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*Full Length Research Paper*

# Ecotype differences in growth and behavioural responses to low energy diets in Tanzanian local chickens

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**Abstract**

**A study was conducted to compare growth and behavioural responses to low dietary energy in three chicken ecotypes at4 weeks old for 7 weeks. 351hens belonging to Kuchi (KU), Ching'wekwe (CH) and Morogoro medium (MM)ecotypes were allocated to 9 pens in a 3 x 3 factorial design, with 3 replicates. They were fed 3 diets containing 40, 55or 0% less energy than a prescribed control diet. Low dietary energy increased feed intake but reduced growth rates in all ecotypes. Among40% restricted groups, KU had significantly higher (p<0.05) weight gains, whereas MM had higher (p<0.05) weight gains and lower feed conversion ratio (FCR) at 55% restriction. Body lengths, shank lengths, chest circumferences and wing spans for KU and CH but not MM were markedly (p<0.05) reduced for both restricted groups. Foraging and feeding behaviours were higher in restricted groups of all ecotypes in the third week. MM had least mortality in both restricted groups and controls. Results of this study show ecotype-specific tolerance to low dietary energy through differences in growth performance, FCRs and behavioural responses. MM showed better tolerance at the lowest energy level whereas KU exhibited better performance at 40% and control energy levels.**

**Key words:** Behaviour, foraging, morphometric, restriction, stress, tolerance.

## INTRODUCTION

Local chickens are prominent livestock in many developing countries including Tanzanian rural areas and they greatly contribute to the income and nutrition of households (Padhi, 2016; Wilson, 2015; Mwalusanya et al., 2001). Several local chicken ecotypes have been identified in Tanzania based on their geographical origin and phenotypic characteristics, andthey show variations in adult body weight, egg weight, plumage characteristics and resistance to disease (Msoffe et al., 2001, 2005). Moreover genetic uniqueness and limited interbreeding among them have been previously reported and these have been attributed to their geographical separation and preferential mate selection (Mayardit et al., 2016; Msoffe et al., 2002, 2005).The focus of the current study was to ascertain the differences in responses to suboptimal diets among selected local chicken ecotypes as a prelude to genetic selection for better stress tolerance. Kuchi (KU), originally from north-west Tanzainain the high moist

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lake regions, Morogoro medium (MM)and Ching'wekwe (CH) local chicken ecotypes both originating from central Tanzania in the plateau regions, were considered in this study because of their productive and disease resistance potential as reported previously (Msoffe et al., 2002, 2005).

Dietary energy levels have an effect on feed intake, feed conversion ratio and growth of chickens as they feed to satisfy their energy requirements (NRC, 1994). The effects of dietary energy levels on productive performance have been extensively studied in commercial broiler and layer chickens (Ribeiro et al., 2014; Chen et al., 2012; Perez-Bonilla et al., 2012) and it is evident that in these chickens feed restriction has been commonly used to reduce metabolic disorders and control bodyweight (Fassbinder-orth and Karasov, 2006). Changes in energy concentration of the diet have resulted in contrasting results with respect to productive performance and feed conversion ratios (FCR). Ribeiro et al. (2014) reported that dietary apparent metabolisable energy ($AME_n$) levels did not influence body weight, egg weight, or livability, and that increasing $AME_n$ levels increased feed intake and feed conversion ratio; whilst Perez-Bonilla et al. (2012) showed that an increase in energy concentration of the diet increased egg production, egg mass, energy efficiency and body weight gain but decreased feed conversion ratio per kilogram of eggs. However, research information on the effect of varied dietary energy levels on production variables in local chickens is scarce.

Despite their usefulness and contribution to the nutrition and income of rural communities, achieving increased productivity and sustainability of local chickens is still a huge challenge mainly because of lack of access to quality feed and failure to balance between energy and protein requirements (Mutayoba et al., 2012; Sonaiya, 2007). The availability of scavenging feed resources is crucial to appropriate rearing of local chickens (Sanka and Mbaga, 2014). Under natural environments scavenging local chickens are exposed to feed and dietary energy stress due to seasonal availability of feed. Thus, it is of interest to know how different local chicken ecotypes respond under different nutritional stresses that may appear in nature especially during the growing phase. A study by Mwalusanya et al. (2010) showed that chemical composition of feeds eaten by rural scavenging chickens of Tanzania was below the nutritional requirements and varied with season, climate and age of birds. This was ascertained after dissecting the crops of the local chickens from different climatic zones and analyzing their contents. A study investigating the response of male Venda local chickens of South Africa to varying energy to protein ratios (Mbajiorgu, 2011) found that the dietary energy to protein ratio of 66 MJ ME/ kg protein supported optimum growth rate. Meanwhile in Uganda, Magala et al. (2012) reported that a 2800 kcal/kg ME and 18% CP diet was sufficient for growing local chicken cockerels.

Expression of behavior has been fundamental in understanding the welfare of chickens at a particular moment and its correct interpretation can be used to compare the effects of particular stressors on chickens of different strains (Ericsson et al., 2014; Costa et al., 2012).Generally, stress modifies the development of the hypothalamic-pituitary axis response thereby affecting growth and behaviour (Ognik and Sembratowicz, 2012). However, limited information is available on the relationship between stress and behavior in chickens. Zulkifli et al. (2006) found that feed deprivation increased non-nutritive pecking activities among laying hens but did not have a significant effect on standing, drinking and preening activities. In a study to compare acute stress behavioral response of two breeds of chicken, Ericsson et al. (2014) reported that Red Jungle fowl had more frequent relaxed and preen behavior but reacted stronger to acute restraint stress than White Leghorn. The present study was designed to compare the growth and behavioral responses to stress induced by low dietary energy in KU, MM and CH local chicken ecotypes. This was done with an assumption that local chickens commonly bred from different geographic regions of Tanzania might have selected ecotypes with stronger tolerance to stress induced by feed of lower energy levels. Selecting for ecotypes with better growth and behavior performance under restricted energy intake is beneficial in breeding programs aimed at conservation of indigenous genetic resources within local chicken stocks.

## MATERIALS AND METHODS

### Experimental Chickens

Day-old MM, CH and KU local chicken ecotypes were obtained from the parent flock kept by the Feed the Future (Genomics to Improve Poultry) Project at Sokoine University of Agriculture. The chicks were brooded and reared under similar environmental, managerial and hygienic conditions before being subjected to treatment groups. Feed and water were supplied *ad libitum*. Initially, all chicks were fed the same diet consisting of 18% crude protein and 2,864 kcal ME/kg up to the 4$^{th}$ week. All chickens were vaccinated routinely against Newcastle disease, Infectious Bursal Disease (Gumboro), and Fowl pox.

### Feed Formulation

Diets were formulated using locally available feedstuffs and ground wood charcoal (Rezaei et al., 2006) was used to dilute the feed. The chemical (proximate) analyses of different feed ingredients were carried out using standard methods (FAO, 1994). Feed samples were analyzed for crude fiber, crude protein (Kjeldahl protein), moisture, ash, nitrogen-free extracts (digestible carbohydrates) and crude lipid; and then metabolisable energy levels were estimated (NRC, 1994; Janssen, 1989). The composition of specific ingredients in the feed is depicted in Table1.

**Experimental Design**

A total of 351 four weeks old female chicks belonging to KU, CH and MM ecotypes were weighed and randomly allocated, according to ecotype, to 9 pens in a 3 x 3 (three ecotypes and 3 types of diets) factorial design, with three replicates. The birds were fed 3 types of iso-nitrogenous (18% crude protein) diets formulated to contain 40, 55, and 0% (control) less energy than prescribed by the NRC (1994) for commercial layer chickens. The chickens were reared on littered (rice husks) floors in a well ventilated house for seven weeks. Feed and water were supplied *ad-libitum* throughout the experimental period (7 weeks). Each pen had on average an area of 2 $m^2$ floor space per 13 birds. The study was conducted at the prevailing cyclic ambient temperatures ranging from 21.6 to 34.3°C. The pens were artificially lit with a 12Light: 12Dark cycle, corresponding to the natural conditions.

**Data Collection**

Growth and behavioural responses were determined for 7 weeks; from 4 to 11 weeks of age. Feed consumption was recorded daily and morphometric parameters (body length, shank length, chest circumference, and wing span) were recorded at 2, 4 and 6 weeks of feed restriction using a measuring tape. Chicken body weights under all treatments and controls were recorded on a weekly basis and feed conversion ratios (conversion index = daily feed consumption/daily weight gain) and growth rates [(final weight – initial)/time interval] were subsequently calculated. Behaviour observations were measured using the direct observation method (Lolli et al., 2013) and classified into 6 categories, namely: feeding (eating and drinking), foraging (scratching and litter pecking), aggression (intense feather pecking of another chicken), resting (sitting and standing), comfort (preening and sand bathing) and locomotory activities (moving around). The number of birds engaged in particular behavior was counted (expressed as percentages) at 5 minute-intervals and mean values per week were computed for each pen. The observations were made between 11 and 14 hours everyday by a single observer wihin the chicken house and precaution was taken not to disturb the natural behaviour of the chickens. All procedures used in this study were in compliance with the Sokoine University of Agriculture's guidelines for care and use of animals in research.

**Statistical Analysis**

One-way ANOVA (SPSS 23) was used to analyze differences among all treatments. In case of detection of differences in treatment means by ANOVA, Dunnett t-test and LSD test were used to separate means, with significance statements based on $P < 0.05$. Data for percent weight gain, Feed Conversion Ratios, morphometric parameters, and behavior are expressed as Mean±SD.

**RESULTS**

**Growth Rate**

The growth curves and mean growth rates of the chickens over the entire experimental period are presented in Figure 1 (A, B, C) and Table 2, respectively. For all ecotypes, there was a steady increase in body weight with age. The control groups had higher growth rates than the restricted groups (Table 2). Differences in growth rates within ecotypes were from two weeks (at 42 days of age) after the start of dietary energy restriction to the end of the experiment (Figure 1 A, B, and C). For the controls and 40% energy restriction groups, KU had the highest mean growth rate whilst CH had the least. However, for 55% energy restriction MM had the highest mean growth rate (Figure 1 C and Table 2), whilst CH had the least. Therefore, for all the feed-type groups CH had the lowest mean growth rate.

**Weight Gain**

The mean percent weight gains of the chickens on days 49, 63, and 77 of age (3, 5 and 7 weeks of experimental period) are presented in Figure 2. For all ecotypes, the control groups had higher mean percent weight gains than restricted groups. For the controls and 40% energy restriction groups, KU had significantly higher ($p < 0.05$) mean percent weight gain on days 49, 63 and 77 than MM and CH. At 55% energy restriction MM had significantly higher ($p < 0.05$) mean percent weight gain than KU at 49, 63 and 77 days of age. KU had the lowest mean percent weight gain for the 55% restriction group.

**Feed Conversion Ratios (FCRs)**

The mean FCRs of the chickens are presented in Figure 3. The FCR tended to increase with reduced dietary

**Table 1.** Composition and nutrient levels of experimental diets.

| | Control diet **2864**Kcal/kg ME | 40%Energy Restriction **1696** Kcal/kg ME | 55%Energy Restriction **1319** Kcal/kg ME |
|---|---|---|---|
| **Ingredients** | **(%)** | **(%)** | **(%)** |
| Maize meal | 37.8 | 14.5 | 10 |
| Maize bran | 26 | 10.3 | 2 |
| S.flr. meal | 20.5 | 22.5 | 21 |
| Fish meal | 11 | 18 | 22.3 |
| G. charcoal | 0 | 30 | 40 |
| Limestone | 2 | 2 | 2 |
| Premix[n] | 0.3 | 0.3 | 0.3 |
| Methionine | 0.3 | 0.3 | 0.3 |
| Lysine | 0.3 | 0.3 | 0.3 |
| DCP | 1.3 | 1.3 | 1.3 |
| Salt | 0.5 | 0.5 | 0.5 |

[n]Vitamin-mineral premix provided the following per kg of diet: vitamin A: 8000IU, vitamin D3: 3000IU, vitamin E: 10mg, vitamin K3: 200mg, vitamin B12: 2.5mg, niacin: 6mg, pantothenic acid: 5mg, selenium: 0.2mg, Fe: 80mg, Cu: 80mg, Zn: 100mg, and Mn: 120mg, S. flr.: Sun flower.

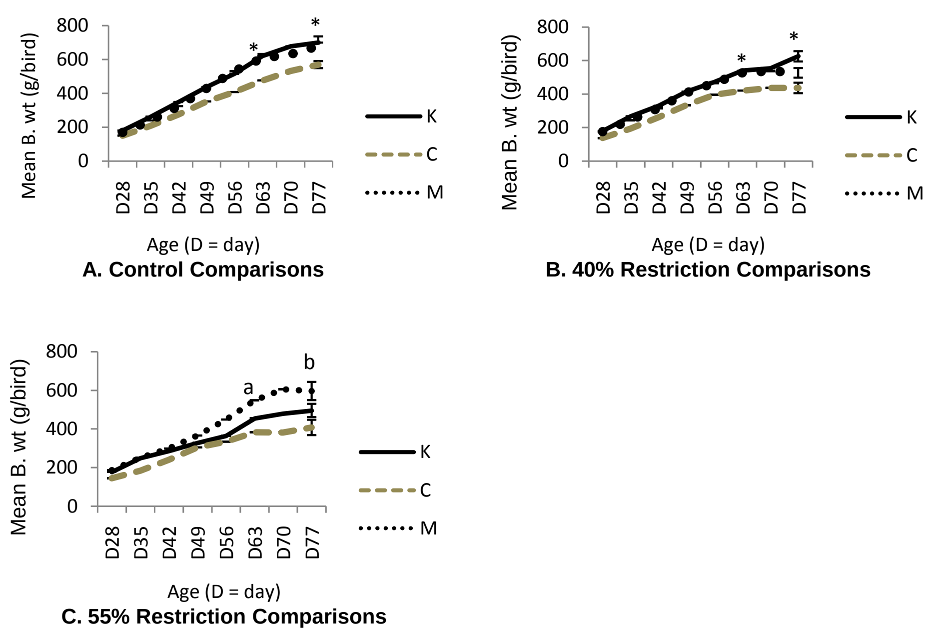


**Figure 1.** Growth curves of the three chicken ecotypes. *significantly higher than C; [a] significantly higher than K and C; [b] significantly higher than C; *K = kuchi, C = ching'wekwe, M = Morogoro medium, B.wt = body weight.*

energy in all groups. Controls had significantly lower ($p<0.5$) FCRs when compared with respective restricted groups for all ecotypes. MM had a significantly lower ($p<0.05$) mean FCR than CH among the controls. At 40% energy restriction no significant difference in mean FCRs was observed among the three ecotypes. At 55% energy

**Table 2.** A summary of mean growth rates* for the entire experimental period**.**

| Ecotype | Feed-type | Growth rate (g/day) | Drop in growth rate (%) |
|---|---|---|---|
| K | Control | 10.6 | |
| | 40R | 9.11 | 14.0 |
| | 55R | 6.49 | 38.7 |
| C | Control | 8.54 | |
| | 40R | 6.11 | 28.4 |
| | 55R | 5.36 | 37.2 |
| M | Control | 10.39 | |
| | 40R | 7.18 | 30.9 |
| | 55R | 8.35 | 19.6 |

*(final weight – initial)/time interval; K = kuchi, C = ching'wekwe, M = Morogoro medium, 40R=40% energy restriction group, 55R=55% energy restriction group.

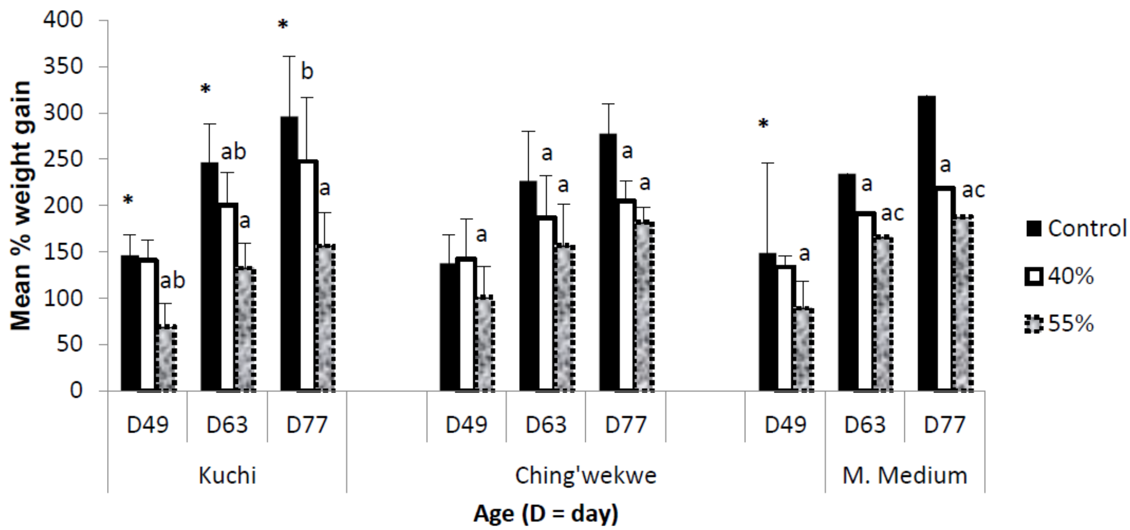


**Figure 2.** Mean % weight gain at 49, 63, and 77 days of age (3, 5, and 7 weeks of feed restriction) – feed-type and ecotype comparisons; a: significantly different from the control, *: significantly higher than in Ching'wekwe; b: significantly higher than in Ching'wekwe and M. Medium, ab: significantly different from the control and from that in Ching'wekwe and M. Medium; ac: significantly higher than in K (p<0.05).

restriction MM and CH had significantly lower mean FCRs than KU.

**Morphometric Traits**

The measured morphometric traits are presented in Table 3. There was no significant difference between controls and restricted groups for all morphometric traits at two and four weeks of energy restriction. KU and CH had their body lengths, shank lengths, chest circumferences, and wing spans significantly reduced (p<0.05) for the 40% and 55% restricted groups after 6 weeks of low dietary energy. MM had its body length and shank length significantly reduced (p<0.05) only for the 40% restricted group, with the chest circumference and wingspan not significantly different from the control for

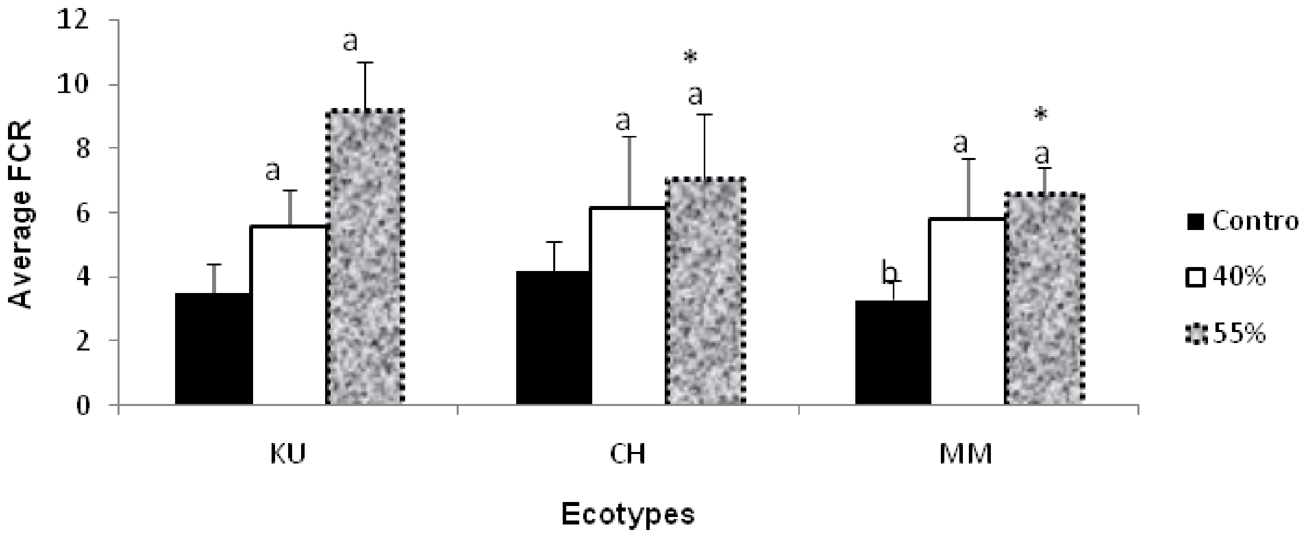


**Figure 3.** Mean feed conversion ratios (FCR) (conversion index = daily feed consumption/daily weight gain); KU: Kuchi; CH: Ching'wekwe; MM: Morogoro medium; a: significantly different from the control; b: significantly lower than the control in CH; *****: significantly lower than KU (p<0.05).

Table 1. Effect of low dietary energy on morphometric parameters after 6 weeks (data presented as Mean ± SD in cm).

| | BL | SL | CC | WS |
|---|---|---|---|---|
| **K Cont** | 31.5±0.8 | 7.10±0.3 | 24.4±1.0 | 39.8±1.6 |
| **K 40** | 28.6±1.5$^{n}$ | 6.36±0.4$^{n}$ | 22.3±1.3$^{n}$ | 36.7±1.3$^{n}$ |
| **K 55** | 28.3±1.2$^{n}$ | 5.80±0.6$^{n}$ | 21.5±1.8$^{n}$ | 36.3±2.0$^{n}$ |
| **C Cont** | 28.0±1.0$^{*}$ | 5.68±0.4$^{*}$ | 21.8±0.4$^{*}$ | 35.5±1.4$^{*}$ |
| **C 40** | 27.0±1.1 | 5.20±0.6 | 20.4±1.3$^{n}$ | 32.6±2.1$^{n}$ |
| **C 55** | 26.6±0.9$^{n}$ | 5.00±0.5$^{n}$ | 19.6±1.0$^{n}$ | 32.9±1.8$^{n}$ |
| **M Cont** | 30.3±1.3 | 6.77±0.5 | 23.8±1.7 | 39.0±2.1 |
| **M 40** | 28.7±1.2$^{n}$ | 6.34±0.3$^{n}$ | 22.7±1.1 | 37.0±1.9 |
| **M 55** | 30.0±1.3$^{i}$ | 6.43±0.4$^{i}$ | 22.7±1.3$^{o}$ | 38.0±2.3$^{o}$ |

K: kuchi; C: ching'wekwe; M: Morogoro medium; 40: 40% restriction; 55: 55% restriction; Cont: control; BL: body length; SL: shank length; CC: chest circumference; WS: wingspan; w: week. $^{n}$: significantly different (p<0.05) from the control of the respective ecotype; $^{*}$:significantly lower (p<0.05) than the controls in K and M; $^{i}$ : significantly higher (p<0.05) than in K and C at 55% restriction; $^{o}$: significantly higher (p<0.05) than in C at 55% restriction.

all the feed-types (Table 3). KU had higher whilst CH had the least values in morphometric measurements for all traits studied.

**Behaviour**

Behavioural analysis results are presented in Figures 4 and 5. The mean percent of the number of chickens exhibiting feeding behaviour was significantly higher (p<0.05) in the 55% energy restriction group than controls for all ecotypes in the third week of energy restriction. Similarly, the mean percent of chickens involved in foraging was significantly higher (p<0.05) in both restricted groups than controls for all ecotypes. The mean percent of chickens exhibiting resting behaviour per time interval was significantly lower (p<0.05) in both restricted groups than the controls, but MM showed no significant difference with controls (Figure 4). Fewer birds exhibited other behaviours such as locomotion, comfort and aggression in all the groups except for the controls. There were no ecotype-specific differences except among the control groups whereby MM exhibited significantly lower (p<0.05) level of resting behaviour.

In the seventh week of energy restriction, there was no

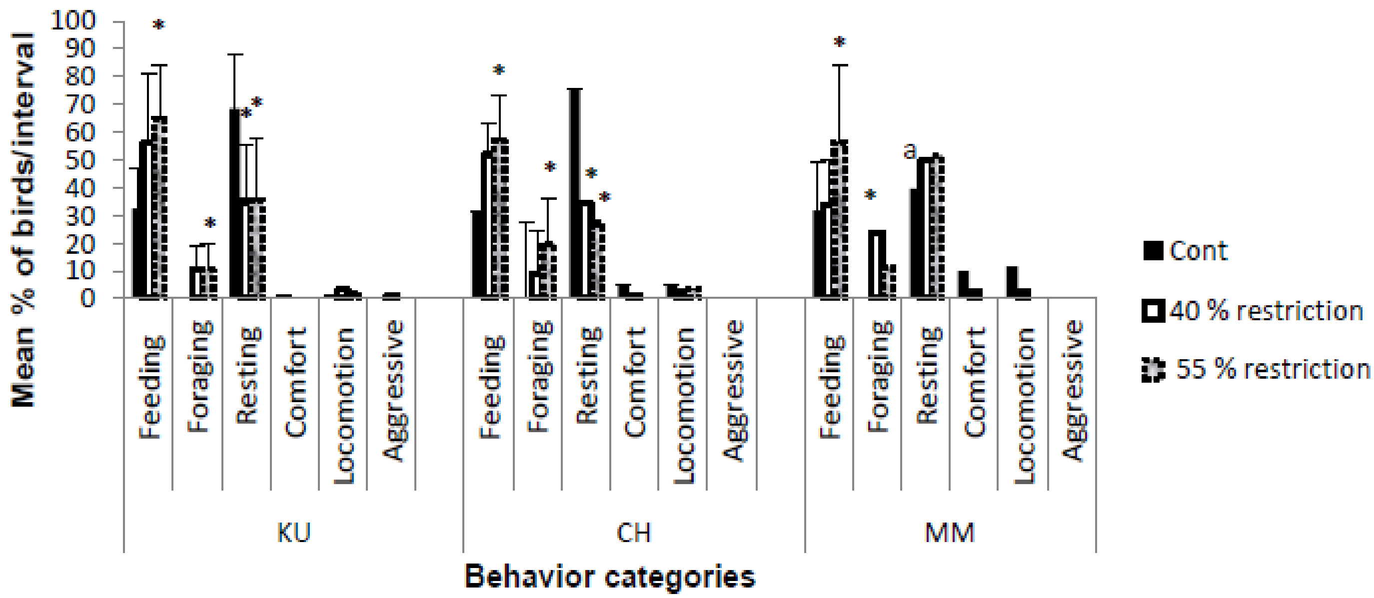


**Figure 4.** Mean % of chickens exhibiting particular behaviour per 5 minute interval – **week 3; ***: significantly different from the control, a: significantly lower than in KU and CH (p<0.05). Cont: control; KU: Kuchi; CH: Ching'wekwe; MM: Morogoro medium.

significant difference between the restricted groups and controls in the mean percent of chickens exhibiting feeding behaviour in all ecotypes (Figure 5). Both restricted groups for KU showed a significantly higher (p<0.05) mean percent of chickens involved in foraging than the control. Mean percent of birds exhibiting resting behaviour was significantly lower (p<0.05) than the controls for KU and CH in the 40 and 55% restricted groups. For both restricted groups, the mean percent of birds exhibiting all behaviour types for MM was not significantly different from the controls (Figure 5). There were no ecotype-specific differences except among the 55% restricted groups where KU exhibited significantly lower (p<0.05) mean percent resting behaviour than CH and MM. Similarly, just like in the third week, fewer birds were involved in the other behaviours such as locomotion, comfort and aggression in all the groups at this stage.

**Mortality**

Mortality was lower in the control groups when compared to restricted groups; and it was the lowest in MM for controls and both levels of restriction (Table 4). There was higher mortality in the restricted groups for KU and CH than for MM. Mortality was first recorded in the fourth week of energy restriction, with body weakness and muscle wear-out being the major cause.

**DISCUSSION**

The present study compared the growth and behavioural responses to stress induced by low dietary energy in local chickens commonly bred from different geographic regions of Tanzania. It was observed that dietary energy restriction at both 40 and 55 % (1696 and 1319 kcal/kg ME, respectively) levels reduced growth rates and feed utilization efficiencies in all the chicken ecotypes involved. The birds were able to similarly tolerate and adapt to this stress but in some cases differently and in an ecotype-specific manner.

Dietary energy restriction increased feed consumption in all the ecotypes during the study period. This was probably an adaptive measure to meet the deficit in the daily energy requirement. Birds usually eat to satisfy their energy needs and adjust their feed intake according to their metabolisable energy requirements (Nakkazi et al., 2015; NRC, 1994). The MM ecotype performed better when compared to other groups at 55% dietary energy restriction throughout the experimental period with respect to growth rates, FCRs and percent average weight gains. This was the lowest dietary energy restriction level used in the present study. Although CH ecotype also had significantly lower average FCR than KU at 55% energy restriction, it had an inferior growth rate and percent weight gain.

KU ecotype, however, showed a better performance under less stressing energy levels as exemplified by a significantly higher percent weight gain and higher growth rates up to the end of the experiment for the controls and at 40% energy restriction. The growth performance of KU at control conditions in this study is in line with Lwelamira et al. (2008) who reported a better body weight for KU when compared to MM under both extensive and intensive management in a study to evaluate on-station and on-farm differences. However, the current study is the first to compare various Tanzanian local chicken ecotypes under dietary energy restriction conditions.

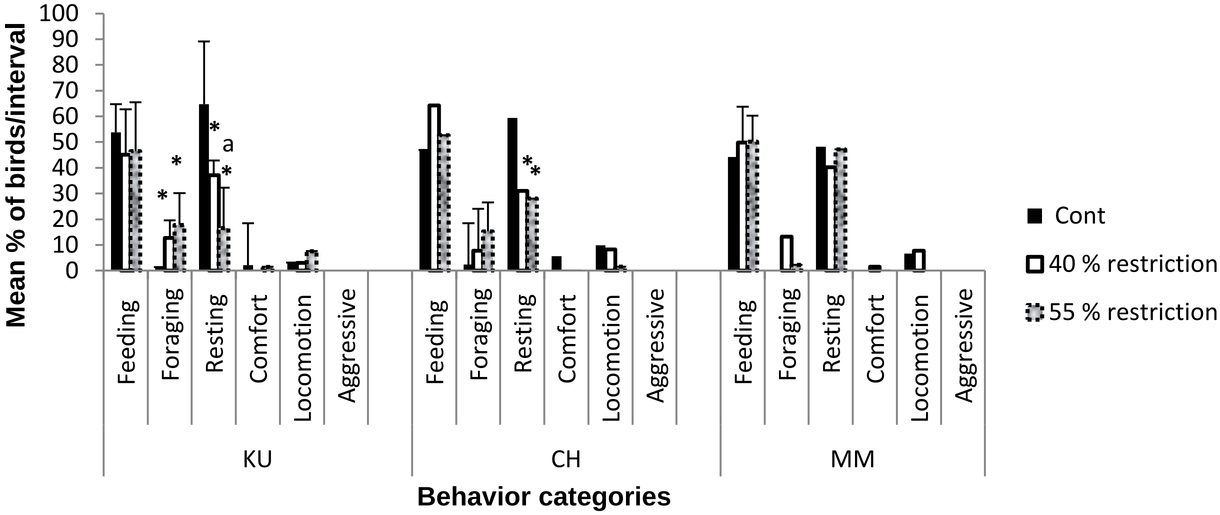


**Figure 5.** Mean % of chickens exhibiting particular behavior per 5 minute interval – **week 7;** *: significantly different from the control, a: significantly lower than in CH and MM (p<0.05). Cont: control; KU: Kuchi; CH: Ching'wekwe; MM: Morogoro medium.

**Table 2:**Mortality summary (%) during seven weeks of dietary energy restriction.

| **Ecotype** | Control | 40% Restriction | 55% Restriction |
|---|---|---|---|
| **K** | 7.7 | 45.1 | 25.7 |
| **C** | 11.7 | 39.1 | 46.4 |
| **M** | 5 | 15 | 5 |

K: kuchi; C: ching'wekwe; M: Morogoro medium.

The results of the current study are also in agreement with other previous studies on commercial lines with respect to decreasing feed utilization efficiency, growth rate and weight gain as dietary energy density is decreased (Chen et al., 2012; Rosa et al., 2007; Bruggeman et al., 2005; Leeson et al., 1996). In contrast to the findings of the current study, Chen et al. (2012) reported that energy restriction significantly increased the feed efficiency of female broiler chickens from 40 to 48 days old. The differences can be due to less stressful restriction regimes (30% energy restriction) used in their study and also because of differences in the chicken strain and phase of growth with the current study. Furthermore, Magala et al. (2012) found that an increase in dietary energy from 2800 kcal/kg to 3000kcal/kg did not affect weight gain and FCR in Ugandan local chicken cockerels, leading to a conclusion that 2800kcal/kg was sufficient for growing these chickens. It can be said that the restriction dietary energy levels used in the present study were much lower than optimal, leading to inhibition of normal growth rates in all the chicken ecotypes.

Feed efficiency, expressed as the amount of feed intake per body weight gain, is reflected in the FCR, and lower FCR means a better performance as the birds were more efficient in using the feed supplied (Aggrey et al., 2010). Dietary energy, as a priority, is directed towards basal metabolism and maintenance, with the remaining energy used for growth and tissue accretion; and therefore, any limitation in dietary energy intake results in reduced growth and tissue accretion (Veldkamp et al., 2005). In the present study, 1696 Kcal/kg ME (40% restriction) only led to 14% drop in growth rate for KU as compared to 28.4% and 30.9% drop for CH and MM, respectively. This shows that at this restriction level KU was better tolerant to low dietary energy levels than both CH and MM. Nonetheless, reducing the energy level to 1319 Kcal/kg ME (55% restriction) led to 38.7, 37.2 and 19.6 % drop in growth rate for KU, CH, and MM, respectively, indicating a better tolerance at this dietary energy restriction level for MM. The MM ecotype's better performance at very low energy levels could be an evolutionary adaptation to how these chickens have been bred in localities they originate from. This might be the reason why MM is the most widespread ecotype in Tanzania (Minga et al., 2003) just as the present findings imply that it can better withstand periods and seasons of the year when feed supply is limiting or scarce. On the other hand the current findings suggest that KU thrives better only when dietary energy levels in the feed are optimum.

Nutritionally stressed individuals rely on catabolism of proteins to fuel their activities thereby leading to loss of skeletal muscle proteins and hence loss of body weight (Kitaysky et al., 2001; Axelrod and Reisine, 1984). In the current study it is evident that after two weeks of restriction (42 days of age) the birds in the restricted groups could no longer compensate energy deficiency in the feed through increased feed intake as shown by a genesis of their reduced growth rate lasting up to the end of the experiment.

Comparisons of morphometric measurements show that KU and CH had their body lengths, shank lengths, chest circumferences, and wing spans significantly reduced for both restricted groups after 6 weeks of energy restriction. However, with MM having all of the morphometric parameters not significantly different from the control for the 55% restriction (1319 kcal/kg ME) group is again an indication of better performance under very low dietary energy (stress) conditions. The ecotype-specific differences in body weights and morphometric traits of Tanzanian local chickens have been reported in previous studies (Msoffe et al., 2001, 2002), and it is in agreement with the current study. Nonetheless, this is the first study to compare these chickens under dietary energy restriction conditions. Meanwhile Prieto and Campo (2011), reported that quantitative feed restriction (60% of *ad libitum*) effect was significant for the fluctuating asymmetry of wing length, being greater in feed restricted white leghorn chicks than the controls (2800 kcal/kg) in an experiment conducted from 1 to 42 days of age. Generally, linear or morphometric body measurements could serve as predictors of body weight; therefore, their variability in poultry arises due to genotypic and environmental effects, and the magnitude of variability may differ under different environmental conditions (Assan, 2015).

In the current study, feeding and foraging behaviours were dominant in all ecotypes in the restricted groups through to the third week of energy restriction. Very few birds (less than 10% in each case) exhibited the other behaviors such as locomotory activities, comfort and aggression. At this stage, metabolic hunger may be linked to such increased activity in the energy-restricted birds (Webster, 2003).The energy restricted chickens appeared to have experienced metabolic hunger and the reduction in other behaviours such as locomotory activity was vital as a way of energy conservation. All the chicken ecotypes in the current study showed a similar trend without between-ecotype differences. However, by the seventh week there were no significant differences between restricted groups and controls in the number of chickens exhibiting feeding behavior in all ecotypes. This observation may entail that by this time the hypothalamic hunger stimulation was minimized in the restricted groups and adaptation had since ensued.

KU restricted groups, unlike the other ecotypes had a higher percentage of chickens exhibiting foraging behaviour, showing between-ecotype differences at this stage (seventh week). This is in agreement with other findings of the current study that have shown that KU 55% restricted group was the most negatively affected in terms of growth parameters. On the other hand, for both restricted groups, the number of birds exhibiting particular behaviour types for MM was not significantly different from the control in the seventh week. This may signify that the restricted groups for MM were less impacted (or were able to adapt faster) by low energy levels than CH and KU. Moreover resting behavior was significantly lower than controls in CH and KU restricted groups. Research by others on behaviour in Tanzanian local chicken ecotypes as affected by dietary energy restriction stress has not been done. However, between-breed differences in behavioural stress response have been reported in other studies elsewhere. For instance, Ericsson et al. (2014) reported a significant between-breed difference in relaxed and preen behaviors between Red jungle fowl and White leghorn breeds; that is, they were more frequent in Red jungle fowl after acute stress. Cheng and Jefferson (2008) also showed that transportation stress-induced behavioral changes in feeding and preening in the commercial chickens from two strains, with a strain selected for high group productivity and survivability showing a greater increase.

Low dietary energy had an effect on mortality of the chickens in this study. Mortality was the lowest in MM at both levels of dietary energy restriction. Almost all mortality cases recorded were caused by severe muscle wasting and general body weakness. It can be inferred therefore, that MM was the most tolerant to low energy levels with respect to mortality, and this is also in agreement with other parameters assed in this study. However, Miah et al. (2014) reported that energy levels of diet reduced up to 2400 kcal/kg ME had no effect on the survivability of indigenous chickens of Bangladesh. In the current study, the energy levels were reduced to very low levels of 1696 and 1319 Kcal/kg ME and the experiment was for a longer period of time, hence the effect. In cases in which the stressor changes from acute to chronic, individuals may experience the negative effects that may include muscle wasting, impaired immune function, depressed growth, inhibition of reproduction and in extreme cases, death (Walker et al., 2005).

## CONCLUSION

This study has shown that feed containing lower energy levels led to decreased growth rates and feed utilization efficiencies. Ecotype-specific tolerance to decreased dietary energy levels through differences in growth and behavioral stress responses is evident. At control energy levels (2864 Kcal/kg ME) and when energy levels are reduced to 1696 Kcal/kg ME, the KU ecotype has a better performance than MM and CH with respect to growth rate, percent weight gain and feed utilization efficiency. On the other hand, MM is better tolerant than KU and CH at lowest energy levels used in this study (1319 Kcal/kg ME) with respect to growth rate, mean percent weight gain, feed efficient utilization, behavioral and mortality indicators.

## LIST OF ABBREVIATIONS

| | |
|---|---|
| $AME_n$: | Apparent Metabolisable Energy |
| CH: | Ching'wekwe |
| CP: | Crude Protein |
| FAO: | Food and Agricultural Organisation |
| FCR: | Feed Conversion Ratio |
| KU: | Kuchi |
| MM: | Morogoro Medium |
| NRC: | National Research Council |

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