

COMPARATIVE PERFORMANCE OF CHICKEN BREED STOCKS IN DIVERSE REARING ENVIRONMENTS

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SUMMARY

Four genetic groups of chickens namely, a commercial hybrid broiler stock, a White Plymouth Rock, a Tanzanian local ecotype, and a cross between White Plymouth Rock and the local ecotype, were compared for performance under two diverse rearing conditions. These consisted of total confinement plus balanced feeds, and day-time scavenging plus maize meal supplementation.

Substantial differences were revealed among genetic groups for body weight gain, carcass weight, intestinal weight, and abdominal fat weight, in favour of the broiler stock, followed by the White Plymouth Rock and the crossbred group, which tended to rank either closely or similarly in most of these attributes. For most of the attributes considered in the study the differences between genetic groups were two to eight times larger under the intensive than under the extensive rearing system, thus reflecting the existence of important interactions between genetic groups and rearing systems. There was also evidence of the existence of substantial heterosis for most of the attributes considered, particularly within the extensive rearing system.

It is concluded from these results that the apparent superiority of genetically improved stocks would not be available for exploitation in rural areas where the cost of nutritionally balanced composite feeds and other inputs are prohibitively high. Since grains are both abundant and cheap in rural areas the free range rearing system based on crossbred birds and grain supplementation would be most appropriate.

INTRODUCTION

The low productivity of animals in developing countries has often been attributed to the low genetic potential of the animals indigenous to these countries and the adverse environmental conditions to which the animals are exposed (McDowell, 1985; Katule, 1990). Importation of genetic resources from temperate countries has not achieved the expected performance in developing countries due to the unsatisfactory performance of the stocks under the low-input production conditions prevailing in most of these countries (Barker, 1982 and Hickman, 1982). On the other hand it is common knowledge that attempts to provide appropriate environments for the improved breeds have not been successful in developing countries, most likely due to the low economic and infrastructure capacity in these countries. The failure of improved temperate breeds to perform satisfactorily under low-input production conditions is due to their failure to adapt to local conditions (Alberro, 1982). The ability to adapt to local production conditions is a key component of merit of any genetic resource (Frisch and Vercoe, 1982; Barker, 1982; Hickman, 1982; and Siegel, 1993). The phenomenon is known as "genotype x environment interaction" and may attain considerable biological and economic significance particularly when substantial differences exist between the environment from which a stock

originates and that in which it is required to perform (Horn, 1982, and Falconer and Mackay, 1996).

With regard to poultry production in the tropics rearing environment has been shown to be one of the most important attributes affecting productivity (Leenstra, 1991; Yalçin *et al.*, 1997). Due to its low investment requirements, the free-range rearing system might offer prospective opportunities for sustaining reasonably high poultry productivity in developing countries. However it is not well understood whether genetically improved poultry stocks could be profitably utilized in such a system, particularly when a definite supplementation regime is imposed. Should there exist significant genotype x environment interactions involving rearing systems then there would be a need to look for the most appropriate genotypes of chickens for production under free ranging conditions.

The current study was conducted to assess the importance of such interactions on chicken growth performance under two diverse systems of rearing.

MATERIALS AND METHODS

Three hundred and thirty chicks belonging to four diverse genetic backgrounds were wing-banded, brooded, and reared in deep litter pens from day-old up to the age of

ten weeks, after which they were subjected to two different rearing systems. Fifty percent of the birds of each genetic group were raised in complete confinement in deep litter pens, while the remaining 50% were confined in the pens only at night, but had free access to the runs during daytime. The genetic groups and the respective numbers of birds involved were: a commercial hybrid (n=104), a White Plymouth Rock strain (n=84), a Tanzanian local ecotype (n=73), and a cross between the White Plymouth Rock and the local ecotype (n=75). The birds raised under total confinement were offered a compounded ration intended to meet all their nutritional requirements, while those in pens with access to the runs were offered only crushed maize meal which was provided in pens in the evenings. Each genetic group x rearing system treatment combination was replicated twice (i.e. in two replicate pens).

The predominant herbage species in the fields were *Brachiaria spp* (40.5%), *Bothriocloa spp* (19.2%), and *Cynodon spp* (14.3%). Other plant species found in small proportions were *Oxalis corniculata*, *Panicum maximum*, and other miscellaneous species. The space allowance per bird in the field was about 8 m². Birds stayed in the runs from 08.00 hours in the morning to 16.00 hours in the afternoon.

The birds were weighed first, at 10 weeks of age and thereafter at 14 and 18 weeks of age. From these

measurements body weight gains were calculated for the periods of 10 to 18 weeks of age.

Daily food allocations in each pen were weighed, and at the end of each week the unconsumed food was weighed. The difference between the cumulative weekly allocations and the residual food at the end of the week was taken to represent the amount of food consumed by the birds in a given pen in the respective week. In turn the cumulative food consumption per bird during a given period was obtained by summing up the weekly food intake in that period and dividing the sum by the average number of birds present in a given pen in the respective period.

At the age of 14 weeks five male birds were randomly picked from each pen, weighed and slaughtered. The gastrointestinal tract of each bird was removed and the crops were weighed before and after removing their contents. In addition empty intestinal weights were taken. The weights of the gastrointestinal components were expressed as percentages of slaughter weight and transformed into arcsine units before being subjected to statistical analyses (Snedecor and Cochran, 1989). Other components measured included carcass weight and abdominal fat pad weights. Dressing percentage was calculated by dividing carcass weight by slaughter weight and multiplying the result by 100. Meanwhile samples of crop contents were pooled on pen basis, after which they were analyzed for proximate composition.

Throughout the experimental period forage samples were randomly picked from the runs, after which they were air-dried, bulked, and subsequently analyzed for proximate, calcium and phosphorous content.

The data on body weights and weight gains were analyzed on the basis of the following mode:

$$Y_{ijklm} = \mu + G_i + R_j + S_k + (GR)_{ij} + P(GR)_{ijl} + e_{ijklm}$$

Where,

Y_{ijklm} = any individual observation;

μ = overall mean common to all observations in the study;

G_i = effect due to the i^{th} genetic group ($i = 1,2,3,4$);

R_j = effect due to the j^{th} rearing system ($j = 1,2$);

S_k = effect due to the k^{th} sex ($k = 1,2$);

$(GR)_{ij}$ = interaction effect between the i^{th} genetic group and j^{th} rearing system;

$P(GR)_{ijl}$ = effect due to the l^{th} replicate pen ($l = 1,2$) within i^{th} genetic group and j^{th} rearing system;

e_{ijklm} = error term - NID $(0, \delta^2)$.

Data on slaughter variables were analyzed on basis of a model similar to the above, except that in this case the effects of sex could not be considered since only male birds were

slaughtered. Observations based on pens, (e.g. food consumption and proximate composition of crop contents) were analyzed on the basis of the following model:

$$Y_{ijk} = \mu + G_i + R_j + (GR)_{ij} + e_{ijk}$$

where:

Y_{ijk} = observation from a given pen, and μ, G_i, R_j and $(GR)_{ij}$ were as defined above;

e_{ijk} = error term - NID $(0, \delta^2)$.

All data were analyzed by using the General Linear Models (GLM) procedure of SAS (SAS, 1996).

RESULTS

Chemical composition of feed stuffs and crop contents

The chemical composition of the composite feed, maize meal, sampled forage, and crop contents are presented in Table 1. The results in this table reveal that, with the exception of nitrogen-free extract, maize meal was deficient in almost all components when compared to the composite diet.

The results further reveal that the forage material had a very high fibre content, while its content of ash and nitrogen-free extract were fairly comparable to those of the composite diet. Both maize meal and forage had very low levels of crude protein, calcium, and phosphorus. It is also to be noted that the dry matter content

of the forage was very low. The results in Table 1 further reveal that, whereas there was a reasonably close agreement between the proximate composition of the composite ration and that of the crop contents recovered from the birds eating the ration. The picture for the feed stuffs put at the disposal of the range-reared birds and that of crop contents recovered from the birds was rather inconsistent. The results reveal higher levels of crude protein in the crop contents of birds than was present in

any of the sampled feed stuffs. On the other hand the dry matter and crude fibre content of the feed stuffs available to the range-reared birds were much lower than can be found by averaging their content in maize and forage. The level of ash in the crop contents of range-reared birds was much higher than in the sampled forage material.

Table 1: Chemical composition of feed-stuffs and crop contents

| Component | Content (%) in feed-stuffs | | | Content (%) in crop contents | |
|----------------|----------------------------|------------|--------|------------------------------|-----------|
| | Composite | Maize meal | Forage | Intensive | Extensive |
| Dry matter | 92.8 | 90.9 | 20.1 | 34.4±0.8 | 39.4±0.8 |
| Crude protein | 16.8 | 9.4 | 6.0 | 17.5±0.2 | 10.8±0.2 |
| Crude fibre | 9.5 | 2.3 | 28.5 | 6.1±0.2 | 5.2±0.2 |
| Ether extract | 5.0 | 3.8 | 1.2 | 6.9±0.1 | 1.9±0.1 |
| Ash | 8.8 | 1.0 | 10.6 | 11.0±0.7 | 18.0±0.7 |
| N-free extract | 59.9 | 83.5 | 53.7 | 58.5 | 64.1 |
| Calcium | 1.7 | 0.6 | 1.0 | - | - |
| Phosphorus | 0.7 | 0.3 | 0.3 | - | - |

Growth and Food Intake

The results in Table 2 reveal significant differences ($P < 0.05$) between genetic groups and rearing systems for body weights, weight gains, and food intake. It is evident from the results in Table 2 that in both rearing systems the broiler chickens had the largest body weights and highest weight gains of all the genetic groups, followed by the White Plymouth Rocks, and the White Rock x Local crossbred birds. However, it is to be

noted that in most cases the performance of the White Plymouth Rock and that of the crossbred group were statistically similar. The local ecotype had the lowest performance in these attributes. Regarding rearing systems, the birds under the intensive rearing system were heavier and gained weight much faster than those under the free range system.

The ranking of the genetic groups with respect to food intake was similar, but not proportional to that

for live-weights and weight gains. When the weight gains in the 10-18 week period is expressed as a proportion of the amount of food ingested during the same period it is realized that the broiler birds utilized food more efficiently than all the other genetic groups. Apparently, the local ecotype performed much better than both the White Plymouth Rock, and the crossbred group in this attribute.

With regard to rearing systems the results in Table 2 reveal that the birds under the intensive system consumed about twice as much food as those under the free range system, but their mean body weight gain was four times that of birds on the free range system.

The results in Table 2 further reveal that although the broiler chickens performed better than other genetic groups under both the intensive and free range system the superiority of this group over the others was five to eight times larger in the intensive than in the free range system. The ranking of the White Plymouth Rock relative to the crossbred group was not consistent in the two rearing environments, but in both environments the two genetic groups did not differ from each other significantly. Although the local ecotype had the lowest performance in both environments the difference of this ecotype from the White Plymouth Rock and the crossbred group was not consistent in the two rearing environments.

Table 2: Least square means for Growth and Food intake by birds summarized by various factors*

| | | Performance attributes | | |
|-----------|---------------|------------------------|-----------------------|-------------------------|
| Effect | Components | Wt 18wks (g) | Gain 10-18 wks (g) | Intake 10-18 wks (g) |
| Genetical | Broiler | 2977± 29 ^a | 1772± 26 ^a | 7939± 136 ^a |
| | White P. Rock | 1673± 34 ^b | 611± 30 ^b | 5186± 136 ^b |
| | P.RockxLocal | 1691± 36 ^b | 580± 32 ^{bc} | 5106± 136 ^b |
| | Local | 1044± 38 ^c | 498± 34 ^c | 3445± 136 ^c |
| Rearing | Intensive | 2367± 25 ^a | 1377± 22 ^a | 7113± 96 ^a |
| | Extensive | 1326± 25 ^b | 353± 22 ^b | 3725± 96 ^b |
| Intensive | Broiler | 4191± 41 ^a | 2975± 36 ^a | 11049± 192 ^a |
| | White P. Rock | 1970± 48 ^b | 895± 43 ^b | 6528± 192 ^b |
| | P.RockxLocal | 1964± 51 ^b | 852± 45 ^b | 6563± 192 ^b |
| | Local | 1342± 52 ^c | 785± 46 ^b | 4313± 192 ^c |
| Extensive | Broiler | 1764± 42 ^a | 568± 37 ^a | 4828± 192 ^a |
| | White P. Rock | 1377± 47 ^b | 326± 41 ^b | 3844± 192 ^b |
| | P.RockxLocal | 1417± 50 ^b | 309± 44 ^b | 3649± 192 ^{bc} |
| | Local | 746± 55 ^c | 210± 49 ^b | 2577± 192 ^c |

* Means with different superscript letters within a column and effect are significantly different (P<0.05).

Slaughter and gastrointestinal component attributes

Table 3 shows the least square means for carcass weights, dressing percentage, abdominal fat, intestinal weights and crop content weights summarized by various sources of variation. The results reveal the existence of significant differences among genetic groups with respect to all the attributes. Expectedly, the broiler chickens had the heaviest carcasses of all the genetic groups, followed by the White Plymouth Rock and crossbred birds, which had statistically similar mean carcass weights. A similar trend is revealed with respect to abdominal fat content and crop content weights, except that in this latter case the local ecotype had proportionately the same amounts of crop contents as the broiler stock. When carcass weights were expressed as percentages of slaughter weights (i.e. as dressing percentages) the crossbred group came out as the best group, followed by the broiler and the White Plymouth Rock, which did not differ from each other significantly. It is interesting to note that the local ecotype had proportionately the same mean intestinal weight as the hybrid broiler group.

Regarding rearing systems the results in Table 3 reveal the existence of significant differences between the two systems with respect to carcass weight and dressing percentage in favour of the

intensive system. However, this was not the case for intestinal weight, and abdominal fat weight, and crop content weight.

It is to be noted that, although the ranking of the genetic groups for carcass weights and abdominal fat weights was similar in the two rearing systems the differences between genetic groups for these attributes were different in the two environments. However, in the case of dressing percentage and intestinal weight both the ranking and the differences between genetic groups were similar in the two rearing systems. It is interesting to note that, whereas under the intensive system the broiler stock had proportionately more crop contents than other genetic groups, it is the local ecotype which had proportionately the largest amount of crop contents under the free-range system.

Proximate composition of crop contents

Table 4 shows the least square means for various proximate composition components of crop contents summarized by various effects. It is apparent from these results that, the feed stuffs ingested by the local chickens had the highest dry matter and ash contents, followed by those of the broiler and White Plymouth Rock chickens. Crude protein content was highest in feed stuffs ingested by the White Plymouth Rock and crossbred chickens, followed by that

Table 3: Least square means for weights (as % of slaughter weight) of carcass and gastrointestinal components of birds*

| Effects | Components | Performance attribute | | | | |
|-----------|------------|-----------------------|------------------------|-----------------------|-----------------------|------------------------|
| | | Carcass weight (g) | Dressed weight (%) | Crop content (%) | Intestinal Weight (%) | Abdominal Fat (%) |
| Genetical | Broiler | 1890± 36 ^a | 65.1±0.4 ^b | 1.6± 0.1 ^a | 2.0± 0.1 ^a | 1.2± 0.1 ^a |
| | P. Rock | 1214± 36 ^b | 65.0±0.4 ^b | 0.5± 0.1 ^b | 1.7± 0.1 ^b | 0.5± 0.1 ^b |
| | Crosses ** | 1235± 36 ^b | 66.2±0.4 ^a | 0.5± 0.1 ^b | 1.6± 0.1 ^b | 0.4± 0.1 ^{bc} |
| | Local | 684± 36 ^c | 62.7±0.4 ^c | 2.0± 0.1 ^a | 2.1± 0.1 ^a | 0.2± 0.1 ^c |
| Rearing | Intensive | 1593± 25 ^a | 66.3±0.3 ^a | 0.8± 0.1 ^b | 1.7± 0.0 ^a | 0.5± 0.1 ^a |
| | Extensive | 919± 25 ^b | 63.1±0.3 ^b | 1.5± 0.1 ^a | 1.9± 0.0 ^a | 0.7± 0.1 ^a |
| Intensive | Broiler | 2579± 50 ^a | 66.2±0.5 ^{ab} | 1.8± 0.2 ^a | 1.7± 0.1 ^b | 0.9± 0.1 ^a |
| | P. Rock | 1455± 50 ^b | 66.4±0.5 ^{ab} | 0.4± 0.2 ^c | 1.7± 0.1 ^b | 0.4± 0.1 ^b |
| | Crosses | 1455± 50 ^b | 67.6±0.5 ^a | 0.2± 0.2 ^c | 1.5± 0.1 ^c | 0.4± 0.1 ^b |
| | Local | 893± 50 ^c | 65.1±0.5 ^b | 0.8± 0.2 ^b | 2.1± 0.1 ^a | 0.1± 0.1 ^b |
| Extensive | Broiler | 1200± 50 ^a | 64.0±0.5 ^a | 1.4± 0.2 ^b | 2.2± 0.1 ^a | 1.6± 0.1 ^a |
| | P. Rock | 973± 50 ^b | 63.6±0.5 ^a | 0.7± 0.2 ^c | 1.8± 0.1 ^b | 0.6± 0.1 ^b |
| | Crosses | 1026± 50 ^b | 64.7±0.5 ^a | 0.7± 0.2 ^c | 1.6± 0.1 ^b | 0.3± 0.1 ^b |
| | Local | 476± 50 ^c | 60.3±0.5 ^b | 3.1± 0.2 ^a | 2.1± 0.1 ^a | 0.3± 0.1 ^b |

* Means with different superscript letters within a column and effect are significantly different (P<0.05) ** Crosses = P.RockxLocal

ingested by the broiler group. The crop contents of local chickens had the lowest crude protein content. A rather similar picture is apparent for the ether extract content of the crop contents, but in this case the broiler stock were the highest in this attribute.

Table 4: Least square means for proximate composition of crop contents

| | | Proximate composition of crop contents (%) | | | | |
|-----------|-----------|--|------------------------|------------------------|------------------------|------------------------|
| Effect | Component | Dry matter | Cr. protein | Cr. fibre | Ether extr. | Ash |
| Genetical | Broiler | 36.2± 1.1 ^b | 14.3± 0.2 ^b | 5.9± 0.3 ^{ab} | 5.1± 0.1 ^a | 16.4± 1.0 ^b |
| | P. Rock | 39.2± 1.1 ^{ab} | 14.9± 0.2 ^a | 6.5± 0.3 ^a | 4.5± 0.1 ^b | 9.9± 1.0 ^c |
| | Crosses* | 32.4± 1.1 ^c | 14.8± 0.2 ^a | 5.1± 0.3 ^b | 4.2± 0.1 ^c | 8.5± 1.0 ^c |
| | Local | 40.0± 1.1 ^a | 12.5± 0.2 ^c | 5.2± 0.3 ^b | 3.7± 0.1 ^d | 22.9± 1.0 ^a |
| Rearing | Intensive | 34.4± 0.8 ^b | 17.5± 0.2 ^a | 6.1± 0.2 ^a | 6.9± 0.1 ^a | 11.0± 0.7 ^b |
| | Extensive | 39.4± 0.8 ^a | 10.8± 0.2 ^b | 5.2± 0.2 ^b | 1.9± 0.1 ^b | 17.8± 0.7 ^a |
| Intensive | Broiler | 33.2± 1.6 ^b | 18.2± 0.3 ^a | 6.8± 0.4 ^a | 8.4± 0.2 ^a | 10.5± 1.4 ^a |
| | P. Rock | 40.0± 1.6 ^a | 17.7± 0.3 ^a | 6.3± 0.4 ^{ab} | 6.9± 0.2 ^b | 11.8± 1.4 ^a |
| | Crosses | 32.2± 1.6 ^b | 17.9± 0.3 ^a | 5.3± 0.4 ^b | 6.4± 0.2 ^{bc} | 8.9± 1.4 ^a |
| | Local | 32.3± 1.6 ^b | 16.2± 0.3 ^b | 6.1± 0.4 ^{ab} | 6.1± 0.2 ^c | 12.9± 1.4 ^a |
| Extensive | Broiler | 39.1± 1.6 ^b | 10.4± 0.3 ^b | 4.9± 0.4 ^b | 1.9± 0.2 ^a | 22.3± 1.4 ^b |
| | P. Rock | 38.3± 1.6 ^b | 12.2± 0.3 ^a | 6.7± 0.4 ^a | 2.2± 0.2 ^a | 7.8± 1.4 ^c |
| | Crosses | 32.5± 1.6 ^c | 11.8± 0.3 ^a | 4.9± 0.4 ^b | 1.9± 0.2 ^a | 8.0± 1.4 ^c |
| | Local | 47.8± 1.6 ^a | 8.8± 0.3 ^c | 4.3± 0.4 ^c | 1.3± 0.2 ^b | 33.0± 1.4 ^a |

* Means with different superscript letters within a column and effect are significantly different (P<0.05) * Crosses = P.RockxLocal

The results further show that the feed stuffs ingested by the broiler and White Plymouth Rock stocks had the highest fibre content, while those ingested by the crossbred and the local stocks had relatively low fibre content.

The results in Table 4 further reveal that there were significant differences between rearing systems with respect to all crop content composition attributes considered. The dry matter and ash content of the ingesta from the range-reared birds was much

higher than that from indoor reared birds. On the other hand the birds reared under the intensive system had higher crude protein, crude fibre, and ether extract levels in their crop contents than the birds under the free-range system.

From the results shown in Table 4 it is to be noted further that the differences between genetic for dry matter and ash levels of crop contents were much more pronounced under the free range than under the intensive system of rearing. Furthermore, the ranking

of the genetic groups for crude protein, crude fibre, and ether extract content was not consistent in the two rearing systems.

DISCUSSION

Relative nutritional adequacy of experimental and scavenged feed stuffs

The observed disparity in the proximate composition of the composite feed given to confined birds on one hand, and the maize meal and sampled forage material made available to free ranging birds on the other hand, suggest that the birds in the rearing systems were under very different nutritional regimes. This aspect will be explored further in the forthcoming discussion where the results for the growth performance of the chickens and the chemical composition of their crop contents are also examined.

Genetic effects

The observed superiority of the broiler stock to other groups for growth, feed intake, and relative intestinal weights was not surprising, since traits related to growth are known to be strongly influenced by additive genetic effects (McCarthy and Siegel, 1983; Kirkwood and Prescott, 1984; Pinchasov *et al.*, 1985; Sørensen, 1985; Pym, 1985 and Chambers, 1990). Although the observed superiority of the broiler stock to other

stocks may be attributed largely to the superior additive genetic potential of this stock the contribution of heterosis to the overall merit of the broiler stock might also have been substantial. In their development, broiler stocks are initially intensively selected for high growth rate and feed efficiency before being crossed to utilize heterosis in specific traits. On the other hand the observed inferiority of the local ecotype with respect to most growth attributes considered in the study can be attributed to the fact that this stock had never been selected for high performance in such traits.

The observed close ranking between the White Plymouth Rock and the crossbred stock for most attributes in this study needs to be explained. Since in nearly all these traits the local ecotype was considerably inferior to the White Plymouth Rock then the most plausible explanation for the close similarity in the performance of crossbred and White Plymouth Rock birds is heterosis. This is evidenced by the fact that in most attributes considered the performance of the crossbred stock exceeded the mid-parent value, and in a few cases crossbred performance even superceded that of the better parental stock. The occurrence of heterosis or hybrid vigour in crossbred birds is a widely reported phenomenon (Kinghorn, 1980, 1982; Sheridan, 1982; Cunningham, 1982; Hill, 1982; Hickman, 1982). Although the phenomenon has been attributed to non-additive gene interactions, that is

dominance, overdominance, and epistasis (Kinghorn, 1980; McGloughlin, 1980; Cunningham, 1982; Hill, 1982; Falconer and Mackay, 1996), the physiological mechanisms through which it is expressed are yet to be fully elucidated. However, it is generally accepted that heterosis could be the result of crossbred animals being more able to cope up with environmental stresses, and hence to better express their genetic potential than their straight bred contemporaries (Orozco, 1974; Horn, 1980; Clarke, 1982; Cunningham, 1982; Hickman, 1982; Sheridan, 1982). This contention is strongly supported by the findings of the present study. The results in Table 2 and 3 reveal that for most of the attributes considered the superiority of the crossbred stock over the mid-parent value was much more pronounced in the free range than in the confined birds.

Contrary to the above stated general trend, further scrutiny of the results in Table 3 and 4 reveals that the crossbred group had lower least square means than either one or both parental stocks with respect to a number of gastrointestinal attributes which are related to gut fill (e.g. intestinal weight, crop content weights, dry matter, crude fibre, and ash levels in crop contents), thus leading to negative heterosis in these attributes. This result suggests that, probably due to their higher digestive efficiency, crossbred birds were able

to empty their crops more rapidly than the parental stocks. According to Sedcole (1981, after Cunningham, 1982) heterosis may arise from the reduced effectiveness of gene repressors, leading to higher enzyme levels in heterozygotes.

Two contentions have been put forward to explain the occurrence of negative heterosis. The first explanation is that a negative value for heterosis can be obtained if a decrease in the magnitude of expression of a trait represents improved performance in that trait. An example of such traits is age at sexual maturity in birds and other farm animals, in which case the more vigorous animals attain sexual maturity at an earlier age than the less vigorous ones. In such cases if heterosis causes a decrease in age at sexual maturity then crossbred animals would have lower values for this attribute than their pure bred counterparts. A second explanation for the occurrence of negative heterosis is that, after a long period of natural selection in a given environment, a stock may attain certain gene combinations which confer adaptive qualities in some attribute to the stock. In this case crossbreeding would disturb the adaptive gene combinations, thus leading to crossbred animals being less efficient than the adapted pure breed (Dobzhansky, 1950).

The observed close proximity in the ranking of local and broiler chickens with respect to relative gastrointestinal

organ weights and crop content composition attributes is rather surprising. In most of these attributes (e.g. intestinal weight, crop content weights, and dry matter and ash content of crop contents) the two genetic groups were either in tandem or ranked similarly higher than the other genetic groups. It is to be noted that all the above mentioned attributes are somewhat closely linked to gut fill. It is to be noted further that even in those cases where the local and the broiler stocks ranked lower than the other genetic groups (e.g. in crude protein and fibre content of crop contents) still the two genetic groups were either in similar or tandem rank. However, the two stocks were widely separated from each other with respect to abdominal fat and ether extract content of crop contents.

The fact that the local ecotype and the broiler stock ranked similarly higher than other groups with respect to attributes related to gut fill, while ranking similarly low with respect to crude protein level of crop contents, may suggest that both stocks ingested more bulky feed-stuffs than other genetic groups. This could occur if, due to their relatively high appetite, the two stocks become less selective in their feeding behaviour than other genetic groups. Similar views have been expressed by Boa-Amponsem *et al.*

(1991a, 1991b).

Effects of rearing systems

It is interesting to note that, whereas, the birds raised under the intensive system were very much superior to those reared under the range with respect to growth and feed intake attributes. The ranking of the two groups was reversed in the case of gut fill-related attributes such as crop content weights, dry matter, and ash level of crop contents.

The higher levels of crude protein and relatively lower dry matter and crude fibre levels observed in the crop contents of range reared birds than those in maize or forage suggests that there was some degree of selectivity in the feeding behaviour of the range reared birds. On the other hand the observed higher levels of ash in the crop contents of range-reared birds than could be found in the sampled forage material could most probably be due to the ingestion of soil material by the birds.

Overall these results clearly indicate that the range-reared birds ingested more bulky feed stuffs which were nutritionally inferior to those offered to the intensively reared birds. Findings reported by (Hill, 1977) have indicated that food material remain for longer periods in the crop contents of fowls feeding on vegetables than in the crops of indoor birds fed on mash or pelleted rations. Protein and its constituent amino acids are likely to have been the most limiting nutrients in the diet of the range-reared birds.

Another interesting feature to note is that, although the feed intake by intensively reared birds was about twice as much that of range birds, the mean body weight gain of the intensively reared birds was four times that of range birds. This suggests that food utilization was twice as efficient in confined birds as in range birds. It is worth noting that the feed intake being referred to here for range birds was only that which was offered in the pens during evenings. Therefore, if scavenged feed had been accounted for the feed utilization efficiency of the range birds relative to their confined counterparts would have turned out to be very low.

On the other hand if the feed intake and body weight gain data in Table 2 compared with the prices of the feeds used in the study the two systems of rearing might turn out not to differ much. For example in Morogoro town, where the current study was undertaken, nutritionally balanced commercial feeds cost about Tsh. 170 (US cents 17.9) while maize grain costs about Tsh. 100 (US cents 10.5) per kilogramme. In such a circumstance the intensive rearing system would be only about 20% more efficient than the range system in terms of cost per unit body weight gain. When the cost per unit body weight is considered for each genetic group separately it becomes apparent that with some genetic groups (e.g. the White Plymouth Rock and the White Rock x Local cross) the range rearing system might be slightly more efficient than the intensive system.

In Tanzania, as one moves further away from urban areas the prices of balanced feeds increase while those of cereal grains decrease dramatically. This implies that as one moves further into rural areas the economic merits of the intensive system of rearing chickens would become less and less prospective, while that of supplementing cereal grains to scavenging chickens would become more and more promising.

Interaction effects

The observed interactions between genetic groups and rearing systems could be explained by the fact that, although the ranking of the genetic groups was about the same for most attributes in both the intensive and free range system the magnitudes of the differences were profoundly different in the two environments. For example, under the intensive rearing system the superiority of the broiler stock over other stocks was five to eight times that observed under the free range system with respect to live-weights, weight gains, and feed intake. The differences between genetic groups for carcass weights were much more pronounced in the intensive than in the free range rearing system. On the other hand, the differences between genotypes for abdominal fat and proximate composition of crop contents were in most cases five times more substantial in the free range rearing system than in the intensive rearing system. It is interesting in this respect

to note that the local birds had particularly large amounts of crop contents relative to their body weights, as well as high levels of dry matter and ash in their crop contents in the free range system. Furthermore, the ranking of the genetic groups for crude protein, crude fibre, and ether extract levels of the crop contents was not consistent in the two environments.

These findings reflect differences among genotypes for tolerance to sub-optimum rearing conditions. In this case the main environmental conditions which differed between the two rearing systems were food quality and presentation form. While under the intensive rearing system a nutritionally balanced feed was presented in a compounded form, the free ranging birds were offered only maize meal but had opportunity to scavenge for other feed materials from the range. In general, these results indicate that superior genotypes under the intensive system were not able to maintain their level of superiority under the free range system. This was probably due to the inability of the genetically superior birds to forage and scavenge as much as their less genetically endowed counterparts. This proposition is supported by the proportionately large crop contents, as well as by the high dry matter and ash levels of crop contents from the range-reared local ecotype. It is speculated that if maize meal had not been offered a complete reversal in the ranking of the genetic groups might have been manifested

in the free range system. The results of the present study are in agreement with those of Siegel *et al* (1997) who concluded that fast growing stocks have a greater preference for diets containing high levels of protein than slow growing birds. Similar findings have been reported by Marks *et al* (1993a, 1993b) who observed that populations which have been selected under high dietary protein levels require high protein diets, while stocks which have been selected under low dietary protein levels do not require high protein levels for full expression of their genetic potential for growth.

The phenomenon whereby the relative merits of genotypes vary from one environment to another is termed as "genotype x environment interaction" and has been widely reported from various studies. This has led to the notion that superior performance of a genetic stock in a relatively stress-free environment could in some way involve physiological, anatomical and behavioral mechanisms quite different from those determining superiority under stressful environmental conditions. Consequently, some workers (Falconer and Mackay, 1996) have proposed that the sets of genes responsible for superior performance of animals could be different in different environments.

CONCLUSIONS

From the results of the present study it is concluded that:

Genetically superior stocks developed for performance under good conditions of feeding and housing may not fully exhibit their potential under free range scavenging conditions;

Heterosis could be an important component of merit for performance in sub-optimum management conditions. Since it only requires few males of a superior novel stock for crossing with females of the local breed the beneficial effect of heterosis should be as far as possible exploited to improve chicken productivity in rural areas;

Intensive systems of management utilizing high performing improved stocks and nutritionally balanced feeds would be more economically sound than free range systems only where balanced feeds are cheap. In rural areas, where such feeds are either unavailable or prohibitively expensive free-range systems based on indigenous stocks or crosses of such stocks with improved novel breeds should be adopted.

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