newer strains of laying hens compared (Tharrington et al., 1999). From comparing the strains with a common ancestral linkage, they concluded that genetic selection had resulted in larger size eggs with a lower percentage of yolk. Furthermore, they found egg quality was maintained or enhanced during the selection process. In an additional study (Jones et al., 2001), United States Department of Agriculture (USDA) egg grades were compared between closed, random-bred strains and a current commercial line. The current commercial hens produced a greater percentage of grade A eggs and lower percentage of loss eggs.

In the review document written by Hunton (1982), it was summarised that several studies selecting for low and high shell strength had been successful. Potts and Washburn (1985) found selecting for shell strength had no effect on egg weight. Johansson and colleagues (1996) selected for shell membrane attachment as a means for increasing shell strength and determined that increased shell membrane attachment resulted in thin shell eggs and vice versa. The authors felt this could be due to natural selection factors since increased shell membrane attachment could impede embryo emergence at hatch. In his review Hunton (1982), summarised that white shells are thicker than brown. Some research suggests brown eggs are more resistant to breakage, but there is great debate amongst researchers in this area. In the Anderson et al. (2004) study, they found that the more current genetic stocks produced eggs with greater shell strength. They did not find a difference amongst the strains for shell thickness, but as mentioned before, the more current strains produced larger sized eggs.

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III. NUTRITION

Hen nutrition can have a direct effect on egg quality. When a hen is nutritionally compromised, the body begins to shut down unnecessary processes. Reproduction is greatly diminished, and the bird becomes immunologically compromised which can lead to increased incidence of disease. If a layer diet is complete except for a lack in the appropriate level of the amino acid lysine, a laying hen will not efficiently produce eggs and the eggs laid will be of inferior quality. Dietary composition can affect egg flavor, shell quality, and yolk pigmentation (Narahari, 1980). A lesser dietary effect can be seen for albumen index, Haugh unit values, yolk index, and blood and meat spot incidence. Conversely, Blair and Lee (1972) found that increased dietary protein above a basal level of 11.5% increased Haugh units.

A lack of calcium and phosphorus in the layer diet will result in the hen leaching these minerals from the bones in order to lay sound eggs. As this condition progresses, the hen will reach a point where it will no longer remove minerals from the bones. After this, a hen will produce soft shell or even shell-less eggs. Keshavarz and Nakajima (1993) found increasing dietary calcium levels above the recommended 3.75 g calcium/hen/day did not enhance shell quality. Furthermore, phasing calcium, phosphorus or combined calcium and phosphorus concentrations in the diet did not affect shell quality. The researchers also examined the role of added cholecalciferol in the diet with increased hen age and found no affect on shell quality. Feeding oyster shell in mid- and late-lay enhanced shell quality no matter the calcium concentration of the diet. Egg production was not affected by any of the dietary treatments examined in the study. Hens laying thick shelled eggs have been found to retain more dietary calcium than thin shell layers (Clunies et al., 1992). There was no difference in egg production between the thick and thin shell layers. Egg weight and shell weight was increased for the thick shell eggs compared to the thin. This disagrees with the findings of Anderson et al. (2004) who found no difference in shell thickness for significantly different egg weights. Shell deformation was lower for thick shelled eggs (Clunies et al., 1992) which falls in line with the previous summary of Hunton (1982) which reported thinner shelled brown eggs to be stronger than thicker white shelled eggs.

Researchers have also examined the role of chloride in egg quality. Keshavarz and Austic (1990) determined that increased dietary levels of chloride, phosphorous or a combination of the two resulted in decreased eggshell quality and blood acid-base indicators. They speculated that the decreased shell quality could be due in part to increased calcium excretion due to the presence of high levels of chloride and phosphorous. Balmave et al. (1989) provided hens with 600 or 2000 mg sodium chloride per liter of drinking water. There was an increase in shell defects with no changes in egg production, weights or food or water intake associated with the treatments. The treatment group receiving 2000 mg sodium chloride per liter had an increased incidence of shell-less eggs. The shell defects persisted after the sodium chloride was removed from the drinking water. There were little to no effects on blood acid-base balance and electrolyte levels. Conversely, Hess and Britton (1989) fed laying hens low chloride diets and found virtually no effects on shell quality. There was a slight increase in specific gravity noted towards the end of the study.

A wide range of other nutritional concepts have been investigated for their role in egg quality. Hess and Britton (1989) reported that dietary protein levels did not affect egg quality or production for the diets formulated for their study. Gossypol, a component of cotton seed, has been linked to yolk mottling as has the use of some coccidiostats (Naraihari, 1980). With the issue of animal waste management becoming a greater environmental concern, the use of phytase in poultry diets to reduce the mineral composition of litter is becoming more common. Scott et al. (2001) found egg weight to be greatest from hens fed a corn-based diet.
with added phytase compared to the control diet. Furthermore, there was a decrease in the percent shell and an increase in albumen height associated with the diet. The investigators also examined a wheat-based diet with added phytase and did not achieve the same results. Distillers dried grains with added solubles have been examined for their potential in laying hen diets (Benadeljelil and Jensen, 1989). Haugh unit values and ovomucin concentration were not increased in fresh or stored eggs produced by hens fed the ration.

IV. PHYSIOLOGICAL STRESS

Minimising physiological stress within the hen can also enhance shell egg quality. During periods of stress there is a breakdown of the reproductive tract. This can lead to reduced egg quality or production. This breakdown can also lead to an increase in the incidence of meat spots. Acute changes in the birds environment can result in a stress response. Marion et al. (1964) found that variations of the proportions of the parts of the egg were due to physiological changes associated with aging and the environment.

Exposure to disease can result in a decrease in shell egg quality. Many diseases can impair the reproductive tract. An example is infectious bronchitis. Initially this disease causes a respiratory response. It is then able to move through the blood stream and infect the reproductive tract. This can cause decreases in the internal and external quality of eggs produced. Both young chicks and adult hens can be infected producing these results. Infectious bronchitis is caused by a coronavirus and is a very contagious disease among chickens. Within 1-2 days, almost 100% of a flock can show signs of the disease (Trampel, 2005).

During the course of infectious bronchitis, oviduct weight and length is reduced and remains so for approximately 3 weeks. There is also a decrease in the number and height of epithelial cells in the lining of the oviduct. Another complication that can occur is the development of false layers. Soft shelled eggs or fully formed eggs are found in the abdominal cavity of a false layer. This comes about due to the egg progressing through the reproductive tract and reverse peristalsis occurring at some point forcing the egg to be deposited in the abdominal cavity.

The age of the laying flock can also have a direct effect on shell egg quality. The longer a hen is in lay, the lower the quality of the eggs produced. As the hen ages, the reproductive tract begins to decline. This results in a decrease in egg quality. Molting a laying flock can serve as a means of rejuvenating the reproductive tract. There are concerns associated with the act of molting and it should be performed in a responsible manner. After a molt, egg quality is enhanced, but declines at a greater rate than during the previous production cycle. Molting a flock multiple times also results in a greater rate of shell egg quality decline. Morris et al. (1985) reported a decrease in albumen quality associated with hen age which they attributed to wear on the oviduct during the laying cycle. This problem could be overcome by molting the flock, followed by a period of rest.

Silversides et al. (1993) reported that the percent albumen changes with hen age and egg weight. Hen age has been found to be a factor in Haugh unit (HU) values. It has been established that HU decreases as the hen ages (Cunningham et al., 1960; Montgomery and Stewart, 1973; Curtis et al., 1985; Izat et al., 1986). Doyon et al. (1986) studied the rates at which the HU and albumen height change. They stated that HU and albumen height decrease at a fairly constant rate as the hen ages. They reported that the HU decreased at a rate of 0.0458 units/day of lay (13.15 units over 287 days). The albumen height measurements decreased at a rate of 1.39 mm over the entire 287 days. Hill (1981) found that the day after the egg is laid, the HU decreased one unit for every month the hen had been in lay. Silversides (1994) reported a linear decrease in albumen height as a hen ages. The
characterisation of a linear relationship for albumen height quality and hen age is called to question when considering the report of Hill (1981) which stated that albumen quality became more variable as the hen ages. Silversides (1994) reported that strain x hen age interact significantly for Haugh unit and log albumen height, suggesting that these change at different rates for hen age and different strains. Anderson et al. (2004) found that as the hen ages, shell breaking strength decreased as did percent shell and specific gravity. De Ketelaere et al. (2002) have also reported decreased shell thickness as a hen ages.

V. ENVIRONMENT

Management practices can have a profound effect on shell egg quality and are some of the easiest to fix. Maintaining the hens on a set lighting schedule can enhance shell egg quality and egg production. Providing a clean environment aids in maintaining bird health. Proper handling of the birds reduces the incidence of body checks. A body check occurs when the egg is cracked in the reproductive tract and the bird is then able to mend the crack. These eggs are considered to be less sound than a normal shell egg. A trauma that would result in the cracking of the egg within the hen would be required. For this reason, proper employee training is imperative.

Exposure of hens to high heat results in decreased bird performance, shell thickness, and increased shell breakage (Lin et al., 2004). The authors reported no change in shape index. There were no changes in static stiffness, dynamic stiffness or modulus of elasticity of the shell associated with hen exposure to higher environmental temperatures. Arima and colleagues (1976) examined the role of high environmental temperature on young and old laying hens. The egg quality of the older hens was more severely affected by the increased temperature. The authors also reported that the function of the ovary and oviduct appeared to be affected by the high environmental temperature. The greatest shell strength was found in eggs produced by hens housed at 27°C. The greater the environmental temperature, the lower the shell strength of the eggs produced. Additional work found that hen exposure to cyclic temperature patterns allowing for periods of cooler temperature exposure results in greater shell breaking strengths, thicker eggshells, and lower body weight changes in the hens (Deaton et al., 1981). When European brown egg hens were provided cool drinking water, feed intake increased as did shell thickness (Glatz, 2001). When Australian tinted layers were tested, only 5°C water had an affect on feed consumption and shell thickness. The effect for this particular breed was also lost as the hens acclimatised.

VI. PROCESSING

Thompson et al. (1985) concluded that factors other than shell quality affect egg breakage in processing. Proper maintenance of production equipment can also improve egg quality. Collection belts which are working improperly can result in an increase in the incidence of impact checks. An impact check is a cracked egg with intact membranes that resulted from two eggs colliding. Repairing cages to prevent protruding wires decreases the risk of cracked eggs. Proper cleaning of belts, cages, and collection flats reduces the risk of shell contamination with egg contents. In the US, adhering matter results in a grade of Ainedible®. These eggs can not be sold for human consumption.

Egg processing has a definitive effect on shell egg quality. There are many steps in the processing procedure where egg quality can be enhanced. When the egg is laid it is approximately 39°C. The quicker an egg is cooled, a greater level of interior quality is maintained. As the internal egg temperature increases above 7°C, the protein structures of the thick albumen and vitelline membrane breakdown faster. For this reason, care should be
taken to ensure the egg is properly cooled throughout the shell egg processing procedure. One of these steps is the on-farm holding room. Collecting eggs from the laying house several times throughout the day instead of once or twice will reduce the amount of time those eggs are exposed to higher environmental conditions and they are less likely to be exposed to environmental contamintes. In the egg holding room an environment of 7–13°C and relative humidity of 50–60% will help to maintain egg quality. This room should also be sanitised and the chiller system maintained in good working order to help in reducing possible microbial contamination.

Care should also be taken to process eggs as quickly as possible after being laid. For off-line farms, egg trucks should visit farms at least twice a week. Holding eggs for greater than 4 days on the farm reduces the quality of the processed shell egg. The sooner eggs can reach the market, the greater your perceived consumer quality. During transport, shaking of the eggs should be held to a minimum since shaking has been found to have a detrimental effect on egg quality (Walker et al., 1972).

A more ideal solution is an in-line operation where eggs move directly from the laying house to the processing line. With this process, there is no need for an on-farm holding room. There is a limit to the ability of a processor to run exclusively an on-line operation due to flocks coming in and out of production and meeting processing needs for brown and white shelled eggs. For this reason, there is a need to adjust shell egg processing to accommodate both on- and off-line eggs.

Clean flats should be utilised to move eggs from farms to the processing facility. These flats need to provide an appropriate amount of protection to prevent damage to the eggs. Either sanitisable material or disposable paper flats should be utilised. Permanent flats should be sanitised before leaving the processing facility to return to the farm. Egg trucks should also be sanitised completely before returning to any farm to increase biosecurity. If a flock has been identified as *Salmonella Enteritidis* positive, special care should be taken to prevent potential introduction of the bacteria to other contract farms and eggs in the processing facility. Current recommendations are for all known *Salmonella Enteritidis* positive eggs to be diverted to pasteurisation facilities.

When eggs enter a processing facility from an off-line farm, internal egg temperature ranges from 17–20°C. In-line eggs enter a processing line with an internal egg temperature of 31 to 36°C. Current USDA regulations require egg wash water to be 32°C or 11°C warmer than the warmest egg. When both off-line and in-line eggs are processed at the same time there can be an increase in the incidence of thermal checks. A temperature difference of greater than 22°C between the egg and the wash water can cause thermal checks. A thermal check is a hairline crack in the shell surface along the vertical axis caused by abrupt changes in egg temperature. In a facility that processes both off- and in-line eggs, it would be advisable to initially process the off-line eggs then increase the wash water temperature (perhaps during a break or during lunch) to process the in-line eggs.

The internal temperature of an egg increases approximately 8°C during processing. When these warm eggs are placed into paper flats, cartons, or foam cartons then packaged in wire baskets or cardboard cases, they continue to increase in temperature. A maximum temperature is reached within 4-6 hours of processing. Under the current USDA regulations eggs must be maintained at 7°C ambient temperature post-processing. Research has shown that a case in the center of a 30 case pallet will require 7-14 days for the center most egg to reach an internal temperature of 7°C under these conditions (Anderson et al., 1992). In the US, most processed shell eggs for retail sell stay in the processing facility for 1–4 days before going into distribution. Furthermore, Bell et al. (2001) determined in a national survey that white shell eggs in the US were on average 11 days post-processing when purchased by the consumer.
Due to the fast distribution cycle, researchers have been developing methods of rapidly cooling shell eggs at the end of processing (Curtis et al., 1995; Thompson et al., 2000). Rapid cooling of shell eggs increases the internal quality of the eggs and enhances the microbiological integrity (Jones et al., 2002). Haugh unit scores have been enhanced by these methods and vitelline membrane strength and elasticity have been increased compared to control eggs. Rapid cooling of shell eggs has been found to cause eggshell damage (Fajardo et al., 1992). The initial quality of the eggshell affects the severity of the damage. During cold storage, it has been reported that albumen height decreases while albumen pH and whipping volume increases (Silversides and Budgell, 2004). Egg and albumen weight also decreased during storage with yolk weight increasing.

Clean, appropriate packaging material should be utilised for processed shell eggs. This serves two purposes: 1) protect the egg from damage during transport and storage and 2) reduce exposure to microbial contaminants. Cartons from returned retail product should not be re-used and should be destroyed. Packaging material should not trap condensation. If a facility is located in a high humidity area, care should be taken in packaging material choices since eggs tend to sweat under these conditions. Sweating has been associated with a higher probability of microbial penetration into the egg.

Processing equipment needs to be kept in good working order. If transfer units are not maintained, eggs can be dropped and broken before processing leading to a higher organic load being introduced into the washer. High levels of organic matter can render sanitising agents in the wash water inactive. USDA regulations, in inspected plants, require wash water to be dumped every 4h in order to maintain wash water effectiveness. If eggs remain in the washer for too long of a period they can become partially cooked.

Belts should be cleaned to prevent the transfer of egg contents to other eggs. Once again, any adhering matter, including egg contents, renders an egg inedible in the US. Packer heads should be kept in careful working order to prevent damage to the eggs during packaging. Packers should also be properly calibrated to prevent crowding on the belts which can lead to an increase in impact checks.

Employee training in the processing plant is extremely important in enhancing egg quality. The movement of eggs throughout the processing plant should always be from dirty to clean areas. Employees should also understand the sanitation standard operating procedures (SSOPs) and good manufacturing practices (GMPs) utilised in the processing procedures.

VII. MONITORING EGG QUALITY

Baker and Vadehra (1970) stated that candling does not always correspond with the internal quality of an egg. Bokhari et al. (1995) examined the eggs pulled by candlers in commercial processing plants in California. They determined in a commercial facility with an average line speed of 240 cases/hr, 17.3% of the pulled eggs were over-pull. Forty-three percent of the over-pulled eggs were due to the presence of cage marks. The authors concluded good employee training is necessary to prevent over-pull. Due to the subjective nature of egg candling, other methods are needed to evaluate internal egg quality. The HU measurement for interior egg quality was developed by Haugh (1937). The measurement has been modified to account for egg weight. This modification corrects for all eggs to be compared as large size eggs through mathematical manipulations, regardless of the actual weight of the egg. Therefore, it is a correlation of albumen height and egg weight. There are those who feel that this correction factor, as it is called, is unnecessary and actually causes the HU to be incorrect, thereby distorting comparisons which have been made. Researchers have suggested that a direct measurement of albumen height might be a better determinant of
interior egg quality. Silversides et al. (1993) suggested that the effect of egg weight on albumen height was of minor importance within flocks and inconsistent between flocks. They further stated that the statistical relationship between albumen weight and albumen height was weak. In a pooled data set, it was found that egg weight and albumen weight significantly affected HU. For this reason, the authors argued that the correction for egg weight was unnecessary. In contrast, Kidwell et al. (1964) reported that the correction for egg weight was probably unnecessary, but that it did not take away from the HU measurement. Baker and Vadehra (1970) contradict the complaints of accounting for egg weight by stating that the position of the thick albumen was of more importance than the actual amount when determining the HU.

Izat et al. (1986) and Williams (1992) stated that there was not a seasonal effect on HU. Brown egg layers have been found to produce eggs with greater HU (Curtis et al., 1985). Additional authors reported that HU values were more variable within the brown egg layers compared with those that lay white-shelled eggs (Hill, 1981; Williams, 1992).

Various methods have been utilised to assess egg shell quality. Both indirect and direct methods have been developed. Some of the easiest assessments to perform include: egg weight, shell weight, percent shell, shell thickness, and shell weight per unit of surface area. Another traditional laboratory measurement for shell quality is to determine egg specific gravity. There has been extensive publication of methods for its determination. With the advent of new technologies, it is now possible to assess the deformation and compression force an eggshell can withstand.

In 2002, De Ketelaere and colleagues compared a variety of methods for determining eggshell strength. They found all measurements gave different information. Sound eggs require a greater force to puncture than cracked eggs (Carnarius et al., 1996). Mean force was not different between cracked and leaker eggs. Shell weight, percent shell, shell thickness, specific gravity, and shell weight per unit surface area were all significantly greater for intact versus cracked eggs from a commercial processing plant (Thompson et al., 1986). In young and old flocks, a single specific gravity solution was able to identify eggs with low specific gravity and therefore a higher likelihood for cracking during commercial processing (Bennett, 1993). Research has shown that eggshell stiffness modulus (non-destructive shell quality measurement) was able to detect cracks when they were located in the vicinity of the testing site (Lin et al., 1993).

Several factors have been identified to affect eggshell quality measurements: egg temperature, time between lay and testing, sequence which indirect measurements are made, compression rate and response time of recording equipment for compression and deformation determinations, moisture content of the shell, and configuration and roughness of testing surfaces contacting the egg (Hamilton, 1982). The authors concluded that this information should be included when data is reported. The orientation of the egg can also affect detected force associated with shell breakage (Pandey et al., 1984). Differences exist for recorded force associated with the large and small ends as well as the equator of the egg, with the small end being the strongest. Therefore, the orientation of the egg during measurement should be presented with data.

Several correlation studies have been conducted to determine how the various measures of shell quality integrate. In 1983, Thompson and colleagues published work showing strong correlations for egg weight, shell weight, specific gravity, shell deformation, shell compression strength and shell thickness when comparing eggs from individual hens. This created an understanding that the measurements were accurate in assessing the quality of various eggs from a single hen. The report also stated that shell compression strength had a greater correlation than shell deformation between eggs. A negative correlation was found to exist between egg weight and egg specific gravity and percent shell (Pandey et al., 1985).
Shell thickness, shell weight per unit of surface area and percent shell were able to be predicted from specific gravity measurements. Shell weight was more accurately predicted with specific gravity and egg weight together.

Thompson and Hamilton (1986) found intact and cracked eggs were significantly different for shell weight, percent shell, specific gravity, and shell weight per unit area. Egg weight had the highest correlation with egg breakage in shipment (0.591) but this was not a strong correlation. The authors concluded that laboratory methods examined were not adequate in predicting egg breakage during transport. Subsequently, a significant negative correlation was found between the percentage of eggs cracked during commercial processing and specific gravity and percent shell (Strong, 1989). Breaking strength, shell thickness, and shell weight were not significantly correlated with egg breakage during commercial processing. The width of the palisade layer of the shell has been found to be correlated with shell puncture force (Carnarius et al., 1996). Furthermore, a negative correlation has been identified between cracked eggs and percent shell, shell weight per unit surface area, specific gravity, and shell weight (Abdallah et al., 1993). The authors also found a positive correlation between the percentage of cracked eggs in a lot and egg weight.

Roberson et al. (1987) concluded specific gravity was the best method for determining the quality of intact shell eggs. They further stated that shell thickness was the preferred method for assessing broken eggs since it can easily be measured and is highly correlated with shell breaking force. Due to the errors involved with specific gravity measurements, Abdallah et al. (1993) recommended percent shell and shell weight per unit surface area as more accurate methods for determining shell quality. The concern over errors in assessing specific gravity in eggs is part of what prompted Bennett (1993) to analyse the potential of utilising a single solution and grouping eggs as “low” or “high” specific gravity for shell quality evaluations.

The advent of modern technology has allowed for more precise rearing and laying practices to enhance egg quality. Shell egg processing technology has also evolved to allow for the production of a safer, higher quality product. The development of more objective testing methodologies makes shell egg quality assessment much more precise. Many of the older quality determination methods are still applicable and often more appropriate in the processing environment.

REFERENCES


