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Full Length Research

Restricting conventional feed intake for pasture-raised broilers in Papua New Guinea: Effect on growth parameters and carcass yield

Jeremiah Ahizo[1]*, Stanley Amben[1], Martin W. Lobâo[2], Arthur D. Roberts[3] and Janet Pandi[3]

[1]National Agriculture Research Institute (NARI), Highlands Regional Centre - Tambul, P.O. Box 120, Mt. Hagen, Western Highlands, Papua New Guinea.
[2]NARI, Islands Regional Centre - Keravat, P.O. Box 204, Kokopo, East New Britain, Papua New Guinea.
[3]NARI, Momase Regional Centre - Labu, P.O. Box 1639, Lae 411, Morobe, Papua New Guinea.

*Corresponding author: ahizojeremiah37@gmail.com, jeremiah.ahizo@nari.gov.pg

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ABSTRACT: Using agro-industrial by-products and root crops as feed sources in broiler nutrition is gaining momentum. Yet, it is uncertain whether farmers should utilize outdoor movable pens and pasture to raise broilers. In this study, growth responses of 96 Ross strain broilers reared on pasture versus conventional rearing system were evaluated. The former involved subjecting broilers to kikuyu-white clover pasture and restricting finisher ration by 50%. The latter were kept totally confined and fed the same diet *ad libitum*. All birds were fed a starter ration from days 1-2 and introduced to both rearing systems at finishing-phase (days 22-42) using a completely randomized layout. There were four replicates, each with 12 birds randomly allotted to eight experimental pens. Daily feed intake (DFI), daily weight gain (DWG) and associated costs were recorded over 42 days. Feed conversion ratio (FCR) was calculated weekly while carcass yields were measured at day 42. DFI (116.1 g, b^{-1} vs. 165.2 g, b^{-1}), DWG (10.47 g, b^{-1} vs. 21.15 g, b^{-1}) and final weights (1,912 g, b^{-1} vs. 2,978 g, b^{-1}) varied significantly ($p<0.05$). Pasture-raised broilers consumed less feed, gained less weight and were comparably lighter than full-fed broilers. FCR also differed significantly (2.26 vs. 1.66; $p<0.001$); pasture-raised broilers were less efficient at converting feed to body mass. While carcass weights (2,058 g, b^{-1} vs. 2,715 g, b^{-1}) and dress percentages (71.65 vs. 76.73) were statistically ($p<0.05$) lower for pasture-raised broilers. They were less expensive (PGK14.08, b^{-1} vs. PGK11.05, b^{-1}; $p<0.05$) to produce with significantly higher benefit-cost ratio (2.35 vs. 1.99; $p>0.05$). Raising broilers on kikuyu-white clover pasture is feasible but needs further evaluation, particularly with 30-40% feed restriction and its implications on compensatory weight gain.

Keywords: Benefit-cost ratio, broilers, carcass yield, growth parameters, pasture.

INTRODUCTION

The demand for animal products for human consumption in developing countries is continuously growing, mainly for pork and poultry products (Food and Agriculture Organisation of the United Nations, 2010 cited in Martens *et al*., 2012). This growth is related to an increase in animal protein consumption and rising consumer income per capita (Renaudeau *et al*., 2012). According to Conroy *et al*. (2005), opportunities for smallholder poultry enterprises in developing countries have also expanded due to advancements in infrastructure and access to markets. Hence, according to Marterns *et al*. (2012), smallholder farmers now have the opportunity to improve their household income and livelihoods by merging with poultry value chains. However, the growth of this industry is often impeded in countries that are not self-reliant in grain crop production (Branckaert, 2000 cited in Menghesa, 2012).

Smallholder farmers in Papua New Guinea (PNG) operate separately from a vertically integrated commercial broiler industry. These farmers produce about 6 million birds annually to meet domestic informal market demands (Glatz, 2007; Glatz *et al*., 2013). Considering its low investment requirement and quick turnover, small-scale broiler production is continuously growing with an estimated 50,000 families currently involved (Glatz, 2007). However, farmers face several challenges that limit their productivity; information on innovative farming practices, particularly with the continuous challenges imposed by climate change, is lacking. Moreover, national, provincial, and local support services are inadequate to meet farmer's needs. Nevertheless, the key constraint in raising poultry continue to revolve around high cost of inputs, primarily from imported feed ingredients (Glatz, 2007).

According to Renaudeau *et al*. (2012), the intensification of animal production in developing countries rely on feed rations frequently imported from western countries which are heavily induced by unstable global market prices. Similarly, most of the grains used to produce feed in PNG are usually imported (Ayalew, 2015). Worse still, the expansion and sustainability of small broiler enterprises are further burdened by the associated costs of freighting feed from point of manufacture to other centres nation-wide. In response to these challenges, research priorities have continuously focused on maximum utilization of non-conventional feed resources available locally (Quartermain, 2000). Such efforts need to be complemented with economically feasible production systems.

The intensive rearing system is widely practised in PNG where birds are raised indoors with little or no outdoors accessibility. This production method is often constrained by high stocking densities with birds experiencing high levels of stress, and increased risks of diseases (Dozier *et al*., 2005). Such scenarios are often encountered by farmers in PNG, needing appropriate counteractive measures. Alternative production systems could be useful in managing the risks associated with raising broilers intensively. Over the last two decades, poultry meat production has diversified and become more focused on other aspects, with different rearing systems gaining increased importance (Bogosavljevic-Boskovic *et al*., 2012). One such alternative is pasture-raised poultry where farmers may opt to raise chickens using elements of the traditional method; combining outdoor movable shelters and utilizing pasture to complement feeding options and encourage animal welfare.

Pasture-poultry involves raising chickens primarily on either a natural grass environment or directly on propagated pasture (Sossidou *et al*., 2011). According to Salatin *et al*. (1996), it is a sustainable production system that integrates well with other farm activities and can help farmers utilize limited resources including land. It involves producing meat and eggs through frequent moving of poultry to fresh pasture, using portable pens or movable fencing. Birds forage on pasture with access to grass, seeds, and insects in a semi-intensive setting with reduced stress and increased comfort (Blokhuis *et al*., 2000). Meat and eggs from birds reared this way are perceived to be healthier (Husak *et al*., 2008) than those produced conventionally. Consumers believe the production method is humane, and the products have distinct flavour and quality (Latter-Dubois 2000; Chen *et al*., 2013) and are willing to pay more for it, hence promoting a specialty product and market (Bartlett *et al*., 2015). According to Pavlovski *et al*. (2009), consumer demand for poultry products from semi-intensive rearing conditions have also increased. This instigates a genuine opportunity for farmers to reduce costs while improving animal welfare and farm profitability simultaneously.

Situated in the tropics, there are a wide range of native and exotic pasture species suitable for livestock grazing in PNG. Kikuyu (*Pennisetum clandestinum*) is a deep-rooted perennial grass found in most parts of the country. It is suitable for pasture at high elevations with well distributed annual rainfall of 1,000 - 1,600 mm. Kikuyu is quite competitive and generally incompatible with other grass species but integrates well with some leguminous species. It is high in crude protein and palatable even at maturity and the presence of the legume white clover (*Trifolium repens* L.) within the sward increases its utilization (Fukumoto and Lee, 2003; Fulkerson *et al*., 2007). White clover is a perennial legume that spreads by stolons across the soil surface. It thrives best in cool, moist climate where yearly rainfall exceeds 750 mm. Its high nutritive value (Table 1), high acceptability by livestock, and role in fixing atmospheric nitrogen makes it suitable for grazing. It can be propagated together with kikuyu to provide a mixed grass-legume sward (Ogle and St. John, 2008; Abbasi *et al*., 2009: Kiraz, 2011).

Work on pasture-based rearing systems is widespread mostly in developed countries but with varying conclusions. Current research in PNG is focused on efficient utilization of local feed resources in feeding broilers; particularly agro-industrial by-products like copra meal (Nano, 2015), rice bran (Solomon *et al*., 2017) and root crops such as sweet potato (Ayalew *et al*., 2017; Pandi *et al*., 2017) and cassava (Solomon *et al*., 2016; Ahizo *et al*., 2017). Exploitation of non-conventional feedstuffs as cost-effective options for broiler nutrition is important. However, these efforts are concentrated more on nutritional aspects and less on alternate production systems. The purpose of this study was to evaluate the growth responses and carcass yield of broilers subjected to a kikuyu-white clover pasture-based production system.

MATERIALS AND METHODS

Study area

This study was conducted from August to September (2017) at the NARI high-altitude research station (5.942° S, 144.0113° E, at 2,200 m above sea level) in Tambul, Papua New Guinea. The climate is typically cold and wet; annual rainfall and temperatures range from 2,300 – 4,000 mm and 18 - 20°C accordingly whilst relative humidity (RH) levels vary between 65 and 75% (Hanson *et al*., 2001). The total precipitation recorded during the experimental period was 327 mm. The observed indoor; outdoor temperature and RH levels within the same period were 15-30°C; 14-27°C and 40 - 63%; 43 - 67% respectively with a photoperiod of 12 hours (12L:12D).

Birds, housing, and study design

A total of 96 unsexed Ross strain broilers were obtained from a commercial hatchery for this experiment. The study was conducted in a naturally ventilated shed constructed with corrugated iron roofing, concrete floor, and outer v-crimp walls. All experimental pens have an equal floor area of 5 m^2 and were partitioned with mesh wire. The floors were covered with wood-shavings as bedding material up to a depth of 10 cm. A completely randomized layout was used in this experiment and involved two rearing systems (pasture-based system vs. conventional system) represented by four replicates; each stocked with 12 birds randomly assigned to eight experimental pens.

Pasture establishment, feeding, and management

Kikuyu and white clover pastures were established in alternating rows through rhizomes and stolons, embedded at a spacing of 10 and 30 cm within and between rows accordingly. Poultry manure was hand broadcasted at the base to encourage pasture growth and establishment. These pastures were trimmed to promote young growth and subsequently maintain pasture at a uniformed height of 3 - 4 cm. All birds were raised indoors with a Flame® starter ration (Lae Feed Mills) from 1 - 21 days-old before shifting to a Flame® finisher (Table 1) ration from 22 - 42 days-old.

The management and feeding strategies were initiated at finishing-phase and involved feeding broilers with the finisher *ad libitum* and keeping birds in total confinement. The same diet was offered to broilers reared on pasture but was restricted at 50% with birds having daily outdoor access to propagated kikuyu-white clover pasture. Birds were allowed access to pasture using mobile pens constructed from timber; each with a height and floor area of 0.75 m and 3 m^2 accordingly. All pens were covered with mesh wire and shade cloth to avoid predation and exposing birds to direct sunlight. These mobile pens were constantly moved to provide broilers with *ad libitum* access to fresh pasture. The starter and finisher rations were offered as crumbles and pellets respectively while birds have unrestricted access to clean fresh water throughout.

Carcass yield and crop content evaluation

The final weights were recorded on day 42; and birds were starved for eight hours in preparation for slaughter. Pre-slaughter weights were obtained before birds were slaughtered, and exsanguinated. Slaughtered birds were submerged in hot water for 30 seconds to loosen feathers which were manually removed. The birds were eviscerated, and internal organs (giblet, heart, liver, intestines, crop, lungs, and gall bladder) and other non-carcass (feet and neck) component were removed and weighed with a kitchen scale (5,000 g ± 1 g). The carcasses were then weighed, rinsed, and chilled in a refrigerator. All carcass components such as the liver, heart, gizzard, and abdominal fat were separated and weighed individually. Crop contents were weighed, visually separated according to contents, and re-weighed to establish percentage compositions. The pasture component was separated again and weighed to determine species make-up.

Data analyses

Data on feed intake, weight gain and associated feed costs were recorded over a 42-day experimental period. The quantity of feed provided, and its residuals were recorded daily with a kitchen-scale (10 kg ± 0.025 kg). Weekly live weights of broilers were also obtained using the same scale. Daily feed intake (DFI), feed conversion ratio (FCR), daily weight gain (DWG), carcass weight, dress percentages, and benefit-cost ratios were obtained using the following equations.

$$\text{DFI (g)} = \text{Feed offered} - \text{Feed refusal}$$

$$\text{FCR (weight gain)} = \frac{\text{Feed consumed (g)}}{\text{Weight gained (g)}}$$

$$\text{DWG (g)} = (\text{weight of bird at end of week} - \text{weight of bird at start of week}) / 7 \text{ days}$$

$$\text{Carcass weight (g)} = \text{final weight of birds} - \text{all non-carcass components}$$

$$\text{Dress percentage (\%)} = \frac{\text{dress weight per bird (g)}}{\text{live weight per bird (g)}}\ x\ 100$$

$$\text{Benefit-cost ratio} = \frac{\text{Total returns (PGK)}}{\text{Total costs (PGK)}}$$

Table 1. Nutrient and energy specifications of the starter and finisher diets, including kikuyu and white clover pasture.

Nutrient component	Starter	Finisher	Kikuyu	White clover
Dry matter (%)	89.8	89.7	25.0	98.6
Ash (%)	9.81	5.89	9.5	9.77
Crude fibre (%)	4.1	5.0	20.9	10.32
Fat (%)	7.7	7.5	2.9	--
Crude protein (%)	21.0	19.0	24.8	15.8
Calcium (%)	1.26	1.28	0.39	1.10
Phosphorus (%)	0.7	0.71	0.29	0.32
Nitrogen free extract (%)	47.19	52.31	40.8	--
Metabolizable energy (MJ, kg^{-1})	12.13	12.2	9.2	10.5

Adapted from Abbasi *et al*. (2009), Kiraz, (2011), Glatz *et al*. (2013) and Ahizo *et al*. (2015).

All data were sorted in MS Excel® 2007 version and analysed using a one-way analysis of variance (ANOVA) in GenStat® Release 4.2 (Lawes Agricultural Trust, 2005) to determine the main effects of rearing system on measured parameters. There was homogeneity of variance, hence, the least significance difference test, at 95 % confidence interval, was used to separate means where significant main effects were detected in the ANOVA.

RESULTS AND DISCUSSIONS

Feed intake, feed conversion and weight gain

The effect of rearing systems (Table 2) on DFI (116.1 g, b^{-1} vs. 165.2 g, b^{-1}), and DWG (10.47 g, b^{-1} vs. 21.15 g, b^{-1}) differed significantly (p<0.05) with broilers kept under PPS consuming less feed and subsequently gaining less weight than conventional-broilers. This was similar to observations made by Inci *et al*. (2016) who reported high feed intake for birds reared indoors than those on pasture. However, Bartlett *et al*. (2015) observed no differences in DFI of birds raised in a similar manner while Chen *et al*. (2013) reported high DFI for birds raised with outdoor access. The lower DFI for pasture-raised broilers is indicative of the 50% feed restriction regime. More importantly, pasture-raised broilers were only able to partially compensate for this restriction by obtaining 30% (Table 4) of their dietary intake through foraging.

Final body weights at 42 days-old also differed significantly (p<0.05) with the CPS yielding heavier birds (2,978 g, b^{-1} vs. 1,912 g, b^{-1}) than PPS. High FBW were also reported by Poltowicz and Doktor (2011) on birds produced conventionally. Wang *et al*. (2009) made similar observations with DWG and FBW on slow-growing Gushi chickens while Inci *et al*. (2016) reported high FBW for Japanese quails reared using a similar approach. According to Bogosavljevic-Boskovic *et al*. (2012), broilers reared under semi-intensive or non-intensive conditions generally have low body weights compared to birds reared intensively. In contrast, Bartlett *et al*. (2015) and Moyle *et al*. (2014) reported no differences in FBW and DWG between birds reared conventionally and on pasture. The low DWG and FBW in this study could be attributed to increased exercise and less deposition of fat in pasture-raised broilers. Moreover, the differing observations from other studies could be associated with poultry genotype.

As further demonstrated in this study, pasture-raised broilers were inefficient at converting feed to body mass (2.26 vs. 1.66; p<0.001) than conventional-broilers. Wang *et al*. (2009) and Inci *et al*. (2016) also reported significantly higher FCR (4.41 vs. 3.95; p<0.05 and 3.2 vs. 3.1; p<0.01 respectively) for birds raised with access to pasture compared to others kept indoors. Similar observations were reported by Lima and Nääs (2005) who noted higher FCRs for birds reared with outdoor-access. Further, kikuyu and white clover pastures have a crude fibre content of 20.9% and 10.32 % respectively (Table 1). Hence, this may have influenced feed utilization as according to Ponte *et al*. (2008) that pastures with high fibre can have a restricting effect on utilization of other nutrients. Yet, Mikulski *et al*. (2011), Poltowicz and Doktor (2011) and Li *et al*. (2017) reported comparable FCRs with no significant variations at finishing-phase; pasture-raised broilers attained FCRs that were relatively similar to conventional-broilers. Similar observations were made by Bartlett *et al*. (2015) and Moyle *et al*. (2014) where raising birds on pasture had no effect on FCR compared to birds raised conventionally. In line with the views of Bartlett *et al*. (2015), Inci *et al*. (2016) and Li *et al*. (2017), the contrasting observations could be associated with variations in genotype, environment, length of rearing period and pasture species. Birds raised conventionally began reaching market weights (2 kg, b^{-1}) earlier at 28 days-old whilst pasture-raised broilers reached market weights from 35-42 days-old. This is reflective of the high DFI, better FCR and DWG for conventional-broilers and the 50% feed restriction in pasture-raised broilers.

Table 2. Effect of rearing system on broiler growth parameters at finishing-phase (22-42 days-old).

Parameter	Age	Raising system		Significance		
		CPS	PPS†	S.E.M	*p*-value	CV (%)
DFI (g, b^{-1}, d^{-1})	Wk4	145.4[a]	99.1[b]	2.21	*<0.001*	3.6
	Wk5	166.8[a]	113.8[b]	4.92	*<0.001*	7.0
	Wk6	183.3[a]	135.5[b]	5.25	*<0.001*	6.6
	Wk4-6	165.2[a]	116.1[b]	3.54	*<0.001*	5.0
FCR (kg, kg^{-1})	Wk4	1.26[a]	2.06[b]	0.07	*<0.001*	8.7
	Wk5	1.93[a]	2.55[b]	0.07	*<0.001*	6.1
	Wk6	1.80[a]	2.17[b]	0.10	*0.043*	10.6
	Wk4-6	1.66[a]	2.26[b]	0.05	*<0.001*	5.7
	Wk4	29.02[a]	12.05[b]	1.25	*<0.001*	12.2
DWG (g, b^{-1}, d^{-1})	Wk5	17.30[a]	8.93[b]	0.52	*<0.001*	7.9
	Wk6	17.14[a]	10.42[a]	0.59	*<0.001*	8.6
	Wk4-6	21.15[a]	10.47[b]	0.54	*<0.001*	6.9
FBW (g, b^{-1})	Wk6	2,978[a]	1,912[b]	51.1	*<0.001*	4.2

Within-row means bearing different superscripts (a, b) differ significantly (*P<0.05*). CPS = conventional production system, PPS = pasture-production system, DFI = daily feed intake, FCR = feed conversion ratio, DWG = daily weight gain, FBW = final body weight, S.E.M = standard error of means, CV = coefficient of variation. † DFI for PPS is inclusive of 30 % herbage intake as per crop composition.

Table 3. Effect of rearing system on production costs and bird mortality.

Parameter	Age	Raising system		Significance		
		CPS	PPS	S.E.M	*P*-value	CV (%)
Cost (PGK, b^{-1})	Wk4	2.05[a]	1.10[b]	0.03	*<0.001*	3.1
	Wk5	2.31[a]	1.26[b]	0.08	*<0.001*	8.6
	Wk6	2.52[a]	1.50[b]	0.05	*<0.001*	5.5
	Wk4-6	6.89[a]	3.86[b]	0.14	*<0.001*	5.3
Total cost (PGK, b^{-1})	Wk1-6	14.08[a]	11.05[b]	0.14	*<0.001*	2.3
Benefit-cost ratio	Wk1-6	1.99[a]	2.35[b]	0.02	*<0.001*	1.9
Bird mortality (%)	Wk4-6	16.3	0	--	--	--

Within-row means with different superscripts (a, b) vary significantly (*P<0.05*). Cost/Total Cost = based on gross margin analysis. PGK = PNG Kina; 1 PGK = 0.38 AUD (as of 05th October 2017).

Production costs and bird mortality

While pasture-raised broilers gained less weight daily and were less heavy at 42 days-old, they were inexpensive to produce compared to conventional-broilers (PGK11.05, b^{-1} vs. PGK14.08, b^{-1}; p<0.05) with a 21% reduction in cost per bird (Table 3). The benefit-cost ratio for pasture-raised broilers were significantly higher than that of conventional-broilers (2.35 vs. 1.99; p>0.001). Liles *et al*. (2015a) also reported high benefit-cost ratios and up to 8% reduction in cost per bird reared in a pasture-based system. Based on a selling price of PGK28.00 per bird, and regardless of the production system, the benefit-cost ratio may not be an exact representation of what each production system can attain in terms of real market value. The more affluent and health-conscious consumers may pay more for pasture-poultry products which can further inflate its rate of return and hence benefit-cost ratio.

Nevertheless, these observations indicate that raising broilers on pasture is economically feasible and together with its health benefits (Husak *et al*., 2008) present a more realistic option for additional returns and diversifying

Table 4. Crop content composition of broilers with daily access to kikuyu-white clover pastures at finishing-phase.

Crop content	(*n*)	Crop make up (%)	Pasture composition (%)		
			Kikuyu	White clover	Others
Finisher	12	70	--	--	--
Pasture	12	30	50	40	10

n = number of birds used for crop content analysis.

Table 5. Effect of rearing system on broiler carcass characteristics at 42 days-old.

Parameter	(*n*)	Raising system		Significance		
		CPS	PPS	S.E.M	*p*-value	CV (%)
Pre-slaughter weight (g, b^{-1})	12	2,947^a	2,222^b	33.2	*<0.001*	2.6
Carcass weight (g, b^{-1})	12	2,715^a	2,058^b	32.1	*<0.001*	2.7
Dressed weight (g, b^{-1})	12	2,261^a	1,592^b	26.5	*<0.001*	2.7
Dress percentage (%)	12	76.73^a	71.65^b	0.60	*<0.001*	1.6
Abdominal fat (g, b^{-1})	12	7.0^a	6.3^a	0.85	*0.61*	22.1
Heart weight (g, b^{-1})	12	18.8^a	10.7^b	0.48	*<0.001*	6.7
Gizzard weight (g, b^{-1})	12	38.0^a	36.7^a	2.10	*0.67*	11.2
Liver weight (g, b^{-1})	12	71.3^a	81.7^a	6.15	*0.30*	13.9

Within-row means bearing different superscripts (a, b) differ significantly ($p<0.05$). *n* = number of broiler carcasses examined.

opportunities on limited-resource farms (Liles *et al*., 2015a). Considering there were no mortalities associated with PPS makes it a more viable option as mortality rates can have a marked influence on profitability. All mortalities (16.3%) observed at finishing-phase were observed in broilers under CPS. These mortalities were caused by ascites or water belly which is common under high-altitude conditions (Huang *et al*., 2011) and could be aided with the build-up of ammonia and dust normally associated with intensive production systems (Liles *et al*., 2015a). While Poltowicz and Doktor (2011), and Ipek and Sozcu (2017), observed low mortality rates of 4.17% and 2.85% respectively in pasture-raised broilers, no mortality was observed in this study. Inci *et al*. (2016) also reported no mortality in birds reared on pasture which could be attributed to the fact that pasture-birds had regular access to fresh air and increased mobility and were less stressed than conventional-birds. Moreover, Liles *et al*. (2015b) maintained that birds reared on pasture experience low stress levels than those raised intensively. The variations in these observations could also be influenced by genotype, environment, and production period.

Crop content and carcass yield

The crop content analysis for pasture-raised broilers showed a composition of 70% finisher ration and 30% herbage (Table 4). This is in accordance with the views of Salatin *et al*. (2006) and indicate that for pasture-based systems, conventional feed can be substituted at 30% with pasture. Producers also estimate anywhere from 5-25% of intake being supplied through foraging on pasture, insects, and seeds (Liles *et al*., 2015a). The herbage intake comprises mostly of kikuyu (50%), white clover (40%) and other grass species including insects and grit (10%). All herbage consumed were young growth at 2 – 4 cm down from the tip where it is mostly soft and palatable. As explained by Miao *et al*. (2005), visually separating the crop contents may provide some guides on diet components, however, it cannot be used to further quantify pasture species ingested by poultry.

Carcass yield (Table 5) in-terms of pre-slaughter weight (2,222 g, b^{-1} vs. 2,947 g, b^{-1}), carcass weight (2,058 g, b^{-1} vs. 2,715 g, b^{-1}) and dressed weight (1,592 g, b^{-1} vs. 2,261 g, b^{-1}) were significantly lower ($p<0.001$) for pasture-raised broilers, likewise for dress percentages (71.65 vs. 76.73; $p=0.001$). Inci *et al*. (2016) reported carcass weights of quails raised with outdoor access to pasture to be lower than those raised indoors. Similarly, Li *et al*. (2017) found dress percentages of medium-growing chickens to be high for birds kept indoors compared to others with outdoor-access to pasture. On the contrary, Poltowicz and Doktor (2011) reported no significant variations in dress percentages between chickens raised with access to pasture and others raised intensively. Likewise, Bartlett *et al*. (2015) found that raising birds either on pasture or conventionally had no effects on both pre-slaughter and carcass weights, and dress percentages. Again, the varying views may be related to genotype, feeding regimes, production environment and pasture species.

While gizzard weights (38.0 g, b^{-1} vs. 36.7 g, b^{-1}; $p=0.67$)

remained comparable, heart weights were significantly heavier (18.8 g, b^{-1} vs. 10.7 g, b^{-1}; $p<0.001$) in conventional-broilers. However, Inci *et al*. (2016) reported no differences in heart weights of quails reared in a similar manner. Bartlett *et al*. (2015) also observed no differences in heart, gizzard and liver weights between birds raised conventionally and on pasture. Though abdominal fat content for pasture-raised broilers were observably lower (6.3 g, b^{-1} vs. 7.0 g, b^{-1}) than conventional-broilers the difference was not significant ($p = 0.85$) which is akin to the observations of Poltowicz and Doktor (2011), and Chen *et al*. (2013). However, Wang *et al*. (2009), Li *et al*. (2017) and Ipek and Sozcu (2017) observed abdominal fat content of birds raised on pasture to be considerably lower than others raised conventionally. These differing observations could be influenced by genotype and pasture species, study period or variations in the outdoor environment. Nevertheless, the low abdominal fat content is reflective of the reduced feed intake and increased mobility, and thereby less deposition of fat in pasture-raised broilers.

Conclusion

The pasture-based system did not improve feed conversion and broiler growth parameters at finishing-phase. As observed in this study, however, pasture-raised broiler carcasses were leaner with less abdominal fat and together with its relatively better benefit-cost ratio and perceived health benefits present a realistic option for additional income on limited-resource farms. This option needs to be explored further, particularly by restricting conventional feed at 30-40% and observing its implications on compensatory weight gain. Furthermore, combining pasture-based systems with least-cost feed options and investigating its potential as a strategy to alleviate ascites in broilers under high-altitude conditions are opportunities worth considering.

CONFLICT OF INTEREST

The work described in this study and the findings herein are original and free of any competing interests unless cited otherwise.

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