



Roles of the sire and dam quail in egg, yolk, albumen, and shell weight alterations due to the parthenogenetic trait[☆]

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ABSTRACT

Infertile eggs from Chinese Painted quail exhibit parthenogenesis, and the 1st egg in a clutch sequence is more likely to develop a parthenogenetic embryo. Also, hens that exhibit parthenogenesis have shorter clutches and heavier egg weights. These larger eggs may be a result of the egg residing in the oviduct longer, allowing more time for the parthenote to develop. However, it is unknown which components of the egg are altered due to the parthenogenetic trait or the role of dams and sires from the parthenogenetic line of quails in these alterations. Therefore, our objective was to determine if the parthenogenetic trait in dams, sires, or both contributes to alterations in egg components, such as yolk, albumen, and shell weights. Two selected lines of quail, 1 line selected for parthenogenesis and 1 line that was unselected for the parthenogenetic trait (control), were utilized in a 2 x 2 factorial arrangement of dam and sire lines to create 4 breeding treatments: control dams + control sires (CC), control dams + parthenogenetic sires (CP), parthenogenetic dams + control sires (PC), parthenogenetic dams + parthenogenetic sires (PP). Daily, fresh eggs were collected, labeled, weighed, and the germinal disc was classified as fertile, unfertilized without development, or parthenote. Yolk, albumen, and shell weights were obtained, and their weights were also calculated as percentage of total egg weight. A dam main effect revealed heavier weights for total egg, yolk, albumen, and shell as well as a larger percentage of albumen and ratio of albumen to yolk in parthenogenetic line dams versus control line dams. However, the percentage of yolk was higher for control than parthenogenetic line dams. The increase in total egg and egg component weights due to the parthenogenetic trait suggests that the transit time of the egg through the oviduct is altered. Perhaps transit through the magnum and uterus is delayed the most yielding greater albumen and shell weights, respectively.

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1. Introduction

Parthenogenesis is the embryonic development in an unfertilized egg and was reported in Chinese Painted quail by Parker and McDaniel [1]. Parthenogenesis is thought to occur due to either the retention of the second polar body with the egg nucleus or absence of meiosis II [2]. However, most avian parthenogenesis is an abortive form of development [2]. In fact, parthenogenetic embryos are only at the early blastula stage of development when the egg is laid [3] and require 2 additional days of incubation as compared to the

normal embryo from a fertilized egg [2]. Interestingly, the first egg in a clutch sequence is 2 times more likely to exhibit parthenogenesis versus subsequent eggs in the clutch sequence [1]. Additionally, Warren and Scott [4] reported that the egg destined to be first in a clutch stays in the hen's body 16 h longer than subsequent eggs in the clutch. The additional time that the first egg remains in the hen's body could allow parthenotes a greater opportunity for embryonic development due to increased length of exposure to the hen's body temperature.

In chickens, Robinson et al. [5] reported that the first egg in a clutch sequence weighed more at lay than subsequent eggs in the clutch. In parthenogenetic line virgin Chinese painted quail, Wells et al. [6] reported that the eggs exhibiting parthenogenesis were heavier at set than the eggs with no development. Again, perhaps the larger egg size reported by Wells et al. [6] and Robinson et al. [5] was a result of slower transit time in the hen's body, because it has been reported that the first egg in a clutch sequence stays in the

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hen's body longer [4]. The additional time that the parthenote remains in the hen's body could perhaps relate to an extended period in the uterus and therefore more time for shell secretion. Also, it is possible that as the parthenote develops within the oviduct, it modifies formation of albumen in the magnum, resulting in heavier eggs at lay.

In fact, in parthenogenetic line virgin and mated quail, Santa Rosa et al. [7,8] reported that eggs containing parthenotes are capable of altering the ionic composition of albumen within the egg and these alterations are similar to fertilized eggs [8]. For example, the parthenote utilizes O₂ from the egg's albumen and then releases CO₂ into the albumen. As a result, eggs exhibiting parthenogenesis have a low pH. In addition, Parker et al. [9] reported that both dams and sires selected for parthenogenesis were responsible for this lower fresh egg albumen pH.

As parthenogens alter albumen ionic concentration similar to fertilized eggs [8] it is also possible that other internal components of the egg such as yolk, albumen, and shell weights are altered due to parthenogenesis. In fact, Parker et al. [9] reported that both dams and sires selected for the parthenogenetic trait negatively impact reproductive performance by altering egg set weight, albumen pH, sperm-egg penetration, and fertility. Therefore, parthenogenetic line dams, sires, or both may have an impact on the internal components of eggs exhibiting parthenogenesis. The objective of the present study was to determine if yolk, albumen, or shell weights are altered due to the parthenogenetic trait and which parental sex contributes to these alterations in egg weight and egg components.

2. Materials and methods

2.1. Housing and care

In this trial, Chinese Painted quail consisted of a random breeding stock (control) and a line selected for the parthenogenetic trait [10] over 10 generations of genetic selection. For the parthenogenetic and control line of quail, both sexes were brooded together from hatch until 4 wk of age. At 4 wk of age, when male plumage was visible and prior to sexual maturity, females from both lines were separated from the males and placed into colony cages. At 6 wk of age, females from the parthenogenetic line of quail were moved into individual cages to monitor their incidence of parthenogenesis. The quail chicks in this trial were fed a commercial starter diet (DuMor[®] Chick Starter, 24% Crude protein and 2.5% crude fat) until 4 wk of age. Beginning at 4 wk of age, females and males from both lines of quail were fed a commercial breeder diet ad libitum and were exposed to 17 h of light. Birds were treated in accordance with the Guide for Care and Use of Laboratory Animals [11].

2.2. Egg collection for parthenogenetic virgins

To determine each virgin hen's incidence of parthenogenesis, eggs were collected daily, labeled, and then incubated for 10 d at 37.5 °C and 50% relative humidity. At 10 d of incubation, eggs were broken open to determine the existence of parthenogenesis using a 2 x magnifying lamp [1].

2.3. Parthenogenetic line virgin quail selected for mating and treatment combinations

After each virgin hen laid 20 eggs, their incidence of parthenogenesis was calculated prior to selection for mating. If the incidence of parthenogenesis from the virgin hens ranged from 20 to 40%, they were used for mating purposes. Selection of the parthenogenetic line males used for mating was based on their sister's

incidence of parthenogenesis as virgins, which also ranged from 20 to 40%. There were 4 breeding pair treatments: control line dam with control line sire (CC); control line dam with parthenogenetic line sire (CP); parthenogenetic line dam with control line sire (PC); and parthenogenetic line dam with parthenogenetic line sire (PP). There were a total of 48 breeding pairs in this study.

2.4. Fresh egg components examined

After breeding pairings were determined, fresh eggs were collected daily and each egg was individually labeled and weighed ($n = 768$). Total egg weight as well as yolk, albumen, and shell weights were determined for each egg. For yolk, albumen, and shell weights, each parameter's weight was also calculated as the percentage of total egg weight. Additionally, the ratio of albumen to yolk was calculated by dividing albumen by yolk weight. When fresh eggs were broken open, the germinal disc was examined using a 2 x magnifying lamp [1] to determine if the germinal disc was fertilized, unfertilized without development, or exhibiting parthenogenesis [8]. Eggs classified as fertile exhibited an area opaca, area pellucida, and a periblastic ring while eggs exhibiting parthenogenesis appeared as dense layers of tissue covering the germinal disc. For eggs classified as unfertilized, no visible embryonic development was present (see Parker and McDaniel [1]). Also, for further validation of eggs exhibiting parthenogenesis, albumen pH was measured, because eggs with parthenotes have a lower albumen pH as compared to unfertilized eggs without development [7]. Further, early dead embryos were differentiated from parthenotes by the germinal disc size; parthenotes measure 7 mm or less in diameter with very little differentiation compared to early dead embryos from fertilized eggs [12]. Because most parthenotes at oviposition appeared as unorganized and undifferentiated epithelial sheets of cells covering the germinal disc area, the embryos were not staged according to the Hamburger and Hamilton procedure [13].

2.5. Statistics

A 2 dam (C and P) x 2 sire (C and P) factorial arrangement of treatments was utilized in this study. Data were analyzed as a completely randomized design with each parental pairing serving as the experimental unit. After making each parental pairing, breeding pair means were determined for total egg weight, different egg components and germinal disc classification. When global $P \leq 0.10$, means were separated using Fisher's protected least significant difference with α set at 0.05 [14].

3. Results

When averaged across all egg classifications (fertilized, unfertilized without development, and parthenogen), there were dam main effects for total egg, yolk, albumen, and shell weights (Fig. 1A). The dams from the parthenogenetic line had the heaviest egg, yolk, albumen, and shell weights as compared to the control line dams ($P < 0.0001$, 0.05, <0.0001 , and 0.005, respectively). No differences due to the sire line were detected for egg ($P = 0.94$), yolk ($P = 0.55$), albumen ($P = 0.67$), and shell weights ($P = 0.60$; Fig. 1B). When examining albumen ($P = 0.005$) and yolk ($P = 0.006$) weight expressed as a percentage of total egg weight, the dam main effect revealed that the parthenogenetic line dams had a higher percentage of albumen yet a lower percentage of yolk as opposed to the control line dams (Fig. 2A and B). However, there were no differences due to the sire line for albumen ($P = 0.46$) and yolk ($P = 0.50$) weights when expressed as a percentage of total egg weight (Fig. 2A and B, respectively). There was also a dam main

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