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Determination of Fertility, Hatchability and Stage of Embryonic Death in Non-Hatching Eggs at Rubilizi National Hatchery

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Abstract

Background: This study was undertaken to evaluate the major causes of mortality at different stages of incubation and their economic impact in response to sustainability challenges at the Rwandan National Hatchery.

Methods: The study evaluated the fertility, hatchability and embryonic deaths in broiler-producing flocks (B series) and layer-producing flocks (L series) at Rubilizi, a state-owned hatchery in Kigali, Rwanda.

Results: Mean fertility in the B series (94.23%) was not significantly different ($P > 0.05$) from that of the L series (93.24%). Mean hatchability in the B series (57.39%) was significantly ($P < 0.05$) higher than that of the L series (42.2%). Early embryonic deaths in the L series (8.6%) were significantly ($P<0.05$) higher than those in the B series (3.9%). Middle embryonic deaths in the L series (6.2%) were significantly ($P < 0.05$) higher than those in the B series (1.8%). Late embryonic deaths in the L series (21.6%) were significantly higher ($P < 0.05$) than those encountered in the B series (13.0%). The occurrence of hatch debris in the L series (34.14%) was significantly ($P<0.05$) higher than that in the B series (24.42%). There was no significant difference in the proportions of pips, rots and malformations/malpositions between the B and the L series ($P > 0.05$).

Conclusions: Low hatchability in the L series possibly resulted from the higher number of embryonic deaths and hatch debris and not from reduced fertility or cull chicks. Total chick losses during the study amounted to US$54 327.00. The hatchery was experiencing more losses in layers than in broilers as emanating from low hatchability of the layers. Further investigations are needed with aim to maximise the hatchery's capacity.

INTRODUCTION

Rwanda is a small (26 338km^2) landlocked country in East Africa whose human population was estimated at 11.4 million as of July 2011 with a population growth of 2.9% per year. The country had the highest population density (407people/km^2) in Africa with some areas exceeding 1000 inhabitants/km^2. Only 8% of Rwanda's total area produces dependable harvests when cultivated [1]. As of June 2008, Rwanda had a poultry population of 4.08 million 99.7% of which were chickens. The chicken population comprises of exotic layers (Leghorn, Sussex, Rhode Island Red, Derco, Isa Brown and Norman) averaging 300-350eggs/hen/year, local indigenous (Inyarwanda) breeds averaging 40-100eggs/hen/year and broiler breeds (Cobb 500, Hubbard and Derco). In 2010 Rwanda had to import 1.09million day-old chicks and 200 000 metric tonnes of chicken meat to meet the local demand [2]. The country has 9 major chicken hatcheries with a total of 15 468 chickens as parent stock and a total incubation capacity of 95 618 eggs. Rubilizi National Hatchery in Kigali is the biggest operation with 54.1% of the total parent stock but only 39.8% of the total incubation capacity [3]. The performance and productivity of hatcheries is determined by the hatchability and fertility of the eggs passing through them. A decrease in the hatchability results in reduced productive efficiency and an increase in economic loss of the hatchery [4]. Mean hatchability is defined as the number of viable chicks hatched per 100 fertile eggs. Studies have shown that a decrease in hatchability can increase the cost of broiler chick production by up to 1.2% [5]. Whitehead, Maxwell (6) re-

corded 86.4% mean hatchability in studies which showed 64% mortality during the first week, 6% mortality in the second week and 30% mortality in the third week of incubation. Infertility and embryonic mortality are the major causes decreasing hatchability. Increased embryonic mortality during incubation is due to environmental and genetic effects on the physiological and developmental functioning of the embryo [7-9]. Probabilities of mortality are estimated by observing the proportions of mortality during the first (EED: Early Embryonic Death), second (MED: Middle Embryonic Death) and third week (LED: Late Embryonic Death) of incubation even though embryonic mortality is always considered a continuous process. Prolonged storage of eggs prior to incubation has also been noted to increase embryonic mortality during incubation [10, 11]. Studies in Tanzania reported 52% hatchability in local breeds, 64% in Rhode Island Red and 80.6% in cross breed chickens [12]. In the same studies fertility was reported at 92%, 91.1% and 94.5% in local breeds, Rhode Island Red and cross breed chickens, respectively.

Fertility is defined as the percentage of eggs incubated that are fertile. Infertile eggs may erroneously include those that have suffered embryonic death before incubation and the distinction can be made with the aid of candling. Genetic (cock and hen), nutritional, bird (age, weight, breed, strain), egg (weight, shell thickness, porosity, shape index) and incubator factors can all determine the fertility, embryonic mortality and hatchability of eggs in hatcheries [13]. Not all fertile eggs hatch successfully. Even eggs from 'good' flocks follow a predictable embryonic mortality pattern [13]. EED's are usually higher because organ systems are still being formed in the embryo. MED's are usually few due to the rapid growth of the embryo. LED's are usually higher than MED's but lower than EED's and these are due to changes in the physical orientation of the embryo a few days before hatching [14]. The procedures for monitoring hatchery performance aim to assess fertility by breaking out fresh un-incubated eggs, partially incubated eggs or incubator 'clears'. 'Clears' are eggs that fail to show embryonic development and allow most of the light through when candled during incubation. Cull eggs are those eggs not suitable for sale or incubation due to small size, thin white shell, abnormal shape (wrinkled or ridged), double yolks, cracks, dirt (excreta, yolk or blood) or stains [13]. Examination of hatch debris for recognition of normal developmental stages, normal hatching positions, malformations and malpositions also provides valuable information on hatchery performance. The monitoring of egg weight loss, chick weight, hatch window, incubator and eggshell temperatures are also important procedures for assessment of hatchery performance [13]. The factors that generally affect hatchery performance are well known[13]. However, the relative contributions of individual factors and their effects on the two production lines (B-series and L-series) and to the viability of the whole enterprise at Rubilizi Hatchery are not known. The aim of this study was to evaluate the fertility, hatchability and embryonic deaths in broiler-producing flocks (B series) and layer-producing flocks (L series) at Rubilizi, a state-owned hatchery in Kigali, Rwanda.

METHODS

At the time of study, Rubilizi National Hatchery was home to 8 368 female parent stock. These consisted of five broiler-chick producing flocks (totalling 958 birds) and eight layer-chick producing flocks (totalling 7 410 birds). Incubations from the five broiler-chick producing flocks of Rubilizi National Hatchery were designated B1 to B5 (B series). For this study, incubations of eggs from the B series were set on the 3rd, 7th, 9th, 18th and the 28th of June 2015. A total of 7004 eggs from the B series were incubated. Incubations from the eight layer-chick producing flocks of Rubilizi National Hatchery were designated L1 to L8 (L series). For this study, incubations of eggs from the L series were set on the 4th, 7th, 12th, 18th and the 25th of June and the 7th and the 9th of July 2015. A total of 72 336 eggs from the L series were incubated. To assess the performance of Rubilizi National Hatchery, the authors analysed random samples of both broiler and layer-producing incubated eggs condemned and removed at the 8th day and 18th day candlings. They also counted the number of good/cull chicks and analysed random samples from the hatch debris of the flocks under investigation. Candling was performed by a mass candler on day 8 of incubation at which time cull eggs and all 'clears' were counted then removed from the incubator. Random samples of 100'clear' eggs were broken out for enumeration of infertile eggs and early embryonic deaths (EED's). All the removed 'clears' were broken out for analysis whenever the number of 'clears' was less than 100. Candling was repeated on day 18 of incubation at which point all 'clears' were removed and random samples of 100 eggs were broken out for enumeration of middle embryonic deaths (MED's) and late embryonic deaths (LED's). All 'clears' were broken out in the event of there being less than a 100 'clears' at the 18-day candling. On the day of hatching, enumerations of the good chicks and cull chicks were done. Random samples of 100 eggs from the hatch debris from each flock were all analysed for malpositions/malformations, pips and rots. When fewer than 100 eggs failed to hatch, all the eggs in the debris were analysed. Pairs of scissors and forceps were used for breaking out eggs and handling embryos and contents during examinations. All good chicks hatched at Rubilizi National Hatchery were sold at an equivalent of US$1.30 per chick.

Classification of Abnormalities in 'Clears'

Cull eggs were those removed at the 8th day candling due to small size, thin white shell, abnormal shape (wrinkled or ridged), double yolks, cracks, dirt (excreta, yolk or blood) or stains. Infertile eggs were 'clears' that showed the dense white area of the blasto disc and no obvious sign of embryonic development when broken out at the 8th day candling. EED's were 'clears' that showed cream coloured extra-embryonic membranes or an obvious 'blood ring' and the beginning of formation of the sub-embryonic fluid when broken out at the 8th day candling. MED's showed the obvious black pigmentation of the embryo's eye and presence of wings and legs (featherless or with very few feathers showing) of the dead embryo when broken out at the 18th day candling. LED's showed presence of feathers over the entire body of the dead embryo.

Classification of the Hatch Debris

Rots showed deep discolouration of egg contents (with or without obvious embryo) and emission of rotten odours.

Pips showed the beak of the embryo (live or dead) having penetrated the inner shell membrane into the air cell or having broken through the eggshell. Malformations included those of the head (beak/face abnormalities, missing eyes, exposed brain), legs/toes (shortened, bent or twisted legs, extra legs, malformed toes), ectopic viscera and extra wings. Malpositions included head between the thighs, head in small end of the egg, head turned to the left, break away from air cell, feet over head and beak above right wing.

CALCULATIONS

Fertility (%)=(Total number of set eggs – infertile eggs)/(Total number of set eggs) x100

Hatchability(%)=(Total number of good chicks)/(Total number of fertile eggs set) x100

Proportions of EED's=(Total number of EED's)/(Total number of embryonic deaths) x100

Proportions of MED's=(Total number of MED's)/(Total number of embryonic deaths) x100

Proportions of LED's=(Total number of LED's)/(Total number of embryonic deaths) x100

Occurrence of early embryonic death (%) =(Total number of early embryonic deaths)/(Total number of eggs set) x100

Statistical Analysis

The Pearson Chi-Square test of the Statistical Package for Social Sciences (SPSS version 16) was used in the statistical analysis of the results. P values < 0.05 were considered significant.

RESULTS

The mean occurrence of hatch debris in the B series was 24.42%. In the B series cull chicks occurred at 1.74% and infertile eggs occurred at 5.77%.

The mean occurrence of hatch debris in the L series was 34.14%. In the L series cull chicks occurred at 1.65% and infertile eggs occurred at 6.75% (Table 2). Statistical analysis of the results in from Table 1 and 2 showed that there was no significant difference in the mean fertility between the B and the L series (P>0.05). The hatchability of the B series was, however, significantly higher than that from L series (P<0.05). The L series had significantly higher occurrence of hatch debris (34.14%) than the 24.42% in the B series (P<0.05). There was no significant difference in the mean occurrence of infertile eggs and cull chicks between the B series and L series.

Table 1: Fertility and Hatchability of Eggs from the B Series

Flock	Total Number of Eggs Set	'Clear' Eggs at 18th Day Candling	Infertile Eeggs	Eggs in Hatch Debris	Cull Chicks	Good Chicks	Fertility (%)	Hatchability (%)
B1	1126	195	70	50	36	775	93.78	73.39
B2	2011	322	163	648	34	844	91.89	45.67
B3	2093	256	113	679	19	1026	94.46	51.82
B4	1086	117	30	92	24	823	97.23	77.74
B5	688	89	28	242	9	320	95.93	48.48
Total	7004	979	404	1711	122	3788	94.23	57.39

Table 2: Fertility and Hatchability of Eggs from the L Series

Flock	Total Number of Eggs Set	'Clear' Eggs at 18th Day Candling	Infertile Eggs	Eggs in Hatch Debris	Cull Chicks	Good Chicks	Fertility (%)	Hatchability (%)
L1	10.267	2.076	763	2.833	382	4.213	92.57	44.33
L2	9.201	1.792	753	3.115	88	3.453	91.82	40.87
L3	9.526	2.023	814	4.088	151	2.450	91.45	28.12
L4	8.236	1.841	580	3.413	146	2.256	92.96	29.47
L5	10.071	1.705	567	4.888	177	2.734	94.37	28.77
L6	8.033	1.078	509	2.015	101	4.330	93.66	57.55
L7	8.068	1.120	412	1.970	113	4.453	94.89	58.16
L8	8.934	1.461	486	2.371	37	4.579	94.56	54.20
Total	72.336	13.096	4.884	24693	1.195	28.468	93.24	42.20

Table 3: Comparison of Abnormal/Normal Findings between the B and L Series

Condition	Number Affected in the B Series	Number Affected in the L series	P value
Removed at 8th Day Candling			
Cull eggs	186	652	0.00*
Infertile eggs	404	4.884	0.17#
Eed's	240	6.574	0.01*
Removed at 18th Day Candling			
Med's	131	4.257	0.00*
Led's	933	14.683	0.00*
Hatch debris			
Malformations and Malpositions	122	1.164	0.31#
Live pips	183	1.544	0.99#
Dead pips	356	3.026	0.86#
Rots	135	983	0.08#
Hatched eggs			
Cull chicks	122	1.195	0.86#
Good chicks	3.788	28.468	0.00*

*Significant difference between B and L series ($P < 0.05$) #No significant difference between B and L series ($P > 0.05$)

Table 4: Comparison of the Relative Proportions (within Category) of Abnormalities between the B and L Series

Condition	Number Affected in the B Series	Relative Within Category Proportion (%)	Number Affected in the L Series	Relative Within Category Proportion (%)
Embryonic Deaths				
Eed's	240	18.40	6.574	25.27
Med's	131	10.05	4.257	16.68
Led's	933	71.55	14.683	57.55
Subtotal	1.304	100.00	25.514	100.00
Hatch Debris				
Malformations and Malpositions	122	15.33	1 164	17.33
Live pips	183	22.99	1.544	22.99
Dead pips	356	44.72	3.026	45.05
Rots	135	16.96	983	14.63
Subtotal	796	100.00	5.553	100.00
Hatched Eggs				
Cull chicks	122	3.12	1.195	4.03
Good chicks	3.788	96.88	28.468	95.77
Subtotal	3.910	100.00	29.663	100.00

Table 5: Revenue Losses in the B and L Series

Flock	L Series	B Series
Total Eggs Set	72.336	7.004
% Fertility	93.24	94.23
Total Number Fertile Eggs	67.446	6.600
% Hatchability	42.2	57.39
Total Number of Good Chicks	28.468	3.788
Total Number of Eggs Lost	38.978	2.812
Total Revenue Loss (US$)	50.671	3.656

Statistical analysis showed that the proportions of EED's, MED's and LED's in the L series were significantly higher than those in the B series ($P < 0.05$) (Table 4). Results also showed that the proportions of LED's in both series were significantly higher than the proportions of EED's ($P < 0.05$). There was no significant difference in the proportions of malformations/malpositions, live pips, dead pips and rots between the B and L series ($P > 0.05$).

DISCUSSION

The mean fertility of eggs from both the B (Table 1) and L series (Table 2) was very good, indicating that both flocks at Rubilizi were still in their prime. Fertility from Rubilizi flocks was similar to the fertility reported in other good flocks in the region [12]. Hatchability values from the B series (57.39%) were slightly lower than those reported for Rhode Island Red breeder flocks from the same study. However, the mean hatchability in the L series (42.2%) was much lower than any of those reported in East Africa, indicating the existence of hatchery inefficiency in the handling of layer-producing eggs. The low mean hatchability in the L series (42.2%) was not due to the incidence of live/dead pips, rots and malformations/malpositions, as there was no significant difference in the occurrence of these hatch debris between the L series than in the B series. The proportions of MED's in both the B series (10.05%) and the L series (16.68%) (Table 3) were higher than the 6% encountered in hatcheries studied by Whitehead, Maxwell (6) whose team recorded reasonably good hatchability (86.4%). These MED's in the B and L series can thus be contributory to the low hatchability in both the Rubilizi series, more so in the L series. A decrease in hatchability usually results from feeding laying hens with a low energy to protein diet to flocks (Pearson and Herron, 1982). The composition of the feed provided to the flocks at Rubilizi was, however, not analysed to confirm or refute this possible cause of a reduction in mean hatchability. It was also noted in this study that Rubilizi hatchery handled 10 times more layer-producing eggs than broiler-producing eggs which is highly suggestive of problems arising from incubation of high volumes of eggs. The unusually high proportion of MED's in the L series may thus have resulted from these high volumes incubated. Bacterial contamination (secondary to cracked eggshells or poor nest hygiene) and sudden changes in temperature and/or humidity during handling are some of the non-nutritional factors resulting in an increase in the proportion of MED's in hatchery flocks. Researchers in the current study, however, did not carry out investigations to verify the microbial threat to eggs handled at Rubilizi. Even though the MED's in the L series were lower than the EED's and LED's as expected, they still failed to fall into the expected quartiles of an efficient hatchery [13].

The higher occurrence of hatch debris in the L series (34.14%) than in the B series (24.42%) (Table 3) was also possibly responsible for the observed lower hatchability in the L series. It was, however, noticed that mean hatchability in both flocks were much lower than those encountered in 'good' flocks [6]. Such high occurrence of hatch debris is usually associated with inappropriate temperature or humidity in setter or hatcher, damage of eggs at transfer, bacterial contamination, turning problems in setter, setting eggs upside down, inadequate ventilation, inadequate turning, excessive storage time before incubation, excessive fumigation during hatching and nutritional deficiencies [13]. Though the general expected pattern EED, MED and LED proportions was reported in the results, the magnitudes of all the stages of embryonic mortality in both flocks were higher than those expected from a well-managed hatchery handling eggs from well managed flocks. EED's values for the B series were suggestive of eggs being produced from ageing (51-60-week-old) flocks. Since the values of EED's (Table 3) from the L series were even higher, they indicated the possible existence of other compounding factors (prolonged eggs storage before incubation, storage of eggs with the small-end-up, jarring of eggs during handling, failure to let eggs settle before setting, high early incubation temperatures, incubator humidity, age of breeder flock, nutritional deficiency and bacterial contamination). The same discrepancy was noted for the LED's in both series and the MED's in the L series. Excess LED's are usually caused by nutritional deficiency, bacterial contamination and inappropriate incubation conditions [15-22]. The MED's of the B series were within the expected quartile for a well-managed hatchery.

The conclusion of this study was that the fertility of the eggs from both B and L series incubated at Rubilizi hatchery was within the acceptable range for a well performing breeding flock. The mean hatchability for both B and L series were well below those for well performing hatcheries. The even lower mean hatchability value in the L series was a direct result of higher levels of embryonic deaths which in turn possibly resulted from various factors within the hatchery (storage, handling, high volumes, temperature, humidity, egg turning frequency and egg contamination). Future investigations may reveal the responsible factors by comparing the way both the B and the L series are handled throughout the hatchery. Further investigations should also aim to maximize the hatchery capacity but this can only be done effectively when the constraints brought to light in this study have been investigated and corrected.

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CONFLICTS OF INTEREST

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

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AUTHOR S' CONTRIBUTIONS

B.M. Designed the study, co-supervised the project and wrote up the manuscript draft and edited the final manuscript. T.B. Designed the study and undertook the data collection and analysis and did the write up of the manuscript draft. S.C. Did the statistical analysis and the write up of the manuscript draft and the editing of the final manuscript. E.K. Did data analysis and the manuscript draft and editing. A.S. Undertook the data analysis and aid the editing of the final manuscript. A.B. Undertook the data analysis and aid the editing of the final manuscript. G.H. Did the data collection, the initial write up and the editing of the final manuscript and coordinated the publication of the manuscript.

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