Xavier Poshiwa
G. Ravindra Chary *Editors*

Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas

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Feed Management for Smallholder Pig Farming Systems in Zimbabwe

Chipo Gombwe, Ngavaite Chigede, Tinoziva Hungwe, Rumbidzai Blessing Nhara, Everson Dahwa, Prosper Bright Muvhuringi, and Brighton Emmanuel Maburutse

Abstract Higher costs of commercial feed coupled with a hyper-inflationary environment in Zimbabwe is impeding developments in the pig industry. The performance and economic effect of substituting commercial feed with iso-nitrogenous and iso-energetic on-farm diets in smallholder pig production systems was investigated. Two diets (sorghum-soyabean and sorghum-sunflower) were compared with commercial pig grower feed to weaner pigs with feed change overs made fortnightly. Diets were restricted at 1.2 kg per pig per day during the first 14 days and adjusted to 1.5 kg per pig per day for the next 28 days. Average daily weight gains were significantly ($p < 0.05$) different between treatment diets: 300.0 g; 571.4 g; 757.1 g for sorghum-sunflower diet; sorghum-soyabean diet and commercial pig grower meal diet, respectively. Feed cost analysis indicated that, sorghum-sunflower diet cost US $3.38 to gain a kilogram of live weight, while that of sorghum-soyabean diet was US $1.79 per each kilogram live weight gain against a US $3.01 per kilogram with commercial feed. On-farm feeds can be used in pig production achieving the same performance goals under smallholder pig farming systems. Substitution of commercial pig feeds with on-farm protein and energy alternatives improves gross margins. On-farm feed management is instrumental to the smallholder sector as it cushion them from climate change induced feed challenges and inflationary price increases.

Keywords Pig farming · Feed management · Iso nitrogenous diets · Iso energetic diets · Smallholder farm · Zimbabwe

C. Gombwe
Zimbabwe Prisons and Correctional Services, Mutimurefu, Masvingo, Zimbabwe

C. Gombwe · N. Chigede (✉) · T. Hungwe · R. B. Nhara · E. Dahwa
Livestock, Wildlife and Fisheries Department, Great Zimbabwe University, Masvingo, Zimbabwe
e-mail: nchigede@gzu.ac.zw

P. B. Muvhuringi
Animal Science Department, Africa University, Mutare, Zimbabwe

B. E. Maburutse
Animal Science Department, Marondera University of Agricultural Sciences and Technology, Marondera, Zimbabwe

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Introduction

Feed is one of the most critical contributors to costs of pig production contributing up to 75% of total costs (Alagawany et al. 2015; PIB 2018). Feed challenges are exacerbated by seasonal variability and climate change (Rauw et al. 2020) which can take extremes either cold or hot. Feed intake is affected in both cold and hot climatic conditions as the thermoneutral zone of pigs is affected (Babinszky et al. 2011). In cold conditions feed intake increases whereas in hot conditions it decreases reducing growth performance of pigs. Energy and amino acids are the most costly components of pig diets (Lange and Birkett 2005) with energy constituting approximately 87% of the total cost (Noblet 2007). Thus, it is key for farmers to estimate precisely the energy value of feeds for less costly feeds. A guaranteed on-farm feed supply is a prerequisite in determining success of a piggery enterprise. With the adverse effects of climate change coupled with high feed costs, smallholder farmers should adapt to feeding low cost feeds which are formulated from ingredients which are less affected by changes in climate, such as sorghum which uses C_4 photosynthesis pathway (Babinszky et al. 2011). The quantity and quality of feed ingredients especially those of plant origin are affected by a combination of temperature and carbon dioxide increases as well as variation in precipitation (Ume et al. 2018). Commercial farmers can afford to purchase commercial feed for their piggery enterprise but not the smallholder farmers in rural areas as they have low capital base. Smallholder farmers rely on a variety of feed resources, using what is available at a particular time. On-farm feed mix can be done using climate adapted on-farm produced feed resources and cut on feed costs for the resource constrained smallholder farmers.

Feed given to pigs must provide energy, amino acids and minerals in their rightful proportions. On-farm energy sources come from cereal grain crops like maize, sorghum and wheat. In pig diets, corn is the widely used energy source in Zimbabwe because of its availability country wide (Mungate et al. 1999). However, due to incessant droughts, availability of corn for the feed industry is limited as the human demands takes center stage and gets first priority. Sorghum is commonly grown in low rainfall regions because of its drought tolerance (Seed Co 2019), for human consumption, livestock feed and ethanol extraction. Low-tannin and correctly processed sorghum (*Sorghum bicolor*) can replace corn in pig diets without reducing growth performance of pigs at a reduced feed cost (Cousins et al. 1981). These merits make sorghum grain an excellent constituent of on-farm feedstuff in dryland agriculture that can be used as the primary energy source in swine diets. Sorghum has 85–96% of the feeding value of maize (PIB 2018).

On-farm protein sources include crushed oil seeds (Whittemore et al. 2001): soyabean meal, cotton seed meal, sunflower seed meal, copra and canola meal (Bell 1993). Soyabean and sunflower are common among the Zimbabwean smallholder farmers. Stein et al. (2007) revealed that dehulled and non-dehulled soyabean meals are excellent sources of protein in pig production because of its excellent balance in essential amino acids. Soya bean requires roasting to inactivate the trypsin inhibitors it contains which bind protein digesting enzymes resulting in poor growth of pigs as protein availability will be reduced for body building (Goebel and Stein 2011). Overheating will result in reduced digestibility of lysine and other amino acids (Gonzalez-Vega et al. 2011). Sunflower (*Hellanthus annus*) meal composition depends on whether it contains the hulls or not. Hulled sunflower meal is of lower nutritive value and this affect palatability and digestibility which affect both voluntary feed intake and growth performance than dehulled meal (Alagawany et al. 2015). However, sunflower meal can be used in pig diets because of its sweet taste which appetize pigs (Mavromichalis 2014) and also low cost compared to soyabean meal and absence of anti-nutritional factors (Alagawany et al. 2015). Mavromichalis (2014), asserted that pigs will readily consume diets based on sunflower meal, if upper crude fiber limits are not exceeded.

Climate change induced feed shortages as a result of recurrent droughts calls for adaptive measures especially to the smallholder sector. High performing sows are sensitive to environmental changes, irrespective of their genetic make-up (Rauw et al. 2020). Production of feed from drought tolerant crops like sorghum and sunflower under smallholder farming systems goes a long way in mitigating pig feed challenges. In this context, a study was carried out targeting smallholder pig farmers, with sorghum as an alternative energy source and either sunflower or soyabean as the protein source. The objectives of the study were to assess potential of on-farm diets based on sorghum to promote growth in mixed breed weaner pigs under smallholder farming systems in a changing climate and to compare economics of on-farm sorghum based diets.

Materials and Methods

Study Area

The research was conducted at Mutimurefu[1] Prison farm which is situated 23 km East of Masvingo town, Zimbabwe. The farm is located under agro-ecological region IV of Zimbabwe and characterized with an average annual rainfall of 650 mm (Vincent and Thomas 1960), mean annual temperature of 18 °C with a range of 0 to 28 °C, light frost confined to low lying areas, shallow sandy clay soils with effective depth of less than 1 m and with natural vegetation of *Acacia sp, Combretum*, on shallow stony grounds. *Peltophorum africanum, Isoberlina globiflora, Number-jacks, Brachystegia glaucescens* on higher crest and slope areas. The predominating grasses are *Aristida sp mixed* with *Tragus sp.*

[1] Mutimurefu prison farm is a government institute under the department of Prisons and Correctional Service under the Ministry of Justice in Zimbabwe.

Health and Welfare of Pigs

Pigs were checked to assess thermal comfort (shivering and panting), diseases (labored breathing, coughing, diarrhoea, nasal discharge) and lameness (claw damage) during feeding time. Dry grass bedding was provided in the sties to insulate the floors and cushion pigs from temperature drops. Pigs were washed with soapy water at the beginning of the experiment. Hand spraying was done at weekly intervals alternating Triatix dip and Tickbuster acaricides as a preventive measure against the mites (*Sarcoptes scabiei*). A total of six eight weeks old Large white cross weaner pigs (initial weight 19.33 kg $\pm$ 1.03) were selected. Weaner pigs were randomly allocated to three pig sties with an area measuring 3 m $\times$ 2.35 m. Dry grass bedding was spread on the rough floors. The sties were well ventilated with built in feed and water troughs. Pigs were weighed individually on weekly basis. Records of weights including the induction weights were kept. Clean water was supplied ad libitum.

Preparation of Diet Constituents

All the feed ingredients were coarsely ground using a grinding mill with a screen size 2 to achieve a homogenous particle size. Sorghum variety, Marcia was used in the study. Reducing particle size is of great importance in improving feed efficiency (Healy et al. 1994). The grain size was reduced to produce a coarse meal which became more palatable to weaner pigs. Soyabean seeds were roasted on fire until the outer shell turned golden brown. Overheating was avoided as it has been shown to reduce digestibility of lysine and other amino acids (Gonzalez-Vega et al. 2011). Roasting was done to inactivate trypsin and chymotrypsin inhibitors found in raw soybeans (Goebel and Stein 2011). Roasting the soyabean produced an aromatic meal which was later on mixed with other feed constituents. Sunflower seeds were crushed making them more palatable to the pigs.

Feed was formulated using Pearson square method with two ingredients targeting a final diet with 18% crude protein. Sorghum meal used had 8.4% CP, soyabean meal 44% CP and sunflower meal 30% CP. Sorghum and Sunflower meal based diet was mixed using a ratio of 1 part protein to 1.25 parts energy source by weight while sorghum and soyabean meal based diet was at a rate of 1 part protein to 2.7 parts energy source. The commercial diet i.e. pig grower meal with crude protein content of 18% from a feed company was used as control.

Feeding of Weaner Pigs During the Experimental Period

The experimental period was split into three phases, with each phase being two weeks long. The first week was used for adaptation to the new diet and clearing of residual feed in the system of the pig. Weight changes were recorded during the second week of each phase. All the weaners received the same quantity of feed for two weeks period at a rate of 1.2 kg of feed per pig per day which was split by half and given twice daily, during morning, 0700 h, and late afternoon, 1500 h. Feeding times were consistently followed. In the first day of the experiment feed was gradually changed from pig grower meal to either sorghum-sunflower or sorghum-soyabean diet to prevent stomach upsets. During the second and third period of the experiment, feed quantity per pig was adjusted to 1.5 kg of feed per day to match increase in body size. Observations on voluntary feed intake were made 30 min after every feeding session to assess on intake of the formulated diets.

Experimental Design

A Latin square design, replicated twice, was used with the diet and time period as sources of variation. Three diets were allocated randomly to the pigs in the pens. Randomization was done such that each treatment diet occurred only once in each column and row. Feed was rotated after every two weeks in a cross over fashion (Table 1).

A standard model for Latin Square Design used: $Y_{ijk} = \mu + R_i + C_j + T_k + e_{ijk}$

Where, Y_{ijk} = growth of pig in the ith row, jth column subjected to kth treatment

μ = the overall mean of all observations

R_i = added effect common to ith row

C_j = added effect common to the jth column

T_k = added effect of the kth treatment

e_{ijk} = a random error.

Induction weights and weekly weight changes were measured using an analogue scale. Average daily gain (ADG) and feed conversion ratio (FCR) were computed.

Table 1 Layout of the design and treatment randomization

Period	Pen		
	1	**2**	**3**
1	T1	T2	T3
2	T2	T3	T1
3	T3	T1	T2

There were two weaner pigs in each pen
Key: Treatment diets: T1—Sorghum meal with soya bean meal; T2—Sorghum meal with sunflower meal; T3—Pig grower meal

Table 2 Average weight gain (kg)

Period	Pen		
	1	**2**	**3**
1	T1(5.5)	T2(3.0)	T3(10.5)
2	T2(1.2)	T3(1.25)	T1(3.05)
3	T3(4.0)	T1(3.5)	T2(2.0)

Treatments key: T1: Sorghum-soya bean meal; T2: Sorghum-sunflower meal; T3: Pig grower meal
The commercial diet produced a higher average weight gain, followed by sorghum-soyabean, and lastly sorghum-sunflower (Table 3)

Feed cost per weight gain was also computed to give an indication of fattening costs associated with each diet. Voluntary feed intake was checked.

Statistical Data Analysis

Two way analysis of variance was carried out, using Genstat 18th edition. Microsoft excel was used to compute cost of each live weight gain based on current prices of the on-farm feeds. Significant differences were indicated by a p value less than 0.05. Means were separated using Fisher's protected l.s.d.

Results

Average weight gain in each pen at a given period (6 weeks) is indicated in Table 2. Despite the diets being iso-nitrogenous, sorghum-sunflower meal diet had the lowest gains ($p < 0.05$) across the three phases whilst sorghum-soyabean meal diet produced similar growth performance to commercial diet in phases 2 and 3 (Table 2).

Discussion

In the face of climate change, feed supremacy need to be exhibited in terms of reduced stress to animals by environmental factors like increased ambient temperature and decreased feed quality. Sorghum-sunflower meal diet had the lowest gains during period one (Table 2). During period two, pigs fed sorghum-soyabean diet outperformed pigs on the other diets. However, all diets produced weight gains which were below the national average of 650 g per day (Kagande 2014). Commercial feed produced good weight gain in phase three followed by sorghum-soyabean meal. Despite the diets being iso-nitrogenous, sorghum-sunflower meal diet had the lowest

Table 3 Treatment means

Diet	Mean weight gain (kg)	ADG (g)	Cost/kg LW (US$)
Sorghum-sunflower	2.07[a]	300	3.38
Sorghum-soya bean	4.02[ab]	571.4	1.79
Pig grower meal	5.25[b]	757.1	3.01
Grand mean (kg)	3.78	542.8	
LSD	2.481		
***p* value**	$p < 0.05$		

On-farm feeds cost source: AGRITEX monthly reports. Mean weight gains with different superscripts indicates significant differences. ADG—Average Daily Gain.
Groups with the same superscript are statistically similar when using l.s.d to separate the means, thus [a] is not significantly different from [ab] and [b] from [ab]

gains ($p < 0.05$) across the three phases though a good voluntary feed intake was displayed by the pigs. The low performance of pigs fed sorghum-sunflower diet may be attributed to high fibre in sunflower meal (Alagawany et al. 2015; Mavromichalis 2014) as hulled sunflower seed was used to make the meal. The high fibre in the diet may reduce energy digestibility impacting negatively on weight gain of pigs relying on such diets (Li et al. 2018). Climate change, due to increased mean temperatures, support C_4 type of plants (Babinszky et al. 2011, p. 167) which are high in fibre component (Barbehenn et al. 2004). The current findings resemble utilization of such high fibre locally available feed components in pig production to economize piggery under a changing climate.

The low performance from sorghum-sunflower diet noted in this study is in line with findings from Green et al. (1988), who reported higher apparent digestibility coefficients (AD) of nitrogen (N) and amino acids for soyabean than sunflower meal fed to growing pigs. However, Green and Kiener (1989), reported similar amino acid digestibility of the sunflower meals and soya-bean meal and also asserted that digestibility of sunflower was not influenced by dehulling. There is need to limit the inclusion level of hulled sunflower meal in diets of growing pigs. Sunflower meal may perform better if mixed with other protein sources such as soyabean meal or when it is dehulled (Li et al. 2018). On the other hand, hulled sunflower has a higher dietary thermic effect[2] which does not go well with conditions of increased average temperatures due to climate change effects, hence reduced performance was observed from pigs fed a high fiber diet.

The weight gain produced from sorghum-sunflower diet was 46% of the standard weight gain considering a national average gain per day of 0.65 kg. This below average performance can be explained partly by the high dietary fibre, 25%, (Mavromichalis 2014) which is rich in lignin, an indigestible component associated with hulled sunflower meal (Goff et al. 2002). High fibre diets can reduce the apparent faecal digestibility of other dietary nutrients like crude protein and fat (Noblet 2007).

[2] Dietary thermic effect: refers to heat produced in the course of digestion and conversion of the dietary nutrients in an animals' body.

Sorghum-soyabean meal diet produced a gain which was 88% of the standard weight gain per day. The sorghum-soyabean results testify the potential of on-farm feeds under smallholder farming systems if ingredients are processed considering their limitations.

The cost to fatten pigs using sorghum-sunflower meal was high. The costs come in the form of housing, labour and feed costs as the pigs have to eat more and stay for more days to reach the desired weight gain. Sorghum-soyabean meal diet produced the gain with low cost compared to commercial feed. The low cost of on-farm feeds maybe partly due to no transport cost as they were on the farm.

Conclusions

On-farm feeds from drought tolerant crops such as sorghum can be used to fatten pigs. Sorghum is a C_4 plant which can do well with high carbon dioxide, a common feature with climate change, therefore, smallholder farmers can make a shift from maize to sorghum based diets in the face of adverse climatic changes. Sorghum-soyabean based diets perform better than sorghum-sunflower diets. Low weight gains are experienced when using hulled sunflower meal as the sole protein source and a limit has to be put on its inclusion level. Overall, on-farm feeds are cheap to use when rearing pigs.

Further research may be carried out on performance of pigs when fed with compound diet based on sorghum, sunflower and soyabean meal, on effects of partial substitution of commercial diet with on-farm feed to achieve cost effective and efficient diets and metabolism trials may be taken up to ascertain degree of use of the nutrients in the on-farm diets. To develop climate resilient pig farming, there is need for further studies on how best the higher fibre component in sunflower can be utilized. There is a need to study on impacts of using feed additives, such as enzymes, need attention with regards to fibre utilization for climate resilient pig production under smallholder systems. Most importantly, adaptive capability of different pig breeds need to be ascertained.

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