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GROWTH PARAMETERS AND CARCASS CHARACTERISTICS OF GROWER RABBITS FED TIGER NUT OFFAL MEAL-BASED DIET SUPPLEMENTED WITH KINGZYME® ENZYME.

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ABSTRACT

A 42 days feeding trial was conducted to evaluate the effect of tiger nut offal meal based diet supplemented with Kingzyme enzyme on growth parameters and carcass characteristics of grower rabbits. A total of 48 weaned composite rabbits were randomly allotted to the experimental diets in 3x2 factorial arrangement fitted into a Complete Randomized Design (CRD) which was replicated 4 times having two rabbits per replicate. Six experimental diets were formulated to be isocaloric (2500kcal/kg) and isonitrogenous (15% crude protein) for the grower rabbits with tiger nut offal meal levels of (0, 50 and 100%) and two levels of Kingzyme (0ppm and 200ppm). Rabbits were reared in an open-sided rabbits hutches for 6 weeks, fed with weighed amount of experimental diets and watered at all time. Light and other standard routine management practices were strictly observed throughout the experimental period. There was no significant variation (P> 0.05) in all the growth parameters evaluated except for feed intake (64.11 vs 51.76 vs 52.59g/rabbits/day) and protein intake (10.41 vs 8.44 vs 8.81) which significantly reduced as the level of tiger nut offal increased while carcass characteristics results indicate significant improvement (P< 0.05) in the weights of head (8.48 vs 7.66 vs 7.87%), shanks (1.58 vs 1.28 vs 1.56), thigh (11.58 vs 11.21 vs 12.93) thoracic cavity (6.98 vs 7.26 vs 8.48%), liver (4.42 vs 3.24 vs 3.93%) and lungs (1.24 vs 1.09 vs 0.89%). The observation was due to Tiger nut offal meal inclusion level. The results for enzymes supplementation showed that body weight (242.50 vs 283.33g/rabbits), weight gain/day (5.77 vs 6.74g/day) and energy efficiency ratio (9.63 vs 11.33) were significantly improved (P< 0.05) while carcass characteristics results indicate no significant (P> 0.05) variation in all the parameters except in the weights of head (8.33 vs 7.68%) and shanks (1.58 vs 1.34%) which significantly (P< 0.05) reduced as the level of enzymes supplementation increased from (0ppm to 200ppm).The interaction of the enzyme and tiger nut offal meal affect all the growth parameters significantly (P< 0.05) except for initial and final weights which were not affected (P> 0.05) across the treatments while carcass characteristics results indicate significant (P< 0.05) improvement in the weights of head, forelimbs, shanks, thigh, thoracic cavity, liver and caecum. Based on the results of this finding, inclusion level of tiger nut offal meal at 50% and enzymes supplementation at 200ppm is recommended for optimum performance and better carcass quality in grower rabbit production.

Keywords: Kingzyme®, Rabbits, Growth rate, Carcass characteristics, Tiger nut offal meal.

INTRODUCTION

The target of an animal nutritionist is to fully utilize locally available ingredients and produced feeds that supply basic nutrients to the animal at a very low and affordable cost. Nigerian livestock industry is facing great challenges which could be reduced by improving the nutritional status of highly fibrous plant materials tha are predominantly abundant

in Nigeria (Alu, 2012). The growth of Nigerian livestock industry has always been limited by feed which accounts for about 70 – 80% of the total cost of production intensively (Ukachukwu and Osuagwu, 2006). Different unconventional feed resources have been identified and improved by various researchers (Madubuike and Ogbonnaya, 2003). Most of these plant based materials are underutilized, cheap, easily sourced and converted to feed (Tuleun *et al*., 2005).

Rabbit with several features that support its production at both commercial and subsistence levels as one of the solutions that solves the problems of low protein intake in the developing countries (Oloruntola *et al*., 2015). Among these features are small body size, rapid growth, high reproduction potential, short generation time, production of high quality meat, good potential for genetic improvement, ability to utilize non-competitive feeds among others (Oloruntola *et al*., 2015).

According to Bamishaiye (2011) and Sánchez-Zapata (2012), tiger nut (*Cyperus esculentus*) is an underutilized crop of the family Cyperceae, that produce rhizomes from the based and tubers which contain soluble glucose of about 21%. It has been reported by Bamishaiye (2009) that tiger nut (*Cyperus esculentus*) was also cultivated for its nutritive edible nuts and it is rich in vitamin E and C. However, the present reality in search of alternative energy sources to cereal grains (corn, wheat, sorghum, etc.) and oilseed meals (soybean, canola, and others) that was been constantly increasing in price due to competition between human and animals (Onunkwo and Ugwuene, 2015).Tiger nut (*Cyperus esculentus*) was believed to have certain phytochemicals such as phytate, tannin, saponin and phenols (Alagbe, 2017), it has an excellent nutritional values with a higher fat content similar to that of olive oil, also rich in minerals like phosphorus, potassium and calcium but lower in sodium (Belewu *et al*., 2007).

Report had shown that the use of exogenous enzymes as a way of reducing the effect of these anti-nutritional factors in feed ingredient as well as effective utilization of the available nutrient in the feedstuffs has been encouraged (Alu *et al*., 2018), some of the uses of exogenous enzymes include the reduction of anti-nutrients found in feed ingredient, enhancing feed utilization and efficiency, decreases non-starch polysaccharides and intestinal viscosity as well as separate inherent thermo- stability and supply calcium, phosphorus and other mineral ions that would commonly remove and attached to the phytate by making it unavailable for absorption (Alu *et al*., 2018).

Kingzyme is unique in that it is the only fibre degrading enzyme that is fully intrinsically thermostable as a granule that has the effectiveness of making cellulose and hemicellulose component of the cell wall of the plant available for absorption (Anuradha and Barun, 2015). Kingzyme can withstand pelleting temperatures as high as 85ºC (185ºF) maintaining enzyme activity post-pelleting. The stability has been demonstrated in a wide range of pelleting tests within institutes and commercial feed mills (bio-ingredient, 2004). It has also been postulated that excess supplementation of Kingzyme enzymes complex had no effect on performance or even inhibited endogenous enzyme secretion and destroyed small intestine structure (Guo *et al*., 2014). It is for this reason that: necessitates the feeding of grower rabbits with tiger nut offal meal-based diet supplemented with Kingzyme® Enzyme on growth parameters and Carcass Characteristics.

MATERIALS AND METHODS

Experimental Site

This experiment was conducted at the Teaching and Research Farm of the Department of Animal Science, Faculty of Agriculture, Nasarawa State University Keffi, Shabu-Lafia Campus, located in the Guinea Savannah Zone of Nigeria. It lies on Latitude $6^0 15^0$ and $9^0 30^0$ and longitude $6^0 30^0$ N and $11^0 0^0$E. The mean annual rainfall is usually 823mm (NIMET, 2010).

Source of Feed Ingredients

Tiger nut offal was sourced from the local kunun aya processors within Keffi and Lafia Local Government Area of Nasarawa State and sun-dried for 2-3 days under natural condition while other ingredients such as maize, maize bran, rice bran, groundnut cake, fish meal, bone meal lysine methionine etc. were purchased from feed suppliers in Lafia town, Nasarawa State while enzymes was purchased from a registered dealer of animal feed products.

Experimental Rabbits and Management

Forty eight (48) grower rabbits of the same age and similar live weight were purchased from National Animal Production Research institute NAPRI and reared in an open- sided mesh rabbit hutches at the rabbits unit of the Research and Teaching Farm of the Nasarawa state university Keffi. They were randomly assigned to a six dietary treatments with four replicates in each and 2 rabbits per replicate (incorporating Tiger nut offal meal and enzymes in a 3 x 2 factorial design). Each hutch wa equipped with feeders and drinkers. Light were provided at night using electric bulb throughout the period of the experiment to enable rabbits eat both day and night. Rabbit were fed with weighed amount of the experimental diets and drinking water *ad-libitum* and broad antibiotics, coccidiostats, and anti-stress were administered occasionally in their drinking water. Other routine management practices were observed daily such as washing of drinkers, daily cleaning of hutches, repairing of hutches and daily inspection.

Proximate Analysis of Tiger Nut Offal

Proximate composition (crude protein, dry matter, ether extract, crude fiber and nitrogen free extract) of the experimental test ingredient were determined using the procedure outlined by AOAC (2006) as described by Alu *et al.* (2018) and the results are presented in Table 1.

Experimental Diets and Composition

Six experimental diets were formulated to be isocaloric (2500kcal/kg) and isonitrogenous (15% crude protein) for the grower rabbits with three levels inclusion of the tiger nut offal meal (0, 50 and 100%) and two levels inclusion of exogenous enzymes (0, 200ppm Kingzyme) as T1 = 0% TNO with 0ppm enzymes serves as control, T2 = 0% TNO with 200ppm enzymes, T3 = 50% TNO with 0ppm enzymes, T4 = 50% TNO with 200ppm enzymes, T5 = 100% TNO with 0ppm enzymes, T6 =100% TNO with 200ppm enzymes. The nutrients were balanced to meet the nutrient requirement of the rabbits for that particular class and the diets are presented in Table 2.

Growth Parameters

The growth performance include body weight gain which was computed as the difference between the final weight and the initial weight of the rabbits, feed intake 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 while protein efficiency ratio was computed as the gain in body weight to the protein consumed, protein intake as feed intake x % crude protein in the diet/100, energy efficiency ratio (EER) were calculated as the gain in body weight to the Metabolizable energy x 100.

Carcass Characteristics

At the end of the experiment, two (2) rabbits were randomly selected from each treatment (one from each replicate) and were deprived of feed overnight. The fasted live weights of the rabbits were recorded before the rabbits were slaughtered and bled by severing the jugular vein. The slaughtered weights of the rabbits were recorded accordingly and immersed in warm water. The dressed weight and cut-up parts (head, neck, forelimbs, shanks, thighs and thoracic cavity) and the visceral organs (liver, heart, kidney, lungs, intestinal length and

caecum) were weighed and recorded. The weights of the carcass cuts were expressed as % of fasted weight while visceral organs as % of dressed weight. Dressing percentage was determined and expressed as follows: dressing percentage

$$(DP\ \%) = \frac{\text{Carcass weight} \times 100}{\text{Live weight}\quad 1}$$

Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) for factorial experiment using (SPSS, 2007) Model. Significantly different means were separated using Duncan's Multiple Range Test (Duncan, 1955). The following statistical model was used: $Y_{ijk}= U +A_I +B_J + (AB)_K+e_{ijk}$ where Y_{ijk}=individual observation, U= population mean, A_i = effect of factor A, B_j= effect of factor B, and AB_K = effect of interaction of factor A and B.

RESULTS.

The results for the proximate composition of tiger nut offal meal (*cyperus esculentus*) analysis is presented in Table 1. The result indicate crude protein (CP) content of 9.43%, nitrogen free extract (NFE) representing the carbohydrate level of 65.43%, while the ether extract of 3.54%, fiber (CF) 6.77%, ash 2.88% and the Metabolizable energy (ME) is 2905.243kcal/kg calculated from the proximate composition data using the formula as described by Pauzenga (1985), ME (kcal/kg) = 37x % CP x 81.1 x % EE + 35.5 x % NFE while that of nutrient composition of the experimental diets for grower rabbits with six (6) different experimental treatments in Table 2.

The result for the main and interactive of tiger nut offal meal supplemented with enzymes on growth performance parameters of grower rabbits is presented in Table 3. The results for the effects of tiger nut offal meal at (0%, 50% and 100% TNO) indicate non-significant (P>0.05) differences in all the growth parameters except for feed intake (64.11vs 51.76 vs 52.59) and protein intake (10.41 vs 8.44 vs 8.81). Rabbits fed 0% recorded the highest feed intake (64.11g) and protein intake (10.41) compared with 50% and 100% TNO inclusion levels.

There was significant (P< 0.05) difference in the weights of head (8.48% vs 7.66% vs 7.87%), shanks (1.58 vs. 1.28 vs. 1.56%), liver (4.42 vs 3.24 vs 3.93%) and lungs (1.24 vs 1.09 vs 0.89%) Table 4. Rabbits fed 0% TNO had the highest value for head (8.48%), shanks (1.28%), liver (3.24%) and lungs (1.24%). However, the weights of thigh (11.56% vs 11.21% vs 12.93%) and thoracic cavity (6.98% vs 7.26% vs 8.48%) were significantly improved with an increased in the levels TNO meal inclusion.

The effects of enzyme supplementation at (0ppm and 200ppm) in Table 3 showed that body weight gain (242.50 vs 283.33g), weight gain/day (5.77 vs 6.74g/day) and energy efficiency ratio (9.63 vs 11.33) were significantly (P< 0.05) different. Rabbits fed 200ppm supplemented diets had higher body weight and efficient energy than non- enzyme rabbits at 0ppm supplemented diets. while the results for carcass characteristics showed non-significant (P>0.05) variation in the weights of all carcass parameters except for head (8.48% vs 7.68%) and shanks (1.58% vs 1.34%) which were significantly reduced when supplemented with enzymes from 0ppm and 200ppm (Table 4).

The interaction effects of tiger nut offal and enzymes showed significant (P< 0.05) difference in all the growth parameters except initial and final body weight which showed no significant (P>0.05) difference. There was significant (P< 0.05) different in the weight gain (372.50 vs 337.50g), weight gain/day (8.89 vs 8.03g/day), PER (0.99 vs 0.80) and EER (14.86 vs 13.05) at T4 (50%TNO with enzymes) compared with T1 (0%TNO without enzymes Table 3). FCR results were very poor across the treatment diets owing to the fact that

T2 has the poorest value (13.49) than T4 (6.31) which indicate better conversion. There was significant (P< 0.05) variation in the weight of head, forelimbs, shanks, thighs, thoracic cavity, liver, kidney, lungs and caecum weigh

DISCUSSION

The significant increase in feed intake and protein intake with increasing levels of tiger nut offal meal in the diets may be attributed to lower metabolizable energy and the present of anti-nutritional factors still present in TNO meal. This observation compared favourable with the results obtained by Agbabiaka *et al*. (2012) who reported significantly reduction in feed intake when broiler chicks were fed different levels of Tiger nut seed meal.

The significant reduction in the weights of head, shanks, liver and lungs was due to increase in the level of TNO meal (Table 4). This implies poor conversion of dietary fibre and energy to flesh by rabbits under 50 and 100% TNO included diets. This observation agrees with the finding of Olayemi *et al*. (2006) who revealed that shrunk weight, empty carcass weight and head weight of weaner rabbits were significantly affected when fed maize milling waste based-diets. This supports the general assertion that high fibre diets reduced carcass weight due to high levels of fibre. However, there was significant improvement in the weights of thigh and thoracic cavity with an increased in the levels TNO meal inclusion. This results is in contrary with the reports of Agbabiaka *et al*. (2012) who observed non- significant variation in the weights of thigh, back and shank when broiler finisher fed varying levels of tiger nut meal as dietary supplement.

Enzyme supplementation significantly (P< 0.05) improved body weight gain, weight gain/day and energy efficiency ratio. Rabbits fed 200ppm supplemented diets gained more weight and efficiently utilized more energy compared with non- enzyme at 0ppm supplemented diets. This result is in agreement with the findings of Alu *et al*. (2012) who reported significant improvement in the body weight of Japanese quail when fed sugarcane scrapings and 200ppm Maxigrain enzymes supplemented diets. However, there was significant (P< 0.05) reduction in weight of head and shanks as enzymes supplementation increased from 0ppm to 200ppm (Table 4). This observation could be attributed to high inclusion level of enzymes supplementation at 200ppm. This finding agrees with the previous report of Wafar *et al*. (2019) who revealed both carcass and organs morphology were significant reduced by enzymes supplementation when grower rabbits fed enzyme supplemented 50:50 bovine rumen digesta and blood meal mixture. This also supports the finding of Yakubu *et al*. (2017) and Oloruntola (2018) who reported an increase in carcass characteristics and dressing % in weaner rabbits fed enzymes supplemented diets.

The significant increased for weight gain, weight gain/day, protein efficiency ratio and energy efficiency ratio at T4 (50%TNO with enzymes) compared with T1 (0%TNO without enzymes Table 3). This shows that combination of enzymes and dietary fibre (TNO) can be utilized by grower rabbits. Feed conversion ratio results were very poor across the treatment diets owing to the fact that T2 has the poorest value compare with T4 which indicate better conversion. The significant variation in the weight of head, forelimbs, shanks, thighs, thoracic cavity, liver, kidney, lungs and caecum weight could be attributed to the interaction of tiger nut offal and enzyme, high level of anti-nutritional factors as well as the level of inclusion of both enzymes and tiger nut offal meal across the treatment diet.

CONCLUSION AND RECOMMENDATION

Based on this finding, rabbits fed 50% tiger nut offal meal supplemented with 200ppm performed better than those fed 100%. This means that 50% inclusions will lead to better

performance without any adverse effect on growth and better carcass quality.

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Table 1: Proximate composition of Tiger nut offal

Parameters	(%)
Crude protein	9.43
Crude fibre	6.77
Ether extract	3.54
Ash	2.88
Moisture	11.95
Carbohydrate	[a]72.20
Nitrogen free extract	[b]65.43
Dry matter	[c]88.05
Metabolizable energy (kcal/kg)	[d]2905.243

a. Carbohydrate =NFE+ CF, b. NFE=100 - % (CP + CF + EE +ASH+ MOISTURE),
c. Dry matter=100% - MOISTURE. AOAC (2010)
d. Pauzenga (1985); ME=37 x % CP+81.1 x % EE+35.5 x % NFE.

Table 2: Ingredients composition of the experimental diets for grower rabbits

Ingredients (%)	T1(0%TNO) +0%ppm	T2(0%TNO) +200%ppm	T3(50%TNO) +0%ppm	T4(50%TNO) +200%ppm	T5(100%TNO) +0%ppm	T6(100%TNO) +200%ppm
Maize	30.00	30.00	15.00	15.00	0.00	0.00
TNO*	0.00	0.00	15.00	15.00	30.00	30.00
Maize offal	15.00	15.00	15.00	15.00	15.00	15.00
GNC	10.75	10.75	10.75	10.75	10.75	10.75
Rice offal	24.00	24.00	24.00	24.00	24.00	24.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Full fat soya	11.00	11.00	11.00	11.00	11.00	11.00
palm oil	3.00	3.00	3.00	3.00	3.00	3.00
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00
Common salt	0.25	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Toxin binder	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Enzymes(ppm)	0.00	200.00	0.00	200.00	0.00	200.00
Calculated Analysis						
ME Kcal/Kg	2586.82	2586.82	2506.16	2506.16	2425.49	2425.49
CP (%)	16.24	16.24	16.32	16.32	16.40	16.40
Lys (%)	1.01	1.01	1.13	1.13	1.25	1.25
Meth (%)	0.53	0.53	0.69	0.69	0.85	0.85
EE (%)	8.75	8.75	8.71	8.71	8.67	8.67
CF (%)	12.83	12.83	13.54	13.54	14.26	14.26
Ca (%)	1.14	1.14	1.16	1.16	1.19	1.19
P (%)	0.54	0.54	0.56	0.56	0.59	0.59
ASH (%)	5.76	5.76	5.99	5.99	6.23	6.23
Feed cost(₦/kg)	123.963	123.963	114.963	114.963	105.963	105.963

*TNO tiger nut offal inclusion levels. 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 (thiamin) 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 214mg. Using Feedwin software version 1.0

Table 3: Main and interactive effects of tiger nut offal and enzyme (Kingzyme) on growth parameters of grower rabbits

Treatments	IBW(g)	FBW(g)	BWG(g)	WG(g)/D	Parameters FI(g)	FCR	PI	PER	EER
Tiger nut offal									
0%	1006.25	1282.50	276.25	6.58	64.11^{a}	10.76	10.41^{a}	0.64	10.68
50%	958.75	1296.25	275.00	6.55	51.76^{b}	9.23	8.44^{b}	0.77	10.97
100%	956.25	1193.75	237.50	5.65	52.59^{b}	9.40	8.81^{b}	0.67	9.79
SEM	59.12	68.87	16.22	0.39	2.03	0.86	0.33	0.06	0.64
LOS	NS	NS	NS	NS	*	NS	*	NS	NS
Enzymes									
0ppm	983.33	1267.50	242.50^{b}	5.77^{b}	53.95	10.09	8.79	0.65	9.63^{b}
200ppm	964.17	1247.50	283.33^{a}	6.74^{a}	58.36	9.50	9.52	0.73	11.33^{a}
SEM	48.27	56.23	13.24	0.32	1.66	0.70	0.27	0.05	0.52
LOS	NS	NS	*	*	NS	NS	NS	NS	*
Interaction									
T1	1027.50	1365.00	337.50^{a}	8.03^{a}	62.43^{ab}	8.03^{c}	10.14^{ab}	0.80^{ab}	13.05^{ab}
T2	985.00	1200.00	215.00^{bc}	5.12^{bc}	65.80^{a}	13.49^{a}	10.69^{a}	0.48^{c}	8.31^{cd}
T3	960.00	1262.50	177.50^{c}	4.23^{c}	48.30^{c}	12.15^{ab}	7.88^{c}	0.54^{c}	7.08^{d}
T4	957.50	1330.00	372.50^{a}	8.89^{a}	55.22^{bc}	6.31^{c}	9.01^{bc}	0.99^{a}	14.86^{a}
T5	962.50	1175.00	212.50^{bc}	5.06^{bc}	51.11^{c}	10.31^{abc}	8.35^{c}	0.63^{bc}	8.77^{cd}
T6	950.00	1212.50	262.50^{b}	6.25^{b}	54.07^{bc}	8.69^{bc}	8.87^{bc}	0.71^{bc}	10.83^{bc}
SEM	83.61	97.39	22.94	0.55	2.88	1.22	0.47	0.08	0.90
LOS	NS	NS	*	*	*	*	*	*	*

abcd means on the same column having different superscript differ significantly ($p<0.05$); NS = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significance; IBW = Initial body weight; FBW =Final body weight; BWG = Body weight gain (g); WG(g)/D = Weight gain in grams/Day ; FI=Feed intake (g); FCR = Feed conversion ratio; PI= Protein intake; PER= Protein efficiency ratio; EER= Energy efficiency ratio.

Table 4: Main and interactive effects of tiger nut offal and enzymes (Kingzyme) on carcass cuts and visceral organs characteristics of grower rabbits as expressed in percent fasted weight (Carcass cuts) and dressed weight (Visceral organs)

Treatments	TNO					ENZ				INTR							
	0%	50%	100%	SEM	LOS	0ppm	200ppm	SEM	LOS	T1	T2	T3	T4	T5	T6	SEM	LOS
Parameters																	
CUT PARTS																	
FST W (g)	1215.00	1187.50	1217.50	31.43	NS	1205.00	1208.33	25.66	NS	1280.00	1150.00	1150.00	1225.00	1185.000	1250.00	44.44	NS
SLA W (g)	1112.50	1115.00	1147.50	34.22	NS	1133.33	1116.67	27.94	NS	1165.00	1060.00	1090.00	1140.00	1145.00	1150.00	48.39	NS
DRS W (g)	702.23	660.58	693.73	30.37	NS	690.33	680.68	24.79	NS	760.15	644.30	681.10	640.05	629.75	757.70	42.95	NS
HD W (%)	8.48^{a}	7.66^{b}	7.87^{b}	0.15	*	8.33^{a}	7.68^{b}	0.13	*	9.15^{a}	7.82^{b}	8.00^{b}	7.33^{b}	7.85^{b}	7.89^{b}	0.22	*
NCKW (%)	3.40	2.92	3.10	0.25	NS	3.24	2.94	0.21	NS	3.57	2.87	3.37	2.47	2.83	3.38	0.36	NS
FL W (%)	7.99	7.37	7.62	0.29	NS	7.89	7.43	0.21	NS	8.41^{a}	7.57^{ab}	8.13^{a}	6.62^{b}	7.15^{ab}	8.10^{a}	0.40	*
SHK L (%)	0.77	0.79	0.78	0.02	NS	0.77	0.79	0.02	NS	0.75	0.79	0.77	0.81	0.80	0.76	0.03	NS
SHK W (%)	1.58^{a}	1.28^{b}	1.56^{ab}	0.07	*	1.58^{a}	1.34^{b}	0.06	*	1.66^{a}	1.49^{ab}	1.49^{ab}	1.45^{b}	1.65^{a}	1.38^{ab}	0.09	*
TH W (%)	11.58^{b}	11.21^{b}	12.93^{a}	0.19	*	11.68	12.13	0.06	NS	11.76^{b}	11.39^{b}	11.65^{b}	10.77^{b}	11.63^{b}	14.23^{a}	0.28	*
TRX W (%)	6.98^{b}	7.26^{b}	8.48^{a}	0.2	*	7.41	7.74	0.21	NS	6.96^{b}	6.99^{b}	7.39^{b}	7.14^{b}	7.87^{ab}	9.09^{a}	0.37	*
DRESSN %	57.73	58.25	56.77	1.89	NS	57.27	57.90	1.54	NS	59.40	56.06	59.28	57.23	53.13	60.42	2.67	NS
VISCERAL ORGANS																	
LVR W (%)	4.42^{a}	3.24^{b}	3.93^{a}	0.18	*	3.87	3.85	0.14	NS	4.94^{a}	3.90^{bc}	3.23^{c}	3.25^{c}	3.45^{c}	4.41^{ab}	0.25	*
KDYW (%)	1.14	1.36	1.23	0.07	NS	1.27	1.22	0.05	NS	1.29^{ab}	0.99^{b}	1.32^{ab}	1.40^{a}	1.19^{ab}	1.26^{ab}	0.09	*
ST/CW (%)	29.77	27.45	28.78	1.73	NS	28.95	28.38	1.42	NS	27.43	32.10	26.64	28.26	32.77	24.79	2.45	NS
HRT W (%)	0.44	0.43	0.43	0.04	NS	0.48	0.39	0.03	NS	0.48	0.40	0.48	0.38	0.48	0.38	0.06	NS
LGS W (%)	1.24^{a}	1.09^{b}	0.89^{b}	0.07	*	0.98	1.18	0.06	NS	1.11^{ab}	1.41^{a}	0.96^{b}	1.22^{ab}	0.87^{b}	0.91^{b}	0.11	*
INTS W (%)	49.18	47.12	45.88	1.90	NS	47.87	46.92	1.55	NS	49.25	49.10	45.69	48.55	48.66	43.00	2.68	NS
CCMW (%)	10.99	11.22	11.02	0.66	NS	11.07	11.08	0.54	NS	9.67^{bc}	12.42^{ab}	10.23^{bc}	12.21^{ab}	13.42^{a}	8.63^{c}	0.94	*

abc means on the same column having different superscript differ significantly ($p<0.05$); NS = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significant; TNO = tiger nut offal; ENZ = enzyme; INTR = interaction; FST W =fasted weight (g) ; SLAW = slaughtered weight (g); DRS W= dressed weight (g); HDW= head weight (%); NCKW= neck weight (%); FLW= forelimb weight (%); SHKL= shank length(%); SHKW= shank weight (%); THW= thigh weight(%); TRXW= thorax weight (%); DRESSN % = dressing percentage; LVR= liver weight(%); KDYW = kidney weight(%); ST/CW = stomach/content weight(%); HRTW = heart weight(%); LGSW = lungs weight (%); INTS W= intestinal weight(%); CCMW = caecum weight (%).

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MONOGASTRIC NUTTRITION GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF RABBITS FED DIETS CONTAINING VARYING LEVELS OF ACHA OFFAL SUPPLEMENTED WITH MAXIGRAIN® ENZYME

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ABSTRACT

This study aimed at evaluating the growth performance and carcass characteristics of rabbits fed diets containing varying levels of Acha Offal (AO) supplemented with Maxigrain® enzymes. Forty eight (48) rabbits of mixed breeds and similar live weight were used in two experiments consisting of weaner and grower phases which lasted 42 days each. The experiment was arranged in a 3x2 factorial fitted into Completely Randomized Design having AO (0, 15 and 30%) and enzyme(0 and 200ppm) as the main factors. Feed and water were provided to the animals daily and all standard routine management practices were strictly observed throughout the experiment. At weaner phase, average Feed intake and protein intake due to AO were significant (P<0.05) higher in 15%,(62.79 and 9.21g) and 30% (65.01 10.73g) than 0% (58.39 and 9.21g) respectively. Animals on 30% diets recorded significantly (P<0.05) higher (178.24/kCal/ME) energy intake than those on 0% (163.94kCal/ ME) AO diets. There was no significant (P>0.05) effect of enzyme in all the growth performance parameters measured. In the grower phase, feed intake was significantly lower in T1 (54.91g) than T2 (61.69g), T3, (63.69g), T4 (61.89), T5 (66.96), and T6 (63.06). Rabbit on T5 diets had significantly (P< 0.05) higher protein intake (11.05g). Although not significantly (P>0.05) different from T6 (10.41g). Energy intake was significantly lower in T1 (154.41kCal/ME) than the remaining treatment. There was no significant (P>0.05) effect of AO, enzyme or their interactive effective in all the growth performance parameters measured during the grower phase. Animals on 15 and 30% AO diets had significant (P<0.05) higher weight of Live animals (1595.00 and 1672.50g), slaughtered (1527.50 and 1592.50g), forelimb (165.18 and 169.50g), liver (3.10 and 2.94g), thigh (222.03 and 228.18g) and intestinal length (20.55 and 20.42g). Shank weight (42.70g), thoracic cavity (10.37g), shank length (0.74 cm), and caecum length (5.21cm) were significantly (P<0.05) higher in rabbits fed 30% diets than the rest. Rabbit diets slaughtered supplemented with 200ppm enzyme had significantly (P<0.05) higher live weight (1643.33g), slaughtered weight (1560.00g), and caecum length (4.56 cm) than those on 0ppm respectively. Interactive effect of acha offal and enzyme showed that neck weight was significantly (P<0.05) higher in T1 (4.53g) than the rest of the treatments. Liver weight was significantly (P<0.05) lower in T1 (2.35g), T2 (2.76g), T4 (2.71g) T6(2.68g) than T3 (3.49g) and T5 (3.20g). T6 (0.61g) had significant (P<0.05) lower kidney weight although not different from T1 (0.64g) and T3 (0.69g). Shank length was significantly (P<0.05) higher in T5 (0.78cm) and T2 (0.76cm) rabbits fed diets, but no difference was observed between T1 (0.71cm) and T2 (0.76cm) and T6 (0.71cm). T1 (3.73cm), T2 (3.80cm), T3 (3.90cm) had lower caecum length. In conclusion, feeding rabbits with diets containing 30% AO supplemented with Maxigrain® enzyme had no detrimental effect on growth performance and carcass characteristics.

Keywords: Acha offal, carcass characteristics, growth performance, grower rabbits, Maxigrain®, rabbits, weaner rabbit

INTRODUCTION

In the tropics, maize, sorghum and wheat are the most utilized cereal in the animal feed industry and its future utilization is hampered by its growing global demand for industrial uses and attendant high cost Oko*et al*. (2018). Cadoni and Angelucci (2013) identified high cost of feeds as the major obstacle militating against rapid expansion of the poultry industry in developing countries. Therefore, the success of the livestock industry would depend on the availability of qualitative and relatively inexpensive feed ingredients for livestock feed. There is also the need to pay attention to the faster and cheaper ways of increasing animal production as wells as to increase the availability of animal protein (Aguda*et al*., 2014), hence the need to utilize inexpensive non-conventional feed resources such as acha offal.

Acha (Fonio) is also called "hungry man rice" as it is perceived as the food for the poor probably due to its unique small grains (Cruz *et al*., 2011). However, the presence of anti-nutrients such as phytate has been a major limiting factor to the extensive utilization of acha and its by-products (Al-Numair*et al*., 2009; Azeke*et al*., 2011).Fonio is highly rich in amino acids and iron (De Lumen *et al.*, 1991). It is also very nutritious for pregnant women and children. It is free of gluten and is a great alternative for gluten-intolerant people, in particular those living with Celiac Disease (De Lumen *et al.*, 1991). Due to its high fiber content, this grain is also recommended for the elderly, and or people suffering from digestive problems. Moreover, because of its insulin secreting properties, Fonio products have found that diabetics are their key customers. Fonio is richer in calcium, magnesium, zinc and manganese than other grains. This grain also contains high levels of methionine and cystine, amino acids essential to our health which our body cannot produce on its own. Fonio grains can play a vital role in nourishing human health (Balde*et al*., 2008). It has been reported that many of the cereals by-product and grains contain some phytochemicals which can be reduced by enzymes supplementation (Alu, 2012). Similarly, studies have reported increased feed breakdown especially of fibrous feed materials into easily digestible nutrients by exogenous enzyme supplementation in monogastric feeds Ogbe*et al*. (2013). Previous study by Ademola*et al*. (2012) indicates that maxigrain enzyme improved performance of laying hens fed wheat offal, corn bran and brewery dry grain diets. Enzymes are beneficial to rabbits diets in; reduction in digesta viscosity, enhanced digestion and absorption of nutrients especially fat and protein, improved Apparent Metabolizable Energy value of the diet, increased feed intake, weight gain, increased feed gain ratio, reduced beak impaction and vent plugging, decreased size of gastrointestinal tract, altered population of microorganism in gastrointestinal tract, reduced water intake, reduced water content of excreta, reduced production of ammonia from excreta, reduce output of excreta and also reduced nitrogen and phosphorus (Khattak*et al*., 2006). However, there is little information on utilization of acha offal and how enzyme could influence the performance of rabbits fed acha offal based diets. Therefore, this research aimed at evaluating the growth performance and carcass characteristics of rabbits fed diets containing varying levels of acha offal based diets supplemented with Maxigrain enzym

MATERIALS AND METHODS

Experimental Location

This experiment was conducted at the Teaching and Research Farm of Department of Animal, Faculty of Agriculture, Nasarawa State University Keffi, Shabu-Lafia Campus.

Feed Ingredients, Animals and Experimental Design

Acha offal was sourced from the local acha processors within Riyom Local Government

Area of Plateau State and preserved under natural condition while other ingredients such as maize, maize bran, rice bran, groundnut cake, fish meal, bone meal lysine methionine were purchased from the suppliers in Lafia, Nasarawa State. Six experimental diets were formulated to be isocaloric (2700kcal/kg) and isonitrogenous (18% crude protein) for the weaner phase whileisonitrogenous (15% crude protein) and isocaloric of (2500kcal/kg) for the grower phase with three levels of inclusion of the acha offal (0, 15 and 30%). The treatments T1, T2, T3, T4, T5 and T6 were 0% AO with 0ppm enzymes (control), 0% AO with 200ppm enzymes, 15% AO with 0ppm enzymes, 15% AO with 200ppm enzymes, 30% AO with 0ppm enzymes and 30% AO with 200ppm enzymes respectively. Forty-eight (48) rabbits of similar live weight wererandomly assigned to the test diets in a 3x2 factorial. Each of the experimental treatment was replicated four times in each pen having 2 rabbits each.

Data Collection

Chemical analysis:

The proximate analysis of the feed was carried at the Institutes of Tropical Agriculture (IITA) Ibadan using the standard procedure of AOAC (2000). Nitrogen Free Extract (NFE) was calculated using the formula: NFE (%) = 100 – CP + CF + EE + Moisture + Ash. Metabolizable energy (ME) was calculated using Pauzenga Formula (1985), ME =37 x % CP + 81 x %EE + 35.5 x % NFE.

Growth performance parameters evaluated

The required quantity of feed were weighed daily with a sensitive scale before given to the animal. Left over were measured and subtracted from feed offered to get actual feed intake. The rabbits were weighed at the beginning and at the end of each week using a scale. Weight gain was determined by subtracting the initial weight from the final weight. Feed conversion ratio was calculated by dividing feed intake by weight gain. Protein intake was calculated as protein in feed x feed intake; Energy intake as Energy in feed x feed intake; Protein efficiency ratio as weight gain divide by protein intake; and Energy efficiency ratio as weight gain divide by energy intake.

Carcass Evaluation

At the end of 12 weeks, one rabbit was randomly selected from each treatment and replicate group for organ and carcass analyses at the end of the experiment. Feed and water were withdrawn for 6-8 hours preceding slaughtering of the animal. Each rabbit was tagged accordingly and weighed before and after slaughtering to determine the live and carcass weight, respectively. Other parameters measured include: dressed weight, head weight, cervical weight, forelimb weight, shank weight, thigh weight, neck weight, thoracic cavity weight, liver weight, kidney weight, stomach content weight, lungs weight, intestinal length, shank length, ceacum length.

Data Analysis

Data obtained were subjected to Two Way Analysis of Variance (ANOVA) and significant means were separated using Duncan's Multiple Range Test (DMRT) of Statistical Analysis Software (SAS, 2000).

Table 1: Nutrients composition of the experimental diets for weaner rabbits

Ingredients (%)	T1(0%AO +0ppm)	T2 (0%AO +200ppm)	T3 (15%A0 +0ppm)	T4 (15%AO +200ppm)	T5(30%AO +0ppm)	T6 (30%AO +200ppm)
Maize	44.00	44.00	37.40	37.40	30.00	30.00
AO*	0.00	0.00	6.60	6.60	13.20	13.20
Maize bran	11.75	11.75	11.75	11.75	11.75	11.75
GNC	10.00	10.00	10.00	10.00	10.00	10.00
Rice bran	14.00	14.00	14.00	14.00	14.00	14.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Fall fat soya	10.00	10.00	10.00	10.00	10.00	10.00
palm oil	2.00	2.00	2.00	2.00	2.00	2.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00
Salt	0.25	0.25	0.25	0.25	0.20	0.20
Premix	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Toxic binder	0.25	0.25	0.25	0.25	0.25	0.25
Enzymes(PPM)	0.00	200.00	0.00	200.00	0.00	200.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients and energy composition						
ME (kcal/kg)	2894.45	2894.45	2860.12	2860.12	2825.78	2825.78
Crude protein (%)	18.24	18.24	18.58	18.58	18.93	18.93
Lysine (%)	1.32	1.32	1.30	1.30	1.29	1.29
Methionine (%)	0.53	0.53	0.51	0.51	0.50	0.50
Moisture (%)	0.72	0.72	1.04	1.04	1.35	1.35
Ether extract (%)	6.56	6.56	6.59	6.59	6.62	6.62
Crude fibre (%)	5.90	5.90	6.53	6.53	7.17	7.17
Calcium (%)	0.79	0.79	0.79	0.79	0.79	0.79
Phosphorus (%)	0.81	0.81	0.79	0.79	0.77	0.77

AO = Acha offal; ME = metabolizable energy; *A15,000 I.U, vitamin D3 300,000 I.U., vitamin E 3,000 I.U., vitamin K 2.50mg, vitamin B_1 (thiamin) 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 214mg.

Table 2: Nutrients composition of the experimental diets for growing rabbits

Ingredients (%)	T1(0%AO +0ppm)	T2 (0%AO +200ppm)	T3 (15%A0 0ppm)	T4 (15%AO +200ppm)	T5 (30%AO +0ppm)	T6 (30%AO +200ppm)
Maize	40.00	40.00	34.00	34.00	28.00	28.00
AO*	0.00	0.00	6.00	6.00	12.00	12.00
Maize bran	15.00	15.00	15.00	15.00	15.00	15.00
GNC	10.00	10.00	10.00	10.00	10.00	10.00
Rice bran	17.75	17.75	17.75		17.75	17.75
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00
Full fat soya	7.00	7.00	7.00	7.00	7.00	7.00
palm oil	2.00	2.00	2.00	2.00	2.00	2.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25
*Premix	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Toxic binder	0.25	0.25	0.25	0.25	0.25	0.25
Enzymes	00.00	200.00	0.00	200.00	0.00	200.00
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrients and energy composition						
ME (kcal/kg)	2712.07	2712.07	2674.67	2674.67	2637.28	2637.28
Crude protein (%)	15.71	15.71	16.01	16.01	16.31	16.31
Lysine (%)	1.00	1.00	0.99	0.99	0.97	0.97
Methionine (%)	0.56	0.56	0.55	0.55	0.54	0.54
Moisture (%)	4.45	4.45	4.37	4.37	4.30	4.30
Ether extract (%)	7.11	7.11	7.12	7.12	7.14	7.14
Crude fibre (%)	10.50	10.50	11.08	11.08	11.67	11.67
Calcium (%)	1.16	1.16	1.16	1.16	1.16	1.16
Phosphorus (%)	0.58	0.58	0.57	0.57	0.57	0.57

AO = Acha offal; ME = metabolizeable energy; *A15,000 I.U, vitamin D3 300,000 I.U.,vitamin E 3,000 I.U., vitamin K 2.50mg, vitamin B_1 (thiamin) 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 214mg.

RESULTS

Presented in Table 3 are the main and interactive effects of diets containing varying inclusion level of acha offal supplemented with enzymes on growth performance of weaner rabbits.There was significant effect (P<0.05) of inclusion of acha offal on average feed intake, protein intake and energy intake of the animals. Feed intake and protein intake were significantly (P<0.05) higher in 15% (62.79 and 9.21g) and 30% (65.01 10.73g) than 0% (58.39and 9.21g), respectively. Animals on 30% diets recorded significantly (P<0.05) higher (178.24kcal/kg, ME) energy intake than those on 0% (163.94kcal/kg, ME) AO diets. There was no significant (P>0.05) difference between the rabbits in initial weight, final weight, average weight gain per day, feed conversion ratio, protein efficiency ratio and energy efficiency ratio.There was no significant (P>0.05) effect of enzyme supplementation in all the growth performance parameters measured. The range of values for feed intake (61.85 – 62.210g) and weight gain (9.82 – 10.71g). There was significant (P<0.05) interactive effect of AO and enzyme in average feed intake, protein intake and energy intake of the rabbits. Feed intake was significantly lower in T1 (54.91g) than T2 (61.69g), T3, (63.69g), T4 (61.89g), T5 (66.96g), and T6 (63.06g). Rabbit on T5 diet had significantly higher (11.05g) protein intake than T1 (8.67g), T2 (9.74g), T3 (10.28g) and T4 (9.99g) although not significantly (P>0.05) different from those fed the T6 (10.41g). Energy intake was significantly lower in rabbits fed diet T1 (154.41kcal/kg, ME) than those of T2 (173.46kcal/kg, ME), T3, (176.92kcal/kg, ME), T4 (171.91kcal/kg, ME), T5(183.58kcal/kg, ME) andT6 (172.90kcal/kg, ME). The initial weight, final weight, average weight gain per day, feed conversion ratio, protein efficiency ratio and energy efficiency ratio were not significantly (P>0.05) affected by the interaction of acha offal and enzyme supplementation. Table 4 shows the result of main and interactive effects of diets containing varying inclusion level of acha offal supplemented with enzymes on growth performance of growing rabbit .There was no significant (P>0.05) effect of acha offal in all the growth performance parameters measured. All the growth performance parameters measured were not significantly (P>0.05) affected by the enzyme supplementation. There was no significant (P>0.05) interactive effect of acha offal and enzyme supplementation on all the parameters measured.

Main and interactive effects acha offal and enzyme on carcass characteristics of rabbit is presented in Table 5. Live weight, slaughtered weight, forelimb weight, liver weight, intestinal length, thigh weight, shank weight, thoracic cavity weight, shank length, and caecum length were significantly (P<0.05) affected by inclusion of acha offal. Animals on 15 and 30% AO diets had significant (P<0.05) higher weight of Live animals (1595.00 and 1672.50g), slaughtered (1527.50 and 1592.50g), forelimb (165.18 and 169.50g), liver (3.10 and 2.94g), thigh (222.03 and 228.18g) and intestinal length (20.55 and 20.42g). Shank weight (42.70g), thoracic cavity (10.37g), shank length (0.74g), and caecum length (5.21g) were significantly (P<0.05) higher in 30% diets than the rest.

The result showed no significant (P>0.05) difference between 0, 15 and 30% acha offal in dressed weight, head weight, cervical weight, kidney weight, stomach content weight and lungs weight.The results indicates significant (P<0.05) effect of enzyme supplementation on live weight, slaughtered weight, neck weight, thoracic cavity weight, liver weight, and caecum length but not significant (P>0.05) in weights of dressed animal, head, cervical , forelimb weight, shank , thigh, kidney, stomach content , lungs , intestinal and shank lengths. Rabbit diets supplemented with 200ppm enzyme had significantly (P<0.05) higher live weight (1643.33g), slaughtered weight (1560.00g), and caecum length (4.56cm) than those on 0ppm

(1575.00, 1481.67g and 4.36cm) respectively. Meanwhile,(4.23, 10.40 and3.02g) values for neck, thoracic cavity and liver weights in 0ppm diets respectively were significantly (P<0.05) higher (3.91, 9.11 and 2.72g) obtained from 200ppm diets. There was significant (P<0.05) interaction effect of acha offal and enzyme supplementation on live weight, slaughtered weight, dressed weight, forelimb weight, neck weight, thoracic cavity weight, liver weight, kidney weight, shank length and caecum length. Animals fed T6 diets recorded significant (P<0.05) higher live weight (1740.00g), slaughtered weight (1679.00g) and forelimb weight (179.60g) than the rest. This might be attributed to the interaction effect of acha offal and enzyme supplementation.Neck weight was significantly (P<0.05) higher in T1 (4.53g) although not significantly (P>0.05) different from T2 (4.25g) and T4 (4.19g) fed animals. Liver weight was significantly (P<0.05) lower in T1 (2.35g), T2 (2.76g), T4(2.71g) and T6(2.68g) than T3 (3.49g) and T5 (3.20g). T6 (0.61g) had significant (P<0.05) lower kidney weight although not different from T1 (0.64g) and T3 (0.69g). Shank length was significantly (p<0.05) higher in T5 (0.78cm) and T2 (0.76cm) but no difference was observed between T1 (0.71cm) and T2 (0.76cm) and T6 (0.71cm). T1 (3.73cm), T2 (3.80cm), T3 (3.90cm) had lower caecum length than the rest of the groups. There was no significant (P>0.05) difference between the diets in dressed weight, head weight, cervical weight, shank weight, thigh weight, stomach content weight, lungs weight, and intestinal length of the animals.

DISCUSSIONS

The increased feed intake recorded in this study during the weaner phase might be attributed to the increased level of acha offal. Earlier, Ogunsipe*et al.* (2014) reported no significant effect of sorghum offal diets in performance of rabbits.The similar weight gain and feed conversion ratio recorded could be attributed to the similar energy and protein level of the test diets. Additionally, rabbits are referred to as pseudo-ruminants due to the presence of microbial fermentation of fibrous feeds in their hindgut which could be effective in degradation and utilization of high fibrous diets. Earlier, Adenij*et al.* (2014) reported decreased in weight gain as a result of increasing high fibrous diets in monogastric animal's diets. The result of feed intake due to enzyme supplementation in this work were similar to those (7.46 – 13.82 and 49.42 – 64.11g)reported by Aguda and Omaje (2014) when they supplemented Maxigrain enzymes to pigeon pea diets of weanerrabbits.According to Allen *et al*. (1997), enzymes are added to feedstuffs to breakdown and release more nutrients for the use of the animals. Addition of enzymes to monogastric animal feed reduced viscosity of ingesta in the intestine and showed marked improvements on the various morphological effects of feeding fibrous materials to non-ruminant.The improvement in feed intakeof T5 diets may be due to a reduction in bulkiness and intestinal viscosity as proven efficacy of enzyme hence higher feed intake to satisfy the nutritional requirement (Ademokun, 1999; Adeniji, 2009).The similar performance recorded during growing phase might be attributed to the similar energy and protein contents of the different diets. Moreover, rabbits are known to utilize high fibrous feedstuffs due to the nature of their gastrointestinal tract which allows for fermentation of cellulose components of fibrous roughages.

The non effects of enzymes on growth performance during the growing phase disagrees withYaghobfar and Kalantar (2016) who posited that anti-nutritional activity of cell wall non starch polysaccharides impaired impacts growth rate and feed efficiency. AbdEl-Latif*et al*. (2008) found that adding enzymes supplementation improved daily body weight gain for rabbits fed dietary 10% crude fiber. Makled*et al*. (2005) who found that average daily feed intake of rabbits was increased due to

adding optizyme which contains xylanase, protease, cellulase, hemicellulose and amylase at levels of 500 or 750 mg/kg feed. The variation observed between the present experiment and others might be attributed to the type of enzymes and diets used. Similarly, this study showed that enzyme did not influence the effect of acha offal. This might be attributed to the insignificant main effects recorded from both acha offal and enzymes supplementation. Diverse reports exist on the relationship between exogenous enzyme supplementation and feed intake. Adrizal and Ohtani, (2002) reported that enzymes have no effect on feed intake while Kadam*etal*. (1991) reported reduction in feed intake as a result of enzyme supplementation.

This work revealed that enzyme supplementation had positively increased some carcass parameters. Previous report by Ademola*et al*. (2012) also showed that Maxigrain enzymes improved performance of laying hens fed wheat offal, corn bran and brewery dry grain diets.

Table 3: Main and interaction effects of diets containing varying inclusion level of acha offal supplemented with enzymes on growth performance of weaner rabbit

Factors		Parameters								
		Initial weight (g)	Final weight (g)	Average weight gain/day (g)	Average feed intake (g)	Feed conversion ratio	Protein intake (g)	Protein efficiency ratio	Energy intake (g)	Energy efficiency ratio
Inclusion of Acha offal (AO)	0%	803.75	1272.5	11.16	58.30^{b}	5.64	9.21^{b}	1.23	163.94^{b}	0.07
	15%	853.75	1262.5	9.73	62.79^{a}	6.82	10.13^{a}	0.98	174.41^{ab}	0.06
	30%	847.5	1263.75	9.91	65.01^{a}	6.72	10.73^{a}	0.92	178.24^{a}	0.06
	SEM	51.87	54.94	0.94	1.41	0.56	0.23	0.11	3.94	0.01
	LOS	Ns	Ns	Ns	*	Ns	*	Ns	*	ns
Enzymes supplementation	0ppm	820	1270	10.71	61.85	6.19	10	1.1	171.64	0.06
	200ppm	850	1262.5	9.82	62.21	6.6	10.04	0.99	172.76	0.06
	SEM	42.35	44.86	0.77	1.15	0.46	0.19	0.09	3.21	0.01
	LOS	Ns	ns	Ns	Ns	Ns	Ns	Ns	Ns	ns
AO*E	T1(0%AO+0ppm)	767.50	1285.00	12.32	54.91^{b}	4.78	8.67^{c}	1.43	154.41^{b}	0.08
	T2 (0%AO+200ppm)	840.00	1260.00	10.00	61.69^{a}	6.51	9.74^{b}	1.03	173.46^{a}	0.06
	T3 (15%A0+0ppm)	847.50	1255.00	9.70	63.69^{a}	6.90	10.28^{b}	0.96	176.92^{a}	0.06
	T4 (15%AO+200ppm)	860.00	1270.00	9.76	61.89^{a}	6.73	9.99^{b}	0.99	171.91^{a}	0.06
	T5 (30%AO+0ppm)	845.00	1270.00	10.12	66.96^{a}	6.88	11.05^{a}	0.92	183.58^{a}	0.06
	T6 (30%AO+200ppm)	850.00	1257.50	9.70	63.06^{a}	6.56	10.41^{ab}	0.93	172.90^{a}	0.06
	SEM	73.36	77.70	1.33	2.00	0.79	0.32	0.16	5.57	0.01
	LOS	Ns	ns	Ns	*	Ns	*	Ns	*	Ns

ab means on the same row having different superscript differ significantly ($p<0.05$); ns = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significance; AO*E = Interaction of Acha offal and Enzyme

Table 4: Main and interaction effects of diets containing varying inclusion level of acha offal supplemented with enzymes on growth performance of growing rabbit

		Parameters								
Factors		Initial weight (g)	Final weight (g)	Average weight gain/day (g)	Feed intake (g)	Feed conversion ratio	Protein intake (g)	Protein efficiency ratio	Energy intake (g)	Energy efficiency ratio
Acha offal (AO)	0%	1272.50	1635	8.63	66.80	7.74	10.55	0.82	187.83	0.05
	15%	1262.50	1676.25	9.85	65.04	6.60	10.50	0.94	180.66	0.06
	30%	1263.75	1651.25	9.23	69.11	7.49	11.40	0.81	189.48	0.05
	SEM	55.29	59.51	0.8	2	0.59	0.33	0.07	5.53	0.01
	LOS	ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns
Enzymes	0ppm	1271.67	1633.33	8.61	65.24	7.58	10.53	0.82	181.17	0.05
	200ppm	1260.83	1675	9.86	68.72	6.97	11.10	0.90	190.81	0.05
	SEM	45.15	48.59	0.65	1.64	0.48	0.27	0.06	4.52	0.01
	LOS	ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns
AO*E	T1(0%AO+0ppm)	1285.00	1582.50	7.09	66.49	9.38	10.50	0.68	186.97	0.04
	T2 (0%AO+200ppm)	1260.00	1687.50	10.18	67.11	6.59	10.60	0.96	188.70	0.06
	T3 (15%A0+0ppm)	1260.00	1640.00	9.05	61.94	6.84	10.00	0.91	172.05	0.06
	T4 (15%AO+200ppm)	1265.00	1712.50	10.66	68.14	6.39	11.00	0.98	189.27	0.06
	T5 (30%AO+0ppm)	1270.00	1677.50	9.70	67.29	6.94	11.10	0.87	184.49	0.05
	T6 (30%AO+200ppm)	1257.50	1625.00	8.75	70.93	8.11	11.71	0.75	194.47	0.05
	SEM	78.20	84.16	1.13	2.83	0.84	0.46	0.10	7.82	0.01
	LOS	ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns

ns = not significantly different (p>0.05); SEM = standard error of mean; LOS = level of significance; AO*E = Interaction of Acha offal and Enzyme; T1(0%AO+0ppm) T2 (0%AO+200ppm) T3 (15%A0+0ppm) T4 (15%AO+200ppm) T5 (30%AO+0ppm) T6 (30%AO+200ppm)

Table 5: Main and interaction effects acha offal and enzyme on carcass characteristics of rabbit

		Parameters																
Factors	Parameters (g)	Live weight	Slaughtered weight	Dressed weight	Head weight	Cervical weight	Forelimb weight	Shank weight	Thigh weight	Neck weight	Thoracic cavity weight	Liver weight	Kidney weight	Stomach content weight	Lungs weight	Intestinal length	Shank length	Cecum length
Acha offal(AO)	0%	1560.00^{b}	1442.50^{b}	1355.53	136.35	59.35	139.68^{b}	29.05^{b}	173.23^{b}	4.39^{a}	9.38^{b}	2.56^{b}	0.69	20.68	0.69	18.36^{b}	0.73^{a}	3.76^{c}
	15%	1595.00^{b}	1527.50^{a}	1423.71	152.73	60.63	165.18^{a}	28.30^{b}	222.03^{a}	4.15^{a}	9.51^{b}	3.10^{a}	0.74	19.87	0.77	20.55^{a}	0.69^{b}	4.42^{b}
	30%	1672.50^{a}	1592.50^{a}	1516.09	155.68	54.9	169.50^{a}	42.70^{a}	228.18^{a}	3.68^{b}	10.37^{a}	2.94^{a}	0.68	21.03	0.66	20.42^{a}	0.74^{a}	5.21^{a}
	SEM	18.98	19.95	4.12	4.91	1.53	2.36	1.63	7.18	0.08	0.17	0.08	0.02	0.71	0.05	0.44	0.01	0.06
	LOS	*	*	ns	Ns	ns	*	*	*	*	*	*	Ns	Ns	Ns	*	*	*
Enzymes	0ppm	1575.00^{b}	1481.67^{b}	1394.16	144.52	59.25	158.22	32.47	201.65	4.23^{a}	10.40^{a}	3.02^{a}	0.69	19.52	0.65	19.87	0.73	4.36^{b}
	200ppm	1643.33^{a}	1560.00^{a}	1469.39	151.98	57.33	158.02	34.23	213.97	3.91^{b}	9.11^{b}	2.72^{b}	0.71	21.53	0.77	19.68	0.71	4.56^{a}
	SEM	15.5	16.29	3.37	4.01	1.25	1.93	1.33	5.87	0.07	0.14	0.06	0.02	0.58	0.04	0.36	0.01	0.05
	LOS	*	*	ns	Ns	ns	Ns	Ns	ns	*	*	*	Ns	Ns	Ns	ns	ns	*
AO*E	T1	1555.00^{c}	1460.00^{c}	1366.28	138.55	61.35	146.50^{c}	27	162.65	4.53^{a}	10.47^{b}	2.36^{b}	0.64^{bc}	18.81	0.57	18.40	0.71^{bc}	3.73^{c}
	T2	1565.00^{c}	1425.00^{c}	1344.77	134.15	57.35	132.85^{d}	31.1	183.8	4.25^{ab}	8.29^{c}	2.76^{b}	0.75^{ab}	22.55	0.81	18.32	0.76^{ab}	3.80^{c}
	T3	1565.00^{c}	1470.00^{c}	1375.66	137.3	58.45	168.75^{ab}	27.65	218.2	4.10^{b}	11.23^{a}	3.49^{a}	0.69^{abc}	19.21	0.66	19.91	0.70^{c}	3.90^{c}
	T4	1625.00^{ab}	1585.00^{ab}	1471.76	168.15	62.8	161.60^{b}	28.95	225.85	4.19^{ab}	7.80^{c}	2.71^{b}	0.79^{a}	20.52	0.88	21.19	0.68^{c}	4.94^{b}
	T5	1605.00^{b}	1515.00^{bc}	1440.54	157.7	57.95	159.40^{b}	42.75	224.1	4.06^{b}	9.51^{b}	3.20^{a}	0.75^{a}	20.54	0.71	21.30	0.78^{a}	5.46^{a}
	T6	1740.00^{a}	1670.00^{a}	1591.65	153.65	51.85	179.60^{a}	42.65	232.25	3.30^{c}	11.23^{a}	2.68^{b}	0.61^{c}	21.53	0.62	19.55	0.71^{bc}	4.96^{b}
	SEM	26.85	28.21	5.83	6.94	2.16	3.34	2.3	10.16	0.11	0.25	0.11	0.03	1.00	0.08	0.63	0.01	0.09
	LOS	*	*	ns	ns	ns	*	Ns	ns	*	*	*	*	Ns	Ns	ns	*	*

ab means on the same row having different superscript differ significantly ($p<0.05$); ns = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significance; AO*E = Interaction of Acha offal and Enzyme

CONCLUSION AND RECOMMENDATIONS

Feeding weaner and growing rabbits with diets containing up to 30% acha offal meal supplemented with Maxigrain® enzyme has no detrimental effect on their growth performance. Maxigrain® enzyme supplementation positively influenced the acha offal containing diets in the carcass characteristics parameters. Therefore, rabbit can be fed diets containing up to 30% acha offal supplemented with Maxigrain enzyme for better growth performance and carcass characteristics.

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CARCASS CHARACTERISTICS OF BROILERS FED SUNDRIED SWEET ORANGE PEELS SUPPLEMENTED WITH QUANTUM BLUE®ENZYME

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ABSTRACT

A 3x3 factorial was used to evaluate the carcass characteristics of broilers chicks of 270 (Cobb 500) randomly allotted to 9 experimental diets, replicated three (3) times having ten (10) birds per replicate. Sundried orange Peel (SDOP) meal at inclusion levels of 0, 25 and 50% and three levels of Enzyme, 0 100 and 200ppm were formulated to provide isocaloric (3020.31 - 3075.35 Kcal/kg ME) and isonitrogenous (20.22 – 20.23 % Crude protein CP) diets. During the eight (8) weeks, routine management was done, and feeds and water were provided *ad libitum*. The effect of sundried sweet orange peels indicates significant ($P<0.05$) decreased in the weights of live birds, de-feathered weight, dressed weight, chest, back, thigh, drumstick, and wings as the level of SDOP increased. The head, neck, heart, gizzard, liver and intestinal weight were significantly ($P<0.05$) higher at 50% SDOP included diets than 0% and 50%SDOP. The result for enzyme supplementation indicate significant ($P<0.05$) increase in the live weight, de-feathered weight, dressed weight, gizzard and liver weight at 100 and 200ppm than 0ppm enzyme supplementation. In contrast, head weight, wings, back, thigh, shanks, drumstick, heart and intestinal weight were significantly lower at 100 and 200ppm than 0ppm enzyme supplementation. The results for the interaction of SDOP and enzymes supplementation on carcass characteristics of broiler finisher birds showed significant ($P<0.05$) variation in all the carcass characteristics except for the weight of neck, shank and liver that showed non-significant variation ($P>0.05$). The result for this finding indicates that SDOP at both 25% and 50% cannot replace maize in the broiler finisher birds, but enzymes at 100ppm can be supplemented with 25% of SDOP to give better carcass traits.

Keywords: Broiler chicken, Carcass characteristics, Orange peel meal, Enzyme

INTRODUCTION

The utilization of agricultural by-products as animal feeds resource is gaining attention, as agricultural residues constitute an increasingly more significant part in the diets of domestic animals (Kunkle *et al*., 2001). Due to shortages of national feed resource, particularly in developing countries necessitated the investigation of novel sources of feedstuff, such as sweet sun-dried orange (*Citrus sinensis*) peels (SDOP), a by-product with potentials for the supply of some valuable nutrients, and a source of natural antioxidants. SDOP is produced by extracting juice from citrus that is made on a large scale in orange consuming areas. The dried or pelleted citrus pulp is one of the most desirable energy feeds resource from agricultural by-products to be considered as a feed resource, because of its high digestible nutrient content, because it is a mixture of citrus peel, pulp, and seed(Arthington*et al.*, 2002),

which are converted as energy concentrate feed for domestic animals. Agu *et al*. (2010) reported high calcium but deficient phosphorus and carotene in SDOP.

Arthington and Pate (2001) estimated that the waste from feeding wet citrus pulp could be as high as 30% which make it typically and uneconomical to feed wet pulp because of the increased cost of shipping (Kunkle *et al*., 2001) and processing. Therefore, SDOP is used as a cheap ingredient to improve animal performance and to reduce the cost of production in these animals. In contrast, fresh or dehydrated *Citrus sinensis* pulp is mainly used in ruminant feeding (Lanza *et al.,* 2001). Yang and Chung (2011) reported the use of 10% dried *C.sinensis* peel in diets of laying hen with no adverse effect on feed intake, egg production and egg weight; the utilization of 5% citrus peel in broiler chicks gave similar results and reduced serum cholesterol concentration. Chaudry *et al.,* (2004); and Oluremi et al., 2006) opined that sweet orange (*C. Sinensis*) rim replaced up to 15% of maize in the diet of broiler without any adverse effect on performance. While Mourão *et al*. (2008) showed that incorporating CSP (5–10%) reduced daily gain by 26% in birds of 10% citrus pulp treatment, and feed intake increased in birds fed with diets with 5% or 10% CSP compared with the control group, which resulted in higher feed conversion ratio. Hon *et al*. (2009) observed the effect of dried sweet orange (*C.sinensis*) fruit pulp meal on the growth performance of rabbits and concluded that sweet orange fruit pulp meal could be used as a replacement feedstuff for maize in the ration of grower rabbit up to a level of 20%. Nazok*et al*. (2010) studied the effect of different levels of dried citrus pulp on performance, egg quality, and blood parameters of laying hens in the early phase of production. Agu *et al.* (2010) evaluated the effect of sweet orange peel meal (SOPM) as a feed resource in broiler production. They found that dietary SOPM had no impact on the kidney, liver, heart, spleen, gall bladder and lung but had a significant effect on proventriculus and gizzard as the SOPM levels increased. Oluremi *et al.* (2010) also studied the effect of fermentation of sweet orange (*C.sinensis*) fruit peel on the growth performance of broiler chicken in the starter period but found a relatively negative conclusion. Ebrahimi *et al*. (2012, 2014) evaluated the effects of different levels of *Citrus sinensis* peel extract (CSPE) on the blood parameters of broilers. They found that cholesterol, glucose, uric acid, low-density lipoprotein (LDL) and high-density lipoprotein (HDL) at the rearing period was significantly influenced. Pourhossein *et al.* (2012a) found the positive effect of different levels of dried *Citrus sinensis* peel (SOPM) on broiler gastrointestinal microbial population stating that the mean of *Lactobacilli* in cecum on the postnatal 42 d indicated no significant results. Pourhossein*et al.* (2012b,c) experimented with evaluating the effects of different levels of *Citrus sinensis* peel extract (CSPE) on gastrointestinal microbial population of broilers and revealed that the means of *Escherichia coli* in the ileum on the postnatal 42 days was significantly different from the control too. Ebrahimi et al. (2013a) evaluated the effect of varying levels of dried *C.sinensis* peel on broiler carcass quality and observed the effects of experimental treatments on FW, FBW, as well as carcass percentage of broilers, were not significantly different from the control. Still, those of treatments on carcass characteristics and the jejunum and ileum were significantly different from the control. The objective of the present study was to evaluate the effect of different dietary levels of dried *Citrus sinensis* pulp (SDOP) and enzyme supplementation on carcass characteristics of the experimental broiler birds.

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MATERIALS AND METHODS

Experimental site

The experiment was conducted at Ibas Farms Nig Ltd, Keffi, Nasarawa State. It lies in the guinea savanna zone of North Central Nigeria,

at latitude 08^0 35'N and longitude 08^0 33'E. The mean monthly temperature is 35.06^0C and means monthly relative humidity of 74%. The rainfall is about 168.90mm (NIMET, 2015)

Source of Test ingredient

The Sweet orange were sourced from (SOP) Orange Market, Mararaba in Nasarawa State Nigeria. The SOP was sun dried cleaned, and extraneous materials like dry leaves, stones, and dirt were removed while enzyme was purchased from a registered dealer of animal feed products.

Experimental birds and management

Two hundred and seventy (270) day old were purchased from Olam Farm Kaduna, and reared in a deep later system. They were randomly assigned to the dietary treatments (T1, T2, T3, T4, T5, T6, T7, T8 and T9) and replicated in three treatment groups of 10 birds each.Each unit pen was equipped with feeders, drinkers and light was provided at night using an electric bulb throughout the experiment. Broilers were fed with a weighed amount of the experimental diets, and drinking water was provided *ad-libitum*. Other routine management practices and medication were observed daily, such as the washing of drinkers, weekly cleaning of the pens, and daily inspection.

Proximate analysis of sun-dried sweet orange peels

Proximate composition of the test ingredient was determined using the procedure outlined by AOAC (2006) as described by Alu *et al.* (2018), and the results are presented in Table 1

Experimental diets and composition

Nine experimental diets were formulated (T1, T2, T3, T4, T5, T6, T7, T8, and T9) as isocaloric and isonitrogenous for the broiler starter and finisher diets, using three levels inclusion of the sun-dried sweet orange peels meal (0, 25 and 50%) and three levels inclusion of exogenous enzymes (0, 100, 200ppm Enzymes) and T1, 0% SDOP with 0ppm enzymes serves as control, T2, 0% SDOP with 100ppm enzymes, T3, 0% SDOP with 200ppm enzymes, T4, 25% SDOP with 0ppm enzymes, T5, 25% SDOP with 100ppm enzymes, T6, 25% SDOP with 200ppm enzymes, T7, 50% SDOP with 0ppm enzymes, T8, 50% SDOP with 100ppm enzymes, T9, 50% SDOP with 200ppm enzymes. The nutrients were balanced to meet the nutrient requirement of the broiler starter for that particular class, and the diets are presented in Table 2

Table 1: Proximate composition of sundried orange peels

Parameters	(%)
Crude protein	6.44
Crude fibre	15.77
Ether extract	11.66
Ash	4.27
Moisture	11.13
Carbohydrate	[a]133.03
Nitrogen free extract	[b]50.75
Dry matter	[c]88.88
Metabolizable energy (kcal/kg)	[d]2984.94

a. Carbohydrate =NFE+ CF, b. NFE=100 - % (CP + CF + EE +ASH+ MOISTURE),
c. Dry matter=100% - MOISTURE. AOAC (2010)
d. Pauzenga (1985); ME=37 x % CP+81.1 x % EE+35.5 x % NFE.

Table 2: Gross composition of experimental diets for finisher broilers

Feed Ingredients	T1 (0%OPM+0 ppm)	T2 (0%OPM+100 ppm)	T3 (0%OPM+200 ppm)	T4 (25% OPM+0ppm)	T5 (25%OPM+10 0ppm)	T6 (25%OPM+200pp m)	T7(50%OPM +0ppm)	T8(50%OPM+ 100ppm)	T9(50%OPM +200ppm) s
Blood meal	2.00	2.00	2.00	1.00	1.00	1.00	2.00	2.00	2.00
Salt	0.30	0.3.00	0.30	0.30	0.30	0.3.00	0.30	0.30	0.30
Maize bran	9.00	9.00	9.00	10.00	10.00	10.00	1.00	1.00	1.00
GNC	12.00	12.00	12.00	18.00	18.00	18.00	17.00	17.00	17.00
FFSB	18.00	18.00	18.00	16.00	16.00	16.00	18.75	18.75	18.75
Premix	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Maize	35.00	35.00	35.00	13.25	13.25	13.25	6.00	6.00	6.00
Rice bran	17.25	17.25	17.25	10.00	10.00	10.00	1.00	1.00	1.00
Palm oil	4.50	4.50	4.50	4.50	4.50	4.50	2.00	2.00	2.00
Bone meal	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
SDOP	0.00	0.00	0.00	25.00	25.00	25.00	50.00	50.00	50.00
Lysine	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methionine	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Enzyme(PPM)	0.00	100	200	0.00	100	200	0.00	100	200
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient composition									
Energy	3075.35	3075.35	3075.35	3020.31	3020.31	3020.31	3011.74	3011.74	3011.74
Protein	20.22	20.22	20.22	20.23	20.23	20.23	20.33	20.33	20.33
Crude fibre	5.35	5.35	5.35	8.05	8.05	8.05	9.89	9.89	9.89
Ether Extract	12.94	12.94	12.94	14.10	14.10	14.10	13.16	13.16	13.16
Ash	3.83	3.83	3.83	4.10	4.10	4.10	4.21	4.21	4.21
Calcium	0.54	0.54	0.54	0.57	0.57	0.57	0.45	0.45	0.45
Phosphorus	0.68	0.68	0.68	0.58	0.58	0.58	0.48	0.48	0.48
Lysine	1.42	1.42	1.42	2.71	2.71	2.71	4.12	4.12	4.12
Methionine	0.7849	0.7849	0.7849	1.3024	1.3024	1.3024	1.8611	1.8611	1.8611

*Supplied the following per kg of diet as specified by the manufacturer: Vitamin A, 12500 IU; Vitamin D3, 2500 IU; Vitamin E, 50,00 Mg; Vitamin K3, 2.50mg; Vitamin B1, 3.00mg; Vitamin B2, 6.00mg; Vitamin B12, 0.25mg; Pantothenic acid, 5.00mg; Nicotinic Acid, 20,00mg; Folic acid, 1.00mg; Choline Chloride, 300mg; Manganese, 100mg; Iron, 50mg; Zinc, 45mg; Copper, 2.00mg; Iodine, 1.55mg; Cobalt, 0.25mg; Selenium, 0.1mg.

Parameters measured

Carcass characteristics

At the end of 8 weeks of the feeding trial, two birds per treatment were selected at random and starved for about 18h to empty their gastrointestinal tract. They were slaughtered plucked and eviscerated. The carcass and internal organs were removed, weighed and expressed as a percentage of live weight according to the 'Modified Kosher' method

Statistical analysis

All data collected were subjected to Analysis of Variance (ANOVA) for the factorial experiment using (SPSS, 2007) Model. Significantly different means were separated using Duncan's Multiple Range Test (Duncan, 1955). The following statistical model was used: $Y_{ijk}= U +A_I +B_J + (AB)_K+e_{ijk}$ where Y_{ijk}=individual observation, U= population mean, A_i = effect of factor A, B_j= effect of factor B, and AB_K = effect of interaction of factor A&B.

RESULTS AND DISCUSSION

The result for the main effect of SDOP on carcass characteristics of broiler finisher birds is presented in Table 3. The results indicate significant (P<0.05) decreased in the weights of live birds (1416.17, 998.83 and 449.67g/birds), de-feathered weight (1283.50, 844.33 and 415.00g/bird), dressed weight (935.67, 573.83 and 242.50g/bird), chest (20.83, 16.83 and 13.01%), back (10.68, 9.93 and 9.23%), thigh (10.23, 9.31 and 7.38%), drumstick (10.75, 9.40 and 8.61%/bird), and wings (8.01, 7.87 and 7.90g/birds) respectively. Higher numerical values were observed on birds fed 0% SDOP. This could be due to an increased level of sundried sweet orange peels meal. The weight of head (2.73, 3.02 and 4.36%/bird), neck (4.89, 4.66 and 4.98g/birds), heart (0.76.0.76 and 1.04%/bird), gizzard (7.54, 9.58 and 14.68%/bird), liver (2.74, 3.76 and 4.99%/bird) and intestinal weight (21.53, 39.94 and 88.00%/bird) were significantly (P<0.05) higher at 50% SDOP included diets. This could be a result of the increased levels of SDOP, and the lowest value was recorded at 0% SDOP included diets. This observation is associated with the level of SDOP inclusion in diets. The result of this finding is contrary with the earlier work reported by Amanga *et al*. (2019) who investigated growth performance and carcass characteristics of broiler fed diets containing various duration of water soaked sweet orange peels and stated that there is no significant difference in the carcass cuts and internal organs of broiler chicken when fed 24% orange peels.

The result for enzyme supplementation at 0, 100 and 200ppm inclusions level in Table 4 indicates significant (P<0.05) increase in the live weight (846.00, 1106.33 and 912.33g/bird), DFW (765.00, 979.00 and 798g/bird), dressed weight (552.00, 671.17 and 528.83g/bird), neck (4.79, 4.99 and 4.75g/birds), gizzard (10.57, 10.37 and 10.87g/birds) and liver weight (3.76, 3.95 and 3.78g/birds) respectively. Higher (P<0.05) values were observed at 100 and 200ppm supplementation. Head weight (3.69, 3.14 and 3.32g/bird), wings (8.09, 7.66 and 8.03g/birds), chest (17.28, 16.12 and 16.88g/birds), back (10.08, 9.91 and 9.84g/birds), thigh (9.02, 8.92 and 8.99g/birds), shanks (4.75, 4.27 and 4.29g/birds), drumstick (9.75, 9.35 and 9.19g/birds), heart (1.04, 0.77 and 0.75 g/bird) and intestinal weight (61.94, 43.28 and 44.26 g/birds) respectively. Higher (P<0.05) values were at 0ppm compared with 100ppm and 200ppm enzyme supplementation. This observation disagrees with the previous report of Alu *et al*. (2012). They stated significant improvement in the bodyweight of Japanese quail when fed sugarcane scrapings and 200ppm Maxigrain enzymes supplemented diets.

The effects of the interaction of SDOP and enzymes supplementation on carcass characteristics of broiler finisher birds in Table

5 shows significant (P<0.05) variation in all the carcass characteristics except for the weight of neck, shank and liver. The higher values were recorded at T2 for the live weight (1576.00g/bird), DFW (1517.00g/bird) and dressed weight (1090.00g/bird) while T7 recorded the lower live weight (314.00g/bird), DFW (281.00g/bird) and dressed weight (146.00g/bird). The weight of the head (4.95%/bird) at T7 was higher while T3 had a lower value for the head (2.59%/bird). The wings (9.21%) and thigh weight (11.20%) were higher at T1 while T3 had the lower wings weight (6.71% /bird) and T7 had lower thigh (6.35%/bird) respectively. The increased values in the weights of the chest (22.95%/bird) and back (11.95%/bird) were due to supplementation of enzymes at 100ppm and 0% SDOP. Drumstick weight was higher at T1 (11.91%/bird) and the lowest value recorded at T7 (7.14%/bird). Heart weight (1.39%/bird) was higher at T2 (0.60%/bird). The weight of gizzard was higher at T8 (13.31%/bird) and lowered at T5 (5.93%/bird). This could be attributed to the increased levels of SDOP and Enzyme. Intestinal weight was higher at T9 (66.17%/bird) and the corresponding lower value at T7 (17.15%/bird).

CONCLUSIONS AND RECOMMENDATION

The result for this finding indicates SDOP at 50% cannot replace maize in the broiler finisher birds, but 25% SDOP with enzymes at 100ppm can be supplemented

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Table 3: Main effect of SDOP on carcass characteristics of broiler finisher chicken.

Parameters (%)	O%	25%	50%	SEM	LOS
Live w	1416.17[a]	998.83[b]	449.67[c]	40.33	*
DFW	1283.50[a]	844.33[b]	415.00[c]	52.69	*
Dressed w	935.67[a]	573.83[b]	242.50[c]	37.25	*
Head w	2.78[b]	3.02[b]	4.36[a]	0.13	*
Neck w	4.89	4.66	4.98	0.26	NS
Wings w	8.01	7.87	7.90	0.32	NS
Chest w	20.83[a]	16.83[ab]	13.01[b]	1.53	*
Back w	10.68[a]	9.93[ab]	9.23[b]	0.36	*
Thigh w	10.23[a]	9.31[a]	7.38[b]	0.45	*
Shank w	4.75	4.38	4.18	0.27	NS
D. stick w	10.75[a]	9.40[ab]	8.16[b]	0.49	*
Heart w	0.76[b]	0.76[b]	1.04[a]	0.07	*
Gizzard w	7.54[b]	9.58[b]	14.69[a]	0.65	*
Liver w	2.74[b]	3.76[ab]	4.99[a]	0.49	*
Intestinal w	21.53[c]	39.94[b]	88.00[a]	3.17	*

abc means on the same column having different superscript differ significantly ($p<0.05$); NS = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significant; SDOP = sweet dried orange peels; w= weight; DFW = de-feathered weight; D = drumstick.

Table 4: Main effect of enzymes supplementation on broiler finisher chicken.

Parameters	0ppm	100ppm	200ppm	SEM	LOS
Live w	846.00[b]	1106.33[a]	912.33[b]	40.33	*
DFW	765.00[b]	979.00[a]	798.83[b]	52.69	*
Dressed w	552.00[b]	671.17[a]	528.83[b]	37.25	*
Head w	3.69[a]	3.14[b]	3.32[ab]	0.13	*
Neck w	4.79	4.99	4.75	0.26	NS
Wings w	8.09	7.66	8.03	0.32	NS
Chest w	17.28	16.12	16.88	1.55	NS
Back w	10.08	9.91	9.84	0.36	NS
Thigh w	9.02	8.92	8.99	0.45	NS
Shank w	4.75	4.27	4.29	0.27	NS
D. stick w	9.75	9.35	9.19	0.49	NS
Heart w	1.04[a]	0.77[b]	0.75[bc]	0.07	*
Gizzard w	10.57	10.37	10.87	0.65	NS
Liver w	3.76	3.95	3.78	0.44	NS
Intestinal w	61.94[a]	43.28[b]	44.26[b]	3.17	*

abc means on the same column having different superscript differ significantly ($p<0.05$); NS = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significant; w= weight; DFW = de-feathered weight; D = drumstick

Table 5: Interaction effects of SDOP and enzymes on carcass characteristics of broiler finisher chicken.

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	SEM	LOS
Live w	1352.00 ^{b}	1576.00^{a}	1320.50 ^{b}	872.00 ^{c}	1215.00^{b}	909.50^{c}	314.00 ^{d}	528.00 ^{d}	507.00 ^{d}	69.85	*
DFW	1247.50^{ab}	1517.00^{a}	1086.00^{bc}	766.50^{de}	929.50^{cd}	837.00^{cd}	281.00 ^{f}	490.50 ^{ef}	473.50 ^{ef}	91.27	*
Dressed w	974.00 ^{a}	1090.00^{a}	743.00 ^{b}	536.00 ^{b}	623.00 ^{b}	562.50 ^{b}	146.00 ^{b}	300.50 ^{c}	281.00 ^{c}	64.52	*
Head w	2.81 ^{d}	2.94 ^{d}	2.59 ^{d}	3.32 ^{cd}	2.68 ^{d}	3.06 ^{cd}	4.95 ^{a}	3.81 ^{bc}	4.33 ^{ab}	0.23	*
Neck w	5.07	4.99	4.59	4.72	4.33	4.95	4.59	5.66	4.70	0.45	NS
w	9.21 ^{a}	8.12 ^{abc}	6.71 ^{c}	8.04 ^{ac}	6.88 ^{c}	8.71 ^{ab}	7.03 ^{c}	8.00 ^{ac}	8.67 ^{ab}	0.55	*
Chest w	22.37 ^{a}	22.95 ^{a}	17.18 ^{ab}	17.17 ^{ab}	14.61 ^{ab}	17.52 ^{ab}	12.31 ^{b}	10.80 ^{b}	15.93 ^{ab}	2.69	*
Back w	11.24 ^{a}	11.36 ^{a}	9.45 ^{ab}	10.59 ^{ab}	8.81 ^{b}	10.38 ^{ab}	8.43 ^{b}	9.55 ^{ab}	9.70 ^{ab}	0.62	*
Thigh w	11.20 ^{a}	10.53 ^{ab}	8.96 ^{abc}	9.51 ^{ab}	8.35 ^{c}	10.07 ^{ab}	6.35 ^{c}	7.87 ^{c}	7.94^{c}	0.77	*
Shank w	5.44	4.73	4.08	4.97	3.83	4.35	3.85	4.25	4.44	0.47	NS
D. stick w	11.91 ^{a}	11.18 ^{ab}	9.16 ^{abcd}	10.25 ^{abc}	7.99 ^{cd}	9.98 ^{abcd}	7.14 ^{d}	8.89 ^{bcd}	8.44 ^{bcd}	0.84	*
Heart w	0.94 ^{d}	0.60 ^{b}	0.74 ^{b}	0.79 ^{b}	0.88 ^{b}	0.63 ^{b}	1.39 ^{a}	0.83 ^{b}	0.90 ^{b}	0.13	*
Gizzard w	5.93 ^{d}	7.95 ^{cd}	8.75 ^{cd}	8.06 ^{cd}	9.86 ^{bc}	10.82 ^{bc}	17.73 ^{a}	13.31 ^{b}	13.04 ^{b}	1.13	*
Liver w	2.71	2.81	2.69	3.62	4.06	3.62	4.95	4.99	5.02	0.76	NS
Intestinal w	17.24 ^{a}	18.56 ^{a}	28.81 ^{cd}	41.89 ^{c}	40.12 ^{c}	37.80 ^{c}	24.69 ^{a}	17.15 ^{b}	66.17 ^{b}	5.48	*

abcdef means on the same column having different superscript differ significantly ($p<0.05$); NS = not significantly different ($p>0.05$); SEM = standard error of mean; LOS = level of significant; SDOP = sweet dried orange peels; w= weight; DFW = de-feathered weight; D = drumstick.

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REPRODUCTION IN RABBIT BUCKS: A REVIEW

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ABSTRACT

Rabbits are found in most continents of the world and the domestic rabbits are descendants of *Oryctolagus cuniculus* a species known to be indigenous to the western Mediterranean basin (Spain and North Africa) and the European wild rabbit. Rabbit bucks attain reproductive maturity at 32 weeks of age at this time sperm production is known to stabilize, puberty occurs between 4-6 months, spermatogenesis occurs between 42-62 days with an average of 51.8 days. The average rabbit sperm morphometric measurement is 16-55µm, bucks have an average ejaculate of 0.3-0.6 ml and sperm concentration of 150-500×10^6 sperm/ml, average abnormalities of rabbit sperm is 18.2%. Lack of proper information and knowledge on the reproductive indicators of rabbit buck is the basis of failure and loses in rabbit enterprise. Proper understanding of reproduction in bucks is key to their usage either for laboratory purposes or production for both economic and also as companion animal as the case may be. This review has highlighted the recent knowledge in rabbit buck reproduction with emphasis in areas as it relate to reproductive anatomy, puberty and sexual maturity, spermatogenesis, sperm production, gel plug, seminal plasma and semen characteristics for better understanding and application in breeding.

Keywords: Reproduction, Rabbit, Bucks, Review

INTRODUCTION

Rabbits are herbivores that feed by grazing forage efficiently and transform it into food (Campos *et al.*, 2014). There are about 38 breeds and 19 strains of domestic rabbits in the whole world recognized by American Rabbit Breeder Association (ARBA) (Das *et al*., 2014), Rabbit breeds are distinguished by different characteristics such as size, shape, colour of the eye, colour of the hair coat (fur) and weight (Omole *et al*., 2007; Ogbuewu, 2008). In terms of meat production, it has the ability to convert plant proteins of low nutritional value into animal protein of high nutrient value (Lebas *et al.*, 1997; Onuaha, 2020). In the United States, rabbits are raised solely for non-food purposes such as toxicology studies (Santos-Filho *et al.*, 2007). The leather is of high quality use for clothes and hats making. Rabbit are used in cosmetics industries, medical and pharmaceutical research laboratories (Dontas *et al.*, 2011). They are raised for exhibition and as pet, it is considered the third most popular pet in the world behind dogs and cats (Brown, 2001; Huerkamp, 2003). This review has highlighted the recent knowledge in reproduction in rabbit bucks as it relates to anatomy, puberty and

sexual maturity, spermatogenesis, semen characteristics and seminal plasma.

REPRODUCTIVE ANATOMY

The reproductive system of rabbit bucks (Figure 1) consists of testes (2), epididymis (2), ampulla (2), vas deferens (2), urethra, penis, preputial gland (1) and the accessory glands. It has a well-developed scrotum located cranial to the penis and urogenital opening (Capello and and Lennox, 2006).

The scrotum has few hairs (Donnelly, 2004) and formed by tunica vaginalis, tunica dartos and cremaster muscle (Campos *et al.*, 2014). Its main function is to keep the testicles away from the abdominal cavity so as to maintain the right testicular temperature of between 0.5^0C – 4^0C below the body's temperature (Alvarino, 1993).

The scrotum communicates with the abdominal cavity through the inguinal ring, which conveys the excretory duct (vas deferens) that comes from epididymis. During sexual inactivity or stress, the testicles return to the abdominal cavity through the inguinal ring and may go down again by the action of cremaster muscles (Alvarino, 1993; Capello and Lennox, 2006). Rabbit testicles are similar to those of cats but can move freely from the scrotum to the abdomen through the inguinal canal (Brewer, 2006). The position of the testicles depends on many factors including body position, body temperature, reproductive activity, repletion of the gastrointestinal tracts, amount of abdominal fat and stress (Capello and Lennox, 2006). Fraser (1988) reported that the appearance and weight of tests depend on the location, testes located in the scrotum are heavier, firm in texture and red in colour. Abdominal testes are light reddish brown, the tail of the epididymis (cauda epididymis) is U shaped in rabbit (Campos *et al.*, 2014). Sperm stored in cauda epididymis in rabbit exhibit vigorous motility in their own fluid (Turner and Reich, 1985).

The reproductive glands differ in number, location, size and proportion with other mammalian species (Vasquez and Delsol, 2009). These sets of glands consist of vesicular gland, bulbo urethral gland, and a complex formed by the prostate, proprostate and paraprostate. They contribute to greater portion of the ejaculate in rabbits (Holtz and Foote, 1978a; Vasquez and Del Sol, 2009).

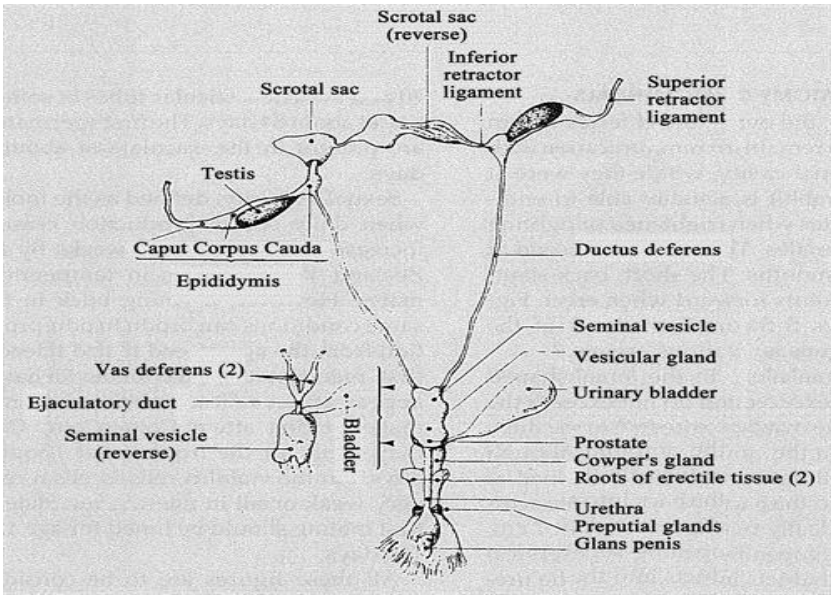

Figure 1: Genital Anatomy of the male rabbit
Source: Lebas *et al*., 1998.

The penis is the copulatory organ, the glans penis is absent in rabbit penis (Brewer, 2006) the penile body is cylindrical 40-50mm long, the diameter decreases at its end (Campos *et al.*, 2014). During rest from sexual activity, the penis lies in the fore skin located ventral to the anus (Alvarino, 1993, Brewer, 2006) and caudally to the testicles (Capello and Lennox, 2006).

Accessory sex glands are complex, they secret many compounds found in the semen of other mammals such as fructose, citric acid, glycerylphosphorylcholine and minerals, secretion of catalase is uniquely high in rabbit semen (Foote and Hare, 2000). The accessory sex glands respond differently to androgens and estrogens, the weights of these organs are a bio-indicator of circulating steroid hormone levels, the gland differ in number, location, size and proportion among other aspects like those in other mammals (Dimitrov and Stamatova, 2011). These set of glands consist of vesicular gland, bulbourethral gland, prostate gland and Vasquez (Vasquez and Del Sol, 2002). The prostate consist of three lobes: Proprostate, prostate and paraprostate and they contribute to the greater portion of the volume of ejaculate, each part of the gland plays specific role in reproduction (Hafez, 1995; Dimitrov, 2010; Onuoha, 2020).

PUBERTY AND SEXUAL MATURITY

Puberty occurs between 4-6 months and occurs earlier in smaller breeds than larger breeds (Harcourt-Brown, 2002). Sexual maturity varies with age in rabbits (125-150 days), breeds, lineage, food and environmental factors such as photoperiod, temperature and seasonality (Campos *et al.*, 2014). Puberty in rabbits precede the appearance of sperm in the ejaculate, hence puberty and sexual maturity are different phases in the rabbits (Macari and Machado, 1978). Skinner (1967) reported that at 63 days of age rabbit testes descend into the scrotum. Some studies revealed that although the rabbit attains puberty at 4 months the testes are not in the scrotum yet it descends into the scrotum at 6 months of age (Fraser, 1988).

Sexual maturity is the moment at which the daily spermatozoa production ceases to increase which is 32 weeks in New Zealand white rabbits (Lebas *et al.*, 1997). Studies revealed sexual maturity at 18 weeks of age (Frame *et al.*, 1994). Rabbits attain puberty when their testicles become androgenically active and accessory glands begin to produce fructose and citric acid and the animal exhibit male behavior. In addition, sperm appear high in concentration than at the onset of puberty (Skinner, 1967).

SPERMATOGENESIS

Spermatogenesis in rabbit occurs between 42-62 days, but sperm do not appear in ejaculated sperm before 119 days (Skinner, 1967). Temperature higher than that of the scrotum may impede spermatogenesis (Hua *et al.*, 2000). The duration of spermatogenesis in rabbit depends on the point chosen at the beginning of spermatogenesis. If it begins with the first part of the series of division of spermatozoa leading to the production of primary spermatocytes, then about four cycles of the seminiferous epithelium (4 x 10.9 = 43.6 days) are required (Swierstra and Foote, 1965). However, if it is assumed that spermatogenesis begins with the formation of spermatogonia stem cells and the life time of such stem cells is a cycle of seminiferous epithelium then spermatogenesis has approximately 4.75 cycles and 51.8 days (Swierstra and Foote, 1965). Morton. (1988) reported one cycle to last 10.8 days and considered 48 days on the duration of spermatogenesis in rabbits.

Campos *et al.*, (2014) reported that during spermatogenesis there is considerable loss of spermatogenic cells in the rabbit, there are about 20% fewer spermatids than expected from theoretical consideration. Swierstra and Foote (1965) reported that most of this loss occurs

during and immediately after the two maturation divisions. Studies have demonstrated the presence of round spermatids in the epididymis (sloughing of spermatids) meaning they leave the testes before maturation (Zhang *et al.*, 2002). The age and season contribute to the sloughing of spermatids and this may occur more frequently after puberty and when spermatogenesis begins to occur in an active form (Zhang *et al.*, 2002). In rabbits, multinucleated spermatids are often found (giant spermatids) but this incidence may be aggravated by stress and environmental conditions (Tsunenari and Kast, 1992; Barakat, 2007).

The testis is the main source of testosterone in rabbits, it is the main androgen produced during sexual maturation (Castro *et al.*, 2002). Although their essential function is the maintenance of normal spermatogenesis, serum testosterone levels above baseline do not appear to influence the efficiency of spermatogenesis (Castro *et al.*, 2002). However, around 6th week there is a quick increase in FSH and LSH concentration in blood this precedes the onset of testosterone secretion and consequently the manifestation of puberty (Chubb *et al.*, 1978) this relationship suggests that FSH may play a regulatory role of steroidogenesis during rabbit puberty (Campos *et al.*, 2014).

Sperm Production

The testicles continue to grow and increase sperm production until six months of age (Morton, 1988) spermatozoa can be found in the cauda epididymis at around 15wks of age (Chubb *et al.*, 1978), Campos *et al.*, (2014) reported that daily sperm production increases from 15 to 52 weeks of age some studies reported that, there is positive correlation between the testicular reserve and testicular weight (Shinkut, 2015) and body of the rabbit (Ewuola and Egbunike, 2010). Different daily production of spermatozoa have been reported $148 \pm 11x10^6$ spermatozoa per day (Amann and Lambiase Jr, 1967), 187 x 10^6/day (Holtz and Foote, 1978b) and 210 x 10^6/day (Amann and Lambiase Jr. 1969). Under normal conditions, the average sperm yield for rabbit buck is $147.4x10^6$/day and 1 g of testis producers 26.5 x 10^6 spermatozoa/day (Orgebin-Crist, 1968).

In addition, frequency of semen collection does not affect daily sperm production (Campos *et al.*, 2014), a recent study showed that sperm reserve in left testes and left epididymis is more in concentration than the right (Shinkut, 2015).

Semen Characteristics

Semen is a "mixture" of spermatozoa produced by the testes and seminal plasma secreted by the epididymis and accessory glands, which are combined at the time of ejaculation (El-Azim and El- Kamash, 2011). However, rabbit semen consist of two main component, a fluid and a gelatinous portion (gel plug) (Mukherjee *et al.*, 1951).

Gel plug

The gel plug or gelatinous mass from rabbit semen originates in the vesicular gland (Del Nino *et al.*, 1997), it is androgen dependent (Bell and Mitchell, 1984). It is made up of significant amount of estrogenic substances, citric acid and small amount of fructose (Mukherjee *et al.*, 1951; Holtz and Foote, 1978b). A significant amount of spermatozoa can be entrapped in the gelatinous mass and rendered inactive but after dilution in saline solution and incubated at 37^0C the mass dissolves releasing the spermatozoa which in turn becomes very active (Mukhrejee *et al.*, 1951). Although common in rabbit semen, no function was ascribed to this mass besides its role in preventing retrograde spermatozoa loss in rodents (Quesenbery *et al.*, 2004). The gel plug is said to fill the vagina lumen as buffer coagulation (Mukherjee *et al.*, 1951). Hence IRRG guidelines (2005) recommend removing the gel immediately after collection and before evaluation.

Seminal plasma

This refers to the fluid portion of the semen and it positively influences the survival and parameter such as spermatozoa motility in rabbits (Castellini *et al.,* 2000; Hagen *et al.,* 2002) seminal plasma constituents include carbohydrates, lipids, proteins and mineral (Zaniboni *et al.,* 2004; Castellini *et al.,* 2006b) these are important for sperm metabolism

The sugar concentration in rabbit semen is well below that found in ruminant (Roca *et al.,* 1993) beside fructose, glucose also identified in this species to be low in concentration (13.8-22mg/dl) and yet very effective constituent (Campos *et al.,* 2014).

Rabbit seminal plasma is known to contain several drops and vesicles (prostatic secretory granules) of different sizes and origins which play roles that are partially unknown (Castellini *et al.,* 2006a). It is suggested that the prostatic secretory granules is a source of protection of spermatozoa against OS *in vitro* by supplying the spermatozoa with endogenous alpha tocopherol (Mourvaki *et al.,* 2010).

Sperm Motility

Motility is a basic feature of spermatozoa in the entire animal kingdom, it is the percentage of spermatozoa moving steadily in a straight line (Chrenek *et al.,* 2007). Thus, for species that undergo internal fertilization, motility is indispensable for the transport in the female reproductive tract and oocyte penetration (Holt and Van look, 2004).

Until recently, sperm quality evaluation has being subjective (mass and individual motility) sperm concentration and morphology (Verstegen *et al.,* 2002). Campos *et al.,* (2014) affirmed that subjective estimates of semen parameters are affected by many factors which include training and experience of the evaluator. Computerized assisted spermatozoa analysis (CASA) was developed for an objective assessment of sperm parameters. This system includes a phase contrast microscope equipped with a heating plate, concentrated to a high resolution video camera and a computer (IRRG Guidelines 2005). However, this requires huge capital investment.

Roca *et al.,* (2000) rated the progressive motility of spermatozoa in rabbit using arbitrary scale 0-5 (0,1,2,3,4, or 0-10, 10-25, 25-50, 50-70, 70-90, or 90-100%, respectively, showing progressive motility.

Sperm Morphology

The rabbit sperm morphometric measurements are reported as total length from 16-55 μm (Eddy, 2006) head length from 7.8-8.6 μm (Bedford 1963; Gravance and Davis, 1995). Middle piece is 8.5 μm with mitochondria arranged and about 41 turns (Eddy, 2006), the tail measures about 38μm long, the head shape is like a spatula and acrosome does not extend beyond the core (Eddy, 2006).

The average abnormalities of rabbit semen as illustrated by Kuzminsky *et al.* (1996) using quantitative optical microscopy (×400) are: 18.2% total abnormalities, comprising of head abnormalities 2.9%, tail abnormalities 13.6% and 1.7% broken spermatozoa. It was further suggested that count only the curly tail to speed up the process of analysis because these are the most representative of abnormalities in the tail and easily observed even at low magnification (Kuzminsky *et al.,* 1996). Furthermore, for an acceptable ejaculate the concentration of spermatozoa with curly tail should not exceed 17-18% of the 200cells counted (Kuzminsky *et al.,* 1996).

Semen volume and sperm concentration

Ejaculate volume and sperm concentration in rabbits may range from 0.3 – 0.6ml and 150-500 x 10^6 sperm/ml respectively (Adams and Singh, 1981; Lebas *et al.,* 1997). Interestingly, seminal characteristics may vary among breeds; Rex

(0.54 ± 0.03ml, 415.10± 10.11 x 10^6 spz/ml), New Zealand white (0.54 ± 0.04ml; 416.72 ± 9.16x10^6 spz/ml), California (0.62+ 0.03ml; 454.11± 11.40 x m10^6 spz/ml) and Baladi Red (0.56 + 0.04ml; 423.23 ±1.2.11 x 10^6 spz/ml) (Hassanien and Baiomy, 2011). Other factors that may affect these parameters are: diets (Kamel and Attia, 2011), collection frequency (Castellini *et al.,* 2006c), age (Theau-Clement *et al.,* 2009), ejaculate sequences and ambient temperature (Finzi *et al.,* 1994). It is worthy to note that semen volume is more affected by temperature than sperm concentration (Roca *et al.,* 2005; Garcia-Tomas *et al.,* 2008).

Colour of Semen

Studies have reported that rabbit semen is white and that the intensity depends on the concentration of the sperm therein (Bilbao, 1996; Alvarez *et al.,* 2006). Semen is often pearly white and ivory but gray semen is considered of poor quality (Bilbao, 1996). Alvarez *et al.* (2006) reported that milky white semen is the best and predominant colour of normal semen of good quality. Yellowish semen is often contaminated with urine, this often happens when the temperature of the artificial vagina is too high during collection (Jordi *et al.,* 2005, Shinkut *et al.,* 2016a), it could also be due to infection. But normal semen is white, homogenous and opalescent (IRRG, 2005).

CONCLUSION

Semen characteristics of rabbit bucks are related to the anatomy of the rabbit genital tract, the understanding of the physiology and anatomy of these sensitive organs of reproduction in rabbit varies greatly with breeds, size of organs, age of puberty and sexual maturity. Semen composition and volume is influenced primarily by testicular testosterone production among other factors. Therefore, adequate knowledge of reproduction in rabbit bucks is very essential in research studies involving rabbit and also in commercial rabbit production. It is hoped that this review would serve as important information tool for knowledge to researchers and those interested in rabbit production and breeding.

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