EVALUATION OF PRODUCTION PERFORMANCE AND MEAT QUALITY OF TANZANIAN LOCAL CHICKEN REARED UNDER INTENSIVE AND SEMI-INTENSIVE SYSTEMS OF PRODUCTION

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EXTENDED ABSTRACT

Local chicken farmers can improve the performance and quality of indigenous chicken meat by modifying the production systems and age at slaughter. However, in Tanzania there is paucity of information on effect of production systems and age at slaughter of local chicken on growth performance, carcass characteristics and meat quality. The effects of rearing systems, sex and age at slaughter on growth performance, carcass traits, meat tenderness, cooking loss and pH of Tanzanian local chicken were investigated. Ninety six local weaned chicks (two months old) were bought from farmers in Morogoro peri-urban and raised in two different rearing system viz. intensive and semi-intensive systems. The birds were initially weighed and randomly assigned to each rearing system with equal number of males and females (48 birds per system); and were housed in deep litter pens with a spacing of 4 birds/m^2. Birds under semi-intensive system had free access to grassy paddock (1 bird/10 m^2). In both groups, birds were given a diet containing 19% CP and 2679 KJ ME with semi-intensive birds getting half of the amount given to intensive birds. At the end of the experiment, a random sample of 24 males and 24 females in each rearing system were slaughtered at five and seven month and carcass parts viz. breast, thigh and drumstick separated. Pieces of meat from these parts were used for tenderness, cooking loss and pH evaluations. The results showed that body weights at slaughter and body weight gain of birds from semi-intensive system were significantly lower than those kept in intensive system. There was no difference in dressing percentage between the two rearing systems, the values being 65.2% and 65.7% for intensive and semi-intensive respectively. Dressing percentage was higher (67.7%) at seven month than at five month of age (63.2%). The rearing systems significantly affected the breast percentage, being higher in semi-intensive (25.1%) compared to intensive system (23.3%). Thigh percentage was not influenced by rearing system or slaughter age, while drum stick percentage was significantly lower at seven month old bird compared to five month old birds. There was no significant difference in breast, thigh and drumstick meat tenderness for birds reared under intensive and semi-intensive systems. Meat from chicken slaughtered at seven month was much tougher (43.9N) than meat from birds slaughtered at five month age (26.5N). The cooking loss of male breast and thigh meat under intensive system were significantly lower than that of birds under semi intensive system. Likewise, higher cooking losses were obtained for birds slaughtered at seven month (21%) compared to birds slaughtered at five month (10%). Rearing systems did not influence meat pH, though female breast under semi intensive system tended to have higher pH values (6.05) than those under intensive system (5.96). There was also an increase in pH value of male thigh and drumstick meat with advanced slaughter age. From the study, it is concluded that local chicken with modest supplementation and assuming availability of scavenging feed resources, semi-confinement system of chicken rearing could be more appropriate for the small holder poultry keepers. Meat tenderness, cooking loss and pH values from both systems were of acceptable standard however, the overall quality of meat was reduced with increased age at slaughter. Thus, to attain tender meat farmers should strive to improve management of their birds to reach slaughter weights at younger age.

DECLARATION

I, **Yeremia Daniel Sanka**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

_____________________________ _____________________

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The above declaration is confirmed by:

_________________________________ _______________

Dr. Said H. Mbaga Date

(Supervisor)

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DEDICATIONS

This dissertation is dedicated to my lovely wife, Paschalina and my son Ivan.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADG	Average daily gain
ANOVA	Analysis of variance
CP	Crude protein
DF	Degree of freedom
FAO	Food and Agricultural Organization
FCR	Feed conversion ratio
GLM	General linear model
IN	Intensive
KJ	Kilojoule
ME	Metabolizable energy
MLFD	Ministry of Livestock and Fisheries Development
N	Newton
n	Sample size
NBS	National Bureau of Statistics
SAS	Statistical Analysis Software
SEM	Standard error of mean
SF	Shearforce
SFB	Scavenging feed base
SIN	Semi-intensive
SUA	Sokoine University of Agriculture
WHC	Water holding capacity

CHAPTER ONE

1.0 INTRODUCTION

The quality attributes of food products, including poultry meat, have been attracting an increasing interest in recent years (Mikulski *et al.,* 2011). Meat quality is determined amongst others, by age at slaughter, breed, nutrition, and management (Castellini *et al.,* 2008). White meat such as chicken meat is known for its superiority in health aspects compared to red meat because of its low content of fat and cholesterol (Jaturasitha *et al*., 2008). Shaarani *et al*. (2006) reported that cholesterol was far lower in the breast and thigh meat of the indigenous chicken strains compared to the imported breeds. In a study by Jaturasitha *et al*. (2008), meat from Black-boned chickens had relatively low contents of saturated fatty acids which provide a successful product for a niche market serving consumers who prefer low fat chicken meat.

Post-mortem pH, meat texture and water holding capacity are some of the important physical meat quality attributes in chickens. For example, low pH is associated with poor water holding capacity and poor functionality (Owens *et al*., 2000; Woelfel *et al*., 2002) and a high pH is related to poor shelf life because it provide a conducive environment for bacterial growth. Generally, slow-growing village chickens are more susceptible to shackling stress than fast-growing broiler breeds. In village chickens, shackling stress results in faster breast muscle acidification whilst in exotic breeds' the pH decline is much slower (Debut *et al*., 2005). Also, village chickens have more motor activities than exotic commercial breeds which are normally reared under confinement for most of their production life-time, rendering outdoor kept birds to result into meat with lower pH and tougher meat (Culioli *et al*., 1990; Castellini *et al*., 2002).

Previous studies by Lonergan *et al*. (2003) and Fanatico *et al*. (2005) indicated a higher cooking loss in slow-growing village chickens than fast-growing broiler chickens; a phenomenon related to the higher fat content in the fast growing chickens. If total moisture loss is considered, slow-growing genotypes lose more moisture than the fast-growing genotypes. Santos *et al*. (2005) reported that the breast meat of a slow-growing genotype had poorer water holding capacity (WHC) than a fast-growing genotype and indoor fast-growing broiler chickens tends to have more drip loss than slow-growing village chickens (Fanatico *et al.,* 2007). In addition, texture, particularly tenderness is an important attribute that consumers consider when purchasing chicken meat (Fanatico *et al*., 2007). Meat tenderness also depends on muscle type and the more tender the meat the more acceptable it is to the consumers (Waskar *et al.,* 2009).

Age also has been found to affect meat quality. According to Katarzyna (2011) the duration of rearing slow-growing chickens had a significant effect on most physico-chemical properties of their meat. In breast and leg muscles, pH at 24h tended to be significantly higher in older chickens. The muscles of chickens slaughtered at different age exhibited differences in water holding capacity. However, in Tanzania there is paucity of information on effect of production systems and age at slaughter of local chicken on growth performance, carcass characteristics and meat quality.

These attributes are very important for developing poultry meat standards for local chicken ecotypes. The main objective of this study was to evaluate factors influencing production performance and meat quality of Tanzania local chickens.

The specific objectives of the study were to:

i. Evaluate the effects of rearing systems, sex and slaughter age on local chicken growth performance and carcass characteristics (Paper I)
ii. Determine the effects of rearing systems and slaughter age on local chicken meat tenderness, cooking loss and meat pH (Paper II)

CHAPTER TWO

2.0 MATERIALS AND METHODS

A total of 96 local weaned chicks (two months old) were bought from farmers in Morogoro peri-urban and reared under two different rearing system viz. intensive and semi-intensive systems. The birds were initially weighed and randomly assigned to each rearing system with equal number of males and females (48 birds per system). Two pens with deep litter were used to house the birds. Spacing for birds in both systems was 4 birds/m^2. Birds under semi-intensive system had free access to grassy paddock (1 bird/10 m^2). In both groups, birds were given a formulated diet containing 19% CP and 2679 KJ ME (Appendix 25) with semi-intensive birds getting half of the amount given to intensive birds. The amount of feed given to the birds under intensive system was increased according to their requirements so as to ensure that the birds are getting the right amount as they progress to grow. On average the amount of feed give to the birds under intensive and semi-intensive system was 86g and 43g respectively per day per bird from 2nd month to 5th and or 7th month of slaughter age. Semi-intensive birds were released to scavenge at 7:00 am and they were given the supplemental feed during the evening hours of the day. All birds were weighed initially and thereafter, once per month.

At the end of the experiment, a random sample of 24 males and 24 females in each rearing system were slaughtered at five and seven month and carcass parts viz. breast, drumstick and thigh separated. Pieces of meat from these parts were used for tenderness, cooking loss and pH evaluations. The birds were fasted for 12 hours, weighed individually and slaughtered by manual exsanguinations. The carcass was eviscerated and the warm carcass weighed. This was followed by removal and weighing of carcass parts mainly; the breast, thigh and drumstick. The dressing percentage was expressed as percentage of eviscerated carcass to the live body weight after fasting. The breast, thigh and drumstick weights were expressed as percentage of dressed carcass weight. Meat pH was measured by a spear-end digital portable pH meter (Knick Portamess ® 910, Germany) at 45 minutes post-mortem. The pH meter was standardized by a two-point method against buffers of pH 4.0 and pH 7.0 standard solutions before measurement of each sample. In this regard, a total of 96 samples for each of the muscle part were used.

During cooking loss and tenderness measurement, forty five minutes post-slaughter raw breast, thigh and drumstick muscle (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^{o}C for 45 minutes as described by Rizz *et al*. (2007). Then, the samples were cooled in running water for 15 minutes, dried with soft tissue and weighed. Cooking loss was calculated as percentage loss of weight during cooking relative to the weight of raw muscle (Petracci and Baéza, 2009). Strips measuring about 1.0×1.0×2.5 cm parallel to the muscle fibres were prepared from cooked breast, thigh and drumstick muscle portion and sheared vertically using Warner-Bratzler shear force device. The shear force values were recorded in Newtons (N). Data collected were analysed using a General Linear Model (GLM) procedure in SAS Software System (SAS, 2006) and student's test with probability of $p<0.05$ was used to assess significance differences between mean values.

CHAPTER THREE

3.0 GENERAL RESULTS, DISCUSIONS AND CONCLUSIONS

3.1 Growth Performance

The results indicated that, the weight gain of chickens in the semi-intensive system was significantly ($P<0.05$) lower (9.84 g/d) than in the intensive system (11.95 g/d), the difference being about 21%. However, birds under semi-intensive system were more efficient in feed conversion ratio. These results are similar to those reported by Mutayoba *et al.* (2012); Magala *et al.* (2012); Dou *et al.* (2009) and Castellini *et al*. (2002) who reported growth rate and feed efficiency in scavenging, free-range and outdoor organic rearing respectively to be lower than in intensive rearing system.

3.2 Carcass Traits Performance

There was no significant difference between dressing percentage in the two rearing systems, the value being 65.2% and 65.7% for birds under intensive and semi-intensive system respectively. The results conform to those reported by Dou *et al.* (2009), Cheng *et al.* (2008), Fanatico *et al.* (2005) and Raach-Moujahed and Haddad (2013). Likewise, there was no significant difference in dressing percent between males and females within slaughter age, the average values being 66.2 and 64.7 percentages for males and females, respectively. However, birds slaughtered at seven month had significantly higher carcass percent (67.7) than those at five month (63.2%). The higher dressing percentage in 7 month birds is expected since, as birds increase in weight there is proportionate increase in muscle and other tissues except bones which at 5^{th} month are most likely to have approached peak growth.

3.3 Meat Tenderness, Cooking Loss and pH

The results show that breast, thigh and drumstick meat from both male and female birds were not influenced ($P>0.05$) by the rearing system. The similarity of effects of rearing system on meat tenderness in the current study could be explained by reduced movements of semi-confined birds. This implies that under semi-confinement, birds have nearly equal movements to those under full confinement. The findings are in accordance with Fanatico *et al.* (2005) and Dou *et al.* (2009) who demonstrated that production system had no effect on tenderness of meat in the slow-growing broilers.

The cooking loss of male breast and thigh meat from birds reared under intensive system was lower than that of semi-intensive reared birds. These results in the current study agree with those of Castellini *et al*. (2002) and Fanatico *et al*. (2007) who observed that outdoor (free range) reared birds have lower cooking loss than birds reared indoors. Furthermore, rearing system did not influence meat pH at 45 minutes post-slaughter although the general trend was for pH to be slight lower in meat cuts from semi-intensive system.

The pH values obtained in the current study at 45 minutes post-slaughter are within the range of 6.16 to 6.31 for 15 minutes and 1 hour post-slaughter respectively reported by Raach-Moujahed and Haddad (2013). Woelfel *et al.* (2002) reported that at a pH of 5.4 to 6.2 the meat is normally considered to be of high quality.

3.4 Conclusion and Recommendations

3.4.1 Conclusions

It is concluded that rearing system had a significant influence on slaughter weight, weight gain and breast percent but, had little influence on meat quality in terms of tenderness and pH at 45 minutes post slaughter. Birds slaughtered at five month yielded more tender meat with lower cooking loss.

3.4.2 Recommendations

In the light of the results of this study, it is recommended that smallholder local chicken farmers should use semi-intensive system for local chickens rearing as this reduce the cost of rearing compared to intensive system and yet produce acceptable tender meat. Furthermore, farmers should be encouraged to sell their local chickens at younger age of between 5 and 7 months if birds are intended for slaughter.

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CHAPTER FOUR

4.0 LIST OF PAPERS

4.1 Paper I: Evaluation of Tanzanian Local Chicken Reared under Intensive and Semi-intensive Systems: I. Growth Performance and Carcass Characteristics

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Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: I. Growth performance and carcass characteristics

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Abstract
The objective of this study was to determine the effect of rearing systems, sex and age at slaughter on growth performance and carcass traits of local chicken. A total of 96 local weaned chicks (two months old) were bought from farmers in Morogoro peri-urban and reared under two different rearing system viz. intensive and semi-intensive systems. The birds were initially weighed and randomly assigned to each rearing system with equal number of males and females (48 birds per system). Two pens with deep litter were used to house the birds. Spacing for birds in both systems was 4 birds/m^2. However, birds under semi-intensive system had free access to grassy paddock (1 bird/10m^2). All birds were offered the same diet with semi-intensive group receiving half of what was offered to the intensive group. Random sample of 24 males and 24 females in each rearing system were slaughtered at five and seven month.

Body weights at slaughter and body weight gain of birds from semi-intensive system were significantly lower than of those kept in intensive system. There was no difference in dressing percentage between the two rearing systems, the values being 65.2% and 65.7% for intensive and semi-intensive respectively. Dressing percent was higher (67.7%) at seven month than at five month of age (63.2%). The rearing systems significantly affected the breast percentage, being higher in semi-intensive (25.1%) compared to intensive system (23.3%). Thigh percent was not influenced by rearing system or slaughter age, while drum stick percent was significantly lower at seven month old bird compared to five month old birds. From the study, it is concluded that local chicken with modest supplementation and assuming availability of scavenging feed resources, semi-confinement system of chicken rearing could be more appropriate for the small holder poultry keepers.

Keywords: Age at slaughter, foraging, rearing system, scavenging, SFB

Introduction
Poultry, particularly chickens are the most widely kept and most numerous livestock species in the world (Perry et al 2002; Moreki et al 2010). Local chickens are widely distributed in rural and peri-urban areas where they play the important role of income

generation, food production and social aspect (Mwalusanya et al 2001; Thornton et al 2002; Moreki et al 2010). In Tanzania, local chickens makeup over 70% of the total chicken population and supply most of the poultry meat and eggs for domestic market (MLFD 2012). Local chickens are reared under different production systems, mainly scavenging, semi-intensive system and to a lesser extent intensive systems. Free range system is dominant in most rural areas and has been practiced for many years in Africa (Sonaiya 1990 and Kitalyi 1998). Although requiring minimal resource input and considered secondary to other agricultural activities by farmers, this type of production has many limitations including diseases, predators and poor growth rate (Mwalusanya et al 2001; Mutayoba et al 2012). Furthermore, scavenging and semi-scavenging are characterized by low plane of nutrition that varies with season (Mwalusanya et al 2002; Goromela et al 2006) ultimately affecting the growth performance.

Presently, most research attempts on local chicken have been focused on increased production, disease management and marketing (Msofe et al 2002; Mwalusanya et al 2002; and Mlozi et al 2003). However, there is an increase in demand of local chicken meat and eggs in Africa owing to their good taste compared to products from exotic commercial strains. In this regard, the increased demand, need to be matched with quality which to a larger extent will depend on the management systems to be adopted. This study therefore investigates the effects of rearing systems, sex and age at slaughter on growth performance and gross carcass characteristics.

Materials and Methods

Study area

The research was conducted at Sokoine University of Agriculture, Department of Animal Science and Production poultry unit. The area is situated 6^{o} S and 37^{o} E and it is about 3 km south of Morogoro town. The area lies on the foot of the slopes of Uluguru Mountain at an elevation of about 500-600m above sea level. The annual rainfall ranges between 600 and 1000 mm per annum and the temperature ranges between 30 ^{o}C and 35 ^{o}C during the hottest months (October to January) and 20 – 27 ^{o}C in the coolest months (April to August).

Experimental design and bird management

A flock of 96 local chickens at two months of age was used with 48 males and 48 female. Two rearing systems were evaluated viz. intensive (full confinement) and semi-intensive (partial confinement). A completely randomized experimental design was applied and males and females were allocated equally in the two rearing systems. Initially the groups were arranged such that the mean body weight in each group was about 519 g. The birds under intensive system were raised on deep litter with a density of 4birds/m^2 in each pen. Temperature was 25±3°C and a relative humidity was 65-75% on average. All birds were group fed with a diet containing 19% CP and 2679KJ ME from 2nd month to 5th and or 7th month of slaughter. On average 86 grams of feed was offered per day to each bird under intensive system.
Birds under semi-intensive system were put in a separate pen (4 birds/m^2), but with a free access to open grassy area (1 bird/10m^2). They were fed half of the amount allocated to birds under intensive system. Feed and water were provided outdoors

using trough feeders and drinkers. Ground predators were excluded by iron sheet fencing. For security reason semi-intensive birds were confined to indoor pens at night.

Data collection

All birds were weighed initially and thereafter, once per month. One half of the birds (n=48) with equal number of males (n=24) and females (n=24) in each rearing system were slaughtered for carcass evaluation at day 150 (approx. 5 month) and the remaining half slaughtered at day 210 (approx. 7 month). The birds were fasted for 12 hours, weighed individually and slaughtered by manual exsanguinations. The carcass was eviscerated and the warm carcass weighed. This was followed by removal and weighing of carcass parts mainly; the breast, thigh and drumstick. The dressing percent was expressed as percent of eviscerated carcass to the live body weight after fasting. The breast, thigh and drumstick weights were expressed as percent of dressed carcass weight.

Data analyses

Data were subjected to analysis of variance using a General Linear Model (GLM) procedure in SAS Software System (SAS 2006). Means were compared using t-test. The following statistical model was used to analyze the effects of rearing system, sex and slaughter age on production and carcass parameters. Interactions were tested but were not significantly different.

$Y_{ijk} = \mu + R_i + S_j + A_k + b(x-\sum x/n)_{ijk} + e_{ijk}$

Where,

Y_{ijk} = an observation for a given variables.

μ = overall mean

R_i = effect of the i^{th} rearing system (i: 1=semi-intensive, 2=intensive)

S_j = effect of the j^{th} sex (j: 1=male, 2=female)

A_k = age at slaughter (k: 1=five month, 2=seven months)

$b(x-\sum x/n)_{ijk}$ = initial weight as covariate

x = initial weight of chicken

$\sum x/n$ = average initial weight

b = regression coefficient

e_{ijk} = residual random error

Results and Discussion

Growth Performance

Figure 1 show that the body weight of chickens reared under intensive system had greater response in body weight beginning week three than those under semi-intensive system. However, at week seven the difference was rather small; the group under intensive system appearing to slow down which could have resulted from inadequate feed intake. The continued growth under semi-intensive system could probably be associated with compensatory effects.

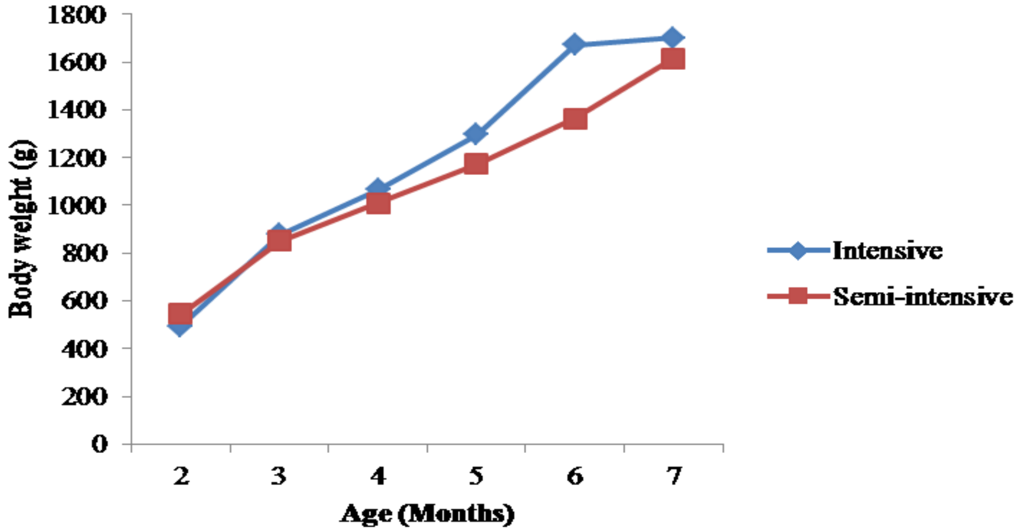

Figure 1: Effect of rearing system and age on live body weight.

On overall, the weight gain of chickens in the semi-intensive system was significantly ($P<0.05$) lower (9.84 g/d) than in the intensive system (11.95 g/d), the difference being about 21% (Table 1). The higher weight of birds kept in full confinement could be explained by higher feed intake, and probably better feed conversion efficiency due to lower energy expenditure for exercise. However, birds under semi-intensive system were more efficient in feed conversion ratio. Birds under partial confinement (semi-intensive) gained less despite the access to range, which provided enough green but, with limitation of energy. It should be noted that birds under semi-intensive system were given only half of the feed that were given to full confined group. These results are similar to those reported by Mutayoba et al (2012); Magala et al (2012); Dou et al (2009) and Castellini et al (2002) who reported growth rate and feed efficiency in scavenging, free-range and outdoor organic rearing respectively to be lower than in intensive rearing system. The ADG ranged from 10.4 to 15.2 g/day in males and 8.4 g/day to 11.6 g/day in females. These results are closer to the average value of 10.81 g/d reported by Raach-Moujahed et al (2011) in Tunisian local chicken, but higher than the value of 6.6 – 8.0g reported by Hassen et al (2006) in Ethiopia. The differences observed in these studies could be attributed to difference in genetic background of the stock used as well as type of management, including feeds.

As expected, body weight at slaughter increased progressively with age and at seven months old, both males and females were heavier compared to five month old birds (Figure 1). Comparison between slaughter ages indicates that under intensive system, the difference in cumulative weight between males and females were about 4% (428.9 g for males and 446.8 g for females). This difference was much higher (10%) under semi-intensive system in favour of males (545.7g for males and 492.2 g for females).

In this study there was a distinct difference in magnitude of decline in growth rate by sex and rearing system. Males under intensive system lost about 4 g between month five and month seven compared to males under semi-confinement (-1.5g). These observations connotes that males under semi-intensive had less stress compared to those under intensive system by having space to escape in case of presence of aggressive males. This probably gave them more access to feed and also explain the higher cumulative weight gain of males under semi-confinement.

The trend in body weight shows that under both systems, birds could be slaughtered at the age of five month and above when birds have attained body weight of more than one kilogram. This implies that if scavenging feed resources are adequate, semi-confinement system of rearing with modest supplementation could thus be more economical for the small holder poultry keepers. Kitalyi (1998) support the contention that free-ranging chicken should be given supplementary feeds depending on seasonal availability of common feed resources. When such feeds are adequate performance of such birds can be improved and the feed costs will always be lower than if birds are fully confined. However, if birds are left to roam freely, the distance moved by the birds in search of feed can have negative effects on growth and ultimately affect slaughter age and meat quality. Nonetheless, body weights at five month old in this experiment are within the range of weights reported for some of the Tanzania ecotypes. For example, Lwelamira et al (2008b) reported body weights of 1295-2318 g for Kuchi ecotype and 1070-2040 g for Medium ecotype under intensive system and 870-1567 g for Kuchi ecotype and 817-1419 g for Medium ecotype under extensive system at the age of 20 weeks. Comparable results were also reported in growth parameters by Hassen et al (2006) in indigenous chickens under intensive management conditions in Northwest Ethiopia.

Table 1: Mean values for growth and feed conversion ratio of local chicken reared under intensive and semi-intensive systems

Traits	Rearing system		SEM	P-value	Sex		SEM	P-value
	Intensive	Semi-intensive			Male	Female		
Slaughter weight (g)	1556	1414	50.79	0.0521	1618	1351	51.9	0.0006
ADG (g/day)	11.95	9.84	0.52	0.0037	12.1	9.67	053	0.0019
FCR(feed/gain)	8.25	5.49	0.55	0.0006	5.77	7.97	0.55	0.0054

ADG = Average daily weight gain, FCR = Feed conversion ratio, SEM = Standard error of mean.

Carcass traits

The effects of rearing system, sex and age on carcass traits are shown in table 2 and figure 2. There was no significant difference between dressing percent in the two rearing systems, the value being 65.2% and 65.7% for birds under intensive and semi-intensive system respectively. The results conform to those reported by Dou et al (2009), Cheng et al (2008), Fanatico et al (2005) and Raach-Moujahed and Haddad (2013). Raach-Moujahed and Haddad (2013) reported a mean dressing percent of 68.6 percent for Tunisia local chicken raised for 112 days with outdoor access. Likewise, there was no significant difference in dressing percent between males and females within slaughter age, the average values being 66.2 and 64.7 percent for males and females respectively. However, birds slaughtered at seven month had significantly higher carcass percent (67.7) than those at five month (63.2%) (Figure 2). The higher dressing percent in 7 month birds is expected since, as birds increase in weight there is proportionate increase in muscle and other tissues except bones which at 5th month are most likely to have approached peak growth.

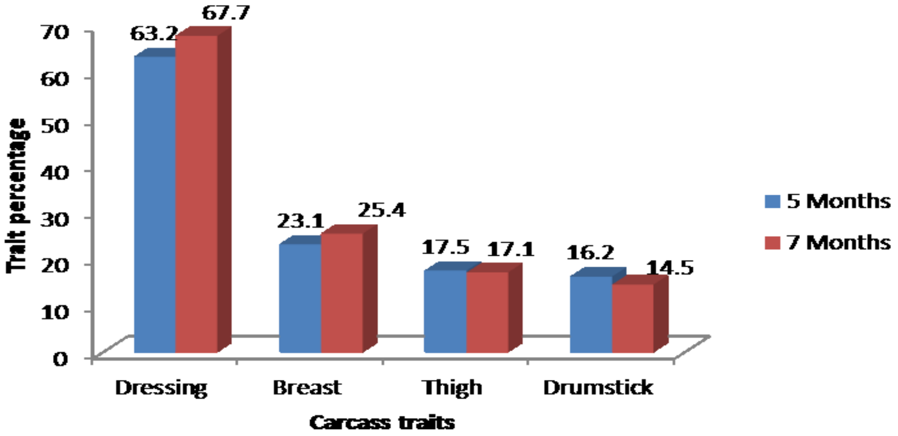

Figure 2: Effect of age on carcass traits percentage of local chicken.

Differences were also observed for breast percent between rearing system and slaughter age. Semi intensively reared birds had significant higher breast percent (24.9) compared to intensively reared birds (23.6%). This observation is similar to that reported by Cheng et al (2008) and Castellini et al (2002) who found that breast meat content of carcass increased when birds had access to outdoor production system. This can be explained that the lower stocking density and increased physical activity could reduce the abdominal fat and increase the percentage of breast meat (Lewis et al 1997). But, the findings are contrary to those of Wattanachatt (2008) who reported high percentage of breast muscle from village chickens reared under full feed supplements compared to those under extensive system. Likewise, older birds at 7 month had higher value for breast compared to those at 5 month. Similarly Baéza et al (2012) reported higher meat yield of breast in broiler chicken slaughtered at different ages.

Table 2: Mean values for carcass traits performance of local chicken reared under intensive and semi-intensive systems

Traits	Rearing system		SEM	P-value	Sex		SEM	P-value
	Intensive	Semi-intensive			Male	Female		
Dressing %	65.18	65.71	0.66	0.5665	66.18	64.72	0.66	0.1213
Breast %	23.56	24.93	0.39	0.0152	23.32	25.18	0.39	0.0011
Thigh %	17.28	17.36	0.18	0.7557	17.81	16.83	0.18	0.0002
Drumstick %	15.36	15.32	0.22	0.9081	16.32	14.36	0.22	0.0001

SEM = Standard error of mean, P-value = Probability value

Percent drumstick was only influenced by sex and age at slaughter, with higher values in males compared to females and lower value at 7 month (14.5%) compared to a value of 16.2% at five month. These observations imply that slaughter age is most critical in determining dressing percent and weights of carcass components.

The only component that was not affected by slaughter age was the proportion of the thigh. Thus, in deciding as to when birds are to be slaughtered a compromise must be reached taking into account the management system to be adopted.

Conclusions

- It is concluded that rearing system has a significant influence on slaughter weight, weight gain and breast percent. Similarly, slaughter age influenced most of the carcass traits except thigh percent. Furthermore, birds under semi-intensive system consumed relatively less supplementary feed and resulted to better feed conversion efficiency. This implies that, with modest supplementation and assuming availability of scavenging feed resources, semi-confinement system of chicken rearing could be more economical for the small holder poultry keepers.

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4.2 Paper II: Evaluation of Tanzanian Local Chicken Reared under Intensive and Semi-intensive Systems: II. Meat Quality Attributes

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Evaluation of Tanzanian local chicken reared under intensive and semi-intensive systems: II. Meat quality attributes

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Abstract
The effect of rearing system and age at slaughter on meat tenderness, cooking loss and pH of male and female local chicken were assessed. The birds were randomly allotted to two rearing systems (intensive and semi-intensive systems). Each system was replicated four times with twelve birds each. In all the management systems, birds were given a diet containing 19% CP and 2679KJ ME with semi-intensive birds getting half of the amount given to intensive birds. At the end of the experiment, all 96 birds were slaughtered and carcass parts viz. breast, drumstick and thigh were separated. Pieces of meat from these parts were used for tenderness, cooking loss and pH evaluation.

There was no significant difference between intensive and semi-intensive systems on breast, thigh and drumstick meat tenderness. Chicken slaughtered at seventh month had higher shear force values than those slaughtered at fifth month. The cooking loss of male breast and thigh meat under intensive system were lower than that of birds under semi intensive system. Likewise, higher cooking losses were obtained for birds slaughtered at seven month than those at five month. Rearing system did not influence meat pH but, there was an increase in pH value of male thigh and drumstick meat with advanced slaughter age. It is concluded that the meat tenderness, cooking loss and pH values from both systems were of acceptable standard, but the overall quality of meat is reduced with increased age at slaughter. To attain tender meat farmers should strive to improve management of their birds to reach slaughter weights at younger age.

Keywords: Cooking loss, local chicken, meat tenderness, meat pH, production systems

Introduction
The poultry industry is going through a gradual but, definite change in product differentiation in response to consumer demands. However, some consumers still regard meat derived from local chicken as being tough. In Tanzania, chicken products are universally popular and in the coming years, the consumption of chicken meat will rise dramatically (FAO 2012). The trend is similar in many other Sub-Saharan Africa and Asia countries, where there has been a shift in demand for broiler meat in favor of local chicken meat. This preference is partly explained by

their chewy texture, color and flavor of their meat (Guèye et al1997; Wattanachant et al 2005). Apart from taste, some consumers consider local chicken to contain less drug residue, since their management mimics that of organically farmed livestock. To ensure a sustainable continued growth and competitiveness of the local poultry meat industry, it is essential that local chicken meat quality and safety are maintained during production process.

Generally, quality of meat is judged by its tenderness, succulence, flavour and nutritive value. The quality is also influenced by strain, age at slaughter, the nutritional regime and rearing system (Sogunle et al 2010). Under scavenging mode of production, local chicken covers a great distance in search of feeds making the meat less tender (Guèye et al 1997; Wattanachant et al 2004; Jaturasitha et al 2008). Minimizing the distance covered by the birds and provision of supplementary feeds is expected to improve growth and quality of meat. Apart from other meat quality attributes, texture particularly tenderness, is an important selection criteria used by consumers when purchasing meat (Fanatico et al 2007). However, meat tenderness also depends on muscle type and some consumer discriminate meat cuts depending on their tenderness (Waskar et al 2009). The other factor influencing meat quality is the age at which the birds are slaughtered. Under traditional systems, often chickens are slaughtered many month (more than seven) post maturity, partly contributed by the slow growth rate. The result of which is increased toughness of meat (Northcutt et al 2001). It was the objective of this work to determine to what extent the quality of local chicken meat specifically; textural characteristics, water holding capacity and pH is affected by management system and slaughter age.

Materials and methods

Study site

The study was conducted at Sokoine University of Agriculture, Department of Animal Science and Production Poultry Unit. The area is situated 6° S and 37° E and it is about 3 km south of Morogoro town. The area lies on the foot of the slopes of Uluguru Mountain at an elevation of about 500-600m above sea level. The annual rainfall ranges between 600 and 1000 mm per annum and the temperature ranges between 30°C and 35°C during the hottest months (October to January) and 20 – 27°C in the coolest months (April to August).

Experimental design and management of the experimental birds

A flock of 96 local chickens at two months old was used with 48 males and 48 females. Two rearing systems were evaluated viz. intensive (full confinement) and semi-intensive (partial confinement). A completely randomized experimental design was applied and males and females were allocated equally in the two rearing systems. The initial mean body weights in each group were about 519 g. The birds under intensive system were raised on deep litter. Density in each pen was 4birds/m^2. All birds were group fed with a diet containing 19% CP and 2679KJ ME from 2nd month to 5^{th} or 7^{th} month of slaughter. On average 86 g of feed per bird were offered to each bird in under intensive system.

Birds under semi-intensive system were raised outdoor allowing a space of 1 bird/10m^2. They were fed half of the amount allocated to birds under intensive system. Feed and water were provided outdoors using trough feeders and drinkers.

Ground predators were excluded by fencing. For security reason, semi-intensive birds were confined to indoor pens at night.

All birds were weighed initially and thereafter, once per month. One half of the birds (n=48) with equal number of males and females in each rearing system were slaughtered for carcass evaluation at day 150 (approx. 5 month) and the remaining half slaughtered at day 210 (approx. 7 month). The birds were fasted for 12 hours, weighed individually and slaughtered by manual exsanguinations. The hot carcasses were divided into breast, thighs and drumsticks. The right part of the carcass was used for pH, cooking loss and tenderness evaluation.

pH measurements in meat muscle

A spear-end digital portable pH meter (Knick Portamess ® 910, Germany) was used to measure the pH of breast, thigh and drumstick of each individual bird at 45 minutes post-mortem. The pH meter was standardized by a two-point method against buffers of pH 4.0 and pH 7.0 standard solutions before measurement of each sample. In this regard, a total of 96 samples for each of the muscle part were used.

Cooking loss measurement

Forty five minutes post-slaughter, raw breast, thigh and drumstick muscle (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 minutes as described by Rizz et al (2007). Then, the samples cooled in running water for 15 minutes, dried with soft tissue and weighed. Cooking loss was calculated as percentage loss of weight during cooking relative to the weight of raw muscle (Petracci and Baéza 2009).

Tenderness (shear force value) measurement

Strips measuring about 1.0×1.0×2.5 cm parallel to the muscle fibres were prepared from breast, thigh and drumstick muscle portion and sheared vertically using Warner-Bratzler shear force device. The shear force values were recorded in Newtons (N).

Statistical data analysis

Data on shear force, cooking loss and pH were sorted by sex and analyzed using the General Linear Models (GLM) procedure of Statistical Analysis System (SAS 2006) software. Comparisons of means were analyzed using t-test. The model for shear force value, cooking loss and pH (pH45) analyses was as follows:

$Y_{ijk} = \mu + R_i + A_j + (RA)_{ij} + e_{ijk}$

Where:

Y_{ijk} = the meat quality variables

μ = overall mean to all observations

R_i = effect of rearing system (full confinement or semi-scavenging)

A_j = the effect of slaughter age (5 months or 7 months)

$(RA)_{ik=}$ the effect of interaction between rearing system and age

e_{ijk} = the residual random error.

Results and Discussions

Effect of rearing system and age at slaughter on meat tenderness

The mean levels of shear force values for meat muscle parts in the two rearing systems and at different age at slaughter are presented in Table 1. The results show that breast, thigh and drumstick meat from both male and female birds were not influenced (P>0.05) by the rearing system. The similarity of effects of rearing system on meat tenderness in the current study could be explained by reduced movements of semi-confined birds. This implies that under semi-confinement, birds have nearly equal movements to those under full confinement. The findings are in accordance with Fanatico et al (2005) and Dou et al (2009) who demonstrated that production system had no effect on tenderness of meat in the slow-growing broilers. Farmer et al (1997) also observed the same tendency for breast meat from birds reared under a lower stocking density, whilst Magala et al (2012) reported breast muscle tenderness in local Ugandan chicken not to be influenced by rearing system. However, these findings were contrary to those of Castellini et al (2002); Cheng et al (2008) and Pripwai et al (2014) who reported production system to have an effect on the shear force values and higher values were generally obtained for breast and drumstick of chicken raised under free range system.

Table 1: Least squares means for shear force value (N) of meat muscle parts of male and female local chickens summarized by rearing systems and slaughter age

Muscle part	Sex	Rearing system		SEM	P-value	Slaughter age		SEM	P-value	RS*SA P-value
		IN	SIN			5Month	7Month			
Breast	Male	34.8	35.6	0.95	0.593	26.5	43.9	0.95	<0.0001	0.028
	Female	28.5	28.9	1.53	0.818	24.4	32.9	1.53	0.0003	0.705
Thigh	Male	26.3	26.6	0.61	0.711	17.4	35.5	0.61	<0.0001	0.449
	Female	22.3	23.4	0.99	0.431	16.4	29.4	0.99	<0.0001	0.757
Drumstick	Male	22.1	23.0	0.48	0.186	16.4	28.8	0.48	<0.0001	0.920
	Female	20.1	20.0	0.73	0.925	15.1	24.9	0.73	<0.0001	0.774

*RS*SA = Interaction between rearing system and age at slaughter, IN= Intensive, SIN = Semi-intensive, N= Newton*

The results of the present study have similarly indicated that birds slaughtered at seven month had higher shear force values than those slaughtered at five month, implying that the meat was less tender (Table 1). The difference in tenderness values between age are explained by differences in thickness of sarcolemma muscle fibre whereby, young birds are expected to have thinner sarcolemma fiber rendering its meat to be more tender (Bals 2009). Age of the animal may be important because myoglobin, the primary muscle pigment, tends to increase with age in chicken (Lyon et al 2004). However, Baéza et al (2012) reported contrasting finding whereby age at slaughter did not influence shear force value of cooked meat from a heavy broiler line raised for 63 days with slaughter age at 35 days, 42days, 49 days, 56 days and 63 days. An interaction effect between ages at slaughter within system on male breast tenderness was significant but, all in all birds slaughtered at older age regardless of the system had less tender meat.

Effect of rearing systems and age at slaughter on meat cooking loss

Results presented in Table 2 show that cooking loss of male breast and thigh meat from birds reared under intensive system was lower than that of semi-intensive reared birds. However, the percentage cooking loss of breast and leg meat observed in the current study are much less than value of 29.81% and 33.69% for Thai indigenous chicken breeds raised indoor for 14 weeks as reported by Pripwai et al (2014). The difference could be attributed to breed effects. These results in the current study agrees with those of Castellini et al (2002) and Fanatico et al (2007) who observed that outdoor (free range) reared birds have lower cooking loss than birds reared indoors. To the contrary, Magala et al (2012) found no difference in cooking loss of Ugandan local chicken meat raised under three rearing system. To the consumer, cooking losses is important in carcass and further-processed meat product, since less cooking loss result to increased juiciness and tenderness of meat (Dabes 2001 and Wang et al 2009).

Table 2 summarizes the effects of slaughter age on cooking loss. Cooking losses were higher in both male and female slaughtered at seven month than those slaughtered at younger age (five months). Likewise, there was an increase in cooking loss in all parts (breast, thigh and drumstick) with age. Similar trend was observed by Baéza et al (2012) in a modern heavy broiler line. As expected, there were a parallel relation between cooking loss and tenderness although, cooking loss did not vary much between parts (Tables 1 and 2). Furthermore, significant interactions were also observed between rearing system and age at slaughter on cooking losses percentage in male breast and thigh meat. The implication of this finding is that one should choose an appropriate age to slaughter local chicken so as to optimize meat quality especially, tenderness.

Table 2: Least squares means for cooking loss percent of meat muscle parts of male and female local chickens summarized by rearing systems and slaughter age

Muscle part	Sex	Rearing system		SEM	P-value	Slaughter age		SEM	P-value	RS*SA P-value
		IN	SIN			5Month	7Month			
Breast	Male	11.8	17.5	0.68	0.0001	9.79	19.5	0.68	0.0001	0.0001
	Female	15.5	16.7	0.89	0.3708	10.4	21.8	0.89	0.0001	0.0942
Thigh	Male	12.6	19.3	0.92	0.0001	10.1	21.9	0.92	0.0001	0.0008
	Female	16.7	18.6	0.84	0.1083	10.8	24.5	0.84	0.0001	0.9478
Drumstick	Male	11.3	12.1	0.46	0.2443	8.57	14.8	0.46	0.0001	0.8184
	Female	16.3	14.8	0.83	0.2003	9.02	22.0	0.83	0.0001	0.1111

*RS*SA = Interaction between rearing system and age at slaughter, IN = Intensive, SIN = Semi-intensive*

Effect of rearing systems and age at slaughter on meat pH

Rearing system did not influence meat pH at 45 minutes post-slaughter although the general trend was for pH to be slight lower in cuts from semi-intensive system (Table 3). In contrast, Culioli et al (1990); Castellini et al (2002); Alvarado et al (2005); Wattanachant (2008) and Hanyani (2012) reported high meat pH in chickens raised under free-ranging systems. Similarly, Husak et al (2008) observed higher pH values in broiler meat raised organically compared to those under conversional production system. Such results are expected, and the difference from current study could be explained by the limited movement of birds under semi-intensive system. It was further revealed that thigh and drumstick meat tended to exhibit higher pH than the breast. These differences are probably attributed to higher muscle activities in leg muscles than breast muscles.

Conversely, Jaturasitha et al (2008) reported pH value of 5.77 at the age of 112 days in Thai native chicken, the value to a large extent being influenced by the nature of rearing. Nonetheless, the pH values obtained in the current study at 45 minutes post-slaughter are within the range of 6.16 to 6.31 for 15 minutes and 1 hour post-slaughter respectively reported by Raach-Moujahed and Haddad (2013). Normally, living muscle has a pH value of 7. pH relatively drop quickly thereafter, post slaughter. At a pH of 5.4 to 6.2 the meat is normally considered to be of high quality (Vacaru-Opris and Col, 2000 cited by Bals, 2009; Owens et al 2000; Woelfel et al 2002).

Table 3: Least squares means for pH of meat muscle parts of male and female local chickens summarized by rearing systems and slaughter age

Muscle part	**Sex**	**Rearing system**		**SEM**	**P-value**	**Slaughter age**		**SEM**	**P-value**	**RS*SA P-value**
		IN	**SIN**			**5Month**	**7Month**			
Breast	Male	6.08	6.10	0.05	0.777	6.02	6.15	0.05	0.090	0.097
	Female	5.96	6.05	0.03	0.054	6.02	5.99	0.03	0.512	0.058
Thigh	Male	6.30	6.24	0.05	0.479	6.15	6.39	0.05	0.003	0.018
	Female	6.34	6.26	0.06	0.313	6.30	6.31	0.06	0.836	0.445
Drumstick	Male	6.34	6.26	0.05	0.279	6.19	6.42	0.05	0.005	0.001
	Female	6.30	6.31	0.05	0.782	6.31	6.30	0.05	0.907	0.519

*RS*SA = Interaction between rearing system and age at slaughter,*
IN = Intensive, SIN = Semi-intensive

With regard to age effects, there was no sex difference in pH values for birds slaughtered at five or seven month of age. Nonetheless, the effect of slaughter age on pH was inconsistent although males exhibited slightly higher pH values for drumstick and thigh respectively, at seven month than at five months (Table 3), implying that, males were probably more active than females. In contrast, Baéza et al (2012) reported major changes in breast meat between the age of 35 and 49 days, with an increase in muscle pH at 15 minutes and 24 hours post-mortem in heavy broiler line. Similar observation was made by Ponte et al (2008c). According Husak et al (2008) higher meat pH is more effective for retaining desirable colour and moisture absorption properties. But, higher pH is also related to poor shelf life since it provides conducive environment for bacterial growth (Owen et al 2000; Woelfel et al 2002). Significant interactions were also observed between rearing system and age at slaughter on meat pH of male thigh and drumstick meat muscles. This has been mainly influenced by effect of age at slaughter.

Conclusions

- It is concluded that rearing system had little influence on meat quality in terms of tenderness and pH at 45 minutes post slaughter and slaughtering birds at five month yielded more tender meat with lower cooking loss.

Furthermore, the meat tenderness, cooking loss and pH values from both systems were of acceptable standard, but the overall quality of meat is reduced with increased age at slaughter. Therefore, poultry farmers should raise their local chicken for meat production for at about five month; which has been observed to have recommendable weight for slaughter and higher quality meat.

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APPENDICES

Appendix 1: Summary of ANOVA table for slaughter body weight of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	599829.147	599829.147	8.60	0.0043
Sex	1	1055921.071	1055921.071	15.14	0.0002
Age	1	5052747.799	5052747.799	72.46	<.0001
System*Sex	1	8688.003	8688.003	0.12	0.7250
System*Age	1	40296.396	40296.396	0.58	0.4492
Sex*Age	1	1692.088	1692.088	0.02	0.8766
System*Sex*Age	1	7088.251	7088.251	0.10	0.7506
INWt	1	4616762.182	4616762.182	66.21	<.0001
Error	87	6066285.82	69727.42		
Corrected Total	95	17379527.96			

R-Square	Coeff Var	Root MSE	SLBWT Mean
0.650952	17.78603	264.0595	1484.646

Appendix 2: Summary of ANOVA table for ADG of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	105.2305808	105.2305808	8.89	0.0037
Sex	1	147.9614606	147.9614606	12.50	0.0007
Age	1	75.3421847	75.3421847	6.36	0.0135
System*Sex	1	0.3074208	0.3074208	0.03	0.8724
System*Age	1	28.6257332	28.6257332	2.42	0.1236
Sex*Age	1	20.1183496	20.1183496	1.70	0.1959
System*Sex*Age	1	0.6007797	0.6007797	0.05	0.8223
INWt	1	27.5949000	27.5949000	2.33	0.1305
Error	87	1030.173692	11.841077		
Corrected Total	95	1531.528916			

R-Square	Coeff Var	Root MSE	ADG Mean
0.327356	31.58681	3.441087	10.89406

Appendix 3: Summary of ANOVA table for dressing percentage of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	6.8587042	6.8587042	0.47	0.4933
Sex	1	50.6922667	50.6922667	3.50	0.0648
Age	1	495.4050667	495.4050667	34.19	<.0001
System*Sex	1	2.7472667	2.7472667	0.19	0.6643
System*Age	1	88.1666667	88.1666667	6.08	0.0756
System*Sex*Age	2	47.9889750	23.9944875	1.66	0.1968
Error	88	1275.133850	14.490157		
Corrected Total	95	1966.992796			

R-Square	Coeff Var	Root MSE	Dressing Mean
0.351734	5.816052	3.806594	65.44979

Appendix 4: Summary of ANOVA table for breast percentage of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	45.0182042	45.0182042	8.83	0.0038
Sex	1	83.1048167	83.1048167	16.30	0.0001
Age	1	135.8028375	135.8028375	26.63	<.0001
System*Sex	1	3.3675042	3.3675042	0.66	0.4186
System*Age	1	56.0592667	56.0592667	10.99	0.0713
System*Sex*Age	2	36.0765208	18.0382604	3.54	0.0833
Error	88	448.7679833	5.0996362		
Corrected Total	95	808.1971333			

R-Square	Coeff Var	Root MSE	Breast Mean
0.444730	9.313599	2.258237	24.24667

Appendix 5: Summary of ANOVA table for thigh percentage of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.14805104	0.14805104	0.10	0.7559
Sex	1	22.96148437	22.96148437	15.09	0.0002
Age	1	3.48462604	3.48462604	2.29	0.1338
System*Sex	1	0.00825104	0.00825104	0.01	0.9415
System*Age	1	1.30433438	1.30433438	0.86	0.3571
System*Sex*Age	2	1.18246875	0.59123437	0.39	0.6793
Error	88	133.9425083	1.5220740		
Corrected Total	95	163.0317240			

R-Square	Coeff Var	Root MSE	Thigh Mean
0.178427	7.123930	1.233724	17.31802

Appendix 6: Summary of ANOVA table for drumstick percentage of chicken

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.03190104	0.03190104	0.02	0.8829
Sex	1	92.53190104	92.53190104	63.34	<.0001
Age	1	63.61898438	63.61898438	43.55	<.0001
System*Sex	1	0.01020938	0.01020938	0.01	0.9336
System*Age	1	3.12842604	3.12842604	2.14	0.1469
System*Sex*Age	2	23.50838542	11.75419271	8.05	0.0666
Error	88	128.5548417	1.4608505		
Corrected Total	95	311.3846490			

R-Square	Coeff Var	Root MSE	DST Mean
0.587151	7.877779	1.208656	15.34260

Appendix 7: Summary of ANOVA table for SF Value of male Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	6.300252	6.300252	0.29	0.5929
Age	1	3641.302602	3641.302602	167.61	<.0001
System*Age	1	112.393802	112.393802	5.17	0.0279
Error	44	955.876792	21.724473		
Corrected Total	47	4715.873448			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.797307	13.24095	4.660952	35.20104

Appendix 8: Summary of ANOVA table for SF Value of female Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	3.0100083	3.0100083	0.05	0.8178
Age	1	870.9144083	870.9144083	15.54	0.0003
System*Age	1	8.0852083	8.0852083	0.14	0.7059
Error	44	2465.836567	56.041740		
Corrected Total	47	3347.846192			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.263456	26.08436	7.486103	28.69958

Appendix 9: Summary of ANOVA table for SF Value of male Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	1.225602	1.225602	0.14	0.7114
Age	1	3949.985102	3949.985102	446.78	<.0001
System*Age	1	5.154852	5.154852	0.58	0.4492
Error	44	389.006692	8.841061		
Corrected Total	47	4345.372248			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.910478	11.23262	2.973392	26.47104

Appendix 10: Summary of ANOVA table for SF Value of female Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	14.896408	14.896408	0.63	0.4309
Age	1	2045.196300	2045.196300	86.77	<.0001
System*Age	1	2.279408	2.279408	0.10	0.7573
Error	44	1037.071783	23.569813		
Corrected Total	47	3099.443900			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.665401	21.21654	4.854875	22.88250

Appendix 11: Summary of ANOVA table for SF Value of male Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	10.110852	10.110852	1.81	0.1855
Age	1	1845.492019	1845.492019	330.18	<.0001
System*Age	1	0.056719	0.056719	0.01	0.9202
Error	44	245.931258	5.589347		
Corrected Total	47	2101.590848			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.882979	10.47904	2.364180	22.56104

Appendix 12: Summary of ANOVA table for SF Value of female Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.114075	0.114075	0.01	0.9251
Age	1	1151.696133	1151.696133	90.34	<.0001
System*Age	1	1.062075	1.062075	0.08	0.7742
Error	44	560.925383	12.748304		
Corrected Total	47	1713.797667			

R-Square	Coeff Var	Root MSE	SFValue Mean
0.672700	17.84049	3.570477	20.01333

Appendix 13: Summary of ANOVA table for CL of female Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	15.583802	15.583802	0.82	0.3708
Age	1	1563.056002	1563.056002	81.99	<.0001
System*Age	1	55.792969	55.792969	2.93	0.0942
Error	44	838.780358	19.063190		
Corrected Total	47	2473.213131			

R-Square	Coeff Var	Root MSE	CL Mean
0.660854	27.11573	4.366141	16.10188

Appendix 14: Summary of ANOVA table for CL of male Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	384.993408	384.993408	35.12	<.0001
Age	1	1133.740800	1133.740800	103.43	<.0001
System*Age	1	272.176875	272.176875	24.83	<.0001
Error	44	482.283717	10.960994		
Corrected Total	47	2273.194800			

R-Square	Coeff Var	Root MSE	CL Mean
0.787839	22.59890	3.310739	14.65000

Appendix 15: Summary of ANOVA table for CL of female Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	27.846533	27.846533	1.69	0.2003
Age	1	2034.765633	2034.765633	123.55	<.0001
System*Age	1	43.548300	43.548300	2.64	0.1111
Error	44	724.624600	16.468741		
Corrected Total	47	2830.785067			

R-Square	Coeff Var	Root MSE	CL Mean
0.744020	26.13677	4.058170	15.52667

Appendix 16: Summary of ANOVA table for CL of male Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	7.2075000	7.2075000	1.39	0.2443
Age	1	464.1364083	464.1364083	89.67	<.0001
System*Age	1	0.2760333	0.2760333	0.05	0.8184
Error	44	227.7552500	5.1762557		
Corrected Total	47	699.3751917			

R-Square	Coeff Var	Root MSE	CL Mean
0.674345	19.47823	2.275139	11.68042

Appendix 17: Summary of ANOVA table for CL of female Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	45.630000	45.630000	2.69	0.1083
Age	1	2224.963333	2224.963333	130.99	<.0001
System*Age	1	0.073633	0.073633	0.00	0.9478
Error	44	747.348600	16.985195		
Corrected Total	47	3018.015567			

R-Square	Coeff Var	Root MSE	CL Mean
0.752371	23.36454	4.121310	17.63917

Appendix 18: Summary of ANOVA table for CL of male Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	548.371200	548.371200	26.88	<.0001
Age	1	1662.159408	1662.159408	81.47	<.0001
System*Age	1	266.209200	266.209200	13.05	0.0008
Error	44	897.703917	20.402362		
Corrected Total	47	3374.443725			

R-Square	Coeff Var	Root MSE	CL Mean
0.733970	28.26815	4.516897	15.97875

Appendix 19: Summary of ANOVA table for pH of female Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.10640833	0.10640833	4.29	0.0441
Age	1	0.01080000	0.01080000	0.44	0.5126
System*Age	1	0.10267500	0.10267500	4.14	0.0478
Error	44	1.09028333	0.02477917		
Corrected Total	47	1.31016667			

R-Square	Coeff Var	Root MSE	PH Mean
0.167829	2.621018	0.157414	6.005833

Appendix 20: Summary of ANOVA table for pH of male Breast

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.00541875	0.00541875	0.08	0.7775
Age	1	0.20150208	0.20150208	3.01	0.0900
System*Age	1	0.52710208	0.52710208	7.86	0.0075
Error	44	2.95025833	0.06705133		
Corrected Total	47	3.68428125			

R-Square	Coeff Var	Root MSE	PH Mean
0.199231	4.252369	0.258943	6.089375

Appendix 21: Summary of ANOVA table for pH of female Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.00421875	0.00421875	0.08	0.7822
Age	1	0.00075208	0.00075208	0.01	0.9071
System*Age	1	0.02296875	0.02296875	0.42	0.5198
Error	44	2.40035833	0.05455360		
Corrected Total	47	2.42829792			

R-Square	Coeff Var	Root MSE	PH Mean
0.011506	3.703618	0.233567	6.306458

Appendix 22: Summary of ANOVA table for pH of male Drumstick

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.08585208	0.08585208	1.25	0.2697
Age	1	0.61426875	0.61426875	8.94	0.0046
System*Age	1	0.84535208	0.84535208	12.30	0.0011
Error	44	3.02345833	0.06871496		
Corrected Total	47	4.56893125			

R-Square	Coeff Var	Root MSE	PH Mean
0.338257	4.159641	0.262135	6.301875

Appendix 23: Summary of ANOVA table for pH of female Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.08003333	0.08003333	1.04	0.3135
Age	1	0.00333333	0.00333333	0.04	0.8361
System*Age	1	0.04563333	0.04563333	0.59	0.4455
Error	44	3.38766667	0.07699242		
Corrected Total	47	3.51666667			

R-Square	Coeff Var	Root MSE	PH Mean
0.036682	4.402037	0.277475	6.303333

Appendix 24: Summary of ANOVA table for pH of male Thigh

Source of Variation	DF	Total SS	Mean Square	F Value	Pr > F
System	1	0.03575208	0.03575208	0.51	0.4787
Age	1	0.69841875	0.69841875	9.97	0.0029
System*Age	1	0.42000208	0.42000208	6.00	0.0184
Error	44	3.08192500	0.07004375		
Corrected Total	47	4.23609792			

R-Square	Coeff Var	Root MSE	PH Mean
0.272461	4.220877	0.264658	6.270208

Appendix 25: Physical composition of the experimental diet (%)

Ingredient	**Inclusion levels**
Sunflower cake	20
Maize	49
Maize bran	18.5
Fishmeal	8
Blood meal	3.0
Limestone	0.25
Bone meal	0.25
Premix	0.25
Salt	0.5
Methionine	0.25
Total	**100**
Calculated CP %	19.26
Calculated Energy ME Kcal/kg	2679.38