Research Article

Lohmann Broiler Growth Performance using Positive Pressure Barn System

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Abstract | This study was conducted to determine the effect of rearing broilers in positive pressure barns on the performance of Lohmann strain broilers. The study used one hundred and eighty Lohmann unsex broilers reared for 4 weeks feeding with commercial feed produced by PT. Japfa Comfeed Indonesia Tbk. The study was designed using a completely randomized design using 180 chickens. All chickens were divided into three groups with six replicates each which were the first group was reared in a closed house, the second and third groups were reared in positive pressure and open houses. Each replicate, in each treatment, was reared in a different barn plot with the number of 10 chickens/m^2 of the barn area. The results showed that feed consumption, body weight, weight gain and carcass weight of the broiler group reared in positive pressure was higher than that of the open house group and lower than that of the closed house group (P<0.01). The feed conversion of the broilers reared in positive pressure was lower than that of the open house and higher than that of the closed house (p<0.01). It is concluded that the use of positive pressure barns in hot humid climates was better than the use of open houses. Therefore, a positive pressure enclosure system was recommended to be applied.

Keywords | Positive pressure, Feed consumption, Feed conversion, Gain, Carcass weight.

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INTRODUCTION

Poultry is a homeothermic (warm-blooded) animal with body temperatures ranging from 40.5-41.5°C (Cândido et al., 2020; Erwan et al., 2013; Erwan et al., 2014). The level of environmental temperature and relative humidity affect the performance of growth and egg production (Oktavia et al., 2021). Maintenance at high temperatures will result in poultry suffering from heat stress (Dayyani and Bakhtiari, 2013; Renata et al., 2018) as well as affecting muscle activity and tissue metabolism (Heat Production/HP) as well as the amount of heat lost due to environmental influences (Heat Loss/HL) (Chang et al., 2018, Gicheha, 2020). If the HP is higher than the HL, the body temperature will rise and vice versa. If the HL is higher than the HP, the body temperature will fall (Nascimento et al., 2017). Therefore, poultry must be kept in the thermoneutral zone, an environmental temperature range in which there is very little change in heat production (Ojano-Dirain and Waldroup, 2002). A comfortable environment for laying hens is below 80°F or 26.66°C (Bhadauria et al., 2017), while the comfortable temperature for 3-week-old broilers ranges from 20-25°C with relative humidity ranging from 50-70% (Jongbo and Falayi, 2013) and will experience stress and will experience serious heat stress if the ambient temperature is higher than 32°C (Lucas et al., 2013).

In some areas in Indonesia, the temperature is around 27°C - 32°C, even more with humidity ranging from 75% - 80%

(Aryani et al., 2021). Poultry rearing in this microclimate suffer from stress and reduces production performance (egg growth and production) (Renata et al., 2018). Therefore, it is necessary to have a barn system with a small investment but able to make the atmosphere in the barn cool and the livestock feels safe and comfortable living in it.

The practice of raising broilers in Indonesia so far has implemented 2 barn systems, an open house and a closed house. The first is a barn whose walls are made with an open system, thus ensuring that wind and sunlight can enter the barn (Maharatih et al., 2017). The later is the most widely and commonly used system. The advantages of open houses are that they require relatively lower costs and faster processing times. While the disadvantages are that it is difficult to regulate external factors of the barn, the microclimate in the barn and it is difficult to control disease (Pakage et al., 2020).

A closed house is a modern type of barn with closed walls and microclimate settings in the barn (temperature, humidity and air circulation) using electronic technology that can be adjusted according to the need (Nuryati, 2019). The lack of contact between chickens and the environment outside the barn resulted in satisfactory production performance. The weakness of this housing system is that it requires a big investment, making it difficult for small farmers to apply (Riswanti et al., 2014). The principal difference between the two barn systems lies in the microclimate setting in the barn, where the microclimate setting in the open house is more difficult to control than in the closed house. Based on this fact, the idea emerged to use a positive pressure system barn, namely regulating the microclimate in an open house barn using a fan that functions to smooth air circulation (similar to airflow in a closed house). The hot air in the house is pushed out so that the temperature in the cage becomes relatively cooler. The advantage of this cage system is that it can reduce the ambient temperature in the cage because it was equipped with a fan, but it cannot match the closed house system because it was not equipped with a cooling source.

The problem is how the microclimate condition in the barn using this positive pressure system and what is the impact on the performance of the broilers that are kept in it? For this reason, this study was therefore designed to evaluate the possibility of the positive pressure barn system is applicable as an alternative housing system in maintaining the genetic potential of broiler chickens reared in the humid tropics with relatively cheaper barn investment.

MATERIALS AND METHODS

Experimental Housing

This study used 3 types of barns, namely closed house, positive pressure and open houses. All three housings were located in the same location in Batu Kumbung Village, Lingsar, East Lombok. Housing size each was 8 m width and 56 m length. Distance between closed house and positive pressure was around 45 m. Distance between positive pressure and open house was 15 m, whilst distance between closed house and open house was around 60 m. A positive pressure barn was an open system barn equipped with an airflow system in the barn by pushing air using a fan to remove ammonia and improve air circulation in the barn (Figure 1). The position of the experimental barn plots in each type of barn was taken in the middle and equipped with insulating fences, feeders, drinking water containers and thermometers. Each treatment was 2 x 3 meters for width and length, so that all groups of treatment chickens were placed at a density of 10 birds per square meter. The implementation of research (data collection) on the three types of cages was carried out at the same time

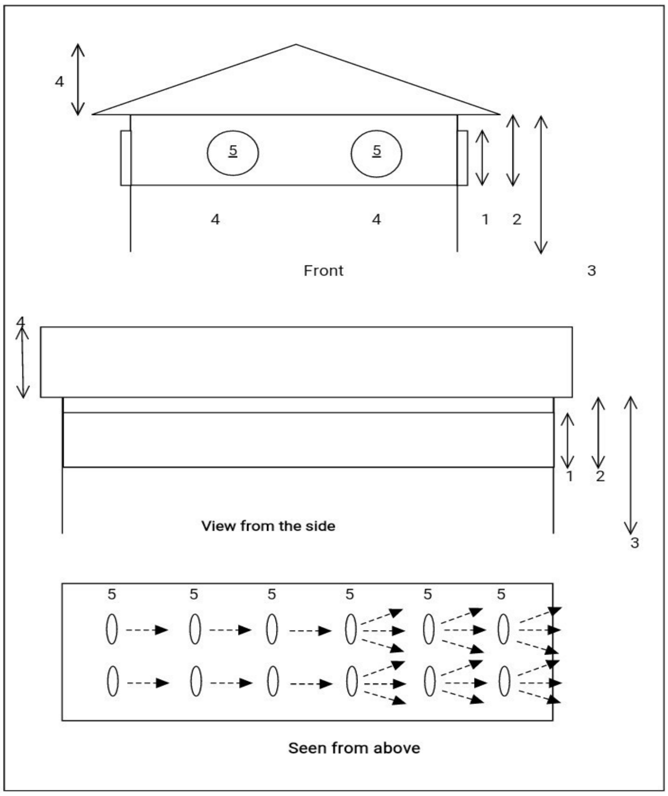

Figure 1: Sketch of positive pressure barn
1: Height of the outer curtain, 2: Wall of the barn, 3: Height of the barn (from ground level to the ceiling of the barn), 4: Roof of the barn, 5: Fan of the barn (wallfan)

Experimental Animals and Research Design

The work was designed using a completely randomized design with a one-way pattern and used one hundred and eighty unsex Lohmann strain broiler chickens. All chickens were divided into three groups. The first group was reared in a closed house; the second group was reared under pos

Table 1: The chemical composition of commercial diets used

Nutritional Content	BR I Crumble	BR I Super Crumble	BR II Pellet
Water content (%)	Max.12	Max.12	Max.12
Ash (%)	Max.7	Max.7	Max.7
Crude protein (%)	22 - 24	21 - 23	19 - 21
Crude fat (%)	Min 5	Min 5	Min 5
Coarse fiber (%)	Max. 4	Max. 5	Max. 5
Calcium (Ca) (%)	0,80-1,10	0,80 -1,10	0,80-0,10
Phosphor (P) (%)	Min 0,5	Min 0,5	Min 0,45
Enzyme (FTU/Kg) (min)	Phytase>400	Phytase>400	Phytase>400
Aflatoxin (μg/Kg)	Max.40	Max. 50	Max. 50
Lysine (%)	Min 1,3	Min1,2	Min1,05
Methionine (%)	Min0,5	Min0,45	Min0,4
Methionine + Cystine (%)	Min0,9	Min0,8	Min0,75
Threonine (%)	Min0,8	Min0,75	Min0,65
Tryptophan (%)	Min 0,2	Min0,19	Min0,18

Source: PT. Japfa Comfeed Indonesia Tbk.

itive pressure and the third group was reared in an open house barn. Each group of chickens was divided into six replicates. Thus, each group used sixty chickens (ten chickens' repetition). Each replicate in each treatment (type of barn) was reared in a different barn plot, with a number of 10 birds/m^2 of the barn area**.** The positive pressure cages were equipped with fans with a diameter of 36 inches of the Katsu brand and were installed in a row with 1 fan every 4 square meters of floor area. The fan was placed at a height of 30 to 60 cm from the surface of the litter (decreases with increasing age of the chickens).

The study lasted for thirty days. Feed and drinking water were provided *ad libitum*. Three commercial feeds produced by PT. JapfaComfeed Indonesia Tbk were offered which consists of pre-starter (0-8 days), starter (9-22 days) and finisher (23-30 days) with nutritional values as shown in Table 1. Vaccination on Infectious Brusal and Newcastle Diseases was applied at the age of 12 and 19 days respectively.

Variables measured

The variables observed in this research are: Temperature outside and inside the barn: The air temperature outside and inside the barn was measured by recording the minimum and maximum temperatures every day.

Feed consumption: Feed consumption was calculated by subtracting the amount of feed given at the beginning of the week by the remaining feed at the end of the week.

Body weight: Body weight was calculated by weighing each chicken on a weekly basis.

Body weight gain: Body weight gain was calculated by subtracting body weight each week from the previous week's body weight.

Feed conversion: Feed conversion was calculated by dividing the amount of feed consumed by body weight in the same period.

Slaughter weight: Slaughter weight was calculated by weighing each chicken before slaughter.

Blood weight: Blood weight was calculated by subtracting the slaughter weight from the weight after slaughter.

Featherweight: Featherweight was calculated by subtracting the weight after slaughter from the weight of the chicken after removing the feathers.

Viscera weight: The viscera weight was calculated by weighing the entire inside of each chicken.

Head and neck weights: The head and neck weight was calculated by weighing the part of the head and neck that was cut at the last cervical spine area (before the clavicle bone).

Leg weight: Leg weight was calculated by weighing the part of the leg that is cut at the joint area between the tibia and metatarsus bones.

Abdominal fat weight: Abdominal fat weight was calculated by weighing all the belly fat in each chicken's stomach.

Carcass weight: Carcass weight was calculated by weighing the carcass of each chicken.

Carcass primal cut: Carcass primal cut was obtained by weighing all carcass primal pieces, namely back weight, wing weight, breast weight, upper thigh weight and lower thigh weight.

Data analysis: The data obtained were tabulated and analyzed using analysis of variance using the SAS Version 9.2 (2009) statistical program and continued with Duncan't test.

RESULTS AND DISCUSSION

The effect of the use of the closed house, positive pressure and open house on the performance of Lohmann strain broiler chickens is presented in Table 2. It can be seen that the barn system (closed house, positive pressureand open house) affected feed consumption, body weight, body weight gain and chicken feed conversion of Lohmann strain broiler from the age of DOC until the thirty days ($p<0.01$). It was also seen that the feed consumption of the broiler group reared in positive pressure barns was higher than the feed consumption of the broiler group reared in the open house, but lower than the feed consumption of the broiler group reared in the closed house. The effect is that the body weight and body weight gain of the broiler group reared in positive pressure barns are higher than the body weight and body weight gain of the broiler group reared in the open house, but smaller than the body weight and body weight gain of the broiler group maintained in a closed house. The next effect is that the feed conversion of the broiler group reared under positive pressure is smaller than that of the broiler group reared in an open house, but larger than that of the broiler group reared in a closed house. This phenomenon is caused by the air temperature in the positive pressure system enclosure being lower than the air temperature in the open house, but higher than the air temperature in the closed house. The effect is that the broiler group that is reared in a cool barn will consume more feed to produce faster growth and end up with smaller feed conversion. This is the reason why the growth performance of broilers reared in positive pressure barns is better than that of broilers reared in open houses and worse than broilers reared in closed houses.

The maximum temperature in the experimental barn was 28.10°, 30.65° and 31.32°C, respectively in a closed house, positive pressureand open house, while the air temperature outside the barn ranged from 30 to 35°C. It means that the closed house barn has the best ability to dissipate the environmental temperature outside the barn, followed by the positive pressure barn system and the worst is the open house system barn.

Broiler chickens are homeothermic animals. The normal body temperature of poultry is between 40.5-41.5°C (Tamzil et al., 2013; Pawar et al., 2016). To be able to live comfortably, three-week-old broilers need a barn temperature between 20-25°C and relative humidity of around 50-70%, while adult broilers need a temperature of 26-27°C-and laying hens need temperatures between 18-23.9°C (Tamzil, 2014, Pawar et al., 2016, Aryani et al., 2021). In the case of barn temperature in this study, only the temperature in the closed house barn was able to produce the lowest maximum temperature limit of 28.10°, while in the positive pressure and closed house barns, each reached a temperature of 30.65° and 31.32°C.

It means that only a closed house can produce a comfortable temperature for boiler chickens. Meanwhile, the temperature in the positive pressure and open house barns was above the thermoneutral zone for poultry (Chang et al., 2018, Andretta et al., 2021). The temperature in the positive pressure barn is much safer from the danger of stress for broiler chickens compared to the temperature in the open house cage. Rearing poultry above the comfortable temperature range in the open house and positive pressure barns (the case of this study), broilers suffer from heat stress due to the difficulty of removing excess body temperature into the environment (Wasti et al., 2020, Kim et al., 2021). Poultry that suffers from heat stress, among others, will show the behavior of reducing feed intake and increasing drinking water consumption (Tamzil et al., 2013). This condition can act as a trigger for various diseases, reduce the rate of growth and egg production and end up in a decrease in profitability. The decrease in growth rate was partly due to reduced nitrogen retention and continued to decrease the digestibility of proteins and some amino acids (Nawab et al., 2018). Another study reported that continuous heat stress in broiler chickens is very dangerous for the life of broiler chickens because it can reduce protein digestibility. Rearing broilers at 32˚C can increase metabolized energy intake by 20.3%, heat production by 35.5%, reduce energy retention by 20.9%and energy efficiency by 32.4%, compared to the chicken group reared in the thermoneutral zone (de Souza et al., 2016). Research on laying hens obtained information that the body weight of chickens that were chronically stressed could decrease up to 19% compared to the body weight of the control group (not stressed) (Habashy et al., 2017).

The effect of the housing system on live weight, carcass weightand non-carcass weight is presented in Table 3. It is clear that the housing system affects slaughter weight, carcass weight, neckand head weight, viscera weight ($p<0.01$), leg weight, feather weight and abdominal fat ($p<0.05$) but

Table 2: Effect of the barn system on feed consumption, body weight, body weight gain and feed conversion of Lohmann strain broilers

Variable	Treatment (Barn type)			*P*. Value
	Closed house	Positive pressure	Open house	
1 week old				
Feed consumption (g/bird)	195.02^{a}	191.12^{b}	186.17^{c}	<.0001
Body weight(g/chicken)	181.65^{a}	177.84^{b}	173.86^{c}	<.0001
Weight gain (g/bird)	141.90^{a}	138.11^{b}	134.10^{c}	<.0001
Feed conversion (g/g)	1.374^{a}	1.384^{a}	1.388^{a}	0.2065
2 weeks old				
Feed consumption (g/bird)	624.02^{a}	614.92^{b}	603.52^{c}	<.0001
Body weight (g/bird)	463.64^{a}	454.47^{b}	443.81^{c}	<.0001
Weight gain (g/bird)	423.89^{a}	414.74^{b}	404.06^{c}	<.0001
Feed conversion	1.472^{a}	1.483^{ab}	1.494^{b}	0.0195
3 weeks old				
Feed consumption (g/bird)	1186.86^{a}	1166.86^{b}	1141.83^{c}	<.0001
Body weight(g/chicken)	866.66^{a}	842.58^{b}	814.19^{c}	<.0001
Weight gain (g/chicken)	827.58^{a}	802.85^{b}	774. 44^{c}	<.0001
Feed conversion	1.434^{a}	1.453^{ab}	1.474^{b}	0.0050
4weeks old				
Feed consumption (g/bird)	2219.34^{a}	2186.83^{b}	2146,51^{c}	<.0001
Body weight(g/bird)	1420.94^{a}	1383.54^{b}	1333.16^{c}	<.0001
Weight gain (g/bird)	1381.19^{a}	1343.80^{b}	1293.41^{c}	<.0001
Feed conversion	1.607^{a}	1.627^{b}	1.660^{c}	<.0001
Cumulative				
Feed consumption (g/bird)	2439.15^{a}	2401.95^{b}	2355.68^{c}	<.0001
Body weight (g/bird)	1580.12^{a}	1530.29^{b}	1469.06^{c}	<.0001
Weight gain (g/bird)	1540.37^{a}	1490.56^{b}	1429.31^{c}	<.0001
Feed conversion	1.583^{a}	1.611^{b}	1.648^{c}	<.0001

^{abc} Superscripts in the same line showed significant differences ($p < 0.05$)

Table 3: Effect of barn system on slaughter weight, carcass weight, non carcass weight and primal cuts of Lohmann strain broiler carcasses

Variable	Treatment (Barn type)			*P* Value
	Closed house	Positive pressure	Open house	
Slaughter weight(g/bird)	1527.88^{a}	1479.13^{b}	1417.57^{c}	<.0001
Carcass weight (%)	71.05^{a}	70.54^{a}	69.82^{b}	0.0007
Blood weight (%)	3.58	3. 49	3.48	0.2714
Feather weight (%)	2.93	2.85	2.94	0.0599
Neck and Head weight(%)	6.41^{c}	6.56^{b}	6.70^{a}	0.0001
Leg weight (%)	3.89^{b}	4.03^{ab}	4.05^{a}	0.0145
Viscera weight (%)	10.73^{c}	11.02^{b}	11.37^{a}	0.0009
Abdominal fat (%)	1.38^{b}	1.48^{b}	1.61^{a}	0.0014
Carcass Primal Cut:				
Wing weight (%)	11.78^{a}	11.85^{a}	11.52^{a}	0.0773
Upper thigh weight (%)	19.37^{a}	19.18^{a}	19.22^{a}	0.4598
Lower thigh weight (%)	12.69^{a}	12.79^{a}	12.77^{a}	0.6866

Breast weight (%)	38.16[a]	37.76[a]	38.14[a]	0.1420
Back weight (%)	18.00[a]	18.42[a]	18.36[a]	0.0672

[abc]Different superscripts in the same line showed significant differences ($p < 0.05$)

did not affect blood weight and featherweight (P>0.05). The broilers reared in positive pressure barns produced slaughter weight and carcass weight percentage greater than the slaughter weight and carcass weight percentage of broiler chickens reared in open house barns, but smaller than the slaughter weight and carcass weight percentage of broiler chickens maintained in a closed house. The broilers reared in positive pressure barns produced a lower percentage of neck and head weight and viscera weight compared to the percentage of neck and head weight and viscera weight of the broiler group reared in open house barns, but higher than the percentage of neck and head weight and the viscera weight of broiler chickens raised in closed house barns.

The phenomenon of high slaughter weight and carcass weight percentage of broilers kept in positive pressure barns compared to slaughter weightsand percentage of carcass weight of broilers reared in open housebarns is the effect of temperature in positive pressure barns which was lower than the temperature in open house barns, so that the feed consumption of the broiler group reared in positive pressure barns was higher than the feed consumption of the broiler group reared in open house barns. High feed consumption will be followed by high growth, resulting in higher body weight and carcass weight. This phenomenon also causes the growth of broilers kept in closed house barns is higher than broilers reared in positive pressure barns and open house.

Broiler rearing in high environmental temperatures causes broilers to suffer from heat stress (Tamzil et al., 2013, Tamzil, 2014), which in turn has a negative impact on the growth and development of muscle tissue (Nawaz et al., 2021; Oktavia et al., 2021). Reduction of feed intake in broilers suffering from heat stress is an adaptive mechanism to minimize metabolic heat production, so that broilers suffering from heat stress grow more slowly compared to groups of chickens that do not suffer heat stress (Nawab et al., 2018; Kim et al., 2021).

The phenomenon of the lower percentage of neck and head weight, viscera weight and abdominal fat weight of the group of broilers reared in positive pressure barns compared to the group of broilers reared in open house barns and larger than the group of broilers reared in the closed house is due to the growth of muscle tissue in the group of broilers reared in positive pressure barns is faster than the group of broilers reared in open houses, resulting in a lower percentage of neck and head weight and viscera weight compared to the percentage of neck weight and headand the weight of the viscera of the group of broiler chickens kept in open house barns and greater than the group of broilers reared in closed house barns. This phenomenon also causes the percentage of neck & head weight and the viscera of the broiler group reared in a closed house to be smaller than the neck & head weight and the viscera weight of the broiler group kept in a positive pressure barn. The same phenomenon also occurs in the variable of abdominal fat weight. The broilers reared in positive pressure barns produced a lower percentage of abdominal fat compared to the abdominal fat percentage of the broilers reared in an open house, but greater than the percentage of abdominal fat in the closed house group. This is a sign that broilers reared in the open house sometimes experienced more acute heat stress than broilers reared in positive pressure barns. It also happened to the group of broilers reared in positive pressure barns. They were more stressed than the group of chickens raised in a closed house. Increased fat content in broilers suffering from stress is an adaptive mechanism in poultry to avoid excessive body heat production by storing more energy in the form of fat (Lu et al., 2019). Heat stress reduces the rate of aerobic metabolism by inhibiting mitochondrial function, decreasing metabolic activityand promoting glycolysis so that fat deposition in muscles increases (Zaboli et al., 2019). This is what causes heat stress to increase abdominal fat and subcutaneous and intramuscular fat deposits in broilers (De Antonio et al., 2017).

The effect of the barn system on carcass weight and carcass primal cut is presented in Table 4. It can be seen that the use of the closed house, positive pressure and open house barns did not affect carcass weight and carcass primal cut (p>0.05). Each group of chickens reared in each type of barn (closed house, positive pressureand open house) showed the same growth pattern of primal carcass pieces. Each of the primal carcass pieces from the group of chickens reared in each type of barn showed different growth. The fastest growing primal carcass in each chicken reared in all types of barns was the breast, followed by the weight of the upper thigh, the weight of the back, the lower thighand the smallest was the weight of the wing. The high breast weight of all groups of broiler chickens in this study was due to the largest meat deposit in poultry, especially broiler chickens located in the breast, followed by the thighs. Similar studies on KUB-1 chickens, Arab chickensand laying-type roosters were reported by Tamzil et al. (2015) who found that the highest carcass components were the breast, upper thighs and lower thighs,

Table 4: Percentage of broiler carcass primal slaughter weights reared in different barn systems

Variables	Barn Type			*P* Value
	Closed house	Positive pressure	Open house	
Carcass weight (%)	1086.58[a]	1044.37[a]	990.73[b]	0.0007
Wings weight (%)	11.78[a]	11.85[a]	11.52[a]	0.0773
Upper thigh weight (%)	19.37[a]	19.18[a]	19.22[a]	0.4598
Lower thigh weight (%)	12.69[a]	12.79[a]	12.77[a]	0.6866
Breast weight (%)	38.16[a]	37.76[a]	38.14[a]	0.1420
Back weight (%)	18.00[a]	18.42[a]	18.36[a]	0.0672

[abc] Superscripts in the same line showed significant differences (p < 0.05)

followed by the back and wings. Thus, rearing broilers in a closed house, positive pressure and open house barns produces carcasses with the same weight as primal carcass cut.

CONCLUSIONS AND RECOMMENDATIONS

The study concluded that feed consumption, body weight, weight gainand carcass weight of broilers reared under positive pressure were higher than those of broilers reared in open houses and lower than those of broilers reared in closed houses. The feed conversion of broilers reared in positive pressure was lower than that of broilers reared in open houses and higher than those of broilers reared in closed houses. The use of positive pressure barns improve the growth performance of broilers reared in the humid tropics. Therefore, a positive pressure enclosure system is recommended to be applied.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

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NOVELTY STATEMENT

Broiler chicken maintenance in open house is susceptible to the heat stress. On the other hand, when maintained in closed house, the growth and the meat quality of the chickens is better than those of in the open house. However, maintaining chickens in closed house requires a large amount of investment, thus small farmers find it difficult to apply the system. The use of positive pressure barns is one of the solutions to overcome the problem. This is because the investment costs of the positive pressure cages are relatively the same as those of open houses. Furthermore, the growth of the chickens reared in the positive pressure barns is higher than those of reared in open houses, even though the growth is still below those of reared in closed houses. Thus, positive pressure barns can be considered as a novelty and can be applied to small farmers.

AUTHORS CONTRIBUTION

All authors have contributed in this manuscript from planning, writing, comprehensive discussion until decision to publish.

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