Journal of Sustainable Development in Africa (Volume 13, No.8, 2011)
ISSN: 1520-5509
Clarion University of Pennsylvania, Clarion, Pennsylvania

TOWARDS SUSTAINABLE BROILER PRODUCTION – DOES USE OF SORGHUM (SORGHUM BICOLOUR) AS AN ADJUNCT SUBSTITUTE OF MAIZE AFFECT BROILER PERFORMANCE?

Marshall Dhliwayo
Department of Animal and Wildlife Management, Bindura University of Science Education, Zimbabwe

ABSTRACT

The sustainability of the poultry industry is threatened, more so in drought years, because maize remains the sole energy source in most poultry diets. A study was undertaken to assess the suitability of employing sorghum as an alternative or an add-on to maize. The main objective of this study was to determine the suitability of sorghum as an energy source in broiler diets by evaluating the performance of birds fed with the locally available white sorghum. In four treatments the maize component of broiler diets was substituted with sorghum at graded levels of 0%, 40%, 60% and 80%. One hundred and twenty (120) day-old unsexed hybrid broiler chicks were randomly assigned to 12 pens, with 10 birds per pen. The pens were then randomly allocated to the four diets in a Completely Randomized Design (CRD) with three replicates. A two-phase feeding system was employed. The starter phase was up to four weeks, and the finisher phase stretched from four to eight weeks. The birds` live weight, voluntary feed intake and feed conversion ratio were measured and calculated weekly. For the first three weeks, live-weight changes between maize and sorghum based diets were not significantly different. However, from week 4 onwards, broilers fed on the maize diet (0% sorghum) grew significantly faster ($p<0.05$) than birds fed on sorghum-based diets. Feed Conversion Ratio (FCR) only showed a significant difference ($p<0.05$) between the maize-only and the 80% sorghum-based diet. Substituting maize with sorghum did not adversely affect Total Feed Intake (TFI), ($p>0.05$) across all diets, which suggests the astringent effects of tannins could not impede upon the high appetite levels bred for in modern broiler breeds. It was therefore concluded that substituting maize with sorghum by up to 40% would not adversely affect broiler performance.

Keywords: Sorghum, Sustainable production, Feed Conversion Ratio, Broiler performance, feeding systems

INTRODUCTION

High feed costs remain one of the major constraints to sustainable Broiler production in the smallholder sector (Ademosun, 1973; Obioha, 1976; Munyau et al., 1998). Feed represents approximately 75 to 80% of total cost of production (Mpofu, 2004; Ravindran and Blair, 1992; Fasuyi, 2005). Ready-to-feed commercial diets are becoming increasingly expensive due to the effects of recurrent droughts which reduce maize production. This decrease leads to an increase in the price of maize due to a sharp rise in demand, as maize is also a staple crop to many families (Balogun et al., 1995). Maize makes up approximately 65 to 70% of the poultry diet (Mutetwa, 1996), such that any increase in its price will radically affect the price of broiler feeds. The prospects of increasing maize output to a magnitude that will satisfy both human and animal requirements are low (Church and Pond, 1982). For this would fuel an industrial approach to farming which involves large capital outlay, rapid technological innovations, large-scale farming, single crops grown continuously over many seasons, extensive use of pesticides, fertilizers and external energy inputs and high labour input. Significant negative consequences have come with the bounty associated with industrial agriculture. These include decline in soil productivity due to wind and water erosion of exposed top soil, soil compaction, salinisation of soils, water pollution, water scarcity due to overuse of surface and ground water for irrigation purposes, etc. These costs are not normally included when costing the current production of food, but they are real costs that are accumulating and swelling to detonate in the near future.

A possible local and comparative alternative (Preston, 1990a) to maize as a source of energy in broiler diets would be supportive as this introduces diversity of inputs, fundamental to sustainable agriculture. Several researches have evaluated substitutes for maize and, in this situation the use of uncommon food ingredients in animal diet formulation must be better appraised. For such evaluations, the nutritional value of the food, the best inclusion level in diets and economic viability should be considered (Jacob et al., 1996).Sorghum has been put forward as a possible alternative to maize. Sorghum can be grown successfully in drier and poorer soils than maize. Sorghum is comparable to maize in terms of its feeding value, as shown in Table 1.

Table 1: Chemical composition of maize and sorghum

Nutrient	Maize	Sorghum
Crude Protein	85g/kg	12g/kg
TDN	800g/kg	780g/kg
CF	23.0g/kg	22.2g/kg
EE	49g/kg	33g/kg
ME	11.9MJ/kg	11.7MJ/kg
Lysine	2.4g/kg	1.6g/kg
Methionine	2.4g/kg	1.6g/kg

Source: Topps and Oliver (1993)

Keywords: TDN = Total Digestible Energy

CF = Crude Fibre

EE = Ether Extractives

ME = Metabolisable Energy

The consumption of sorghum as food by humans is less than that of maize and its cost is about 80% that of maize at the Grain Marketing Board. So successful has been the development of the sorghum growing and handling methods (Dumitru, 2004), such that a large amount of grain is exported to Europe and elsewhere from many African countries, including Zimbabwe. Sorghum is also of remarkable genetic diversity and is suitable for production in the semi- and tropical areas than maize (Cheeke, 1999). These factors make sorghum an ideal energy source for poultry diets in place of maize. The question is why the low adoption and utilisation of sorghum as a feed ingredient when almost every factor seem to favour its adoption? The problem with sorghum is that it contains some Anti-Nutritional Factors (ANFs) which reduce its feeding value, particularly in Monogastrics and birds. Tannins are the most important ANFs found in the Red Sorghum varieties. The high tannin contents in the seed, through their astringent flavour, potentially reduce the damages caused by birds. On the other hand, the seeds also become less palatable and nutritive to our domestic birds, since tannins interfere with the metabolism of carbohydrates and proteins. The level of tannin in sorghum grains varies from 1.3 to

3.6% in high tannin sorghum and from 0.1 to 0.7% in low tannin sorghum (Myer et al., 1986). Inclusion levels of sorghum in poultry diets are normally reduced in order to reduce the detrimental effects of tannins in the growth of broilers. In this study the inclusion of sorghum in place of maize as an energy source was graded in order to come up with a recommendable inclusion level.

OBJECTIVES OF THE STUDY

The main objective of this study was to determine the suitability of sorghum as an energy source in broiler diets by evaluating the performance of birds fed with the locally available white sorghum. The use of sorghum should not be detrimental to the performance of birds but should at least enhance the full expression of their genetic potential.

Specific Objectives were, to determine the effect of substituting maize with sorghum on:

i. Broiler growth
ii. Feed intake
iii. Feed conversion ratio

HYPOTHESES:

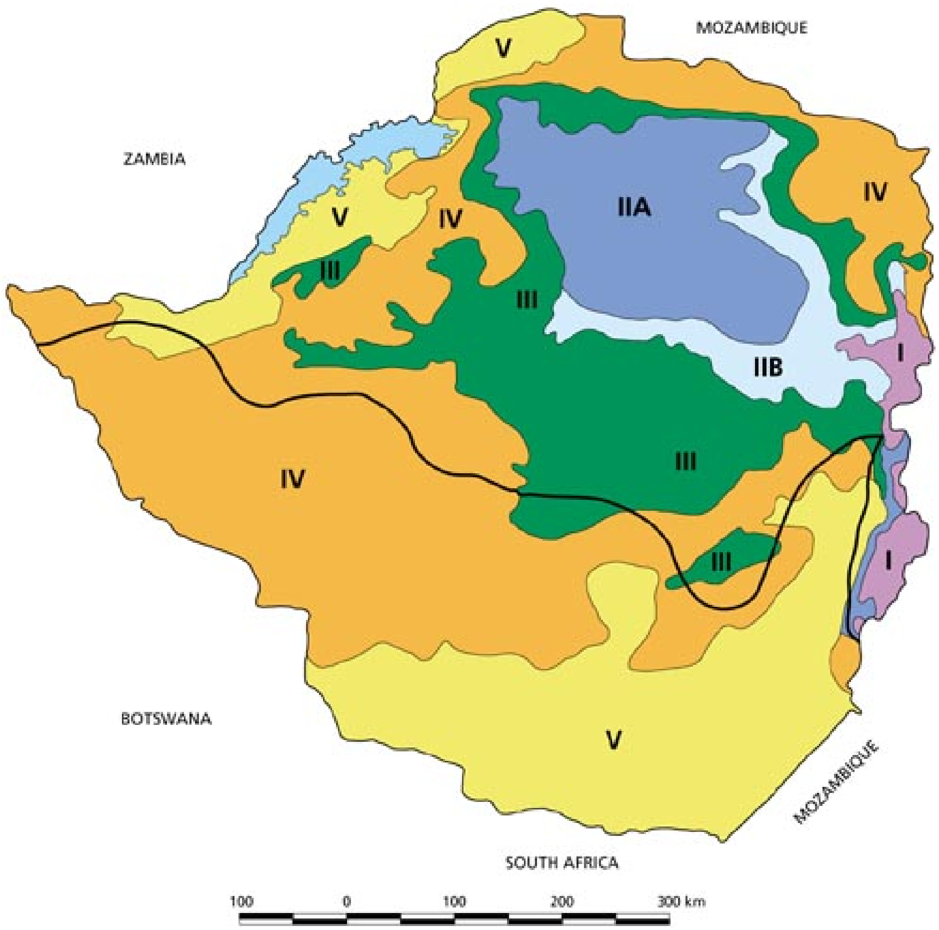
1. Substituting maize with sorghum does not affect the growth of broilers
2. Substituting maize with sorghum does not affect feed intake
3. Substituting maize with sorghum does not affect feed conversion ratio

MATERIALS AND METHODS

Study site

The study was carried out at Henderson research station, 30km North of Harare. The research station is located in agro-ecological region IIB, as shown in Figure 1, which is characterized by high rainfall, ranging from 800 to 1000mm annually and temperature ranges of between 22 to 26 ^{O}C.

Figure 1: Map of agro-climatic zones and farming regions



Source: (Moyo, 2000)

Experimental Design

The study was a one-factor experiment in a Completely Randomised Design (CRD), with four dietary treatments each replicated three times. One hundred and twenty unsexed day-old broiler chicks from Ross Breeders, Harare, Zimbabwe were distributed into 12 pens at random such that there were 10 chicks in each pen. Four diets of graded sorghum levels (0%, 40%, 60% and 80% of maize) were randomly assigned to the 12pens/groups of chicks such that there were three pens/groups per diet. The treatment allocation and replicates are schematically shown in Figure 2.

Preparation of Feeds

Four diets in which the maize component was substituted with sorghum weight for weight (w/w) at 0%, 40%, 60% and 80% sorghum inclusion of the maize component with commercial broiler concentrate from Agriculture-foods Private Limited., Harare, Zimbabwe, were used. The broiler starter and finisher mashes were prepared as summarised in Table 2 and 3, respectively. The chemical composition of the diets used is shown in Table 4.0.

Table 2: Preparation of broiler starter mash per 100kg

Sorghum substitution level	Concentrate (kg)	Maize (kg)	Sorghum (kg)	Total (kg)
0%	40	60	0	100
40%	40	36	24	100
60%	40	24	36	100
80%	40	12	48	100

Table 3: Preparation of broiler finisher mash per 100kg

Sorghum substitution level	Concentrate (kg)	Maize (kg)	Sorghum (kg)	Total (kg)
0%	33	67	0	100
40%	33	40	27	100
60%	33	27	40	100
80%	33	13	54	100

Table 4: Nutritional composition of the sorghum-based diets

	Broiler starter mash			Broiler finisher mash		
	CP	EE	DM	CP	EE	DM
0%	19.4	3.2	84.8	16.8	3.3	85.8
40%	18.6	2.5	84.8	16.9	2.8	86.3
60%	19.0	2.3	87.0	16.6	2.4	86.4
80%	17.9	2.0	87.1	15.4	2.0	87.0

FEEDING AND BIRD MANAGEMENT

Housing the broilers

The treatments were randomised and housed as shown in Table 5. Numbers 1 to 4 represented the diets and letters A to C represented the replicates. Floor space was provided as follows:

- 0 – 3 weeks, birds had a spacing of 2.5m^2/100birds
- 4 – 8 weeks, spacing was raised to 6m^2/100 birds

Table 5: Housing Plan

<table>
<tr><td>Reserves</td><td></td><td>Weighing room</td></tr>
<tr><td>1C</td><td rowspan="7">C
O
R
R
I
D
O
R</td><td>4C</td></tr>
<tr><td>3A</td><td>3B</td></tr>
<tr><td>1A</td><td>4A</td></tr>
<tr><td>2C</td><td>1B</td></tr>
<tr><td>4B</td><td>2B</td></tr>
<tr><td>2A</td><td>3C</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Brooding

Ring boxes were used at brooding stage. Infra-red lamps were used to provide warmth and temperature regulation was based on chick behaviour. The chicks remained in the brooder for 21 days, after which ring boxes were removed. Sixty – watt, infra – red lamps were switched on for 23 hours followed by an hour of darkness. Lamp spacing was 1 lamp per 2m^2.

Feeding and water supply

Feed and water were supplied ad – libitum. Requirements for the broiler starter phase were estimated at 1.5kg of feed per bird. Clean fresh water was supplied at the rate of 5litres per 10 birds at starter phase. The birds did not finish water such that it was changed twice daily to ensure clean and fresh water. 15litre water drinkers were used at the finisher stage and water was changed twice a day. Each pen had a 15litre drinker and a feeder. Drinkers and feeders were adjusted always to suit the broilers` stage of growth such that the lip of the drinker would be at the same height as the backline of the birds.

Figure 2: Schematic representation of treatment allocations and replicates

DIET 1: 0% SORGHUM INCLUSION

Replicates **1** **2** **3**

(10 birds under each replicate)

DIET 2: 40% SORGHUM INCLUSION

Replicates **1** **2** **3**

(10 birds under each replicate)

DIET 3: 60% SORGHUM INCLUSION

Replicates **1** **2** **3**

(10 birds under each replicate)

DIET 4 = 80% SORGHUM INCLUSION

Replicates **1** **2** **3**

(10 birds under each replicate)

Hygiene, Bio-security and Health Management

The broilers were house in a deep litter system with well-combed wheat straw 15cm deep. Bedding was turned frequently to allow good air circulation. As a bio-security measure, a disinfectant was used as footbath on all entrances. The chicken houses were also thoroughly cleared and disinfected before the chicks were housed. The general health of the birds was closely monitored, especially conditions of leg abnormalities. Birds were vaccinated against Infectious Bursal Disease (IBD) using (Nobilis Gumboro D78 vaccine produced by Intervet, South Africa), at day 10 and day 21.

Measurements

The birds were weighed as a group (i.e. per pen) once every week with an electronic scale, for 4 weeks. Thereafter a platform scale was used to weigh the birds in groups up to 8 weeks. Weekly average weights (g/bird) were recorded and the average daily gain was computed as follows:

Average Daily Gain (ADG) = (Final Weight – Initial Weight)/56

Feed consumption (g/bird) was recorded on a broiler record chart once a week for each replicate, and a mean per treatment was taken. The feed given to the bird was weighed and the weight of the leftovers was also recorded. It was assumed that the difference between feed given (grams) and feed left over (grams) was the feed consumed by the birds, or Feed Intake (FI). The computed feed intake and measured live-weight gain were then used to compute Feed Conversion Ratio (FCR) as follows:

FCR = (Cumulative Feed Intake)/Live-weight gain

Weekly mortality was also recorded on broiler record charts.

Statistical Analysis

Data for live-weight, FCR and weekly feed intake were treated as repeated measures. The data were then statistically analysed using PROC Mixed Procedure of the Statistical Analysis Software (SAS, 1996).

The model used was:

$Y_{ijk} = \mu + D_i + T_j + (D*T)_{ij} + E_{ijk}$

Where, Y_{ijk} = the dependent variable (live-weight, FCR and Feed Intake)

μ = population mean

D_i = effect of the i^{th} diet (i = 0%, 40%, 60% and 80% sorghum to maize)

T_j = effect of week of measurement (1, 2 ---- 8)

$(D*T)_{ij}$ = interaction between diet and week of measurement

E_{ijk} = Random error

Average Daily gain (ADG) and Total Feed Intake (TFI) were analysed using General Linear Model (GLM) Procedure of SAS (1996). The model used was:

$Y_{ij} = \mu + D_i + E_{ij}$

Where, Y_{ij} = dependent variable (ADG, TFI)

μ = population mean

D_i = effect due to diet i, (i = 0%, 40%, 60%, 80% sorghum to maize)

E_{ij} = random error

RESULTS

Effect of substituting maize with sorghum on Feed Intake, FCR and ADG

Substituting maize with sorghum did not adversely ($p>0.05$) affect Total Feed Intake (TFI), across all diets as shown in Table 6. ADG showed a significant difference ($p<0.05$) between the maize-based and sorghum-based diets. FCR only showed a significant difference ($p<0.05$) between the maize-only and the 80% sorghum-based diet. There was a significant increase in weekly feed intake.

Table 6: Table of means for TFI, FCR, and ADG for the four diets

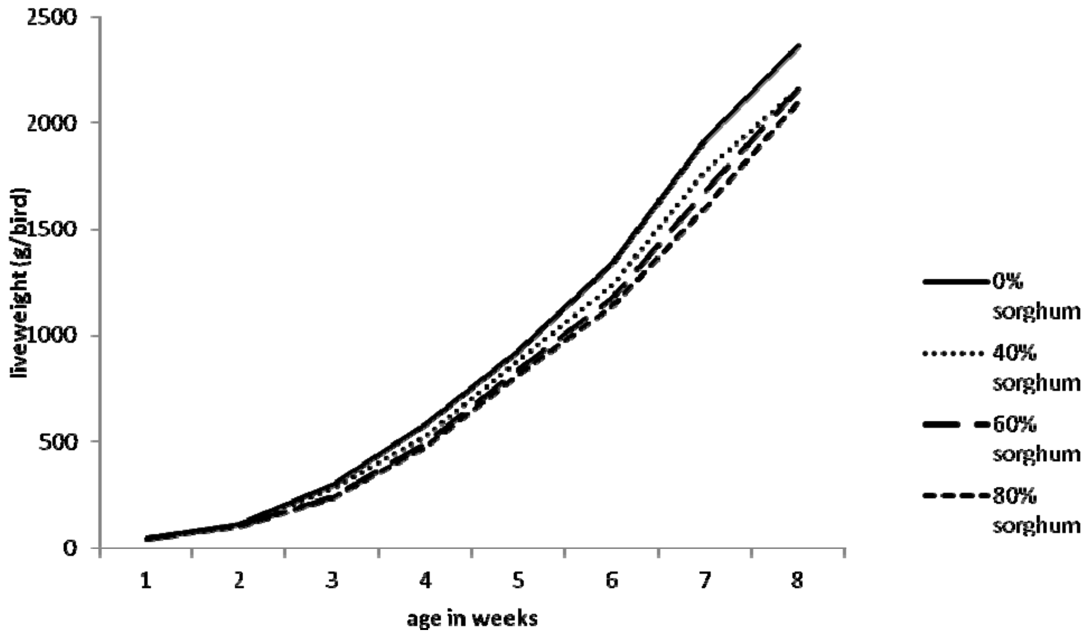
Diet	TFI(g)	FCR	ADG(g)
0%	5925.4^{a}	1.9^{a}	48.8^{a}
40%	5902.5^{a}	2.1^{ab}	44.3^{b}
60%	5614.5^{a}	2.0^{ab}	44.7^{b}
80%	5811.7^{a}	2.2^{b}	43.2^{b}
SEM	12.69	0.89	0.99

Means with different superscripts within a column are significantly different at ($p<0.05$)

Effect of substituting maize with sorghum on live-weight changes

Live-weight changes between maize-based and sorghum-based diets were not significantly different ($p>0.05$) for the first 3 weeks. From week 4, broilers fed on the maize diet (0% sorghum) grew significantly faster ($p<0.05$) than birds fed on sorghum-based diets, as shown in figure 2.0. However, live-weight changes among sorghum-based diets were not significantly different ($p>0.05$).

Figure 2: Weekly live-weight changes



DISCUSSION

Effects of substituting maize with sorghum on live-weight gain

For the first three weeks, live-weight changes between maize-only and maize/sorghum based diets were not significantly different. However, from week 4 onwards, there were significant differences in live-weight gains between the maize-only and maize/sorghum diets. Mutetwa (1996) reported no significant change in body weight gains in broilers fed with figure millet up to 50% inclusion. However, at 50% inclusion, significantly reduced final weights were reported. In another study by Abate and Gomez (1984), it was reported that sorghum was superior to maize in terms of live-weight gain. In this study it has been shown that maize and sorghum would perform the same at starter phase of feeding but maize would be superior for the finisher phase, in as far as live-weight is concerned. In the finisher phase energy becomes most critical, at the same time protein requirements decrease. The low ether extract levels in the sorghum diets could have translated into low energy content in those diets, thereby supporting poorer growth rates in birds. In India, assays carried out using white, tannin-free sorghum varieties showed no significant differences in live weights such that the use of sorghum to replace maize completely was recommended (Subramanian and Metta, 2000). In another study, Mohan et al (1991) concluded that sorghum and millet can completely replace maize in broiler diets without adversely affecting performance, provided the diet was both iso-energetic and iso-nitrogenous. Fasuyi (2005) using maize-sorghum brewer`s grain as a substitute of maize concluded that it can be used at inclusion levels of about 20% in broiler starter diets without any adverse effect on performance, carcass characteristics and muscle development in broiler chicks.

Effect of substitution on Feed Conversion Ratio

There were significant differences ($p<0.05$) on feed conversion efficiency between maize and sorghum diets. Kulube and Mhlanga (1988) at Henderson Research station established that sorghum could equal maize in feed conversion efficiency for substitution levels of up to 50% in layer diets. Similar confirmation of the suitability of sorghum seed meal was established by the work of Karimian et al. (2004), which showed that sorghum can replace maize in the diet of layer quail up to 40% inclusion level without adverse effect on growth and nutrient utilization. A study carried out in India also showed no significant difference in feed efficiency between maize and sorghum diets. The sorghum used in this study was also a tannin-free variety called kharif. The recommendation was 30% substitution levels in poultry diets. Tannins seem to play a major role in discouraging the use of sorghum at high inclusion levels. Despite this fact the inclusion of sorghum even at higher inclusion rate of 40% did not give a poor performance. According to Krogdahl et al. (2005), there could be the possibility of positive effects of combining starch sources. The capacity of the digestive tract for carbohydrate digestion and absorption appeared to be utilized to a greater extent when fed the mixed starch sources than when fed only a single source. Hence, starch digestibility also varies depending on the combination of starch sources in the diet. This supports the idea of cafeteria feeding which is also known to improve feed palatability. Both ideas point to the importance of promoting diversity of feed ingredients to ensuring the sustainability of the undertaking

Effect of substitution on Voluntary Feed Intake

Although chickens are known to regulate their voluntary feed intake primarily on the basis of dietary energy content, there were no significant differences in VFI in this study which suggests, either, the astringent effects of tannins could not impede upon the high appetite levels bred for in modern broiler breeds, or energy levels were not significantly different among the two dietary sources. Reduced VFI is normally associated with the astringent taste created by tannins, which eventually reduce palatability of the diet (Subramanian and Metta, 2000). The white sorghum is known to be low in tannins compared to the red variety.

Its adoption as an animal feed may help in raising awareness as to the importance of this crop to both humans and animals and help reduce its chances of going extinct. It has been shown to have played significant and varied roles to various societies in the past. According to Dumitru (2004), the plant is considered anthelmintic and insecticidal in India, and in South Africa, in combination with *Erigeron canadense* L., it is used for eczema. The stomachic seeds are considered beneficial in fluxes. Curacao natives drink the leaf decoction for measles, grinding the seeds with those of the calabash tree (*Cresentia*) for lung ailments. Venezuelans toast and pulverize the seeds for diarrhea, and Brazilians decoct the seed for bronchitis, cough and other chest ailments, possibly using the ash for goiter, and its roots has been used for treating malaria in Zimbabwe. (Dumitru, 2004).

CONCLUSIONS AND RECOMMENDATIONS

From this study it has been seen that substituting maize with sorghum in concentrate based diets by up to 40% does not adversely affect broiler growth. Feed Conversion is not affected by up to 60% substitutions. Feed Intake is not affected by substitutions of even up to 80% which suggests the astringent effects of tannins could not impede upon the high appetite levels bred for in modern broiler breeds. There is great potential for use of sorghum as a partner or substitute of maize as an energy source in broiler diets, especially in the starter phase when energy is less limiting. The benefit is realised in the long term as cost of feed is gradually cut back. There will be less dependence on maize as the sole source of dietary energy, thus reducing the impact of drought on feed costs. Sorghum is well known for its drought tolerance; therefore it will act as a price buffer. It is very hardy and can be grown in areas of the world that are too hot or too dry for other crops to be grown successfully. The broiler industry would stand to be economically viable, socially equitable and environmentally bearable. It is generally agreeable that production systems that use inputs and resources that humans value less, to produce goods and services that humans value more are economically viable, socially acceptable and environmentally friendly. The use of sorghum in broiler production stands as a clear example in this regard

REFERENCES

ABATE, A.N., and GOMEZ, M. (1984). "Substitution of finger millet (E. Coracana) and bulrush millet (P.typhaides) for maize in broiler feeds" *Animal Feed Sciences and Technology,* 10:291-299

ADEMOSUN, A.S. (1973). "Evaluation of brewed dried grains in the diets of growing chickens" *British Poultry Science*, 14: 463-468

BALOGUN, A.M., and FAGBENRO, O.A. (1995). "Use of macadamia presscake as a protein feedstuff in practical diets for Tilapia, Oreochromis niloticus (L.)" *Aquaculture Research*, 26: 371-377

CHEEKE, P.R. (1999). *Applied Animal Nutrition Feeds and Feeding* (2nd Edition). Pearson Prentice Hall, Wisconsin – Madison, USA.

CHURCH, D.C., and POND, W.G. (1982). *Basic Animal Nutrition and Feeding* (3rd Edn.). John Wiley and Sons. New York

CENTRAL STATISTICAL OFFICE (2001). Smallholder livestock production. Central Statistical Office, Government of Zimbabwe, Harare, Zimbabwe

DUMITRU, Ţ. (2004). Sorghum bicolor – an integrate alternative for agriculture, food industry and bio-energy. http://www.scielo.br/pdf/rbca/v6n2/v6n2a02.pdf. Date accessed on 19 March 2011.

FASUYI, A.O. (2005). "Nutritional evaluation of cassava (Manihot esculenta, Crantz) Leaf Protein Concentrates (CLPC) as Alternative Protein Sources in Rat Assay" *Pakistan Journal of Nutrition*, 4: 50-56

JACOB, J.P., MITARU, N., MBUGU, P.N. and BLAIR, R. (1996). "The effect of substituting Kenyan serena sorghum for maize in broiler chickens starter diets with different dietary protein and methionine levels" *Animal Feed Science Technology*, 61:41-56.

KARIIMIAN, M.R., TOHIDIAN, M., ALIVERDINASIB, R. and KHIYAV I. (2004). Effect of Replacement of Maize by Sorghum on Layer Quail performance. The Joint Agriculture and Natural Resources Symposium, Tabriz - Ganja. p4.

KROGDAHL, A., HEMRE, G.I., and MOMMSEN, T.P. (2005). "Carbohydrates in fish nutrition: digestion and absorption in post-larval stages" *Aquaculture Nutrition*, 11(2): 103-122.

KULUBE, K. and MHLANGA, J.D. (1988). Performance of broilers offered diets containing varying levels of Red and White Sorghum as energy substitutes for maize. Unpublished report, Henderson Research Station, Mazowe, Zimbabwe.

MOHAN, B.H., and GREGORY, F.J. (1991). "The utilisation of Pearl Millet (P.typhoids) as adjunct substitute of maize in broiler rations" *British Poultry Science,* 56:453-458.

MOYO, S., ed. (2000). *Zimbabwe environmental dilemma: balancing resource inequities.* Harare, Zimbabwe Environmental Research Organization. 161 pp.

MPOFU, I. (2004). *Applied animal feed science and technology.* 1st edition, Upfront Publishing Limited, Leicestershire, United Kingdom.

MUNYAU, E.J., CHAKOMA, C., KUWAZA, C. and MACHE, B. (1998). An outline of the production constaints and research needs of small-scale crop and livestock farmers in the Masonaland East Province of Zimbabwe. Unpublished report, Grasslands Research Station, Marondera, Zimbabwe.

MUTETWA, L.R. (1996). *The Utilisation of Millet as a substitute for maize in cereal-based broiler diets*. MSC thesis, University of Zimbabwe

MYER, R.O., GORBET, D.W. and COMBS, G.E. (1986). "Nutritive value of high and low tannin grain sorghums harvested and stored in the high-moisture state for growing-finishing swine" *Journal of Animal Science*, 62 (3):1290-1297

OBIOHA, F.C. (1976). "The contribution of poultry, swine and rabbit production to short term solution of meat scarcity in Nigeria" *Nigerian Journal of Animal Production*, 3: 45-48.

PRESTON, T.R. (1990a). "Livestock production from sugar cane and forage trees" In *G.* Een & S. Joste, eds. *Ninety innovations for development.* Stockholm, Innovations for Dev. Assoc.

RAVINDRAN, V. and BLAIR R. (1992). "Feed resources for poultry production in Asia and the Pacific II. Plant protein sources." *World Poultry Science*, 48: 205-231.

SUBRAMANIA, V., and META, V.C. (2000). Sorghum for poultry feed. In: Patanchera, India (Chandreshekar, A, Bandyodhyay, R and Itall, A.J, (Eds). Technical and Institutional options for sorghum grain mold management. Proceedings of an international consultation, 18-19 May 2000 ICR ISAT, Patancheru 502 324, Andura Pradesh India. *International Crops Research Institute for the Semi and Tropics,* 242-247.

STATISTICAL ANALYSIS SOFTWARE. (1996). SAS User`s Guide: Statistics. SAS Institute, Inc., Cary, North Carolina., USA.

VINCENT, V., and THOMAS, R.G. (1960). *An agricultural survey of Southern Rhodesia: Part I: agro-ecological survey*. Government Printer, Harare, Zimbabwe.

TOPPS, J., and OLIVER, J. (1993)." Animal Feeds of Central Africa." *Zimbabwe Agricultural Journal No. 2 Technical Handbook*

ABOUT THE AUTHOR:

Marshall Dhliwayo: Department of Animal and Wildlife Management, Bindura University of Science Education, Bindura, Zimbabwe.