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Temperature of Eggshell, Weight Loss, and Air Sac on Hatched Local Duck Eggs During Incubation

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ABSTRACT

The study was conducted to analyze the characteristic of eggs (temperature of eggshell, weight loss, and air sac alteration) at various hatching period of local duck hatched (H) and unhatched (UH) at the final observation, and to find out the effective time for estimating the life of embryo during the end of incubation. A total of 146 eggs were incubated and observed between 1 and 25 days of incubation (DOI). The results of weight loss and air sac change showed a significant difference (P<0,05) between H and UH eggs on 7 to 25 DOI, while the temperature of eggshell was only different on 25 DOI. The average characteristic of H group (temperature of eggshell, weight loss, and air sac alteration) on 25 DOI was recorded 38,46ºC, 11,84%, and 51,03%, respectively. It can be concluded that 3 characteristics of eggs influence hatchability of local duck. Weight loss and air sac alteration parameters can be applyed to estimate the hatched eggs between 7 and 25 DOI, but the temperature of eggshell can be administrated after 25 DOI.

Keywords: Air Sac, Incubator, Local duck, Temperature of eggshell, Weight loss

Introduction

In 2016, the highest duck population was found in West Java province (18% of the national population). Local duck number nationwide between 2014 and 2015 was increased slightly (0,06%) (Ditjen PKH, 2016). Slow improve of population can be affected by deplesion of diseases, excessive duck slaughtering, and low availability of day old duck (DOD). Improving availability of DOD is a way for increasing duck number. King'Ori (2011) reported that fertility and hatchability is main parameter highly influencing the availability of day old poultry.

The local duck eggs hatched by a incubator have a high mortality rate, especially during hatcher period (26-28 DOI) (Sadiah, 2015). The high mortality of embryo impacts on low hatchability percentage between 50 and 60% of local duck eggs. Hatchability could be influenced by egg composition, hatching environment, flock age, and egg weight (King'Ori, 2011; Mueller *et al.,* 2015; Ipek and Sozcu, 2017). Wang *et al.* (2014) reported, the environmental factors which easily influence the growth and development of bird embryos are temperature and humidity of hatching.

The DOD supplying effort is mostly carried out by traditional farm of non-industrial breeder. Based on field observation, duck egg incubation of traditional farm in Cirebon district does not focus yet on good environmental management of hatching egg. Factors that cause breeders' lack of attention are due to unavailability of information on good environmental management as guideline of local duck eggs for hatching purposes. The changes of egg characteristic during the incubation period are not having a sufficient attention yet.

The egg characteristic during the incubation period can be observed, i.e. inner temperature of egg, weight loss, and air sac alteration. Meijerhof (2009) revealed, internal termpature or embryo temperature was an important factor in hatching egg. The temperature of eggshell constitutes an alternative way to find out the internal termpeature without interfering the perfectness of eggshell structure (Lourens *et al.,* 2011). A study conducted by Harun *et al.* (2001) showed that there was only a little difference between eggshell temperature and inner temperature of egg. Temperature of eggshell has a linear regression correlation with embryo heat production (Tzschentke and Rumpf, 2011). Tong *et al.* (2013) reported that embryo heat production determines the balance of temperature and changes of energy in the egg.

The reduction of egg weight during the hatching period shows a development and metabolism of embryo by oxygen and carbon-dioxide exchanges as well as the water evaporating through eggshell (Prasetyo and Susanti, 2000). Evaporation will cause the occurrence of weight loss and changes to air sac. Evaporating rate, relative humidity, and incubation phases according to Meijerhof (2009) determined the balance of heat production of metabolism and heat release.

Information on the egg characteristic alterations during incubation period is important as a guideline for managing of incubator environment and is applied to estimate of hatched egg. The objective of this study is to analyze the information on the characteristic of temperature eggshell, weight loss, and air sac alteration of hatched egg, and find out the effective time to predict in hatching by characteristic parameters of hatching egg.

Materials and Methods

This study used 146 duck eggs which survive until 25 DOI of 197 fertile eggs. All eggs were obtained from a breeder flock at 65 weeks of age in Cirebon district, and held for 4 days under standard storage conditions with egg weight 65-75 g. The ducks were reared freely with ration between male and female of 1:12.

The equipment used were an incubator (Lyon Rural Electric Co. of forced air type, USA) modified by the addition of automatic rotation and two holes of 12 cm in diameter at the top of incubator (Figure 1), water sprayer, digital weighing (Otsuka AJ3000, Japan), infrared thermometer IRT 4520, Thermoscan, Braun, Germany), torch, and gauging tape.

Incubator was fumigated by using formalin 40% and $KMnO_4$ at 2:1 ratio. Eggs were rotated automatically once in every 3 hours on the 4^{th} day through the 25^{th} day. The incubator was maintained at optimal temperature range according to Wilson (1990), i.e. 37,0-38,0°C. Incubator temperature was set at 37,8-38,0^{o}C on 1-14 DOI; 37,3-37,5^{o}C on 15-21 DOI; and 37^{o}C on 22 DOI until the eggs hatched. Humidity was set manually by using water basin placed on the base of incubator unit and was controlled by using hygrometer. Humidity was maintained at 55% on 1-13 DOI and 60% on 14-28 DOI. Eggs were sprayed three times a day on 26 DOI until the eggs hatched. Living and dead embryos were identified by candling on 7, 14, 21, and 25 DOI. Dead embryos were removed out from the incubator unit during candling. The final data of survival embryo observation up to 25 DOI were applyed for continuing analysis of H and UH egg groups.

Variables observed during this study were eggshell temperature, weight loss, and air sac alteration of H and UH eggs. In this work, UH groups were survival embryos until 25 DOI (setter period) but were dead (unhatched) during hatcher period (between 26 and 28 DOI).

Eggshell temperature

Observation on eggshell temperature was determined on 1, 7, 14 and 25 DOI using infrared thermometer. The measurement was done by inserting infrared thermometer through the incubator's topside hole (Figure 1), then the end of infrared thermometer was affixed on the eggs' equator side as shown in Figure 2. The measurement of eggs' Eggshell's temperature was done twice on the different sides, then the data of measurement was taken its mean. The use of infrared thermometer referred to Ipek *et al.* (2015).

Egg weight loss

Eggs were weighed on 1, 7, 14, 21 and 25 DOI using digital weights. Egg's weight loss was calculated by formulation below:

$$\text{ST (\%)} = \frac{\text{BT1} - \text{BTi}}{\text{BT1}} \, x\, 100$$

Remarks: ST (%) = Egg's weight loss, BT1 (g)= egg's weight on the first day, BTi (g)= weight on the i-day (7, 14, 21, and 25).

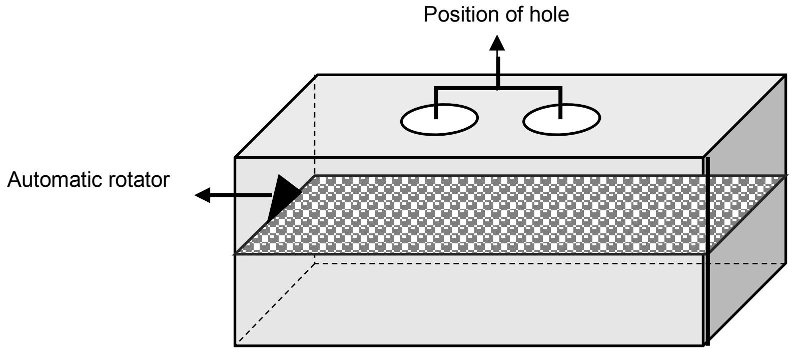

Figure 1. Modification to incubation machine.

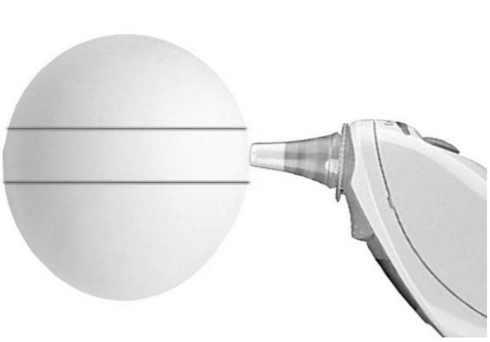

Figure *2*. Position of eggshell temperature at the egg's equator.

Air sac alteration

Observation on the air sac alteration was done on 1, 7, 14, 21 and 25 DOI. Eggs were telescoped by a torch, then the outline of air sac (silhouette) was marked / lined by pencil (Figure 3). The percentage of air sac's changes was measured by formulation below:

$$\text{KU}\ (\%) = \frac{A}{B} x100$$

Remarks: KU (%)= The percentage of air sac alteration, A (cm)= the distance between blunt central point to the farthest line's outline of egg's air sac on the i-day (1, 7, 14, 21, and 25), B (cm)= the distance between blunt central point to the taper central point on egg's surface.

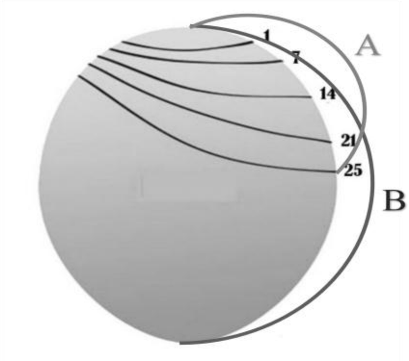

Figure 3. The markings of air sac boundary.

Data obtained was processed by using Microsoft Exel 2013 and Minitab 16 software. Data was conducted a mean difference test upon between H and UH variables at each measured variable (eggshell's temperature, weight loss, and air sac alteration).

Result and Discussion

Eggshell temperature

Shell temperature was commonly affected by 3 factors namely incubator temperature, heat capacity to pass the shell, and heat production of embryonic metabolism (French, 1997). The characteristic of eggshell temperature on duck hatching eggs which H and UH during incubation period is shown in Table 1.

Eggshell temperature usually improved inline with increasing DOI. Enhancing eggshell temperature was closely related to the biological process that occurred inside the egg by increasing embryo metabolism activity (Tzschentke and Rumpf, 2011; Mortola *et al.,* 2015) resulting improved metabolic heat of embryo as increased DOI (French, 1997). Heat production due to metabolism which got higher but not balanced by a sufficient heat release from inside to outside of egg might make eggshell temperatur increased higher at the final DOI (Mortola *et al.,* 2015). The release of heat to outside of egg would be blocked when the incubator was maintained constant during the incubation period (Harun *et al.,* 2001) so after 14 DOI the incubator temperature was decreased to enlarge heat released. France (1997) found that the decrease of incubator temperature to become 37,5-36,5°C in the middle to the end of incubation period resulted in a better hatchability, especially at big size eggs. Willemsen *et al.* (2010) concluded that the decrease of incubator temperature down to 34,6°C at the end of incubation period did not result in embryo death, but the eggs hatched 6 hours longer than those hatched at the temperature of 37,6°C.

Eggshell temperatures of H and UH eggs were not different on 1, 7, 14, and 21 DOI. Shell temperature did not differ on 1 DOI since at the beginning of incubation period, it was still dependent on incubator temperature. It was proved by the shell temperature had lower than incubator unit temperature. This condition was inline with the research by French (1997) who stated that the eggshell temperature was lower than hatchery unit. Mortola and Gaonac'h-Lovejoy (2016) reported that shell temperature was lower than the incubator temperature since embryo had no capability to release or generate heat at the beginning of incubation period yet, so it was dominantly affected by the incubator temperature.

Shell temperature of H and UH groups were recorded increasing above the incubator temperature since the 7 DOI, this indicated an increased activity of embryo as DOI increased. The metabolism activity of H and UH eggs similarly increased up to 21 DOI, it was shown on shell temperature value which did not differ between H and UH eggs on 7, 14 and 21 DOI. Eggshell temperature of H eggs was significantly higher ($P<0.05$) than UH groups on 25 DOI. It was caused by raising heat production of H eggs until 25 DOI marked by difference value between H and IT. In contrast, heat production of UH groups tended to decrease on 21 to 25 DOI shown by difference of value between UH and IT. Harun *et al.* (2001) reported that H eggs had a higher metabolism rate compared to UH eggs.

Egg weight loss

Observations of egg weight loss between 1 and 25 DOI are shown in Table 2. The weight of H and UH eggs had a decreased weight inline with increasing DOI. Egg weight loss of H and UH

Table 1. Eggshell temperature alteration

	n	Eggshell temperature on different age of hatching (days)				
		1	7	14	21	25
		(ºC)				
H	90	37,70±0,47[a]	37,91±0,22[a]	38,15±0,17[a]	38,65±0,34[a]	38,46±0,32[a]
UH	56	37,62±0,39[a]	37,91±0,20[a]	38,15±0,19[a]	38,57±0,35[a]	38,09±0,29[b]
Average	146	37,67±0,44	37,91±0,21	38,15±0,17	38,62±0,35	38,32±0,35
IT		37,8	37,8	38,0	37,3	37,0
H – IT		-0,10	0,11	0,15	1,35	1,46
UH – IT		-0,18	0,20	0,19	0,34	0,28

[a,b] different superscripts at the same column indicate significant differences (P<0.05).
H= hatched eggs, UH= unhatched eggs, IT= incubator temperature.

between 1 and 25 DOI was 11,84% and 10,11%, respectively. It was occured by water evaporation released through egg shell pores (Prasetyo and Susanti, 2000). Water evaporization caused by difference partial pressure between interior (high concentration) and exterior (low concentration) of egg (Mortola *et al.,* 2015).

During the incubation period, eggshell becomes thinner caused by calcium absorption for embryo development. El-Hanoun and Mossad (2008) reported that duck egg becomes thinner 14% for 24 DOI. The thinning of eggshell inline with the increased significant DOI correlated with the increased number of open egg pores (El-Hanoun and Mossad, 2008), so the permeability to release steam was higher inline with the increase of DOI.

The factual higher H weight loss from that of UH egg on 7 DOI was influenced more by the egg quality since at the beginning of hatching the embryo's metabolism activity was still low. Moran (2007) revealed that in the first week of hatching the embryo's metabolic enegy was obtained from the glicolysis of glucose anaerobic in egg in a limited number, this was due to a limited supply of oxygen since the blood cells were not maure yet and the blood vessels system was not developed maximually yet. A factor alleged to be the cause of a lower UH weight loss at the beginning of hatching was shell's quality, such as a thick shell and a small number of egg's pores. This was possible since the duck eggs used came from ducks that are farmed freely, so feed consumed by ducks on field was highly diversified. Manggiasih (2015) revealed a data that ducks feed by feed with Ca content higher than that of control impacted to thicker egg's shell. The condition of UH eggs' shell which was alleged thicker impacted to a lower weight loss from that of H during the next weight loss observation (14, 21 and 25 DOI).

Table 2 shows that significant UH weight loss (P<0,05) was lower than that of H on the 7 to 21 DOI even though the metabolism rate was relatively same (Table 1), this was allegedly due to thicker UH egg's shell factor. A thick shell and a small number of pores could cause water and CO2 release from inside to outside of egg became late. A low water and CO2 release during the incubation period might result in embryo suffering stress (Mueller *et al.,* 2015) which disturbed the embryo's metabolsm, this might result in decreasing UH egg's metabolism from the 21 to the 25 DOI of hatching age as shown in Table 1.

Air Sac

The characteristic of air sac during the incubation period is shown in Table 3. The percentage of H and UH eggs' air sac increased by the increased hatching age. The study conducted by Ar and Rahn (1980) disclosed that air sac alteration occurred inline with the increased age of hatching. Air sac alteration which got bigger related indirectly to the decrease of egg's volume (Mortola and Gaonac'h-Lovejoy, 2016) since 85-90% egg's composition comprised of water (Carey *et al.,* 1980). Factors affecting the weight loss would influence the air sac alteration.

The percentage of changes to H and UH eggs' air sac did not differ on the first day of incubation period. This was because during the storage and transportation process, eggs were

Table 2. Weight loss alteration

	n	Initial weight (g)	Weight loss on different age of hatching (days)			
			7	14	21	25
			(%)			
H	90	69.60±2.55[a]	3.41±0.92[a]	6.65±1.70[a]	9.87±2.44[a]	11.84±2.91[a]
UH	56	70.29±3.52[a]	2.92±1.05[b]	5.74±1.90[b]	8.34±2.99[b]	10.11±3.44[b]
H-UH			0.49	0.91	1.53	1.73

[a,b] different superscripts at the same column indicate significant differences (P<0.05).
H= hatched eggs, UH= unhatched eggs.

Table 3. Air Sac alteration

	n	Air sac on different age of hatching (days)				
		1	7	14	21	25
		(%)				
H	90	10.61±1.30[a]	23.49±3.15[a]	31.73±3.93[a]	38.35±4.86[a]	51.03±6.13[a]
UH	56	10.30±2.00[a]	22.16±3.86[b]	29.93±4.64[b]	35.19±5.97[b]	44.31±8.24[b]
H - UH		0.31	1.33	1.80	3.16	6.72

[a,b] different superscripts at the same column indicate significant differences (P<0.05).
H= hatched eggs, UH= unhatched eggs.

being under the same condition. On the 7, 14, 21, and 25 DOI of incubation period, the percentage of changes to significant H air sac (P<0.05) was higher than that of UH. This indicated that H eggs released more water during the incubation period. The cause of difference in the percentage of water release was due to the difference in shell's quality, the increase of embryo's metabolism, and the thinning of egg's shell.

Air sac formed had an important function to supply oxygen during internal piping. During internal piping, embryo's lungs started functioning to supply oxygen. Oxygen supply through chorioallantois decreased inline with the increase supply of oxygen through lungs by 1.5 to 2 folds up to internal piping. The percentage of change to UH egg's air sac in this study was actually smaller than that of H eggs at the end of incubation period. A small air sac caused the availability of oxygen during internal piping reduced (Menna and Mortola, 2002; Mellor and Diesch, 2007), so it might result in the death of embryo.

Conclusion

Shell's temperature, weight loss, and air sac alteration can be used to estimate the egg's hatchability. The changes to hatching egg's characteristic on the 25 DOI in hatched eggs, i.e.: shell's temperature was 38,46ºC, weight loss was 11,84%, air sac alteration was 51,03%. Weight loss and air sac alteration parameters can be applyed to estimate the hatched eggs between 7 and 25 DOI, but the temperature of eggshell can be administrated after 25 DOI.

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