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Research Article
Performance of Sasso and Kuroiler Chickens under Semi-Scavenging System in Tanzania: Carcass and Meat Quality

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Abstract

Background and Objective: Throughout the world, consumers are increasingly being attracted to chicken meat from naturally grown birds. A study was therefore conducted to evaluate the effect of dietary regimes on carcass and meat quality of genetically improved dual-purpose chicken. **Materials and Methods:** In total, 480 day-old male chicks were randomly assigned to 24 treatment combinations in a 2×3×4 factorial experiment. The treatments were breeds (Sasso and Kuroiler), diets (D_1, D_2 and D_3) and levels of supplementation (100, 75, 50 and 25%). At the age of 20 weeks, five male chickens were randomly selected from each treatment combination and sacrificed for detailed carcass and meat quality assessment. **Results:** The Dressing Percentage (DP), pH, cooking loss, Crude Protein (CP) content of breast, thigh and drumstick joints were higher in Sasso than in Kuroiler. Values for redness (a*) and yellowness (b*) were higher in Kuroiler than in Sasso. Thigh muscle in birds fed D_2 and D_3 tended to be tougher than those fed D_1. CP and ash contents in breast joints from D_1 and D_2 were higher than in D_3 chickens. The ether extract values for drumstick from D_1 and D_2 were comparable but higher than in D_3. The L* and a* value in the breast joint tended to increase with a reduction in the level of supplementation but it was the opposite in the case of the drumstick. **Conclusion:** It is concluded that the feeding regime affects the meat quality of genetically improved dual-purpose chicken in a joint-specific fashion.

Key words: Carcass traits, meat quality, improved dual-purpose chicken, low-cost diet, semi-scavenging, supplementation, breast joints

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chicken meat is a source of high-quality protein with a relatively low content of fat[1]. Fortunately, the expectation of modern consumers has evolved toward the demand for traditional products, usually more respectful of the environment and animal welfare and this is an opportunity for expansion of the local chicken industry[2]. Although local chicken breeds and their hybrids show lower weight gain and a smaller proportion of breast muscle in the carcass compared to fast-growing broilers, their meat has many quality characteristics valued by consumers[3]. Despite their taste and other attributes, the production of local chicken is low due to the inherent low genetic potential for growth, poor feed and feeding practice[4]. As such genetic improvements have focused primarily on selection for growth rate, feed conversion efficiency[5-7], more muscle yield and meat quality traits. Selection within the breed is cumbersome and often takes a long time to achieve significant genetic gain and crossbreeding has been adopted as a way to speed up genetic gains. Sasso and Kuroiler breeds are among the genetically improved dual-purpose chicken for the production of more meat and eggs. These strains have been tested in Tanzania, Nigeria and Ethiopia and are deemed to do fairly well under smallholder semi-scavenging conditions in rural areas[5].

Several studies demonstrated the existence of differences in meat quality between fast and slow-growing chicken breeds, particularly on chemical composition and physical traits as well as consumer preferences[6]. Other factors affecting meat quality include sex, age, feeding and rearing systems[1,7]. The most important meat quality traits preferred by consumers include appearance, juiciness, tenderness, flavor, water holding capacity and colour[8]. Some studies on meat quality have focused on the broiler and local chicken types[7,9,10]. Sasso and Kuroiler are relatively new strains in Tanzania and have been promoted as an alternative to local chicken since they have good scavenging ability. However, there is a scarcity of information on the effect of management on meat quality characteristics. Therefore, this study aimed to evaluate the effect of breed, diet and different feed supplementation levels on carcass characteristics and meat quality traits of genetically improved dual-purpose chickens.

MATERIALS AND METHODS

Study area: This research project was conducted from July, 2018-June, 2019. The experiment was conducted at the Poultry Unit of the Department of Animal, Aquaculture and Range Sciences of the Sokoine University of Agriculture, Tanzania.

Experimental layout: A flock of 480 male birds was used, with 240 birds per breed and reared for 20 weeks. An experiment was designed in a $2\times3\times4$ factorial arrangement with two breeds (Sasso and Kuroiler), three diets (D_1-commercial, D_2-medium-cost feed and D_3-low-cost feed) and four supplementation levels per diet, amounting to 24 treatment combinations each with 20 birds. Birds were fed starter (0-6 weeks) and growers diets (7-20 weeks). Supplementation levels were 100, 75, 50 and 25% of the recommended daily feed allowance for each strain. The grower feed had the energy densities of 2887, 2887 and 2627 kcal kg^{-1} DM for D_1, D_2 and D_3, respectively. Protein contents were 15.5, 15.6 and 15.3% for D_1, D_2 and D_3, respectively. One half of the feed was provided in the morning and the remaining half in the evening while water was given *ad libitum*. All birds had access to a fenced range area (1 bird/4 m^2) during the day, where they scavenged for greens, worms and insects.

Carcass traits: Following 20-weeks on dietary treatments, a total of 120 male chickens (60 Sasso and 60 Kuroiler) and five birds per treatment combinations, were randomly selected and sacrificed. Before slaughter, the birds were fasted for 12 hrs, weighed individually and slaughtered by manual exsanguinations. They were then bled for 5 min before being weighed again to get blood weight and de-feathered. After de-feathering they were weighed and the difference in weight was considered as a featherweight. The carcasses were eviscerated, dissected and the carcass parts weighed the same day of slaughter. Weight after de-feathering (before evisceration) and weights for carcass (dressed weight), intestines, breasts, drumsticks, wings, thighs, back, liver, gizzard, heart, neck and shanks were recorded. Carcass weight was taken after evisceration and the carcass yield (dressing percentage) was calculated as a percentage of pre-slaughter body weight.

Meat quality traits

pH measurement: A spear-end digital portable pH meter (Knick Portamess® 910, Germany) was used to measure the pH of the breast, thigh and drumstick joints of each bird at 45 min post-mortem. The pH meter was standardized before the measurement of each sample using two buffer solutions, one with pH 4.0 and another one with pH 7.0. In this regard, a total of 120 samples for each joint were used.

Color measurement: Meat color was measured on the internal surface of the breast, thigh and drumstick joints, using a portable colorimeter (MINOLTA CR 200b colorimeter, Osaka-Japan) based on CIELAB system with (L*) for relative lightness, a* for relative redness and b* for relative yellowness.

Readings were made at three different areas of the selected muscle[11]. The averages of the three readings for color were used for statistical analysis. In this method, the L* value ranges from 0-100 (from black to white), a* and b* both range from (-120) - (+120) with a* ranging from green if negative to red if positive and b* ranging from blue if negative to yellow if positive[12].

Cooking loss measurement: After 4 hrs post-slaughter, raw breast, thigh and drumstick joints (20-30 g) from the right side of the carcass were cut, weighed and sealed in a plastic bag (30 microns) and cooked in a thermostatically controlled water bath (Fisher Scientific, Pittsburgh, PA) at 75°C for 45 min as described by Rizz *et al.*[13]. Then, the samples were cooled in running water for 15 min, dried with soft tissue and weighed. Cooking loss was calculated as a percentage loss of weight during cooking relative to the weight of raw muscle[14].

Tenderness (shear force value) measurement: Strips measuring about 1.0×1.0×2.5 cm parallel to the muscle fiber direction were prepared from the breast, thigh and drumstick joints and sheared across the muscle fiber direction using Warner-Bratzler shear blade attached to Zwick/Roell (Z2.5, Germany) instrument. The sheer force values were recorded in Newtons (N).

Meat chemical composition analysis: For proximate analysis, a total of 120 breasts, thigh and drumstick joints were skinned, de-boned and frozen at -20°C awaiting further analysis. Individual samples were thawed for 24 hrs, minced through a 5 mm plate meat-grinding machine. Chemical composition analysis of minced meat samples was performed on a wet basis by proximate analysis to determine the dry matter, ash, crude protein and fat content[15]. The dry matter of fresh samples was analyzed by the oven method set at 105°C. Ash was determined after subjecting the samples to a furnace set at 500°C. Protein was analyzed by the Kjeldahl method using a 2200 Foss Tecator Kjeltec distillation unit (Foss, Höganäs, Sweden). Fat contents were analyzed by the Soxhlet method using a 2050 Soxtec Avanti Extract unit (Foss, Höganäs, Sweden).

Statistical data analysis: Data on carcass traits and meat quality were analyzed using the General Linear Models (GLM) procedure of Statistical Analysis System[16]. Breed, diet, level of supplementation and their interactions were considered as fixed effects while the error was considered random. The least-square means were separated by the PDIFF test. Interaction between the factors was tested and found not statistically significant.

RESULTS AND DISCUSSION

Effects of breed on killing out characteristics: Results presented in Table 1 reveals that the Dressing Percentage (DP) of Sasso (68.8%) was about 2 percent unit higher ($p<0.001$) than that of Kuroiler. At 20 weeks, body weights were slightly above 2 kg for both breeds and the slaughter weight and carcass weight were near similar. Values for slaughter weight and DP observed in this study are higher than that of local chicken reported by Sanka and Mbaga[7]. This is attributable to lower carcass weights of local chicken due to the lower growth rate[17]. Since Sasso and Kuroiler chickens are heavier than the local chickens, it is logical that their carcass portions are more than those of the local chickens. Moreover, the results for carcass weight observed in the present study are within the range of 900-1900 g reported by Yaussao *et al.*[18] and Franco *et al.*[17] in local, Label Rouge chickens and Sasso T-44 hybrid line respectively. Also, Aline[19] reported a higher dressing percentage of Kuroiler breed than the local breed.

Sasso and Kuroiler were comparable ($p>0.05$) in carcass joint weights as well as non-carcass portions. According to Sante *et al.*[20], the breast weight to carcass weight is an important criterion in broiler poultry production. Sanka and Mbaga[7] reported the average weight of carcass and breast in local chickens to be 1414.00g and 352.51 g, which is 35.09% and 12.21% lower than that of Sasso and Kuroiler birds obtained in the current study. Thus, Sasso and Kuroiler chickens could be taken as alternative meat birds owing to their high carcass weight compared to the indigenous chickens.

Effects of breed on meat quality: In the present study the pH values measured 45 min Postmortem (PM) in the breast and thigh joints were similar between the two breeds and both were close to 6.0 (Table 2). Higher pH values were reported by Castellini *et al.*[21], with means ranging between 6.02 and 6.25 and by Souza *et al.*[22], with means varying from 5.93-6.22 for broiler under organic production system. The pH values recorded 45 min PM at drumstick was higher ($p<0.05$) for Sasso (6.22) than Kuroiler (6.00). According to Ristic and Damme[23] threshold pH ranges to be considered for standard meat properties are 5.9-6.2, while meat with pH-value $\leq$5.8 is considered Pale, Soft and Exudative (PSE) condition and $\geq$6.3 Dark, Firm and Dry (DFD) condition. Thus,

Table 1: Effect of breed on carcass characteristics and non-carcass traits

	Breeds			
Carcass traits	Sasso	Kuroiler	SEM	p-value
Slaughter weight (g)	2178.33	2169.53	43.70	0.9588
Carcass weight (g)	1498.72	1449.68	33.55	0.5420
Dressing percent (%)	68.80[a]	66.84[b]	0.34	0.0009
Breast weight (g)	401.55	375.40	10.72	0.0876
Thigh weight (g)	247.02	252.67	6.06	0.5116
Drumstick weight (g)	236.95	240.87	4.92	0.5747
Back weight (g)	307.30	313.02	8.24	0.6248
Wing weight (g)	192.30	187.67	4.17	0.4344
Neck weight (g)	93.83	95.58	2.61	0.6369
Non-carcass traits				
Head weight (g)	68.13	71.40	1.24	0.0666
Shank weight (g)	86.85	88.93	1.46	0.3155
Gizzard weight (g)	56.12[b]	61.05[a]	1.22	0.0050
Liver weight (g)	42.32	44.53	1.55	0.3137
Heart weight (g)	9.48	9.80	0.32	0.4858
Spleen weight (g)	3.10	3.07	0.11	0.8277
Intestine weight (g)	133.95	141.50	3.83	0.1664
Blood weight (g)	72.73[a]	67.52[b]	1.66	0.0288
Feather weight (g)	226.63	231.40	6.33	0.5959

[ab] Least significant means values having different superscripts in a row differ significantly at $p<0.05$

Table 2: Effect of breed on chicken meat tenderness, pH and meat color

		Breeds			
Quality traits	Joint	Sasso	Kuroiler	SEM	p-value
pH	Breast	5.80	5.81	0.02	0.5706
	Thigh	6.01	6.03	0.02	0.5224
	Drumstick	6.22[a]	6.00[b]	0.02	0.0001
Colour					
L*	Breast	55.64	55.29	0.80	0.7577
	Thigh	49.99	50.15	0.61	0.8530
	Drumstick	56.49[b]	58.18[a]	0.60	0.0523
a*	Breast	4.48[b]	7.32[a]	0.35	0.0001
	Thigh	13.36	13.84	0.53	0.5237
	Drumstick	10.31[b]	12.60[a]	0.48	0.0010
b*	Breast	5.80[b]	8.71[a]	0.37	0.0001
	Thigh	7.90	8.40	0.35	0.3075
	Drumstick	9.71[b]	11.21[a]	0.39	0.0075
Cooking loss (%)	Breast	20.15[a]	15.80[b]	0.53	0.0001
	Thigh	23.46	22.28	0.64	0.1944
	Drumstick	21.24[a]	18.61[b]	0.60	0.0026
Shear force (N)	Breast	36.20[a]	32.86[b]	0.86	0.0051
	Thigh	32.44	31.90	0.56	0.4961
	Drumstick	27.73	27.79	0.54	0.9364

[ab]Least significant means values having different superscripts in a row differ significantly at $p< 0.05$. L*: Lightness, a*: Redness, b*: Yellowness

the pH-values observed in the present study are within acceptable standard meat properties quality.

Values for redness (a*) and yellowness (b*) measured at breast and drumstick joints were higher ($p<0.05$) in Kuroiler than in the Sasso breed (Table 2). However, the two breeds did not differ in values for lightness (L*) from all the joints or redness (a*) and yellowness (b*) from the thigh joint. Results from the present study differ from the observation by Bianchi *et al.*[24], who compared Cobb 500 and Ross 508 strains and found no difference in broiler breast meat color based on the genotype of the bird. Brewer *et al.*[25] found that the strain of broiler did not have a major effect on breast filet color. Contrary to the present findings, Abdullah *et al.*[26] found that the breast meat in Lohmann broilers was less light in color (L* value 51.14) than in Hubbard (L* value 53.32), even though the pH of the breast meat was essentially identical. Comparing a slow-growing French label-type line and a fast-growing standard line of commercial chickens, Debut *et al.*[27] found that

Table 3: Effect of breed on proximate composition of meat from genetically improved chicken

		Breeds			
Parameters (%)	Joint	Sasso	Kuroiler	SEM	p-value
Dry matter	Breast	26.44	25.92	0.46	0.4278
	Thigh	25.7	24.42	0.29	0.0735
	Drumstick	24.58	24.37	0.27	0.5590
Ash	Breast	4.99[a]	3.84[b]	0.17	0.0001
	Thigh	5.36[a]	4.29[b]	0.16	0.0001
	Drumstick	5.19[a]	4.39[b]	0.17	0.0015
Crude protein	Breast	23.91[a]	22.51[b]	0.23	0.0001
	Thigh	21.61[a]	20.64[b]	0.23	0.0029
	Drumstick	21.28[a]	20.18[b]	0.23	0.0010
Ether extract	Breast	3.39	3.32	0.15	0.7649
	Thigh	3.96	3.72	0.13	0.2123
	Drumstick	3.78	3.59	0.13	0.2769

[ab]Least significant means values having different superscripts in a row differ significantly at $p<0.05$

the breast and thigh meat of the fast-growing line was lighter (L* values 52.82 and 51.22, respectively) than that of the slow-growing line (L* values 50.76 and 50.07, respectively). However, a lack of difference in relative lightness (L*) observed in the present study agrees with the findings reported by Mehaffey *et al.*[28] when comparing five commercial broiler strains using breast joint. Lonergan *et al.*[29] compared inbred Leghorn, inbred Fayoumi, commercial broilers, F5 broiler inbred Leghorn cross and F5 broiler-inbred Fayoumi cross and determined that the breast meat of all strains had equivalent L* values but the inbred leghorns had a more intense red color. Color is one of the main indicators of the quality of most foods. This sensorial quality has a high influence on the meat purchase decision and its acceptance by consumers. It is an important functional quality and it is closely related to other qualities, such as pH, water holding capacity, emulsifying capacity and texture[30]. In most cases, color can be considered as an indicator of these properties, which together, will affect acceptability to consumers, shelf life, tenderness, juiciness and suitability of meat for further processing.

Regarding cooking loss, an indicator for water holding capacity, significant ($p<0.05$) difference was noted between breeds on breast and drumstick joints but not on thigh joint (Table 2). Sasso had a higher cooking loss value compared to Kuroiler both for breast and drumstick joints. Water Holding Capacity (WHC) is affected by several factors including rate and extent of pH decline, sarcomere length, ionic strength and proteolysis[31-33]. The fast decline of pH while the carcass temperature is still high leads to protein denaturation, lower WHC and Pale, Soft and Exudative (PSE) meat. On the other hand, the lower extent of pH decline postmortem leads to higher ultimate pH, higher WHC and Dark, Firm and Dry (DFD) meat[34].

Breast joint was observed to be relatively tougher in Sasso than Kuroiler chicken, whereas the two breeds did not differ in tenderness in other joints (Table 2). The values for the two strains are higher than that of semi-scavenging local chickens (26.5N) slaughtered at 20 weeks as reported by Sanka and Mbaga[7] but lower compared to the same birds slaughtered at 28 weeks (43.9 N). The findings are in accordance with Fengli *et al.*[35], who demonstrated that breed had a significant effect on the tenderness of meat in the slow-growing chickens. However, meat from the two breeds can be considered tender because the amount of force required for shearing the sample was less than 50 N. In general, meat with Warner–Bratzler shear force values that exceed 55 N would be considered as objectionably tough both by a trained sensory panel and by consumers[36,37].

Although meat from the two breeds was comparable in dry matter and fat content, Sasso breed had higher ($p<0.05$) ash and protein contents than Kuroiler (Table 3). The values obtained for protein, fat, ash and dry matter contents are within the range of 20-27, 3-9, 4-12 and 24-30%, respectively reported by Sogunle *et al.*[38]. Ash content in meat determines largely the extent to which the dietary minerals would be available in a particular food sample. The variability in the proximate composition of different meat has also been reported by Wattanachant[34], Tougan *et al.*[39] and Mbaga *et al.*[40]. This implies that consumers can have a choice on the meat cut based on its expected nutritional value in addition to other physical attributes, such as tenderness and color.

Effects of diet on carcass characteristic: Birds in D_1 and D_2 were comparable but superior ($p<0.05$) over those in D_3 in terms of killing out characteristics and weights of different carcass joints (Table 4). The superiority of birds in D_1 and D_2

over those in D_3 can be associated with the difference in energy content of the diets whereby D_1 and D_2 had 2887 KCl kg^{-1} ME while D_3 had 2627 kCl kg^{-1} ME. Low cost-formulation (D_3) had low nutrient density, possibly it can be used for local chickens or Sasso and Kuroiler if scavengeable feed resources are adequate. Similar observations were found by Miah *et al.*[41] and Miah *et al.*[42] in the study of indigenous (Desi) chickens reared in rural households in Bangladesh. Weights of non-carcass components largely followed the pattern displayed by killing out characteristics except for the weight of the intestines. Intestine weights were not influenced by the three dietary groups (Table 4) probably because all birds were exposed to scavenging. Scavenging has been associated with lengthening of the intestine in an attempt to increase digestive areas[43].

Effects of diet on meat quality: Diets did not affect ($p>0.05$) the pH value recorded on three carcass joints (Table 5). However, the obtained values are within the range of acceptable pH for quality chicken meat[23]. Diets affected ($p<0.05$) values for lightness (L*) recorded at the thigh joint, redness (a*) recorded at the thigh and drumstick and yellowness recorded at breast and drumstick. Thigh joints from D_1 and D_2 were comparable in lightness (L*) but with lower ($p<0.05$) values than that from D_3. On the other hand, thigh joints from D_1 and D_2 were comparable in redness (a*) but with higher ($p<0.05$) values than that from D_3. Similarly, breast joints from D_1 and D_2 were comparable in yellowness (b*) but with lower ($p<0.05$) values than that from D_3. Smith *et al.*[44] reported that the composition of the poultry ration may affect meat color, whereby poultry fed a wheat-based diet produced significantly lighter colored fillets than poultry fed a corn-based diet. Also according to Fanatico *et al.*[45] and Ponte *et al.*[46] meat color can be influenced by management factors such as feeds and feeding systems. In the present study, the relatively high values of yellowness of breast joint, compared to observations reported in the literature may be due to the access of pastures. Pasture is rich in beta carotenes, a precursor for vitamin A, which are deposited in fat tissue of scavenging/grazing animals as they are fat-soluble. Overall, values for color variables observed in the present study are within the range for acceptable levels as described by Wattanachant *et al.*[10]. Scavenging chickens cannot find all nutrients they need under scavenging land all year round. Moreover, the nutritional quality of scavenging village chickens is low. Thus, there is a need for adopting nutrient supplementation strategies to improve village chicken meat productivity and quality.

Diets affected ($p<0.05$) cooking loss of the breast joint and tenderness of the thigh joint (Table 5). Diet D_2 had the least cooking loss, whereas those on D_1 had the least shear

Table 4: Effect of dietary treatments on carcass characteristics and non-carcass traits of sasso and kuroiler chickens

	Dietary treatments				
Carcass traits	Commercial (D_1)	Medium-cost formulated (D_2)	Low-cost formulated (D_3)	SEM	p-value
Slaughter weight (g)	2362.15^a	2245.92^a	1931.72^b	53.53	0.0001
Carcass weight (g)	1625.32^a	1540.37^a	1286.90^b	41.09	0.0001
Dressing percent (%)	68.81^a	68.58^a	66.62^b	0.42	0.0008
Breast weight (g)	426.70^a	403.92^a	334.80^b	13.12	0.0001
Thigh weight (g)	273.75^a	259.20^a	216.57^b	7.43	0.0001
Drumstick weight (g)	259.37^a	250.80^a	206.55^b	6.02	0.0001
Back weight (g)	343.32^a	323.85^a	263.30^b	10.09	0.0001
Wing weight (g)	204.80^a	195.80^a	169.35^b	5.11	0.0001
Neck weight (g)	108.92^a	94.97^b	80.22^c	3.20	0.0001
Non-carcass traits					
Head weight (g)	76.67^a	69.92^b	62.70^c	1.52	0.0001
Shank weight (g)	91.07^a	90.20^a	82.40^b	1.79	0.0013
Gizzard weight (g)	61.65^a	57.47^b	56.62^b	1.49	0.0424
Liver weight (g)	45.30^a	47.15^a	37.82^b	1.89	0.0018
Heart weight (g)	10.30^a	10.32^a	8.30^b	1.39	0.0003
Spleen weight (g)	3.65^a	3.02^b	2.57^c	0.13	0.0001
Intestine weight (g)	140.75	140.67	131.75	4.69	0.3003
Blood weight (g)	77.47^a	70.67^b	62.22^c	2.04	0.0001
Feather weight (g)	256.17^a	231.25^b	199.62^c	7.56	0.0001

^{abc}Least significant means values having different superscripts in a row differ significantly at $p<0.05$

Table 5: Effect of Dietary treatments on genetically improved chicken meat tenderness, pH and meat color

Quality traits	Joint	Dietary treatments D_1	D_2	D_3	SEM	p-value
pH	Breast	5.82	5.80	5.78	0.02	0.2637
	Thigh	6.06	6.02	5.97	0.03	0.0847
	Drumstick	6.13	6.11	6.09	0.03	0.5752
Colour						
L*	Breast	55.71	55.89	54.79	0.98	0.6988
	Thigh	48.87^b	49.78^b	51.56^a	0.75	0.0394
	Drumstick	57.09	57.84	57.07	0.74	0.7079
a*	Breast	5.13	6.51	6.06	0.43	0.0742
	Thigh	14.85^a	14.35^a	11.60^b	0.65	0.0013
	Drumstick	12.29^a	10.07^b	12.01^a	0.58	0.0164
b*	Breast	6.94^b	6.58^b	8.25^a	0.45	0.0269
	Thigh	8.38	8.07	7.99	0.42	0.7916
	Drumstick	10.90^a	8.69^b	11.78^a	0.48	0.0001
Cooking loss (%)	Breast	17.92^b	16.16^c	19.85^a	0.65	0.0006
	Thigh	22.13	22.39	24.10	0.78	0.1579
	Drumstick	19.78	19.14	20.84	0.74	0.2600
Shear force (N)	Breast	34.63	35.91	33.05	1.03	0.1531
	Thigh	30.32^b	33.27^a	32.93^a	0.68	0.0031
	Drumstick	28.66	26.95	27.67	0.65	0.1727

[abc] Least significant means values having different superscripts in a row differ significantly at p<0.05, L*: Lightness, a*: Redness, b*: Yellowness

Table 6: Effect of dietary treatments on genetically improved chicken meat proximate composition and meat bone ratio

Parameters (%)	Joint	Dietary treatments D_1	D_2	D_3	SEM	p-value
Dry matter	Breast	25.85	25.73	26.94	0.57	0.2573
	Thigh	25.01	24.95	24.42	0.36	0.4375
	Drumstick	24.06	24.49	24.87	0.33	0.2312
Ash	Breast	4.74^a	4.58^a	3.93^b	0.21	0.0166
	Thigh	4.76	5.13	4.58	0.20	0.1351
	Drumstick	4.89	4.88	4.61	0.21	0.5835
Crude protein	Breast	23.84^a	23.05^{ab}	22.74^b	0.28	0.0202
	Thigh	20.89	21.04	21.44	0.28	0.3617
	Drumstick	20.71	20.71	20.78	0.28	0.9823
Ether extract	Breast	3.36	3.66	3.05	0.18	0.0596
	Thigh	3.78	3.78	3.96	0.16	0.6693
	Drumstick	3.98^a	3.71^{ab}	3.38^b	0.16	0.0261

[abc] Least significant means values having different superscripts in a row differ significantly at p<0.05

force. This difference could be explained by the fact that birds fed D_1 probably met most of the nutrient requirements from the feed, thus spent less time scavenging. The intensity of activity to which meat-producing animal is subjected to affect meat tenderness by influencing the degree of crosslink formation in the collagen fibres[47,48]. The shear-force and cooking loss values obtained in the present study are within the range of the values reported by Sanka and Mbaga[49] in the study of meat quality attributes of Tanzanian local chicken reared under the intensive and semi-intensive system of production.

Birds on D_1 and D_2 diets were comparable but higher ($p<0.05$) in ash and crude protein contents in the breast joint and fat content in the drumstick than D_3 birds (Table 6). The observed variation in protein contents of the joints is attributable to the difference in content and composition of dietary protein. According to Hussain *et al.*[50] and Ferreira *et al.*[51] amino acid deficiency can lead to protein decrease in meat. D_3 diet had no synthetic lysine and methionine and was lower in energy content than the rest. This indicates that variation in the dietary concentration of essential dietary amino acids has a significant impact on the proximate composition of meat. The observed variation in fat content is consistent with the difference in energy contents among diets, with D_1 having similar energy content to D_2, both of which were higher than that of D_3. In agreement with an observation

Table 7: Effect of level of feed supplementation on carcass characteristics and non-carcass traits of sasso and kuroiler chickens

	Level of feed supplementation					
Carcass traits	Full feeding (100%)	75%	50%	25%	SEM	p-value
Slaughter weight (g)	2647.23[a]	2330.40[b]	1949.07[c]	1793.03[c]	61.81	0.0001
Carcass weight (g)	1825.20[a]	1596.70[b]	1318.10[c]	1196.80[c]	47.44	0.0001
Dressing percent (%)	68.79[a]	68.35[ab]	67.27[bc]	66.28[c]	0.48	0.0018
Breast weight (g)	477.83[a]	420.17[b]	341.80[c]	314.10[c]	15.15	0.0001
Thigh weight (g)	301.93[a]	269.53[b]	226.07[c]	201.83[d]	8.58	0.0001
Drumstick weight (g)	292.43[a]	257.43[b]	215.60[c]	190.17[d]	6.96	0.0001
Back weight (g)	369.73[a]	337.83[b]	277.57[c]	255.50[c]	11.65	0.0001
Wing weight (g)	232.90[a]	200.70[b]	172.33[c]	154.00[d]	5.90	0.0001
Neck weight (g)	122.87[a]	101.37[b]	81.27[c]	73.33[c]	3.69	0.0001
Non-carcass traits						
Head weight (g)	81.93[a]	72.27[b]	63.80[c]	61.07[c]	1.76	0.0001
Shank weight (g)	101.97[a]	93.93[b]	80.13[c]	75.53[c]	2.06	0.0001
Gizzard weight (g)	62.43[a]	64.47[a]	57.07[b]	50.37[c]	1.72	0.0001
Liver weight (g)	46.20[a]	51.13[a]	39.03[b]	37.33[b]	2.19	0.0001
Heart weight (g)	11.70[a]	10.13[b]	8.83[c]	7.90[c]	0.45	0.0001
Spleen weight (g)	4.20[a]	3.00[b]	2.60[bc]	2.53[c]	0.15	0.0001
Intestine weight (g)	154.73[a]	145.67[ab]	133.57[b]	117.13[c]	5.41	0.0001
Blood weight (g)	96.13[a]	74.77[b]	59.97[c]	49.63[d]	2.35	0.0001
Feather weight (g)	270.80[a]	253.70[a]	198.77[b]	192.80[b]	8.96	0.0001

[abcd] Least significant means values having different superscripts in a row differ significantly at p<0.05

from the present study, Ferreira *et al.*[51] reported lower fat content in meat from birds fed diets with lower energy levels.

Effects of level of feed supplementation on carcass characteristics: Slaughter weight decreased by 12, 26 and 32% when the feed was reduced to 75, 50 and 25% of recommended daily allowance, respectively (Table 7). Thus, the higher the level of feeding, the higher the slaughter weight and carcass yield which in turn influenced all other carcass components in that order. However, there was no significant difference in dressing percentage, spleen weight and intestinal weight between birds receiving 75 and 50% supplementation levels. Miah *et al.*[42] fed diets of different energy levels to Desi chicken reared at rural households under tropical conditions in Bangladesh and found a similar trend of higher meat yield with higher levels of supplementation. Jahanpour *et al.*[52] also reported that birds kept on a feeding program regime with just 75% of the daily feed allowance had heavier carcasses than those in the less fed group.

Effects of level of feed supplementation on meat quality: Thigh and drumstick joints from birds receiving 100% supplementation level had lower (p<0.05) pH at slaughter than the rest (Table 8). pH at slaughter is affected by several factors including glycogen reserves in muscles and the extent of pre-slaughter stress[53]. Since birds were subjected to similar pre-slaughter handling, the observed difference in pH may be attributable to glycogen reserves, which might have been higher in birds receiving a 100% supplementation level. The L* and b* value in the breast joint tended to increase with a reduction in supplementation level. The increase in yellowness (b*) value with a reduction in supplementation levels might be attributed to an increase in the intake of fresh forages. As indicated above, fresh forages are rich in beta carotenes (vitamin A precursors) that impart yellow color on carcass fat[54]. Cooking loss in the breast and drumstick joints decreased (p<0.05) with a decrease in the level of supplementation. As mentioned above, cooking loss, which is a measure of the water holding capacity of meat, is affected by several factors. Normally, meat with high-fat content tends to have low water content and lower cooking loss[34]. However, based on the proximate composition meat from birds on different levels of supplementation in the present study did not differ in fat content (Table 9). The shear force value for thigh and drumstick joints increased (p<0.05) when supplementation levels were reduced. The birds under low supplementation levels had to scavenge more to meet their daily requirements and hence exercised more than those on high levels of supplementation. However, meat from all the experimental groups can be considered tender as it required less than 50N to shear through[14].

Results presented in Table 9 show that birds on a 100% level of supplementation had the highest content of crude protein for all the three carcass joints but, the lowest dry matter content in the breast joint. The observed variation in meat protein content in birds on different levels of supplementation might reflect the difference in the quality of protein obtained from concentrate and forages. Birds on a

Table 8: Effect of level of feed supplementation on genetically improved chicken meat tenderness, pH and meat color

		Level of feed supplementation					
Quality traits	Joint	Full feeding (100%)	75%	50%	25%	SEM	p-value
pH	Breast	5.79	5.79	5.80	5.79	0.02	0.3837
	Thigh	5.91^{b}	6.00^{a}	6.08^{a}	6.07^{a}	0.03	0.0013
	Drumstick	5.97^{b}	6.14^{a}	6.15^{a}	6.19^{a}	0.03	<.0001
Color							
L*	Breast	52.11^{b}	54.91^{ab}	57.20^{a}	57.63^{a}	1.13	0.0016
	Thigh	50.73^{ab}	51.30^{a}	48.02^{c}	50.22^{b}	0.87	0.0478
	Drumstick	60.32^{a}	55.36^{c}	50.29^{d}	57.37^{b}	0.85	0.0006
a*	Breast	5.55	6.40	5.76	5.90	0.49	0.6575
	Thigh	13.71	12.95	15.24	12.49	0.76	0.0614
	Drumstick	9.78^{c}	12.31^{a}	12.59^{a}	11.13^{b}	0.67	0.0162
b*	Breast	5.93^{b}	7.80^{a}	6.97^{b}	8.34^{a}	0.52	0.0089
	Thigh	7.18^{b}	7.77^{a}	8.94^{a}	8.70^{a}	0.49	0.0447
	Drumstick	8.91^{b}	10.85^{a}	11.44^{a}	10.63^{a}	0.55	0.0109
Cooking loss (%)	Breast	20.23^{a}	18.22^{b}	17.41^{bc}	16.06^{c}	0.75	0.0017
	Thigh	23.74	23.65	22.45	21.65	0.90	0.2977
	Drumstick	22.69^{a}	20.17^{b}	18.81^{c}	18.01^{c}	0.85	0.0011
Shear force (N)	Breast	33.05	33.75	33.45	33.96	1.18	0.1918
	Thigh	29.13^{c}	31.95^{bc}	32.85^{b}	34.76^{a}	0.83	<.0001
	Drumstick	25.09^{c}	26.62^{bc}	27.76^{b}	31.57^{a}	0.76	<.0001

^{abcd}Least significant means values having different superscripts in a row differ significantly at p<0.05. L*: Lightness, a*: Redness, b*: Yellowness

Table 9: Effect of Level of feed supplementation on genetically improved chicken meat proximate composition and meat bone ratio

		Level of feed supplementation					
Parameters	Muscle	Full feeding (100%)	75%	50%	25%	SEM	p-value
Dry matter (%)	Breast	24.75^{b}	28.12^{a}	26.20^{b}	25.63^{b}	0.65	0.0039
	Thigh	24.31	25.26	25.21	24.40	0.41	0.2132
	Drumstick	24.47	24.88	24.54	23.99	0.38	0.4235
Ash (%)	Breast	3.91	6.62	4.62	4.51	0.24	0.1218
	Thigh	5.00	4.55	4.68	5.06	0.23	0.3195
	Drumstick	4.57	4.68	4.71	5.20	0.24	0.2740
Crude protein (%)	Breast	24.63^{a}	22.29^{c}	23.20^{b}	22.72^{bc}	0.35	0.0001
	Thigh	22.26^{a}	21.16^{b}	20.86^{bc}	20.22^{c}	0.34	0.0008
	Drumstick	21.71^{a}	20.71^{b}	20.01^{b}	20.50^{b}	0.35	0.0116
Ether extract (%)	Breast	3.65	3.35	3.16	3.25	0.21	0.3745
	Thigh	4.02	3.79	3.78	3.76	0.19	0.7245
	Drumstick	3.75	3.63	3.91	3.48	0.18	0.3903

^{abcd} Least significant means values having different superscripts in a row differ significantly at p<0.05

lower level of supplementation scavenged more on forages to meet their daily requirements, including protein. The contents of proteins, lipids and minerals observed in the present study are within the range (18.4-23.4, 1.3-6.0 and 0.8-1.2%) recommended for good quality chicken meat[43,55]. Minh and Ogle[56] studied improved dual-purpose growing chickens and concluded that supplementation increases the nutritional values of chicken meat under the scavenging system of production.

The results from this study imply that supplementation of scavenging chickens is required to balance for missing nutrients from scavenged feeds. Consequently, balanced nutrients will improve both the yield and quality of meat. To improve meat yield and quality of dual-purpose improved chickens under a semi-intensive system of production, it is recommended that a cost-effective supplementation strategy be adopted depending on available scavengable feed resources.

CONCLUSION

The question of what diet and at what level of supplementation to be used for semi-scavenging improved dual-purpose chickens has been studied in the current study. It is concluded that commercial (D_1) and medium-cost formulated feed (D_2) gave significantly higher slaughter and carcass weight than the low-cost formulations (D_3). Hence, for semi-scavenging chickens, a higher level of supplementation influenced positively both carcass and non-carcass yields. Feeding regime affects meat colour, cooking loss, tenderness and proximate composition of genetically improved dual-purpose chicken in a joint-specific fashion. Therefore, the choice of what type of feed and levels of supplementation will depend on cost-benefit analysis and availability of scavengable feed resources.

SIGNIFICANCE STATEMENT

This study discovers the effects of the plane of nutrition of supplementary feeds on carcass and meat quality of semi-scavenging genetically improved dual-purpose chicken. The findings from this study will serve poultry keepers with options to choose from when deciding on the strategy to finish feed dual-purpose chickens such as Sasso and Kuroiler.

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