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Original Article

Effect of Housing Design and Location on Production and Economic Performance of Broiler Chickens during Summer in Botswana

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ABSTRACT

Botswana experiences long, hot summer periods which negatively affect broiler productivity and results in economic losses. To determine these negative effects, two parallel broiler production studies were conducted in the North eastern (NE) and South eastern (SE) regions. In each region, three large scale commercial broiler farms were randomly selected based on similarities in bird management and housing systems. In each farm, one house type (Gable, Hoop and See-saw) was selected for long term flock monitoring (1 to 35 days) over three production cycles. Results showed that the production performance of the broilers in the SE region was superior to that in the NE region, with temperatures on being average higher in the NE than in the SE. The European Production Efficiency Factor (EPEF) was significantly higher ($p<0.05$) in the SE (209) than in the NE (174). In the NE region, the broilers reared in the Hoop structure performed significantly better ($p<0.05$) than in both the Gable and See-saw structures in regards to feed consumption, average daily gain, and water consumption. In the SE region, only water consumption was significantly higher ($p<0.05$) in the Gable structure as compared to the other house structures. At the point of slaughter (35 days), there were significant differences ($p<0.05$) between the bird masses across the different house types. Mortality was not significantly different ($p>0.05$) between the regions at 9.0% and 7.4% for the NE and SE, respectively. In the NE, the Gable structure had the highest profitability and economic efficiency and was thus superior in comparison to the other house structures.

INTRODUCTION

Studies involving commercial broiler chickens (*Gallus gallus domesticus*) show that housing (Dawkins *et al.*, 2004) and environmental conditions (Zhao *et al.*, 2014) affect bird welfare much more than the stocking density. From 26.7 °C and above, chickens experience heat stress and begin to pant (Oloyo & Ojerinde, 2019). Panting results in reduced feed intake, body weight gain, meat quality, immunity and increased disease incidences (2014; Zhang *et al.*, 2012; Bhadauria *et al.*), and these effects escalate with age. Increased relative humidity compounds these negative effects as it reduces evaporative cooling of the chickens through panting. For day old chicks, Katelaars (2005) recommended a temperature of 30-32 °C, which should be reduced by 3-4 °C until 4 weeks old. Growing broilers are comfortable at temperature range between 18-22 °C (Daghir, 2008) and 18-24 °C (Holik, 2015).

The summer period in Botswana occurs from October to March. Areas in the South east around Gaborone city (24°39’29’S and 25°54’44”E at 1,010 m above sea level) experience an average high summer temperature of 32.7 °C in January. On the other hand, the

North eastern areas around Francistown city (21° 10′ 24.9996″ S and 27° 30′ 45.0036″ E at 1,010 m above sea level) experience an average summer high-temperature of 30.0 °C in November. In summer, the relative humidity ranges from 60 to 80% in the morning and drops to 30 to 40% in the afternoon.

Housing and management of broilers are designed to ensure optimum performance (Mesa *et al.*, 2017). In tropical regions, naturally ventilated open housing systems, with dwarf sidewalls and chicken mesh along the open side walls, are common due to their simplicity, economic implications, and ease of heat generation management through natural ventilation (Oloyo & Ojerinde, 2019). Design considerations that take into account the orientation; house width, length and height; roof slope and overhang; ridge and sidewall openings, and insulation of walls and roofs are helpful in attaining better indoor conditions during the hot weather (Daghir, 2008; Clark, 2013).

In the past, the poultry industry used to focus on growth rate and feed conversion efficiency as measures of performance. Samarakook & Samarasinghe (2012) suggested that biological performance as well as economic parameters are important in the evaluation of real broiler performance then and in the future. Furthermore, they indicated that there are few indices that measure performance of broilers, with most only depicting the biological performance of the birds where they account for genetic potential, feed quality and technical efficiency of the farm.

The rising cost of poultry feed is a major concern to the development of the poultry industry in developing countries (Hagan, 2013). Kondo *et al.* (2015) and Karangiya *et al.* (2016) indicated that about 70% and 80%, respectively, of the total cost of poultry production is attributed to feeding costs. Hence, giving due attention to proper utilization of feed without adversely affecting the growth performance of broilers (Saiyed *et al.*, 2015) is important, as feed constitutes the major input determining the profit margin (Kalia *et al.*, 2017).

The main objective of any business enterprise is profit maximization. Various approaches have been used to assess the profitability and efficiency of broiler production units, including net return on investment and input-output analysis (Karangiya *et al.*, 2016; Abdurofi *et al.*, 2017), cost-benefit analysis (Adeyemo *et al.*, 2016; Odeh *et al.*, 2016; Abdurofi *et al.*, 2017; Dwivedi *et al.*, 2020), and farm budgetary analysis (Olorunwa, 2018) using gross margin analysis.

Hence, the objectives of this research were to determine if there were: (i) regional environmental and production differences, (ii) house type production differences, and (iii) profitability differences between the house types in a large scale commercial setting in the summer season.

MATERIALS AND METHODS

Experimental sites and house description

Two geographical regions (South eastern, Gaborone, and North eastern, Francistown) were selected for long-term monitoring (2016 to 2017) due to their known different weather conditions and large human population offering lucrative market for broiler meat. They are about 430 km apart. Monitoring in each region was done the entire year and data for the summer period extracted. In each region, three large scale commercial farms were randomly selected for use in the study. In each farm, one chicken house was monitored and was classified by its roof design, namely Gable, Hoop or See-saw. The cross sections and the architectural details are illustrated in Figure 1 and Table 1, respectively.

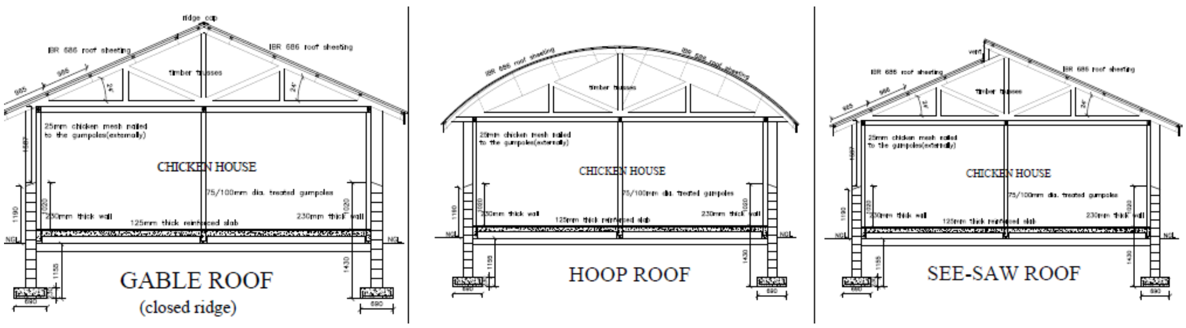

Figure 1 – Cross sectional view of the broiler houses used in the study.

The walls of all the houses were constructed with plastered masonry blocks. The roofs were corrugated iron roof sheets. Bird proofing mesh were installed in all the sidewall openings. Large tarpaulin sheets were used to close the sidewalls during the winter or rainy periods. All the houses had their long axis oriented in the east-west direction and they were not insulated.

Table 1 – Architectural details of the chicken houses monitored.

House type	Length (m)	Width (m)	Eave height (m)	Ridge height (m)	Dwarf wall (m)	Sidewall opening (m)	Floor area (m^2)	Bird capacity
				North eastern region				
Gable	100.0	9.12	2.85	3.72	0.48	2.37	912	12700
Hoop	35.6	6.8	2.0	2.54	0.43	1.57	242	3665
See-saw	90.0	12.0	2.31	3.07	0.54	1.77	1080	14200
				South eastern region				
Gable	100	8.9	2.7	3.6	0.2	2.5	890	10200
Hoop	101.7	9.0	2.8	3.4	0.3	1.4	926	10000
See-saw	80.2	8.0	3.2	4.3	0.4	2.8	642	8000

Bird management

Day old commercial hybrid Ross-308 chicks were obtained from local hatcheries and delivered at each farm as per the farm's production schedule. Upon arrival, the chicks were group-weighed to obtain their initial body mass before being placed in the houses, which had been previously prepared by cleaning, disinfecting and having rested for two weeks after the previous flock. About a quarter of the floor space, covered with wood shavings, was used during a two-week brooding period at stocking density of 0.02 m^2/bird. On the third week, half of the house floor was used at 0.04 m^2/bird. From the fourth to the fifth week, the entire house floor was used at 0.08 m^2/bird. The birds were vaccinated against Gumboro and Newcastle disease, and medicated for Coccidiosis at 3 days of age and again at the third week using Sulfadimidine Sodium 33% (Bremer Pharma GMBH, Germany) via the drinking water. Feed and water were provided *ad libitum* throughout the growth period. In the first 2 weeks, feed was provided via feeder troughs and water via bell drinkers. Thereafter, feed was provided via mechanical feeders and water via nipple drinkers. The feed nutrient composition as analysed at the National Food Technology Research Centre laboratories is shown in Table 2.

Data measurement and collection

The environmental parameters were monitored continuously during each 5-week production cycle using data loggers. These were indoor dry bulb temperature and relative humidity using a data logger (Model SSN-22 temperature/RH, Hairuis Instruments Co., Ltd, Shenzhen, China); and air velocity across the house using an anemometer (Model AZ8905 vane anemometer, AZ Instrument Corp. Taiwan). A wireless weather station (Model HP1000, Fine Offset Electronics Co., Ltd, Taiwan) was installed just outside each house to measure solar radiation, outdoor dry bulb temperature and relative humidity, wind speed and direction, and indoor barometric pressure. Water consumption was measured hourly using a water meter (Model V100-C020, Elster Metering Ltd., UK) connected to a pulse input data logger (Model OM-CP-PULSE101A, Omega, UK) which gave a pulse output for every 0.5 litre of water consumed. These data were measured on an hourly basis and downloaded at the end of each 5-week production cycle. Bird behaviour was observed and recorded during weekly visits.

Table 2 – Feed composition used in the experiment at both regions.

Ingredients	Method	Method type	Dietary feed type (g/kg)			
			Pre Starter	Starter	Grower	Finisher
Ash	AOAC 923.03	Muffle furnace	54.8	53.1	51.0	42.3
Calcium	AOAC 999.10	Atomic absorption spectrometry	9.4	8.5	10.1	6.4
Carbohydrate*	By difference	Calculation	536.1	547.9	512.1	573.3
Crude fat	AOAC 960.39	Petroleum spirit extraction	27.2	27.3	35.0	41.6
Crude fibre	AOAC 962.09	Fibretec	44.6	35.7	41.9	40.4
Crude protein	AOAC 990.03	Dumas method	295.9	286.3	296.4	244.1
Dry matter	AOAC 930.15	Oven drying	914.3	914.1	895.2	897.4
Energy** (kcal/kg)	Calculation	Calculation	3.5	3.6	3.5	3.6
Moisture	AOAC 934.01	Oven drying at 130°C	86.0	85.4	105.5	98.7
Phosphorus	AOAC 995.11	Colorimetric method	6.5	5.3	3.5	2.4
Sodium	AOAC 999.10	Atomic absorption spectrometry	1.0	3.0	1.4	1.1

*The calculation was By difference: Carbohydrates(g/100g) = 100 - Fat(g/100g) - Protein(g/100g) - Moisture(g/100g) - Ash(g/100g); **The calculation was Energy (kJ/100g) = {Fat(g/100g) x 37} + {Protein(g/100g) x 17} + {(Carbohydrates(g/100g) - Fibre(g/100g)) x 17} + {Fibre(g/100g) x 8}. Source: FAO. 2003. Food energy – methods of analysis and conversion factors, FAO, Rome, Italy.

The bird data collected included weekly measurement of bird mass, daily mortality, and daily feed consumption. The derived variables were body weight gain (BWG), average daily gain (ADG), and FCR. The economic efficiency of growth was determined through the calculations of the European Broiler Index (EBI) and European Production Efficiency Factor (EPEF). A high EPEF value indicates a good overall technical efficiency of the broiler operation and is desirable for optimum returns (Samarakoon & Samarasinghe, 2012).

The derived variables were calculated using the following formulae:

$$BWG(g) = BW(g) \text{ at end of period} - BW(g) \text{ on first day} \quad (1)$$

$$ADG\ (g/\ bird/day) = \frac{BWG}{Age\ of\ flock(days)} \quad (2)$$

$$FCR(kg\ feed/kg\ gain) = \frac{cummulative\ feed\ intake(kg)}{total\ weight\ gain\ (kg)} \quad (3)$$

$$EPF = \frac{Average\ live\ weight\ (kg) \times Liveability\ (\%)}{Age\ of\ flock\ (days) \times FCR} \times 100 \quad (4)$$

$$EBI = \frac{ADG\ (g/bird/day) \times Liveability\ (\%)}{FCR\ (kg\ feed/kg\ gain) \times 10} \quad (5)$$

Gross margin analysis

The average production and economic variables were computed from the three replications for each of the houses. To assess the profitability and evaluate the economic efficiency of the broiler production under the different housing structures, gross margin analysis was used. Gross margin, measured per unit, gives the difference between the gross income (total output multiplied by unit price of output), and the total variable cost. Gross margins are used to evaluate the economic viability of an enterprise (Karanja, 2010) and for current and future managerial decision-making. The farm activity with the highest gross margin per unit is considered the most viable.

Given that feed costs constitute almost 70% of broiler production costs, the return on feed costs per bird (ROFC) and per kg was computed as the difference between total income from the sold bird (pula per bird or kg) and the total feed cost (BWP/bird or per kg) (Karangiya *et al.*, 2016). From the calculated return on feed costs per bird, the input-output ratio was computed across the different broiler production houses to evaluate efficiency.

Experimental design and data analysis

The experiment was a Completely Randomised Block Design (CRBD) with geographic regions acting as blocks. The data on BW, BWG, ADG, FCR, EBI and EPEF were subjected to analysis of variance (ANOVA) with $p<0.05$ significance level (SAS, Version 9.4, SAS Institute Inc, Cary, NC, USA, 2002-2012). If significant differences ($p<0.05$) were detected, the Least Significant Difference (LSD) was used to separate the means. The data used in the analysis were those collected in the years 2016 and 2017, each with three 35-day production cycles or replications.

RESULTS AND DISCUSSIONS

Environment conditions

The analysis of variance (ANOVA) revealed significant interactions ($p<0.05$) between the regions (North east and South east) and House types (Gable, Hoop and See saw) with the mean indoor conditions (temperature and relative humidity). These are shown in Table 3.

In the North-eastern region, the average indoor temperature for the Gable-roofed house (28.3.0±0.3 °C) was significantly higher ($p<0.05$) than those for the Hoop and Seesaw-roofed houses, respectively (27.1±0.3 °C and 26.6±0.3 °C). Oloyo (2018) reported that internal temperature above 26.7 °C combined

Table 3 – Average indoor temperature (°C) and relative humidity (%) across the regions.

House type	T_{day}	T_{night}	T_{mean}	SEM	RH_{day}	RH_{night}	RH_{mean}	SEM
	North eastern region							
Gable	31.0^a	25.1^a	28.3^a	0.3	39.7^a	48.8^a	43.9^a	1.8
Hoop	29.1^b	24.6^a	27.1^b	0.3	69.1^b	68.0^b	69.4^b	1.8
Seesaw	29.3^b	23.4^b	26.6^b	0.3	46.5^c	56.1^c	50.9^c	1.8
p value	<0.0001	0.0002	<0.0001		<0.0001	<0.0001	<0.0001	
	South eastern region							
Gable	28.7^b	24.7^a	26.9^a	0.2	56.9^a	72.0^a	63.8^a	1.1
Hoop	29.4^a	24.6^a	27.2^a	0.2	52.4^b	64.0^b	57.7^b	1.1
Seesaw	28.7^b	24.7^a	26.9^a	0.2	43.1^c	37.1^c	40.4^c	1.1
p value	0.0387	0.8805	0.3725		<0.0001	<0.0001	<0.0001	

Means within a column with different superscript differ significantly ($p<0.05$); T=temperature, °C; SEM=Standard error of the mean; RH=relative humidity, %.

with high RH adversely affected the feed efficiency and weight gain of the chickens. The Gable and Hoop roofs did not have ridge openings to allow escape of heat by thermal buoyancy, resulting in indoor heat build-up. The mean wind speed measured about 5 m outside the sidewall openings of the houses averaged 1.09±0.07, 0.94±0.07 and 1.45±0.07 m/s in the Gable-, Hoop-, and See-saw-roofed houses, respectively. In the South-east, the mean indoor temperatures were not significantly different (p>0.05) between the houses. The mean wind speed values were 1.27±0.07, 1.22±0.07 and 1.50±0.07 m/s. Lacy & Czarick (1992) reported better growth rate for broilers reared at a temperature range between 25-30 °C with air velocity of 2 and 3 m/s. The higher air velocity of 3 m/s tends to favour older birds rather than younger birds, since the latter require higher temperatures especially at brooding age (Simmons *et al.*, 2003). The air velocities recorded in both regions were below 2 m/s, which may have contributed to higher average indoor temperatures.

Production performance - Interaction effects

There were significant interaction effects found between the regions and house types for cumulative feed consumption (CFC, p=0.0031), average daily gain (ADG, p=0.0014) and cumulative water consumption (CWC, p=0.0062). The effect of house type contributed more to the interaction significance in the CFC (p=0.0393) and ADG (p=0.002), while effect of the region contributed more to the interaction significance for the ADG (p=0.0013) and CWC (p=0.0041). These are shown in Table 4.

Table 4 – Average cumulative feed consumption (CFC, g/bird/day), average daily gain (ADG, g/bird/day) and cumulative water consumption (CWC, L/bird) of the birds across regions.

House type	North-eastern region					
	CFC	SEM	ADG	SEM	CWC	SEM
Gable	1138.2^{b}	48.8	25.0^{b}	1.3	3.6^{b}	0.5
Hoop	1294.4^{a}	38.6	32.2^{a}	1.0	4.9^{a}	0.2
See-saw	1062.7^{b}	38.6	24.8^{b}	1.0	4.1^{ab}	0.5
	South-eastern region					
Gable	1178.3^{a}	38.6	29.4^{a}	1.0	4.0^{a}	0.3
Hoop	1132.2^{a}	38.6	30.7^{a}	1.0	3.1^{b}	0.2
See-saw	1163.4^{a}	38.6	30.7^{a}	1.3	3.1^{b}	0.2

Means within a column with different superscript differ significantly (p<0.05); SEM=Standard error of the mean.

In the North-eastern region, CFC, ADG and CWC were significantly higher in the Hoop-roofed house as compared to the Gable- and See-saw-roofed houses (p<0.05), with the values of 1294.4 g/bird/day, 32.2 g/bird/day and 4.9 L/bird, respectively. The Hoop-roofed house experienced relatively lower temperatures (29.1±0.3 ºC) during the day compared to the other houses, which perhaps encouraged birds to consume more feed and consequently gain more body mass. High ambient temperature is reported to suppress birds' appetite and cause reduced feed intake (Zhao *et al.*, 2014). The same parameters were not significantly different (p>0.05) between the Gable- and See-saw-roofed houses. In the South eastern region, both CFC and ADG were not significantly different (p>0.05) between the houses, while WC was significantly higher (p<0.05) in the Gable-roofed house as compared to the other houses. This could be due to the high indoor temperature (31.0±0.3 ºC) experienced in the Gable-roofed house, where the birds responded by drinking more water to cool down.

Based on the 35th day of grow-out, the bird stocking densities in the North-eastern region averaged 18, 23, and 16 kg/m^{2} in the Gable-, Hoop- and See-saw-roofed houses, respectively. Correspondingly, they were 16, 19, and 17 kg/m^{2} in the South east. Aviagen (2016) recommends maximum stocking density of 20 to 25 kg/m^{2} at processing during hot weather and 16 to 18 kg/m^{2} during the hottest times of the year. Based on these recommendations, the farms were operating within acceptable limits. Stocking density is a decision based on economics, local welfare regulations, processing weight, and expected weather conditions (Aviagen, 2016; Buijs, 2009) and can be different in various countries and husbandry systems. Stocking density has critical implications in that higher returns can be obtained as the number of birds per unit area increases (Kryeziu *et al.*, 2018). However, if densities are exceeded, economic profit may be reduced due to impairment of bird performance, health, and welfare (Adeyemo *et al.*, 2016).

Production performance – Regions main effects

There were significant differences (p<0.05) between regions for the adjusted FCR, EBI and EPEF. These results are shown in Table 5.

Table 5 – Adjusted feed conversion ratio (FCR), European Broiler Index (EBI) and European Production Efficiency Factor (EPEF) of the birds across regions.

Region	FCR	SEM	EBI	SEM	EPEF	SEM
North east	1.75^{a}	0.05	159^{a}	12.3	174^{a}	11.6
South east	1.54^{b}	0.05	193^{b}	12.3	209^{b}	11.6
p-value	0.0044		0.0519		0.0338	

Means within a column with different superscript differ significantly (p<0.05); SEM=Standard error of the mean.

The birds'performance in the South-eastern region was superior to the North-eastern one as shown by a significantly lower ($p<0.05$) adjusted FCR and significantly higher ($p<0.05$) values of both EBI and EPEF, indicating high production efficiency (Mesa *et al.*, 2017). This could be attributed to cooler temperatures experienced in the Southern region (Table 3), resulting in better feed utilization and conversion.

Production performance – House type main effects

There were significant differences ($p<0.05$) among house types for the body mass of the birds at 35 days of age (BM35d), adjusted FCR, EBI and EPEF. These results are shown in Table 6.

The Hoop-roofed house had the lowest adjusted FCR (1.53±0.06), indicating that the birds were most efficient in converting feed into meat; which is further supported by higher the BM35d of 1703.3±44.6 g/bird when compared to the other house types. The corresponding EBI and EPEF for the Hoop-roofed house are also significantly higher ($p<0.05$) when compared to the other house types, which had lower values. The higher EBI and EPEF values correspond to higher average body weight, superior liveability and higher FCR, indicating overall superior economic feeding in birds (Saiyed *et al.*, 2015) reared in the Hoop-roofed house. Furthermore, higher values indicate that the birds' body weight gain was uniform, and the flock was in good health (Bhamare *et al.*, 2016).

Table 6 – Body mass at 35 days of age (BM35d, g/bird), adjusted feed conversion ratio (FCR), European Broiler Index (EBI) and European Production Efficiency Factor (EPEF) of the birds across house type designs.

House type	BM35d	SEM	FCR	SEM	EBI	SEM	EPEF	SEM
Gable	1442.9^{b}	49.9	1.77^{a}	0.07	216^{b}	17	221^{b}	17
Hoop	1703.3^{a}	44.6	1.53^{b}	0.06	300^{a}	15	307^{a}	16
See-saw	1315.8^{b}	49.9	1.63^{ab}	0.07	180^{b}	17	185^{ab}	17
p-value	0.0005		0.0297		0.0005		0.0005	

Means within a column with different superscript differ significantly ($p<0.05$); SEM=Standard error of the mean.

There were no significant differences ($p>0.05$) detected between regions and house types for mortality and liveability. This could be attributed to similar management practices between the regions, especially regarding routine vaccinations and medications. Generally, performance of human managers might vary greatly in livestock production, with some producing consistently better results than others (Mesa *et al.*, 2017). Cumulative mortality at 35 days of age was 9.0±1.4% and 7.4±1.3% for the North-east and South-east regions, respectively, and were not significantly different ($p=0.4350$). Correspondingly, liveability ratios were 91.0% and 92.6%, and were not significantly different ($p=0.4350$). For the house types, cumulative mortality rates were 8.0±1.8, 8.7±1.6% and 7.9±1.6% for the Gable-, Hoop- and See-saw-roofed houses, respectively, with no significant differences ($p=0.9472$). The corresponding liveability rates were 92.0±1.8%, 91.3±1.6% and 92.1±1.6%, also with no significant differences ($p=9472$).

Economic performance – costs of production

Due to data loss in the Southern region, only data in the Northern region was used to perform an economic analysis (Table 7). It is evident that feed costs constitute the highest variable costs, averaging 48.75% and consisting of almost half of the total variable cost. This is in line with reports by Kondo *et al.* (2015) and Karangiya *et al.* (2016), who reported that feed costs constitute about 70% and 80% of total costs of poultry production, respectively, in developing countries. The second highest cost is for day-old chicks and processing costs, each of which constitutes about 17% of the total cost. The profitability was assessed based on the farm gross margin. From the gross revenue and total variable costs, the gross margin, and the gross margin per kilogram of carcass were computed. Table 7 also shows that the Gable-roofed structure had the highest gross margin and was thus the most profitable among the different broiler house structures. The specific housing features combined with better management procedures may have contributed to amelioration of broiler conditions, leading to high production efficiency (Jacobs *et al.*, 2016).

Table 7a – Revenue generation (BWP) for poultry production at the Northern sites.

Item	Mean values per house type		
	Hoop	See saw	Gable
No. of day-old chicks	42 723	51 898	37 556
No. of birds	38 724	47 268	34 532
Cumulative mortality rate (%)	9.3	8.9	8.1
Average bird mass (kg)	1.60	1.64	1.64
Mass of meat delivered (kg)	61 923	77 633	56 611
Price per kg carcass (BWP)	21.50	21.50	21.50
Gross Revenue, (GR), BWP*	1 331 344.50	1 669 109.50	1 217 136.50

*1USD = 12.5BWP.

Table 7b – Variable costs (BWP) for poultry production at the Northern sites.

Variable costs (BWP)*						
	Mean Amount	% of Total Cost	Mean Amount	% of Total Cost	Mean Amount	% of Total Cost
Day old chicks	224 110.77	17.59	282 714.51	17.69	197 005.83	17.32
Feed	620 167.83	48.69	778 307.87	48.70	555 417.90	48.85
Vaccines	3 083.47	0.24	3 300.25	0.21	2 904.72	0.26
Medications	3 678.53	0.29	3 747.73	0.23	5 707.95	0.50
Bedding	10 333.33	0.81	14 986.67	0.94	9 253.33	0.81
Chemicals	1 905.05	0.15	1 905.05	0.12	1 905.05	0.17
Coal	7 889.00	0.62	8 141.33	0.51	5 051.00	0.44
Wages/ Salaries	69 978.12	5.49	88 228.32	5.52	57 687.59	5.07
Electricity	6 253.01	0.49	7 884.53	0.49	5 159.09	0.45
Water	861.36	0.07	1 089.86	0.07	732.43	0.06
Maintenance	8 009.27	0.63	10 099.13	0.63	6 508.11	0.57
Fuel	4 102.65	0.32	5 172.26	0.32	3 380.08	0.30
Overheads	76 327.04	5.99	95 851.72	6.00	69 885.09	6.15
Processing	214 629.75	16.85	268 411.47	16.80	195 693.27	17.21
Marketing & distribution	22 396.92	1.76	28 255.68	1.77	20 585.17	1.81
Total Variable Costs (TVC)	1 273 726.10	100.00	1 598 096.38	100.00	1 136 876.61	100.00
Gross Margin, GM (GR - TVC)	57 618.40		71 013.12		80 259.89	
GM per kg meat	0.93		0.92		1.42	
GM per bird	1.49		1.50		2.33	

*1USD = 12.5BWP.

Economic performance – Efficiency

To evaluate the efficiency of broiler production under the different housing structures, the input-output ratio or the operating ratio was calculated by dividing the output cost (revenue) by the input or total cost (Table 8).

Table 8 – Value of input cost to output cost (revenue) across the different house types.

Item	House type		
	Hoop	See saw	Gable
Input cost (BWP)*	1 273 726.10	1 598 096.38	1 136 876.61
Output cost (BWP)	1 331 344.50	1 669 109.50	1 217 136.50
Ratio	1: 1.05	1: 1.04	1: 1.07

*1USD = 12.5BWP.

Results are similar across the different housing structures, though the Gable structure had the highest ratio for return on investment of 1:1.07. This indicates that for each BWP1.00 of input invested in broiler production, the farm earns 7 *thebe* as profit. Based on the input costs presented in Table 8, the profits are calculated to be BWP89, 160.83, BWP111, 866.70 and BWP79, 581.36 for Hoop, See-saw and Gable-roofed housing structures, respectively. However, it is not always the case that the most profitable one will also have the highest return on investment (Abdurofi *et al.*, 2017).

CONCLUSIONS

The production performance of the broilers in the South-eastern (SE) region was superior to that of the-North eastern (NE) region, and temperatures were on average higher in the NE than in the SE. In the NE region, broilers reared in the Hoop structure performed significantly higher (p<0.05) than in both the Gable and See-saw structures on feed consumption, average daily gain, and water consumption. In the SE region, only water consumption in the Gable structure was significantly higher (p<0.05) than in the other house structures. At the point of slaughter (35 days), there were significant differences (p<0.05) between bird masses across the different house types. Mortality was not significantly different (p>0.05) between the regions, at 9.0% and 7.4% for the NE and SE, respectively. In the NE, the Gable structure had the highest profitability and economic efficiency, and was thus superior in comparison to the other house structures.

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