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GROWTH RESPONSE, NUTRIENT DIGESTIBILITY AND COST BENEFITS OF RABBITS FED SOLID WASTE PRODUCT OF SUGAR INDUSTRY

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Abstract
Forty weaned rabbits of mixed breeds and similar live weight of about 580-624g were utilized in a 42-day experiment to evaluate the effect of feeding solid waste product of sugar industry (SWAPSI) as a replacement for maize on growth response, nutrient digestibility and cost benefits analysis. Five treatment diets namely T1, T2, T3, T4 and T5 were compounded to be iso-caloric (2700kcal/kg, ME) and iso-nitrogenous (18% CP). The SWAPSI replaced maize at 0, 20, 40, 60 and 80% in a completely randomized design. Each treatment was replicated 4 times having two rabbits per replicate. Feed and water were provided to the animals daily and all standard routine management practices were strictly observed throughout the experiment. At the beginning and end of the feeding trial, initial and final body weight, weight gain, feed intake, feed conversion ratio, dry mater, crude protein, fibre, fat and ash digestibility as well as economics parameters were determined. The results indicated non-significant differences (P>0.05) across all the growth and economics of production parameters except feed intake, protein intake, feed cost consumed and total cost of production which showed significant increase (P<0.05) at T3 (44.32g/rabbit, 8.33, 534.37₦/rabbit and 3084.37₦/rabbit). Similarly, digestibility of nutrients improved (P<0.05) significantly as the level of SWAPSI increased in the diets. It is therefore, concluded that SWAPSI can replace maize in the diets of weaner rabbits up to 40% for fast growth, utilization of nutrients and better revenue generation.
Keywords: Growth performance, SWAPSI, Maize, rabbits, nutrient digestibility, economics of production

Introduction

Animal production is mount up with a serious setback in terms of growth and developments among these problems are disease infestation and high cost of feeds and feeding stuffs. Feed accounts for over 70% of the total cost of animal production. Also, availability and competition between man and livestock to conventional feed resources has been attributed to high cost of animal feeds and products (Alu, 2013).

The role of livestock sector in the attainment of optimal supply of protein, economic earnings and viable business environments in most developing countries will require a continuous search for alternative feed sources that are environmentally friendly, cost effective and in less demand as direct food resource for humans (Ari *et al.,* 2016). This is even more important in the production of micro livestock like rabbits in spite of their reported potentials of bridging the protein – supply gap like poultry in most developing countries. The major nutritional requirements in animal productions are energy and protein (Kanyinji and Moonga, 2014)**.** These are mainly supplied by maize grain and soybean meal in livestock diets, respectively. The high cost of these feed

ingredients resulting from various usages in human diets as well as industrial applications makes it compulsory to quest for alternate replacements that are cost effective. Research has shown that unconventional industrial by-products is given serious attention towards substituting conventional feed resources that will not affect the overall feed quality and the performance of the animal. One of such industrial by-product is SWAPSI an acronym for solid waste product of sugar industry as used in this study. It is the total solid waste obtained in the process of sugarcane juice extraction usually in the sugar industries. It can be considered as the opposite of molasses. SWAPSI is highly fibrous as it contains the sugarcane peels, scrapping and bagasse. It is rich in non- starch polysaccharides, some minerals and vitamins and highly lignified. Previous researches shown that fibrous feeding stuffs of such would require some level of processing, for monogastric animals to be able to utilize them efficiently (Oloruntola *et al*., 2015; Alu 2013; Aletor, 1986)
Feeding agro-industrial by-products (e.g. maize bran, rice bran and sugarcane scrapping) as replacement for maize-based diets to livestock have significantly reduced the cost of producing feed for livestock (Ukim *et al.,* 2012). Agro-industrial waste products such as sugarcane scrapings are readily used as non-conventional feeds resource in replacing energy sources such as maize in monogastric diets (Kanyinji and Moonga, 2014; Alu, 2012; Aletor, 1986). Rabbit production has recently gain attention in most developed countries. This is due to the unique quality that is attributed to the utilization of rabbits. Among these qualities are small body size, rapid growth, high reproduction potential, short generation time, production of high quality meat, good potential for genetic improvement and ability to utilize non-competitive feeds (Oloruntola *et al*., 2015). It is on this background that this research was carried out to evaluate the effects of replacing maize with SWAPSI on gross response and cost benefits of weaner rabbits.

Materials and Methods

Location of the Study

This study was conducted at the Livestock Complex of the Department of Animal Science, College of Agricultural Science and Technology, Lafia. The farm is located in the southern guinea savannah zone of Nigeria on latitude $8^{0}28'$N and longitude $8^{0}31'$E. The average minimum temperature is 23^{o}C and maximum temperature is 36.9^{o}C. Mean monthly relative humidity is 74%. The mean annual rainfall is 823mm and the mean monthly temperature is 35.06^{o}C (NIMET, 2021).

Sources of Experimental Feed Ingredients and Processing

SWAPSI was sourced from sugar processing industry in Numan local government area of Adamawa State. The SWAPSI collected, was sun dried for 2 - 3 days to reduce the moisture content and also to avoid the growth of mould and rancidity after which it was ground to produce SWAPSI meal. Other ingredients such as maize, rice offal, ground nut cake, fish meal, palm oil, lysine, methionine, salt and premix were purchased from Bio-ingredient Ltd Abuja.

Proximate Determination of SWAPSI

Proximate composition such as crude protein, dry matter, ether extract, crude fibre and nitrogen free extract of SWAPSI were determined using the procedure outlined by AOAC (2010) and presented in table 1.

Table 1. Proximate Composition of SWAPSI

Parameters (%)	Values
Crude protein	7.16
Ether extract	5.62
Crude fibre	21.06
Ash	4.12
Moisture	4.13
Nitrogen free extract	57.91
Metabolizable energy kcal/ME	277.51

Experimental Diets

The experimental diets were designed to be iso-nitrogenous (18% crude protein) and iso-caloric (2,700kcal/kg ME) for the weaned rabbits with five levels of inclusion of the SWAPSI replacing maize as source of energy for rabbits. T1 contained 0% SWAPSI which serves as control, T2 with 20% SWAPSI, T3 (40% SWAPSI), T4 (60% SWAPSI) and T5 (80% SWAPSI). The feeds were balanced to meet the nutrients requirement of rabbits as presented in table 2.

Experimental Animals and Management

Forty composite rabbits of equal sex and average live weight (500-600g) were purchased from commercial farm in Plateau state and reared in open-sided mesh hutches. Before the arrival of rabbits, hutches were well fumigated, disinfected and equipped with feeders and drinkers. The rabbits were fed the experimental diets and provided with drinking water *ad-libitum* and other routine management practices were adopted as outlined by Alu *et al.* (2009) throughout the experimental period.

Experimental Design

The rabbits were randomly assigned to the treatments in a complete randomized design with 4 replicates having 2 rabbits per replicate. The following statistical model was used: $Y_{ij} = U + A_i + e_{ij}$ where Y_{ij} =individual observation, U= population mean, A_i = effect of factor A, and e_{ij} = experimental error.

Table 2. Gross Composition Of The Experimental Diets

	Percent inclusion of SWAPSI				
Ingredients	**T1 0%**	**T2 20%**	**T3 40%**	**T4 60%**	**T5 80%**
Maize	40.00	32.00	24.00	16.00	8.00
SWAPSI*	0.00	8.00	16.00	24.00	32.00
Groundnut cake	20.00	18.00	17.00	14.00	11.00
Blood meal	2.00	3.00	3.00	6.00	7.00
Rice offal	28.00	25.00	25.00	21.00	22.00
Palm oil	3.00	4.00	5.00	7.00	7.00
Bone meal	2.00	4.00	4.00	6.00	6.00
Common salt	0.25	0.50	0.50	0.50	1.50
Methionine	0.25	0.50	0.50	0.50	0.50
Lysine	0.25	0.50	0.50	0.50	0.50
Premix	0.25	0.50	0.50	0.50	0.50
Fishmeal	4.00	4.00	4.00	4.00	4.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Probiotics	+	+	+	+	+
Toxin binders	+	+	+	+	+
Acidifiers	+	+	+	+	+
Calculated analysis					
Energy	2757.99	2716.67	2721.00	2788.92	2733.24
Protein	18.82	18.97	18.70	18.72	18.91
Crude fibre	15.55	15.93	15.99	15.57	17.94
Ether Extract	8.30	9.18	9.18	11.87	12.01
Ash	6.78	6.50	6.50	5.60	6.47
Calcium	1.23	1.93	1.93	2.96	3.01
Phosphorus	0.60	0.83	0.83	1.16	1.18
Lysine	1.25	1.51	1.51	2.25	1.80
Methionine	0.89	1.11	1.11	1.65	1.16

SWAPSI= solid waste product of sugar industry; +: define ; The vitamin-mineral premix supplied the following per 100kg of diet: vitamin A15,000 I.U, vitamin D3 300,000 I.U., vitamin E 3,000 I.U., vitamin K 2.50mg, vitamin B_1 (thiamine) 200mg, Riboflavin (B_2) 600mg, pyridoxine (B_6), Niacin 40.0mg, vitamin B_{12} 2mg, Pantothenic acid 10.0mg, folic acid 100mg, Biotin 8mg, choline chloride 50mg, anti-oxidant 12.5mg, manganese 96mg, zinc 6mg, Iron 24mg, Copper 0.6mg, Iodine 0.14mg, Selenium 24mg, cobalt 214mgusing Feed win software version 1.01

Data Collection

Gross Responses Evaluation

The gross responses included body weight gain which was computed as the difference between the final weight and the initial weight of the rabbits, feed intake was determined as the difference between the amount of feed fed and the leftover. Feed conversion ratio was calculated as the rate of feed intake to live weight gain/day. Other parameters such as protein intake were calculated as feed intake/percent protein in the diet. Protein efficiency ratio was calculated as the ratio in body weight gain (g) to protein intake (g) where protein intake = Feed intake (DM) × Percentage Protein in Diet and energy efficiency Ratio = Body weight gain (g)/ total metabolizable energy intake x 100. Where metabolizable energy was calculated using formula by Pauzenga (1985) ME=37 x % CP+81.1x % EE+35.5 x % NFE.

Nutrient Digestibility Evaluation

At the end of the feeding trial, faecal samples were collected for a period of one week. Dried sacks were spread below hutches to collect daily faecal droppings for 7 days. The faeces collected were dried, weighed and thoroughly mixed and sub samples were taken for proximate analysis in the laboratory according to AOAC (2010). Nutrient retained were determined as nutrient intake minus nutrient voided in the faeces using the formula:

$$\text{Digestibility coefficient} = \quad D = I - \frac{F}{I} \times 100$$

Where D = digestibility coefficient, I = nutrient intake and F= nutrient voided in the faecal material (Aduku, 2004).

Cost Benefits Analyses

The costs per kilogram of each experimental diet were calculated based on the prevailing prices of feed ingredients in Lafia. To calculate the cost per kilogram of feed, the price/kg of each ingredient was multiplied by the quantity of that ingredient in 1 kg of feeds and these values for all ingredients were summed. The cost of feeding each rabbit was calculated as the product of the cost of 1 kg of feed and amount of feed consumed by the rabbit. The cost of 1 kg of each diet was multiplied by feed conversion ratio (i.e. Cost/kg WG=Cost / kg feed x FI / WG) to get feed cost per kg weight gain. The total cost of production was estimated by using the equation given by Kpehe *et al.* (2020). Revenue obtained from the sales of the rabbits (1 kg of rabbit was sold at ₦4,000). Gross margin from production was estimated as difference between revenue and total cost of production.

Statistical Analysis

Data collected were subjected to one-way analysis of variance using the general linear model of SPSS (2007). Significantly different means were considered and separated at 5% levels using Duncan's Multiple Range Test as described by (Steel and Torrie, 1990).

Results

Table 3 shows the results for the effect of SWAPSI on gross responses of weaned rabbits. The result indicated non-significant differences ($p>0.05$) across all the gross responses parameters except feed intake and protein intake, which showed significant increase ($p<0.05$). Rabbits on T3 had higher feed and protein intake (44.32g/rabbit and 8.33), followed by T4 (40.33g/rabbit and 7.58), T2 (39.71g/rabbit and 7.46), T5 (38.66g/rabbit and 7.26) than the control diet (30.38g/rabbit and 5.5.71). The final body weight values were 914.50, 1008.25, 1076.25, 1017.50 and 930.00g/rabbit. Total weight gain mean values ranged from 289.63 to 489.38g/rabbits. Daily weight gain falls within 6.89 and 11.65g/rabbits. Feed conversion ratio values were 5.43, 4.59, 3.89, 4.38 and 6.96. Protein efficiency ratio (0.36, 0.54, 0.61, 0.54 and 0.41) and energy efficiency ratio (10.50, 15.50, 17.74 15.48 and 11.81) were not affected ($p>0.05$) by SWAPSI inclusion in the diets. Rabbits fed 40% SWAPSI had higher non-significant ($p>0.05$) values for final body weight (1076.25g/rabbit) and daily weight gain (11.65g/rabbit) with the corresponding better feed conversion ratio (3.89) than the control and the other treatments rabbits. The highest ($p<0.05$) protein intake were at T3 (8.33) and other SWAPSI included diets than the control (5.43).

Table 3. Effect of Solid Waste Product of Sugar Industry on Gross Responses of Weaned Rabbits

	Replacement values of SWAPSI						
Parameters	T1 (0%)	T2 (20%)	T3 (40%)	T4 (60%)	T5 (80%)	**SEM**	**LOS**
IBW (g/rabbits)	624.87	580.62	586.87	590.37	604.12	10.74	NS
FBW (g/rabbits)	914.50	1008.25	1076.25	1017.50	930.00	36.95	NS
TWG (g/rabbits)	289.63	427.63	489.38	427.13	325.88	40.42	NS
WG/d (g/rabbits)	6.89	10.18	11.65	10.16	7.75	0.96	NS
FI (g/rabbits)	30.38^{b}	39.71^{a}	44.32^{a}	40.33^{a}	38.66^{a}	1.34	*
FCR	5.43	4.59	3.89	4.38	6.96	0.51	NS
Protein intake	5.71^{b}	7.46^{a}	8.33^{a}	7.58^{a}	7.26^{a}	0.25	*
PER	0.36	0.54	0.61	0.54	0.41	0.05	NS
EER	10.50	15.50	17.74	15.48	11.81	1.46	NS

IBW= Initial body weight; FBW= final body weight; TBW= total body weight; FI= feed intake; FCR= feed conversion ratio, PER=protein efficiency ratio, EER=energy efficiency ratio; %= percentage, SEM= Standard error means, NS= No significant (p>0.05), LOS= Level of significant, * = significant. a, b = Means on the same row bearing different superscript differ significantly (p<0.05).

The effect of solid waste product of sugar industry on nutrient digestibility of weaned rabbits is shown in table 4. The results indicated significant (p<0.05) improvement in the digestibility of dry matter 60.43, 62.65, 61.39, 59.29 and 62.11%, crude protein 57.35, 67.49, 68.54, 69.50 and 67.92%, crude fibre 36.86, 57.53, 57.02, 57.62, and 58.15% and ash 41.05, 42.88, 43.73, 45.28 and 42.84%, respectively. Highest DM (62.65%) was recorded at 20%SWAPSI but similar with T5 (62.11%), T3 (61.39%) and T1 (60.43%) while the least value was at T4 (59.29%). Higher CP (69.50%) was recorded at 60%SWAPSI but similar to T3 (68.54%). Crude fibre was higher at T5 (58.15%), followed by T4 (57.62%), T2 (57.53%) and T3 (57.02%) but lower at the control diet (36.86%). Similarly, ash (45.84%) was higher (p<0.05) at 60%SWAPSI than control (41.05%) but similar with T3 (43.73%). However, crude fat digestibility decreased as the level of SWAPSI increased in the diets. Least (p<0.05) fat was recorded at T5 (38.86%) while T1 rabbits recorded the highest (46.25%). Nitrogen free extract 42.99, 44.56, 44.06, 42.84 and 42.45 showed no effect (p>0.05) by SWAPSI inclusion.

Table 4. Effect of SWAPSI on Nutrient Digestibility of Weaned Rabbits

	Replacement values of SWAPSI						
Parameters (%)	T1 (0%)	T2 (20%)	T3 (40%)	T4 (60%)	T5 (80%)	**SEM**	**LOS**
Dry matter	60.43^{ab}	62.65^{a}	61.39^{ab}	59.29^{b}	62.11^{a}	0.45	*
Crude protein	57.35^{c}	67.49^{b}	68.54^{ab}	69.50^{a}	67.92^{b}	1.48	*
Crude fibre	36.86^{b}	57.53^{a}	57.02^{a}	57.62^{a}	58.15^{a}	2.76	*
Crude fat	46.25^{a}	42.39^{b}	39.30^{c}	39.12^{c}	38.86^{c}	0.96	*
Ash	41.05^{c}	42.88^{bc}	43.73^{ab}	45.28^{a}	42.84^{bc}	0.48	*
Nitrogen free extract	42.99	44.56	44.06	42.84	42.45	0.51	NS

%= percentage, SEM= Standard error means, NS= No significant (P>0.05), LOS= Level of significant, * = significant. a, b, c = Means on the same row bearing different superscript differ significantly (P<0.05).

The effect of SWAPSI on cost benefits of weaned rabbits is presented in table 5. The results showed increase in feed cost consumed 534.37₦/rabbit and total cost of production ₦3,084.37/rabbit for rabbits under 40%SWAPSI included diets than the control (367.54 and ₦2,917.54/rabbit). Feed cost/kg weight (₦1,566.61, ₦1,357.95, ₦1,118.51, ₦1,275.88 and

₦1,885.27/rabbit), revenue (₦3,658.00, ₦4,033.00, ₦4,305.00, ₦4,070.00 and ₦3,720.00) and gross margin (₦740.45, ₦990.23, ₦1,220.62, ₦1,027.12 and ₦730.19) were not significantly different (p>0.05). Highest FC/kg weight (₦3,084.37/rabbit), revenue (₦4,305.00) and gross margin (₦1,220.62) were recorded at 40%SWAPSI included diets T3 compared to the control (₦740.45) and other (₦990.23, ₦1027.12 and ₦730.19) SWAPSI included diets T2, T4 and T5 respectively. Feed cost consumed (₦534.37/rabbit) and total cost of production (₦3,084.37/rabbit) were higher (p<0.05) at T3 than the control (₦367.54 and ₦2,917.54/rabbit) but similar with the other SWAPSI included diet. The improvement (p<0.05) in the digestibility of dry matter (62.65 %), crude protein (69.50%), crude fibre (58.15%) and ash (45.28%) were due the SWAPSI inclusion in the diets. However, the SWAPSI included diets had higher (p>0.05) non-significant revenue as well as gross margin most especially in T3 (₦4,305.00 and ₦1,220.62/rabbit) than the control with the least values.

Table 5. Effect of SWAPSI on Cost Benefits Analysis of Weaned Rabbits

	Replacement values of SWAPSI						
Parameters	T1 (0%)	T2 (20%)	T3 (40%)	T4 (60%)	T5 (80%)	**SEM**	**LOS**
FC/KG (₦/kg)	288.02	295.45	287.05	290.95	270.85	-	-
FCC (₦/kg)	367.54^{c}	492.76^{ab}	534.37^{a}	492.87^{ab}	439.80^{bc}	17.06	*
FC/KGW ₦/rabbit	1,566.61	1,357.95	1,118.51	1,275.88	1,885.27	140.97	NS
TCP ₦/rabbit	$2,917.54^{c}$	$3,042.76^{ab}$	$3,084.37^{a}$	$3,042.87^{ab}$	$2,989.80^{bc}$	17.06	*
Revenue (₦)	3,658.00	4,033.00	4,305.00	4,070.00	3,720.00	147.82	NS
Gross margin (₦)	740.45	990.23	1220.62	1027.12	730.19	139.92	NS

PER=protein efficiency ratio, EER=energy efficiency ratio, FC/KG=feed cost/kilogram, FCC= feed cost consumed, feed cost/kilogram weight, TCP= total cost of production, %= percentage, SEM= Standard error means, NS= No significant (p>0.05), LOS= Level of significant, * = significant. a, b, c = Means on the same row bearing different superscript differ significantly (p<0.05).

Discussion

The increase in the feeding and protein intake may be due to the SWAPSI inclusion. This probably indicated that SWAPSI have the required nutrients that stimulated the appetite to increase feed consumption thereby, increase growth and development of the animal tissues. This disagreed with the finding of Olayemi *et al.* (2006) who revealed that maize milling waste reduces feed intake as well as final body weight of weaned rabbits. This could suggest better values of energy to the SWAPSI as an industrial by-product. This suggests that rabbit utilized higher fibrous materials in the diets. This concur with Oloruntola *et al*. (2015) who stated that, rabbit has the ability to utilized non-competitive feed ingredients that is fibrous in nature. This is also consistent with Alu (2012). Similarly, the improvement in the digestibility of dry matter, crude protein, crude fibre and ash were also due to the SWAPSI inclusion in the diets. However, the decreased crude fat digestibility as the level of SWAPSI increased in the diets might be attributed to low fat content in raw SWAPSI as an agro-industrial by-product. Also, this indicated how rich is the SWAPSI in terms of supplying basic nutrients, which makes the animal eat more to add to the cost of feed consumed with the concomitant higher cost of production.

Conclusion

It is therefore concluded that 40% SWAPSI may replace maize in weaned rabbit diets. This could equally generate more revenue to production and profit margin and a better utilization and assimilation of needed nutrients. Hence, 40% SWAPSI is recommended for optimum rabbit performance and could be adopted by farmers for profit maximization.

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