EFFECT OF SHEANUT CAKE (*Vitellaria paradoxa)* ON GROWTH PERFORMANCE, NUTRIENT UTILIZATION AND CARCASS CHARACTERISTICS OF CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS

By
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CERTIFICATE

D.SUDEESH *has satisfactorily prosecuted the course of research and that the thesis entitled* **"EFFECT OF SHEANUT CAKE (*Vitellaria paradoxa)* ON GROWTH PERFORMANCE, NUTRIENT UTILIZATION AND CARCASS CHARACTERISTICS OF CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS"** *submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.*

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Place : Tirupati

Chairman of Advisory Committee
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Senior Scientist and Head
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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF SHEANUT CAKE (*Vitellaria paradoxa*) ON GROWTH PERFORMANCE, NUTRIENT UTILIZATION AND CARCASS CHARACTERISTICS OF CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS"** submitted *in partial fulfillment of the requirements for the degree of* ***MASTER OF VETERINARY SCIENCE*** *of the Sri Venkateswara Veterinary University, Tirupati, is a record of the bonafide research work carried out by* **D.SUDEESH** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.*

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **D.Sudeesh,** hereby declare that the thesis entitled **"EFFECT OF SHEANUT CAKE (*Vitellaria paradoxa*) ON GROWTH PERFORMANCE, NUTRIENT UTILIZATION AND CARCASS CHARACTERISTICS OF CROSSBRED (LARGE WHITE YORKSHIRE X DESI) PIGS"** submitted to Sri Venkateswara Veterinary University, Tirupati for the degree of MASTER OF VETERINARY SCIENCE is the result of original research work done by me. I also declare that the materials contained in this thesis have not been published earlier.

Date: **(D.SUDEESH)**

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	-Per cent
DORB	-Deoiled rice bran
LWY	-Large white Yorkshire
SNC	-Sheanut cake
SNE	-Sheanut extract
DM	-Dry matter
OM	-Organic matter
CP	-Crude protein
ADG	-Average Daily Gain
CF	-Crude fibre
EE	-Ether extract
ME	-Metabolizable energy
gm	-Gram
Rs.	-Rupees
kcal	-Kilo calorie
Kg	-Kilogram
mm	-Millimeter
m	-Meter
MMT	-Million metric tons
MJ/kg	-Millijoules/kilogram

^oC	-Degrees Celsius
EFU	-Efficiency of feed utilization
ICMR	-Indian Council of Medical Research
FAO	-Food and Agricultural Organization
AICRP	-All India Coordinated Research Project

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ABSTRACT

In a completely randomized design, the effect of replacing DORB with sheanut cake at 0 (T-1), 50 (T-2), 75 (T-3) and 100% (T-4) in growers (15-35 kg body weight) and finishers (35-70 kg body weight) on the growth performance , nutrient utilization, serum metabolite profile and carcass characteristics were studied using 24 crossbred (LWY x Desi) pigs.

During grower phase the number of days taken (56, 71.6, 91.8 and 92), average daily gain (362, 282, 224 and 219) and feed/kg gain (3.31, 4.11, 4.85 and 5.04) decreased significantly ($P<0.01$) as the level of inclusion of SNC increased in T-1 to T-4 fed rations, respectively.

The digestibility of DM and nitrogen retention expressed as g/d, as % of intake or as % of absorbed decreased ($P<0.01$) as the level of inclusion of SNC in the rations increased. The cost of the ration/kg weight gain was significantly ($P<0.01$) lower in T-1 (Rs. 55.22) than in T-2 (65.75), T-3 (76.28) or T-4 (76.82) fed pigs.

During the finisher phase also increase in number of days taken to reach target weight, decrease in ADG (g), and increased in feed/kg gain was observed and the values were 93, 95, 105 and 156 (number of days), 395, 384, 334 and 223 (ADG) and 3.60, 4.99, 6.15 and 7.25 (feed/kg gain) in pigs fed T-1 to T-4, respectively and the differences among the treatments were significant.

The digestibility of DM, OM and CP decreased while the N retention expressed as g/d, % of intake or % of absorbed was also decreased ($P<0.01$) in pigs fed diets containing sheanut cake (T-2 to T-4) than those fed T-1. The cost of feed/kg gain (Rs.) was 60.07, 77.41, 92.35 and 103.94 in pigs fed T-1 to T-4, respectively.

For the overall growth study, a similar trend of increase in number of days taken to target weight (149,167, 197 and 248), decrease in ADG (379.6, 331.1, 282.5 and 220.4) and increase in feed/kg gain (3.50,4.67,5.67 and 6.45) was observed in pigs fed T-1 to T-4, respectively. The cost of feed/kg gain (Rs.) was significantly ($P<0.01$) increased from 57.81 (T-1) to 73.15 (T-2), 86.47 (T-3) and 94.11 (T-4).

There was no significant difference among treatments for the different carcass traits. However, the serum SGOT, SGPT ad total cholesterol levels were significantly decreased in pigs fed T-2, T-3 or T-4 than those fed T-1 while the total protein content did not differ significantly among treatments.

From the present study it is concluded that the performance of pigs during grower or finisher phase declined as inclusion level increased beyond 50%. Hence safe level of inclusion can be worked out by using SNC below 50% and it requires further studies to utilize sheanut cake as an alternate feed resource in swine feeding.

Chapter-1

Introduction

Pig rearing is one of the most important occupations of rural society especially in tribal masses of India. There are 13.84 million pigs in India contributing 1.47 % of world pig population (FAO, 2009). The share of pork to the total meat production is 10 % which is static for the past 15 years. Pig production, among other species has a high potential to contribute to high economic gain. Pigs have high fecundity, high feed conversion efficiency, early maturing, short generation interval and relatively small space requirement and the best fitted in human waste recycling chain. According to ICMR recommendations, out of 60 gm daily protein requirement, 20 gm should be from animal protein sources. Considering the modest figure of 20 % of the total population consuming meat in India today, and out of 20 gm daily animal protein, assuming 10 gm from pork, the total pork requirement would be about 0.88 million ton whereas the country produces 0.48 million ton (FAO, 2009) indicating a vast demand for pork in India.

Though there are distinct advantages, pork industry has not yet developed to the desired level and one of the reasons being the prohibitive feed cost which accounts to 70-75% of the total expenses. Cereal grains and their by products contribute the largest part of energy in pig rations. Pig farming can be made remunerative mainly by keeping the feed cost low and by achieving high feed conversion efficiency. The prices of these feed ingredients are increasing day by day necessitating the need to explore economical and alternative feed resources. Several attempts have been made at AICRP on pigs, Tirupati to utilize unconventional feedstuffs such as sugarcane bagasse (Reddy *et al.,* 1985), pulse chunies like urad chuni (Ravi *et al.,* 1999), tamarind seed (Ravi *et al.,* 2000), guava pomace (Madhava Rao, 2000), red gram chuni (Honbari Ingtipi, 2003) and mango peels (Suryanarayana, 2007).

. Among the several unconventional and agro-industrial by products available, sheanut (*Vitellaria paradoxa*) cake (Fig no.5) is one such potential ingredient whose chemical composition is almost similar to deoiled rice bran and is less expensive. It is a residue obtained after extracting shea butter from the dried fruits. Traditionally, the residue is used by woman as a fuel and as a source of potassium for traditional soap manufacture (Kariderm, 2006).The annual world production of sheanut cake was estimated to be 1, 22,100 MMT (Misson economique, 2006).

Sheanut cake is now receiving increased attention as a potential feed ingredient for livestock and poultry due to the increased amounts that are available due to high demand for shea fat in cosmetics and as a cocoa butter substitute in chocolate. Feeding trials were conducted in pigs (Okai and Bonsai, 1989; Rhule, 1999), broilers (Atuahene *et al.,* 1998), exotic guinea fowl (Sumani, 2001), layers (Rami Reddy *et al.*, 2008), sheep (Ravindra Reddy *et al.,* 2009), buffaloes (Kishan Kumar *et al.*, 2010) with sheanut cake and observed better results. The major set back of the cake as a feed ingredient is its nutritive value (Atuahene, Donkoh & Asante, 1998). However, there is paucity of information on inclusion of sheanut cake in swine rations. Hence, the present investigation was carried out with the following objectives:

1. To study the optimum level of inclusion of sheanut cake in grower (15-35 kg) and finisher (35-70 kg) swine rations based on growth performance and nutrient utilization.

2. To study the carcass characteristics of pigs upon feeding sheanut cake.

3. To study the economics of the incorporation of different levels of sheanut cake in pig diets.

CHAPTER-2

REVIEW OF LITERATURE

The literature on the nutritive value of sheanut cake for swine and its utilization in swine diets is very limited.

2.1. About Sheanut

Sheanut (*Vitellaria paradoxa*) is a small to medium sized deciduous perennial tree, grows naturally in the dry and sandy clay soils in Savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highlands, where the mean annual temperature and annual rainfall are 24-32 ^{0}C and 600-1400 mm, respectively. It is widely distributed in the southern parts of the Sahel and the Savannas of Sudan and Guinea between latitudes 7^{0} N - 12 ^{0}N. It is an important source of vegetable fat in Africa.

Height of the tree is about 10-15 m, much branched, dense, spreading round to hemispherical crown (Fig.1). Bark is thick, corky, horizontally and longitudinally deep fissured. Leaves are oblong and the juvenile leaves are rust-red in colour which later turns to dark green(Fig.2). Leaf margins vary and are bent. Sheanut trees take approximately 31years to reach maturity. Flowers are hermaphrodite, white or creamy white seen between the months of December and March. Insects help in cross pollination. Fruits which are yellow green/ brown in colour (Fig.3 and Fig.4) with thick butter like mucous pericarp, mature between April and September. Sugary pulp of the fruit is eaten by birds, primates, ungulates and human beings. Fruits contain 1 to 3 oval or round seeds, brown in colour. Shea fruit falls off the tree when it is ripe and gathering of shea fruit starts between the months of July and November. The fruit pulp is removed by fermentation and nuts are boiled or roasted to remove the shell from the kernel. The average yield of sheanut from each tree is about 15-20 kilograms of fresh fruit which may reach upto 45 kg. Each kilogram of fruit gives approximately 400 grams of dry seeds. The annual production of SNC was estimated to be 122,100 MMT (Misson economique, 2006).

Shea butter extracted from the nuts is widely used as vegetable fat in Sahel. Shea butter has a fatty acid composition similar to that of cocoa butter and hence often used as a substitute for cocoa butter in chocolate and confectionary industry. Different methods are used for extraction of butter from sheanut. Screw press and solvent extraction methods are more popular in Ghana and India respectively for extraction of shea butter from sheanuts and by-product obtained is sheanut cake (Von Maydell, 1986; Vogt, 1995; Hong *et al.*, 1996 and Hall 1996). The traditional method of shea butter extraction yields 25-30% shea butter and the cake is generally oily (Dalzich, 1995). The industrial shea nut processing yields more oil than traditional method and thus produce less oily cake (Asante, 1987). This process generates two kinds of sheanut cake with varying levels of fat content of 22-24 % and10-12 % for midway cake and final cake respectively. The differences seen in the chemical composition of sheanut cake especially regarding crude protein and ether extract can be explained by possible differences in the variety of shea tree, the processing method used or contaminants.

2.2. Nutritive Value of sheanut cake

2.2.1. Proximate composition of sheanut cake

The proximate composition of sheanut cake (%) reported was various authors is presented in Table A.

2.2.2. Mineral composition of sheanut cake

The mineral content of sheanut cake (%) reported by several workers in various experiments is presented in Table B.

Alhassan *et al.*,(2011) detected several elements in sheanut and their values were as follows:

Na (mg/kg)	15±1
Mn (mg/kg)	7.4±0.8
Al (mg/kg)	259±3
Cl (mg/kg)	666±27
Ca (wt %)	0.21±0.04
K (wt %)	2.0±0.04
Ce (mg/kg)	3.2±0.06
Se (mg/kg)	0.12±0.004
Sc (mg/kg)	0.40±0.02

Table A: Chemical composition (%) of sheanut cake

S.No	DM	CP	EE	CF	TA	NFE	NDF	ADF	AIA	Hemi-cellulose	Cellulose	Reference
1	91.5	16.2	13.4	9.5	4.2	-	10.07	9.23	-	0.84	-	Atuahene *et al.*, 1998
2	91.25	17.03	13.78	6.25	6.58	-	-	-	-	-	-	Rhule 1999
3	-	16.5	6.5	8.7	6.9	-	-	-	-	-	-	Ewing 2000
4	-	8.0-25	1.7-36.2	5.3-13.8	3.3-7.6	31.8-67.5	-	-	-	-	-	Dei *et al.*, 2007
5	95.6	6.7	7.3	10.9	-	-	-	-	-	-	-	Pousga *et al.*, 2007

6	95.3	14.1	1.8	11.3	5.0	67.8	-	-	0.62	-	-	Sreenivas Kumar *et al.*, 2007
7	-	14.12	1.90	6.70	10.53	66.75	-	-	-	-	-	Rami Reddy 2008
8	93.86	12.25	9.45	1.92	6.94	69.44	61.07	41.67	-	19.4	7.4	Ravindra Reddy *et al.*, 2009
9	93.26	13.21	2.12	9.82	7.81	67.04	60.27	41.13	-	19.14	7.22	Kishan Kumar *et al.*, 2010
10	94.11	9.41	53.0	9.60	12.0	-	-	-	-	-	-	Elemo *et al.*,2011
Mean	93.55	12.75	11.09	7.99	7.03	60.56	43.80	30.67	0.62	13.12	7.31	

Table B: Mineral content (%) of sheanut cake

S.No	Ca	P	Na	K	Mg	Fe	Mn	Zn	Cu	Reference
1	0.373	0.281	0.19	0.03	0.16	0.042	0.03	0.048	0.034	Atuahene *et al.*, 1998
2	0.25-0.37	0.25-0.28	0.05-0.20	0.04-2.0	0.16-0.20	0.04	0.03	0.05	0.03	Ewing 2000
3	0.40	0.19	-	-	-	-	-	-	-	Pousga *et al.*, 2007
4	0.44	0.1	0.12	1.95	-	-	-	-	-	Sreenivas Kumar *et al.*, 2007
5	0.55	0.27	-	-	-	-	-	-	-	Rami Reddy 2008
6	1.69	0.15	-	-	-	-	-	-	-	Ravindra Reddy *et al.*, 2009
7	1.16	0.22	-	-	-	-	-	-	-	Kishan Kumar *et al.*, 2010
Mean	0.69	0.21	0.12	0.67	0.16	0.041	0.03	0.049	0.032	

2.2.3. Amino acid composition of Sheanut cake:

Pousga *et al.*, (2007) reported 0.27 % Lysine, 0.14 % methionine, 0.09% cystine and 0.23% threonine in sheanut cake.

The amino acid composition of sheanut meal in comparison with DORB is presented in table C

Table C: Amino acid composition of sheanut meal in comparison with DORB

Amino acid	**Dei et al., (2008) gm/kg of CP**	**Rami Reddy (2008) % CP**	**DORB(NRC,1998) % CP**
Methionine	16.4	1.85	0.26
Cystine	15.7	1.44	0.27
Lysine	33.6	3.35	0.57
Threonine	28.4	3.57	0.48
Arginine	68.7	7.00	1.00
Isoleucine	38.8	3.99	0.44
Leucine	62.7	7.06	0.92
Valine	49.3	4.94	0.68
Histidine	23.9	2.44	0.34
Phenylalanine	31.4	3.80	0.56
Glycine	37.3	4.31	-
Serine	32.1	3.99	-
Alanine	42.5	4.93	-
Aspartic acid	83.6	9.97	-
Glutamic acid	133.6	14.90	-

2.2.4. Metabolizable Energy content of Sheanut Cake

Okai and Bonsi (1989) estimated ME content of Sheanut extract as 21.5 MJ/kg in growing gilts.

The ME content of Sheanut extract as reported by Atuahene *et al.,* (1998) in poultry was 7.12 MJ/Kg DM.

Dei *et al.,* (2006) determined apparent metabolizable energy (AME) value of sheanut fat in broiler chickens and compared with that of soya bean oil and cocoa fat and reported that the mean coefficient apparent lipid digestibility for shea fat (0.58) was similar to that of cocoa fat (0.54) but lower than that of soya bean oil (0.95).

Pousga *et al.,* (2007) reported metabolizable energy as 13.1 MJ/kg in sheanut cake in poultry.

Rami Reddy (2008) analysed the ME content of sheanut extract in poultry as 2395 Kcal/kg of metabolizable energy.

2.2.5. The effect of inclusion of Sheanut Cake in the diets of pigs and other livestock

Adeogun (1989) observed growth depression when sheanut butter cake was included in the diets at the rate of more than 5 percent in broiler chicks.

Okai and Bonsi (1989) reported that a maximum of 25 to 30 percent level of inclusion could be tolerated by pigs and ruminant and also found that sheanut cake (SNC) inclusion in pig diets significantly ($P<0.05$)depressed the growth rate and feed conversion efficiency but did not affect intake.

Annongu *et al.,* (1996) found that the feeding value of sheanut extract enhanced by molasses supplementation and pre-treatment alleviated the effects of anti-nutrients by fermentation and also by amino acid (methionine, lysine) supplementation in broilers.

Olorede *et al., (*1996*)* reported that 10 % sheanut extract or 15 % palm kernel cake could be included in broiler diets without any apparent adverse effect on their performance.

Olorede *et al.,* (1997) observed poor growth rate in broilers fed 15 percent sheanut cake based diet.

Olorede *et al.,* (1999) investigated the potential of sheabutter cake (SBC) at 0, 100 and 200 g/kg diet as alternative protein and energy source in pullet chicks. Diet with 200 g/kg SBC depressed the growth of pullet chicks ($P<0.05$) and feed / gain ratio, also decreased the digestibility of crude fibre. They concluded that poorer growth rate of pullet chicks fed 200 g/kg SBC based diet could be attributable to the lower feed intake and poor palatability of the ingredients and feeding SBC up to 100 g/kg is nutritionally adequate and without apparent adverse health implications to pullet chicks.

Atuahene *et al.,*(1998) fed broilers with diets containing 2.5, 5.0 and 7.5 percent sheanut extract (SNE) and noticed that feed intake and weight gain were both significantly and inversely related to the level of sheanut extract in the diet. It was further stated that the feed conversion ratio, water consumption, carcass dressing percentage and mortality were strongly influenced by the level of SNE in the diet. The lower growth rates might be caused by reduced level of protein availability for growth. He found that the reduced performance might also be attributed to the fact that as the concentration of SNC in the diets increased, the metabolisable energy values of the diets decreased. However, they reported that the SNE could be included in broiler diets upto 2.5 percent without affecting their performance.

Rhule (1999) reported that the level of inclusion of 90 minutes boiled sheanut extract should not exceed 20 % in the diet for either grower or finisher pigs. Boiling reduced the theobromine content in the sheanut extract. He also reported that the average daily gain (kg/day) in grower and finisher phase was 0.46 and 0.41, respectively and the overall ADG was 0.44kg/day on feeding sheanut cake to the pigs. The feed conversion efficiency was 6.4 kg.

Rhule *et al.,*(2005) observed no deleterious effect on the reproductive performance of sows on feeding dried cocoa husk and cocoa cake with shell but 20 per cent dried cocoa husk level would inhibit the average weaning weight of the piglet.

Dei *et al.,* (2007) observed no significant difference in mean daily weight gain and feed intake (P>0.05) for birds fed diets containing 2.5 per cent SNC and the control. However, there was a significant (P<0.05) depression in weight gain and feed intake when higher levels of SNC (3.5 and 4.5 %) were included in the diets. Feed/gain ratios were similar (P>0.05) for all diets except the diet containing 4.5 % SNC, which was poor. The depression in feed intake and weight gain can be attributed to the presence of anti-nutritional factors in SNC.

Pousga *et al.,* (2007) in an experiment with cockerels observed that DM digestibility of 96% on feeding sheanut cake and the digestibilities of lysine, methionine, cystine and threonine were 96,78,88 and 77 %, respectively.

Samara *et al.,* (2007) found that the general trend of weight loss in the sheanut diet compared to the control was due to calorie inadequacy resulting in reduced food intake.

Rami Reddy (2008) in an experiment included sheanut extract in layer diets at 0, 2.5, 5.0, 7.5 and 10.0 percent by replacing deoiled rice bran on weight by weight basis and concluded that it can be incorporated upto 10 percent in layer diets without any adverse effect on the performance of layers. The income over feed cost per 12 eggs and percent improvement in income were high in the birds fed with 10 per cent sheanut extract compared to feeding of other diets.

Ravindra Reddy *et al.*, (2009) observed higher total body weight gain and average daily gain in weaners of Nellore breed of sheep on feeding concentrate diet prepared by replacement of 16 parts of rice bran with sheanut cake.

Kishan Kumar (2010) reported that feeding of complete diets containing 15 % palm press fibre and 28 % Sheanut cake increased the live weight gain , feed efficiency, nutrient digestibility and rumen fermentation and reduced the cost of feed per kg live weight gain by 12.72% in comparison to conventional ration. Similarly , the production performance and quality of milk in buffaloes increased and the cost of feed per kg 6 % FCM reduced by 4.62% compared to conventional ration.

Solomon Pigangsoa Konlan(2010) reported that addition of sheanut cake from 11.5 % to 23 % (230 g/kg DM) in the supplemental diet of growing Djallonke sheep led to improved growth performance . He also reported that the diet did not cause any negative effect in the haemotology and serum metabolites of the rams.

Elemo *et al.*, (2011) in an experiment observed significantly lower ($P<0.05$) faecal nitrogen as well as percentage of nitrogen absorbed in rats fed the exfactory sheanut and the raw sheanut diets. There was no significant difference in the feacal nitrogen and digestibility of rats fed the exfactory diet or raw sheanut diets. Total urinary nitrogen was lower ($P<0.05$) among rats on the exfactory and raw sheanut meals. The excessive loss of hair observed would account for a negative nitrogen balance in the rats, thus explaining the weight loss.

2.2.6. Anti-Nutritive factors in Sheanut Cake

The anti-nutritive factors of Sheanut cake (%) reported in previous experiments is presented in Table D

Table D: Anti-nutritive factors in sheanut cake

S.No	**Saponin**	**Tannin**	**Theobromine**	**Reference**
1	-	-	0.45	Pearson 1970
2	0.297	-	-	Livingston *et al.*, 1977b
3	-	-	0.36	Tettey 1983
4	0.297	-	0.45	Atuahene *et al.*, 1998
5	-	16.15	-	Rhule 1999
6	0.3-3.0	9.87-15.64	0.45	Dei *et al.*, 2007
7	0.31	-	-	Rami Reddy *et al.*, 2008
Mean	0.301	14.45	0.43	

2.2.7. Effect of anti-nutritive factors on animals and birds

2.2.7.1. Saponins

Ishaaya and Birk (1965) found that soyabean saponins inhibit chymotrypsin and trypsin activity and the reason for lower growth rates might be caused by the reduced amount of protein available for growth. This defect ultimately affected the efficiency of feed conversion into tissue.

Basu and Rastogi (1967) reported that toxic effect of saponins is due to their tendency to alter the cell wall permeability.

Saponins cause irritation to the mucous membrane of the mouth and throat (Pedersen and Wang, 1971) , inhibit smooth muscle activity, reduce peristalsis and rate of passage , contributed to reduced feed intake and also inhibit the cellular enzymes (Cheeke, 1971).

Goodwin and Mercer (1972) reported that saponins are surfactants and they cause haemolysis of R.B.C's.

Several experiments indicated that there was decrease in intake of feed when the feed contains saponins. (Kendall and Leath, 1976; Tung *et al.,* 1977 and Cheeke *et al.*, 1978).

. Livingston, *et al.,* (1977) observed that saponins in diet cause reduced feed intake, inhibit growth rate of swine and poultry and show toxicological effects at higher levels in the diets.

Malinow *et al.,* (1977) reported that saponins reduce cholesterol absorption from about 50 % to about 22 % in rats.

In an experiment conducted by Johnson *et al.*,(1986) on the influence of saponins on gut permeability and active nutrient transport *in vitro* and the results indicate that saponins readily increase the permeability of the small intestinal mucosal cells, thereby indicating active nutrient transport and facilitating the uptake of materials to which the gut would normally be impermeable.

Liener (1990) reported that saponins in high concentration reduce nutrient digestibility.

Longstaff and McNab (1991) observed reduced activity of digestive enzymes in non-ruminants due to the presence of saponins in the feed.

AL-Bar *et al.*, (1993) observed reduced emission of ammonia in animals' excreta on feeding diets that are high in saponin content.

McDonald *et al.,* (1995) reported that saponins cause injury to the digestive mucosa, inhibit smooth muscle activities, slow down digesta flow, cause membranous irritations of mouth and digestive tract and also cause haemolysis in the blood when fed to non-ruminants at higher levels.

Katsunuma et *al.,* (2000) observed lower concentration of faecal ammonia-N, acetic acid, less abundant Veillonella and higher concentrations of propionic, butyric and *n*-valeric acids in pigs fed with diets containing saponins.

Garcia (2004) reported that piglets of lower birth weight with limited intake of colostrums or milk immunoglobulins, the oral administration of saponin could be useful in enhancing passive immunization and subsequent health and growth.

Ilsley, *et al.*,(2005) stated that saponin supplementation during the post weaning period seemed to potentiate an immune response in the weaned piglets but had a detrimental effect on the utilization of feed.

Hauptli *et al.*, (2006) reported that sows fed during the last 10 days of gestation and during the nursing period with diets containing 160 ppm saponins had better corporal score at the end of nursing and the piglets had higher birth and weaning weights.

Wang Cheng Zhang *et al.*,(2008) observed that saponin in alfalfa meal plays a key role in decreasing cholesterol in the serum and also reported decreased triglycerides and LDL-C concentration in the serum, and significantly increased the HDL-C concentration. He also observed reduced liver and loin eye muscle, adjusted the lipid metabolism and improved oxidation resistance and immune function.

Shi YingHua *et al.,* (2010) suggested that the addition of alfalfa saponins can enhance antioxidant ability of piglets and also promoted their growth.

Wang Cheng Zhang *et al.,* (2011) suggested that the alfalfa saponins at 0.25%- 0.50 % can improve the production of weaned piglets.

2.2.7.2. Tannins

Many studies have shown that high dietary tannins result in reduced weight gains and poor efficiencies in birds. (Armstrong *et al.,* 1974; Ahmed *et al.,* 1991; Trevino *et al.,* 1992 and Iji *et al.,* 2004).

Salunkhe *et al.,* (1990) observed that tannins in the diets of non-ruminant species reduce the apparent protein digestibility.

Longstaff and McNab (1991) observed that tannins have shown to inhibit in vivo activities of trypsin and α- amylase, but increased lipase activity.

Garrow and James (1993) reported that tannins reduce the absorption of minerals such as iron.

Jansman *et al.,* (1993) observed increased endogenous nitrogen excretion in piglets after feeding tannin containing diets.

Schmidt et *al.,* (1994) reported that increasing the tannin content of sorghum decreased the digestibility of nutrients especially crude protein in pigs.

Van Leeuwen *et al.,* (1995) observed that aminopeptidase activity was a limiting factor for the rate of digestion of the protein in the ration with a high level of tannins in weaned pigs.

Jansman et *al.,* (1995) reported that tannins reduce the true digestibility of dietary protein and increase the excretion of endogenously secreted proteins in pigs.

Jeroch et *al.,* (1996) concluded that digestibility of organic matter, CP and crude carbohydrates was lower in pigs fed with diets containing higher lignin and tannins.

Salobir *et al.,* (1997) reported that tannin supplementation increased protein excretion in faeces and decreased protein digestibility, but had no effect on phytase efficiency in pigs.

Erlich (1999) observed that during the finishing phase, feed intake was greater in pigs with higher levels of tannins in the diet and low daily weight gain and feed conversion in initial phases.

Farrell *et al.,* (1999) in an experimental trial conducted in poultry and pigs concluded that tannins reduce the digestibility of proteins by complexing with them as well as with some digestive enzymes, and to a lesser extent starch.

Salobir et *al.,* (2005) reported that the addition of tannins significantly reduced apparent protein and crude ash digestibility and utilization of phosphorus and calcium was unaffected by tannin supplementation. In conclusion, the applied concentrations of tannins did not reduce the phosphorus-related efficiency of phytase action in growing pigs.

Antongiovanni et *al.,* (2007) observed that apparent digestibility of both dietary dry matter and nitrogen reduced with level 0.5%, but the decrease of retained nitrogen was not statistically significant, due to the higher dietary nitrogen and a concentration of 250 g tannin per 100 k g mixed feed did not appreciably influence the animals' performance.

Stukelj et *al.,* (2010) observed that diet with acids and tannin did not improve the growth performance of grower pigs but had no deleterious effects on blood parameters.

2.2.7.3. Theobromine

Braude and Foot (1942) reported that cocoa cake meal containing theobromine when fed to piglets resulted in abdominal disorders.

Owusu-Domfeh (1972) reported that theobromine is poisonous to livestock when consumed above certain levels which put limitation on the use of cocoa by products in pig diets.

Trease and Evans (1972); Clarke and Clarke (1979) reported that theobromine, an alkaloid causes diuretic effect in birds.

Clarke and Clarke (1979) observed that theobromine is completely absorbed from the alimentary tact and slowly excreted. Small doses can have a cumulative effect and cause death from poisoning after reaching a critical level and theobromine at a concentration of 75 g/kg of the ration causes unthriftiness and definite harmful effects in weaner pigs.

Longstaff and McNab (1991) reported that theobromine would decrease the digestibility of both protein and energy by forming complexes with digestive enzymes.

Rhule (1999) reported that grower- finisher pigs can tolerate 0.21 per cent theobromine in diets but in breeding sows 0.4 per cent theobromine led to abortions.

Clasadonte *et al.*,(2009) noticed no clear linear relationships or consistent effects between the level of anti-nutritional factors or its intake and voluntary feed intake in pigs

2.2.8. Influence of sheanut cake on blood parameters and serum biochemical profile

Atuahene (1998) observed significant reduction in erythrocyte count, haemoglobin levels and haemocrit values in birds fed on high dietary sheanut cake levels and it may be due to saponin content in SNC and his study indicated that SNC has hypocholesteromic effect.

Olorede and Longe (1999) in an experiment reported reduction in total protein, albumin and cholesterol on 100 or 200 g/kg shea butter cake feeding in chicks indicating inferior quality or nutrition. They have also reported that PCV and red blood cell count increased while white blood cell count decreased as the sheanut cake inclusion increased to 200 g/kg but had no effect on the serum metabolites of the chicks.

Dei *et al.*,(2006) reported that PCV and Hb value had significantly($P<0.05$) increased with increased level of inclusion of sheanut cake in poultry.

Elemo *et al.*,(2011) reported that total protein, albumin, non protein nitrogen, urea as well as glycogen in the liver and serum fall significantly ($P>0.05$) in defatted sheanut seed and whole sheanut seed meals , while the effect is more in the raw sheanut meal. Serum minerals, phospholipids in liver and kidney tissues were not affected. However, transaminases (GOT and GPT) and alkaline phosphatase were elevated in both serum and liver, indicating reduced quality of food value especially calorie and protein in the meals. The observed biochemical indices depict a poor response of the rats to sheanut diets as food.

2.3. Utilization of unconventional feed ingredients in swine rations

Vidyasagar and Yadava (1970) undertook a feeding trail with twenty two Middle White Yorkshire piglets which were divided at random into two groups, namely control group (containing maize) and experimental group (maize replaced by rice polish and molasses). The average daily gains were 277 and 302 g for the experimental and control groups respectively and the differences were not significant. However, feed/ kg gain was higher ($P<0.01$) (4.93 vs 3.88) with experimental group. Per cent drift, hot dressing percentage, per cent yield of ham, backfat thickness and the carcass length were not significantly different between two groups.

Pathak and Ranjhan (1973) fed sal seed meal (DOSM) by replacing maize to gilts and reported that the inclusion did not affect significantly, the rate of body weight gain in the gilts. The digestibility of crude protein and feed efficiency decreased with the inclusion of DOSM.

Adeyanju and Ilori (1979) observed that pigs fed 30 % dried cocoa husk had improved carcass quality with increase in carcass length, percentage ham, loin and loin eye area.

Seshi Reddy *et al.,* (1981) reported that maize (35%) can safely be replaced with rice polish (30%) or tamarind seed (30%) along with molasses (10%) in the swine diets during gestation and lactation without affecting the performance characteristics.

Thomas and Anjaneya Prasad (1983) studied the comparative performance of LWY pigs with 5 types of diets containing maize 35 ; maize, rice polish and molasses at 10,20,10 parts or 0,30,15 parts : maize, tamarind seed and molasses at 15, 20, 5 or 0,30,10 parts, respectively and were iso-nitrogenous. No significant differences were observed in average feed consumption, ADG, EFU, dressing percentage, back fat thickness and loin eye area, among the treatments. It was concluded that diets with tamarind seed and molasses were equally good while diets with rice polish and molasses gave better performance

Roychoudhary and Mandal (1984) used deoiled niger (Guizotia abyssinica) cake to replace deoiled groundnut cake in the rations and stated that the growth and efficiency tended to be reduced by increments of niger cake though the differences were not significant.

It was suggested that water hyacinth after wilting for 2 to 3 hours in the sun could be used upto 37.8% as concentrate replacement in indigenous pigs, without any detrimental effect on the performance of pigs (AICRP on pigs, Guwahati, 1984-85 annual report).

Erickson *et al.,* (1985) recommended a maximum of 10% of wheat shorts in the diets of starter pigs and 40 % in growing –finishing pigs and sows.

Reddy *et al.,* (1985) studied the effect of replacing maize by bagasse and molasses mixture (9:1) in Desi pigs. They reported that ADG of pigs decreased as the level of inclusion increased. There was no significant difference in nitrogen retention among the treatments. It was concluded that 20 parts of maize could be replaced with bagasse and molasses mixture without any adverse effect on feed efficiency.

Gatel *et al.*,(1987) reported that inclusion of 16 % field peas in gestating diets and 24 % in lactating diets had no negative effect on sow or pig performance.

Kumar and Barsaul (1988) in an experiment concluded that by products like molasses, sun dried cattle faeces and deoiled rice bran can safely be incorporated to make the pig rations more economical.

Noggler *et al.,* (1989) reported that rape seed oil can be incorporated upto 25% level in pig diets safely.

Srinivasa Rao *et al.,* (1989) concluded that groundnut haulms could be included in the diets of indigenous pigs at 20-30 percent level replacing maize grain (weight/weight) without adversely affecting the animal performance.

Acurera *et al.,* (1993) obtained satisfactory results by replacing 50% of sorghum meal with sweet potato meal in the diets for growing pigs.

Bora and Singh (1994) studied the effect of feeding air dried mahua (*Madhuca indica*) flowers as replacement of maize on growth performance and feed conversion efficiency of grower crossbred (LWY X Desi) gilts and concluded that mahua flowers can be incorporated in the rations for gilts as a substitute for maize.

Tiwari (1996) reported that mahua seed cake can be incorporated up to 24 percent with replacement of groundnut cake in the rations of growing piglets, without affecting feed consumption and weight gain.

Ravi *et al.,* (1999) reported that inclusion of urad (*Vigna mungo*) chuni at 15 % level in the rations of growing and finishing cross bred barrows did not affect the growth rate and carcass characteristics.

Geethapriya, *et al.*,(1999) included amaranthus (A.cruentus) whole plant meal (AWPM) in grower rations at 0, 15, 20 and 25 percent and fed ad libitum to 24 crossbred barrows during grower phase (20-35 kg). The study revealed that feed intake reduced linearly with increasing AWPM in ration but differences were statistically non significant. There was a linear decrease in ADG, feed/kg gain, digestibility of nutrients (DM, OM, CP and total carbohydrates) and nitrogen retention as the level of AWMP increased in the ration. It was concluded that AMPM can be included up to 15 percent level in the rations of growing crossbred barrows.

Madhava Rao (2000) studied the effect of inclusion of guava pomance at different levels. During growing phase it was reported that differences in ADG among the treatments were non significant. The efficiency of feed utilization, digestibility of DM, OM, CF, NFE and CP decreased as the level of guava pomance increased in the rations. The results during finisher phase indicated that there was increase in ADG, digestibility of DM, EE and NFE and N retention and there were no significant differences for all the carcass characteristics. It was concluded that guava pomance can be included at 30 percent level in pig rations, although inclusion at 20 percent level proved to be economical due to better utilization of nutrients.

Ravi *et al.*, (2000) concluded that water soaked tamarind seed can be incorporated in place of maize in the diets of pregnant and lactating crossbred gilts.

Petersen and Spencer (2006) and Stein *et al.*, (2006) reported that field peas may be included upto 60to 70 % of diets without influencing pig performance.

Ravi et *al.,* (2006) reported that carcass characteristics were not significantly influenced by inclusion of water soaked or cooked tamarind seed kernel in the diets of pigs.

Adesehinwa (2007) reported that palm kernel cake can replace maize upto 30 parts without depressing the performance of the growing pigs.

Patel et *al.,* (2009) concluded that supplementation of jaggery filter cake with concentrate improved the carcass traits.

Xande et *al.,* (2010) reported that gradual inclusion of molasses in ground sugarcane stalks (GCS) based diet did not affect the carcass and meat quality of Creole (CR) pigs

Chu GyoMoon, *et al.,* (2012) observed that feeding of fermented mushroom by products to pigs decreased the growth performance but improvement was noticed in carcass grade.

Thacker (2012) reported that increasing the level of wheat DDGS in the diets of pigs resulted in a linear decline in carcass value index and lean yield while loin fat linearly increased.

CHAPTER-3

Materials and Methods

A study on the effect of Sheanut (*Vitellaria paradoxa*) cake on growth performance, nutrient utilization and carcass characteristics of cross bred (Large White Yorkshire X Desi) pigs was conducted at All India Coordinated research Project (AICRP) on pigs, Tirupati. The laboratory analysis was carried out at Animal Nutrition laboratory of the project.

The experiment was conducted on twenty four crossbred pigs in 2 phases viz., (1) Grower phase (15-35 kg) and (2) Finisher phase (35-70 kg).

The experiments conducted are dealt with under the following topics:

1. Growth studies
2. Nutrient utilization
3. Carcass characteristics
4. Serum biochemistry and
5. Economics

3.1. Procurement of feed ingredients

Sheanut (*Vitellaria paradoxa*) cake was procured from Cattle feed mixing unit of Indian Potash Limited, Gajulamandyam, Renigunta Mandal, Chittoor district. Maize grain, soyabean meal, de oiled rice bran (DORB), vitamin and mineral mixture were procured from the local market.

3.2. Selection of animals

Twenty four crossbred (Large White Yorkshire X Indigenous) males with 75 % exotic inheritance with an average initial body weight of 15.35±0.11 were selected from All India Co-ordinated Research Project on Pigs, Tirupati. The pigs were randomly divided into four equal groups of six animals each.

3.3. Experimental design

The experimental diets were offered to the pigs in a completely randomized design (CRD) with each group having six animals.

3.4. Experimental rations

Four complete iso-nitrogenous grower and finisher rations based on the recommendation of NRC (1998) were formulated using maize, deoiled rice bran (DORB), soyabean meal. Sheanut (*Vitellaria paradoxa*) cake was included to replace DORB at 50 (T-2), 75 (T-3) and 100% (T-4) level on equal weight basis. The rations were fortified with vitamin and mineral supplements.

3.5. Feeding and management of pigs

All the selected pigs were vaccinated against swine fever (supplied from IVRI) and dewormed with piperazine hydrate. Each animal was allotted an individual pen with a floor space of about 2.8 m^2.

The rations were offered *ad libitum* twice daily at 10 AM and 3 PM. The daily feed consumption of individual pigs was recorded. Fresh and clean drinking water was made available at free choice. The body weights of pigs were recorded at fortnight intervals before offering the morning feed (Fig.8). At about 35 kg body weight the grower pigs were shifted to their corresponding finisher rations to study the growth performance, nutrient utilization and carcass characteristics. The feed ingredients used in the finisher rations were similar to those used in grower rations. The experiment was continued till all the pigs attained a pre-determined slaughter weight of 70 kg or 120 days which ever was earlier.

3.6. Metabolism Trial

Two metabolism trials were conducted midway through the grower (25-30 kg) and finisher (50-55 kg) phases to study the apparent digestibility of nutrients and balance of nitrogen (Fig. 7). The pigs were shifted to metabolism cages and acclimatized for 3 days followed by a collection period of 7 days. The feed offered was 90 % of the observed feed intake during the preceding week to avoid feed refusal. The water was provided free choice throughout the trial period. The pigs were weighed before and after the completion of metabolism trial.

3.7. Collection of samples

3.7.1. Feed

During the metabolism trial, samples of different rations offered were composited separately and stored for further analysis.

3.7.2. Faeces

Total quantity of faeces voided daily during the collection period was weighed. About 10 percent aliquot of the daily faecal output was composited in polythene bags and frozen until analyzed. After the trial, the frozen samples were thawed and mixed thoroughly for homogeneity of the faeces and the dry matter was determined. An aliquot from each fresh faecal sample was used for crude protein (N X6.25) determination. The rest of the material was dried at 100 ^{0}C for over night in a hot air oven and ground through a medium mesh screen and placed in airtight bottles for further analysis.

3.7.3. Urine

Urine voided by each animal during the 24 hour period was collected and the volume was measured. Five percent aliquot of urine samples was composited daily in amber colored bottles preserved with few drops of conc. sulphuric acid and stored in a refrigerator for further analysis.

3.8. Slaughtering of pigs

At the end of growth trial at 70 kg body weight or 120 days from the starting day of experiment which ever was earlier, the pigs were fasted for a period of 24 hours. Two pigs from each group were slaughtered (Fig. 9 to 12) as per the standard procedure (USDA, 1970). After evisceration, the carcasses were cleaned thoroughly with running tap water and the water was allowed to drain by hanging the carcasses. The weight of each half of the carcass was recorded. The back fat thickness was measured at the 1^{st} rib, last rib and last lumbar vertebra and the average was taken. The dressing percentage was calculated from hot carcass with intact kidneys and head and feet on. Loin eye area was traced on an acetate paper by keeping it between 10^{th} -11^{th} rib and the traced area was measured by using a graph paper and expressed in cm^2.

3.9. Analytical methods:

Samples of feed ingredients, rations and faeces were analyzed in duplicate for proximate constituents (AOAC, 2005). Crude protein (N x 6.25) in fresh fecal samples and urine samples was estimated. Tannins and saponins in sheanut cake were estimated by (Laboratory manual of Animal Nutrition, 1999).

3.10. Statistical analysis:

The data was subjected to one way ANOVA using trial version of SPSS, 2010.

CHAPTER-4
Results

4.1. Chemical composition of feed ingredients

The chemical composition of different feed ingredients used in the experimental rations is presented in Table 1.

The sheanut (*Vitellaria paradoxa*) cake contained 16.07, 16.23, 16.22, 35.32 and 16.16 % CP, EE, CF, NFE and TA, respectively. The total tannin and saponin content of sheanut cake was 4.36 and 0.33 %, respectively, on dry matter basis (Table 1).

The CP in SBM (43.6%), EE in SNC (16.23%), CF in SNC (16.22%), NFE in maize (80.4%) and TA in DORB (19.1%) were higher than other ingredients.

4.2. Ingredient and chemical composition of grower rations

The ingredient and chemical composition of the grower rations T-1 (control), T-2 (50% SNC), T-3 (75%SNC) and T-4(100% SNC) are presented in Tables 2 and 3, respectively.

The CP content was 18.13, 18.29, 18.51 and 18.46 per cent for T-1 to T-4, respectively. The EE content was 2.95, 3.06, 4.04 and 4.29 percent for T-1 to T-4, respectively. The EE content of T-4 contained 1.34, 1.23, 0.25 percentage units more than T-1, T-2 and T-3, respectively. The CF content of the grower rations was 8.81, 8.67, 9.12 and 9.9 per cent for T-1 toT-4, respectively. The CF content

Table 1: Chemical composition (%) of feed ingredients[a]

Ingredient	Maize	Soybean meal	Deoiled rice bran	Sheanut cake
Dry matter	90.6	90.8	95.4	92.1
Crude Protein	9.3	43.6	9.0	16.07
Ether extract	4.6	1.7	1.2	16.23
Crude fibre	2.9	7.1	15.6	16.22
Nitrogen free extract	80.4	39.5	55.1	35.32
Total ash	2.8	8.1	19.1	16.16
Organic matter	87.8	83.8	76.3	75.94
Tannins	-	-	-	4.36
Saponins	-	-	-	0.33

[a] On dry matter basis except for dry matter.

Table 2: Ingredient composition (%) of grower rations

Constituents	T-1	T-2	T-3	T-4
Maize	45.5	45	45	45
Soya bean meal	25.5	24	24	22.5
Deoiled rice bran	26.5	14.5	7.5	0
Sheanut cake	0	14	21	30
Salt	0.5	0.5	0.5	0.5
Mineral Mixture	2	2	2	2
Lysine	0.2	0.34	0.27	0.31
Meriplex (gm/ 100 kg)	25			
Hyblend (gm/100 kg)	25			
Cost of ration Rs./ Kg.	16.70	16.00	15.70	15.20

Each gm of Meriplex contains Vit B_1-8 mg, Vit B_6-16 mg, Vit B_{12}- 80mcg, Vit $_{E50}$- 80 mcg, Niacin-120 mg, Calcium D pantothenate- 80 mg, calcium-88 mg and carriers-q.s.
Each gm of Hyblend AB_2D_3K contains Vit A- 82,500 I.U, Vit B2-50 mg, Vit D3- 12,000 I.U, Menaphthone sodium bisulphate (Vit K) -10 mg.

Table 3: Chemical composition (%) of grower rations (DM basis)

Nutrients	**T-1**	**T-2**	**T-3**	**T-4**
Dry matter	88.23	88.47	88.29	88.28
Crude protein	18.13	18.29	18.51	18.46
Ether extract	2.95	3.06	4.04	4.29
Crude fibre	8.81	8.67	9.12	9.9
Nitrogen free extract	62.09	62.12	60.71	59.81
Total ash	8.02	7.86	7.62	7.54
Organic matter	80.21	80.61	80.67	80.74
Tannin	-	0.61	0.92	1.31
Saponin	-	0.05	0.07	0.10
**DE Kcal/Kg (Calculated)	3137.81	3174.15	3216.93	3185.12
**ME Kcal/Kg(Calculated)	3027.76	3061.76	3101.54	3071.20

****** Noblet and Perez (1993)- DE=4151-(122*% ash)+(23*%CP)+(38*%EE)-(64*%CF), ME=DE*[1.003-(0.0021*%CP] of T-4 was higher by 1.09, 1.23, 0.78 percentage units than T-1, T-2 and T-3, respectively. The NFE content was 62.09, 62.12, 60.71 and 59.81 per cent for T-1 to T-4, respectively. The total ash content was 8.02, 7.86, 7.62 and 7.54 per cent for T-1 to T-4, respectively. The TA content of T-1 was higher by 0.16, 0.4 and 0.48 percentage units compared to T-2, T-3 and T-4, respectively. The cost of the ration (Rs/kg) was Rs. 16.70, 16.00, 15.70 and 15.20 for T-1 to T-4, respectively.

4.3. Growth performance of pigs during grower phase (15-35 kg live weight)

The growth performance of pigs fed grower rations T-1 to T-4 are presented in Table 4

The initial body weights (kg) of pigs were 15.08, 15.47, 15.22 and 15.62 and final body weights (kg) were 35.27, 35.19, 35.68 and 35.61, respectively for T-1 to T-4 were comparable among treatments.

The body weight gain (kg) of pigs was 20.19, 19.72, 20.43 and 19.99, respectively for T-1 to T-4 during grower phase and was not significantly different.

The number of days taken to reach 35 kg body weight was 51, 72, 92 and 93 days, respectively for the pigs fed rations T-1 to T-4 and the differences were significant ($P<0.01$). The pigs fed on T-1 had taken significantly less number of days ($P<0.01$) than those fed on T-2, T-3 and T-4.

The average daily gain (g/d) of pigs fed T-1 to T-4 was 362, 282, 224 and 219 respectively and the differences were significant ($P<0.01$). The daily gain (g/day) in pigs fed on T-1 was significantly higher ($P<0.01$) than those fed on other rations. The daily gain of pigs fed on T-2 was significantly higher ($P<0.01$) than those fed on T-3 and T-4. However, the differences between daily gain of pigs fed on T-3 and T-4 were not significant.

The feed/kg gain was 3.31, 4.11, 4.85 and 5.04 for pigs fed grower rations T-1 to T-4, respectively and the differences were significant (P<0.01). The feed/kg gain was significantly (P<0.01) lower in pigs fed T-1 than in those fed T-2 and T-4. However, the feed intake/kg gain was comparable between T-3 or T-4 fed trials.

4.4. Digestibility of organic nutrients

The average digestibility coefficients (%) of dry matter and organic nutrients in pigs fed grower rations are presented in Table 5 The digestibility of dry matter in pigs fed T-1 to T-4 was 79.98, 76.21, 76.06 and 73.85 per cent, respectively and the differences were significant (P<0.01). The DM digestibility in pigs fed on T-1 was higher (P<0.01) than those fed T-4. However, the differences among T-1 to T-3 or T-2 to T-4 fed pigs were not significant.

The organic matter (OM) digestibility in pigs fed T-1 to T-4 was 77.4, 76.23, 76.04 and 71.89 per cent, respectively. The differences among the rations were not significant.

The crude protein (CP) digestibility of T-1 to T-4 fed pigs was 82.71, 78.84, 70.49 and 69.68 per cent, respectively and the differences among the rations were significantly different (P<0.01). The CP digestibility was higher in those fed on T-1or T-2 rations and differed significantly (P<0.01) from those

Table 4: Growth performance of pigs fed different grower rations (15- 35 kg body weight)

Characteristics	**T-1**	**T-2**	**T-3**	**T-4**
Number of pigs	6	6	6	6
Initial body weight (kg)	15.08±0.28	15.47±0.1	15.22±0.34	15.62±0.09
Final body weight (kg)	35.27±0.14	35.19±0.14	35.68±0.3	35.61±0.23
Weight gain (kg)	20.19±0.34	19.72±0.23	20.43±0.38	19.99±0.38
No. of days**	56 [c] ±1.94	72 [b] ±4.5	92 [a] ±5.11	93 [a] ±4.55
Daily gain (g/d)**	362 [a].±10.03	282 [b]±22.07	224 [c]±9.29	219 [c]±9.27
Feed consumption (kg/d)	1.20±0.05	1.13±0.02	1.08±0.04	1.10±0.04
Feed / kg gain**	3.31 [c] ±0.07	4.11 [b] ±0.28	4.85 [a] ±0.13	5.04 [a] ±0.15

[abc] Values in a row not sharing common superscripts differ significantly ** P(<0.01)

Table 5: Nutrient digestibility (%) during grower phase

Nutrients	**T-1**	**T-2**	**T-3**	**T-4**
Dry matter**	79.98 ^{a} ±0.88	76.21^{ab}±1.97	76.06^{ab}±0.45	73.85^{b}±1.98
Organic matter	77.4±2.20	76.23±1.39	76.04±1.25	71.89±2.92
Crude protein**	82.71^{a}±1.99	78.84^{a}±2.11	70.49^{b}±3.38	69.68^{b}±2.03
Crude fibre	47.22±2.22	42.86±2.41	39.72±5.87	37.19±4.72
Ether extract	76.33±2.26	75.80±0.94	75.70±1.22	72.42±3.81
Nitrogen free extract	85.41±1.69	83.74±0.93	83.61±2.07	85.50±1.31

^{abc} Values in a row not sharing common superscripts differ significantly ** P(<0.01) fed on T-3 or T-4 while there was no significant difference between T-1 and T-2 and also between T-3 and T-4 fed pigs.

The crude fibre (CF) digestibility of T-1 to T-4 was 47.22, 42.86, 39.72 and 37.19 per cent, respectively and the differences were non-significant.

The ether extract (EE) digestibility of T-1 to T-4 fed pigs was 76.33, 75.80, 75.70 and 72.42 per cent, respectively and the differences were non-significant.

The nitrogen free extract (NFE) digestibility of T-1 to T-4 fed pigs was 85.41, 83.74, 83.61 and 85.50 per cent, respectively and the differences were non-significant.

4.5. Nitrogen utilization in pigs fed grower rations

The nitrogen balance of pigs fed different grower rations is presented in Table 6

The nitrogen intake (g/day) of pigs fed on T-1 to T-4 was 37.65, 29.24, 28.27 and 27.49 respectively, and the differences among the rations were significant ($P<0.01$). In pigs fed on T-1, the N intake was significantly ($P<0.01$) higher than those fed on T-2 to T-4 rations probably due to higher ($P<0.01$) feed intake in T-1 than in other treatments. The N excretion in faeces (g/day) of pigs fed T-1 to T-4 was 6.61, 6.25, 8.41 and 8.32, respectively and the differences were non-significant. The N excretion in urine (g/day) of pigs fed T-1 to T-4 was 8.38, 6.86, 6.91 and 6.98, respectively and the differences among the rations were non- significant. The total N excretion (g/day) of pigs fed T-1 to T-4 was 15.00, 13.24, 15.41 and 15.35, respectively and the differences were non-significant.

Table 6: Nitrogen balance of growing pigs fed different grower rations

Nitrogen balance	**T-1**	**T-2**	**T-3**	**T-4**
Daily feed intake (g/d)	1298.83[a]±80.16	996.60[b]±53.26	952[b]±83.32	925.4[b]±38.56
N intake (g/d)**	37.65[a]±2.34	29.24[b]±4.78	28.27[b]±4.00	27.49[b]±4.37
N excretion (g/day)				
Faeces	6.61±0.88	6.25±1.57	8.41±2.18	8.32±1.82
Urine	8.38±1.28	6.86±1.15	6.91±1.67	6.98±0.93
Total	15.00±1.87	13.24±2.08	15.41±3.68	15.35±1.27
N retention				
g/day**	22.67[a]±2.45	15.88[b]±3.73	12.22[c]±1.78	11.91[c]±3.25
Per cent intake**	60.15[a]±5.35	54.54[a]±5.67	45.37[b]±7.06	43.53[b]±8.46
Per cent absorbed**	72.91[a]±2.36	69.49[a]±4.25	64.65[b]±3.31	63.10[b]±2.89

[ab] Values in a row not sharing common superscripts differ significantly ** P(<0.01)

The N retention (g/day) of pigs fed T-1 to T-4 was 22.67, 15.88, 12.22 and 11.91, respectively. It was higher (P<0.01) in pigs fed T-1 than those fed T-2, T-3 or T-4 rations and N retention of T-2 was significantly higher (P<0.01) than T-3 and T-4. The N retention expressed as per cent intake was 60.15, 54.54, 45.37 and 43.53, respectively for T-1 to T-4 and the differences were significant (P<0.01). It was higher (P<0.01) in pigs fed T-1 or T-2 than those fed T-3 or T-4 rations. The N retention expressed as per cent absorbed was 72.91, 69.49, 64.65 and 63.10, respectively for T-1 to T-4 ration fed pigs and the differences were significant (P<0.01). It was significantly (P<0.01) higher in pigs fed T-1 or T-2 than those fed T-3 or T-4.

4.6. Economics

The economics of feeding different grower rations is presented in Table 7. The cost of the treatment rations was calculated based on the cost of individual feed ingredients. The cost of T-1 to T-4 rations with inclusion of sheanut cake inclusion at 0, 50, 75 and 100 per cent levels by replacing DORB was Rs.16.66, 15.96, 15.72 and 15.22 per kg respectively. The cost of ration/kg gain in pigs fed T-1 to T-4 was Rs.55.22, 65.75, 76.28 and 76.82, respectively and the differences were significant (P<0.01). The feed cost (Rs/kg) gain was significantly higher (P<0.01) in pigs fed T-3 or T-4 than those fed T-1 or T-2, while T-1 being the most economical of all the rations.

Table no.7: Economics of feeding different grower rations

Particular	T-1	T-2	T-3	T-4
Cost of ration /kg weight gain **	55.22±1.25[c]	65.75±4.47[b]	76.28±2.08[a]	76.82±2.28[a]

[abc] Values in a row not sharing common superscripts differ significantly

**P(<0.01)

4.7. Ingredient and chemical composition of finisher rations

The ingredient and chemical composition (%) of the finisher rations T-1, T-2 (50% SNC), T-3 (75% SNC) and T-4 (100% SNC) are presented in Tables 8 and 9, respectively.

The finisher rations contained 16.12, 16.39, 16.52 and 16.67 (CP), 3.79, 4.54, 5.5 and 7.14 (EE), 10.18, 11.8, 12.2 and 13.3 (CF) , 62.90, 59.68, 57.92 and 54.49 (NFE) and 7.01, 7.59, 7.86 and 8.4 % (TA) respectively in T-1 to T-4 rations. The cost of the ration (Rs/kg) was Rs. 16.4, 15.49, 15.00 and 14.32 for T-1 to T-4, respectively.

4.8. Growth performance of pigs during finisher phase (35-70 kg live weight)

The growth performance of pigs fed finisher rations are presented in Table 10.

The initial and final body weights as well as weight gain were not significantly different among treatments.

The number of days taken by the pigs to reach 70 kg was 93, 95, 105 and 156 days, respectively for the rations T-1 to T-4. The number of days taken by pigs fed T-4 was higher when compared to other groups. There was no significant difference among pigs fed T-1, T-2 or T-3 rations.

The average daily gain (ADG) of pigs fed T-1 to T-4 was 395, 384, 334 and 223, respectively and the differences were significant (P<0.01). The average daily gain was the highest in pigs fed on T-1 rations and lowest in pigs fed on T-4. The ADG of pigs fed T-1, T-2 or T-3 was significantly ($P<0.01$) higher than those fed on T-4 whereas it was comparable between T-1 & T-2 and T-2 & T-3 fed pigs.

The average daily feed consumption (kg) of the finisher pigs fed on rations T-1 to T-4 was 1.35, 1.85, 2.05 and 1.60, respectively. The average daily feed intake in T-3 (2.05 kg) was significantly ($P<0.01$) higher from those fed on T-1 (1.35 kg) or T-4 (1.60 kg) whereas it is comparable with T-2 (1.85 kg) fed pigs.

The feed consumption/ kg gain was 3.60, 4.99, 6.15 and 7.25 for pigs fed finisher rations T-1 to T-4, respectively and it was in the order T-4>T-3>T-2>T-1 and the differences among treatments were significant ($P<0.01$).

Table 8: Ingredient composition (%) of finisher rations

Constituents	**T-1**	**T-2**	**T-3**	**T-4**
Maize	54	50	48	45
Soya bean meal	20	18.5	17.5	16
Deoiled rice bran	23.5	15	11	6.5
Sheanut cake	0	14	21	30
Salt	0.5	0.5	0.5	0.5
Mineral Mixture	2	2	2	2
Lysine	0.14	0.18	0.2	0.25
Meriplex(gm per 100 kg)	25			
Hyblend(gm per 100 kg)	25			
Cost of ration (Rs./ kg)	16.40	15.50	15.00	14.32

Each gm of Meriplex contains Vit B_1-8 mg, Vit B_6-16 mg, Vit B_{12}- 80mcg, Vit $_{E50}$- 80 mcg, Niacin-120 mg, Calcium D pantothenate- 80 mg, calcium-88 mg and carriers-q.s. Each gm of Hyblend AB_2D_3K contains Vit A- 82,500 I.U, Vit B2-50 mg, Vit D3- 12,000 I.U, Menaphthone sodium bisulphate (Vit K) -10 mg.

Table 9: Chemical composition (%) of finisher rations of (DM basis)

Nutrients	T-1	T-2	T-3	T-4
Dry matter	92.64	89.05	89.19	89.52
Crude protein	16.12	16.39	16.52	16.67
Ether extract	3.79	4.54	5.5	7.14
Crude fibre	10.18	11.8	12.2	13.3
Nitrogen free extract	62.90	59.68	57.92	54.49
Total ash	7.01	7.59	7.86	8.4
Organic matter	85.63	81.46	81.33	81.12
Tannin	-	0.61	0.92	1.30
Saponin	-	0.04	0.06	0.10
**DE Kcal/Kg (Calculated)	3159.04	3019.31	3000.24	2929.73
**ME Kcal/Kg(Calculated)	3061.58	2924.45	2905.16	2835.96

****** Noblet and Perez (1993)- DE=4151-(122*% ash)+(23*%CP)+(38*%EE)-(64*%CF), ME=DE*[1.003-(0.0021*%CP)]

Table 10: Growth performance of pigs fed different finisher rations (35- 70 kg body weight)

Characteristics	**T-1**	**T-2**	**T-3**	**T-4**
Number of pigs	6	6	6	6
Initial body weight (kg)	35.27±0.14	35.19±0.14	35.65±0.3	35.61±0.23
Final body weight (kg)	70.68±0.29	70.57±0.27	70.57±0.2	70.01±0.12
Weight gain (kg)	35.40±0.36	35.38±0.27	34.91±0.48	34.4±0.27
No. of days**	93^{b}±8.45	95^{b}±3.18	105^{b}±2.02	156^{a}±5.82
Daily gain (g/d)**	395^{a}±34.07	384^{ab}±12.55	334^{b}±5.41	223^{c}±7.16
Feed consumption (kg/d)**	1.35^{c}±0.13	1.85^{a}±0.02	2.05^{a}±0.02	1.60^{b}±0.08
Feed consumption/ kg gain*	3.60^{d}±0.5	4.99^{c}±0.21	6.15^{b}±0.13	7.25^{a}±0.47

^{abcd} Values in a row not sharing common superscripts differ significantly ** P(<0.01), * P(<0.05)

4.9. Digestibility of organic nutrients during finisher phase

The average digestibility (%) of nutrients in pigs fed finisher rations T-1 to T-4 are presented in Table 11

The digestibility of dry matter (DM) was 79.21, 78.10, 77.84 and 74.03 % in pigs fed T-1 to T-4, respectively and the differences among the rations were significant ($P<0.05$). The DM digestibility of T-1 ration fed pigs was significantly higher ($P<0.05$) than T-4 whereas it was comparable among T-2, T-3 or T-4 fed pigs.

The organic matter (OM) digestibility was 81.56, 77.08, 75.82 and 75.74 %, respectively in T-1 to T-4 fed pigs and was significantly higher ($P<0.05$) in T-1 than T-2, T-3 and T-4 fed pigs. There was no significant difference among T-2, T-3 or T-4 fed pigs.

The crude protein (CP) digestibility was 82.3, 76.76, 71.35 and 65.02 per cent, respectively in pigs fed T-1 to T-4 and the differences among the rations were significantly different ($P<0.01$). The CP digestibility of T-1 fed pigs was significantly ($P<0.01$) higher than T-2, T-3 or T-4 ration fed pigs. The CP digestibility of T-2, T-3 fed pigs was significantly ($P<0.01$) higher than T-4 fed pigs.

The crude fibre (CF) digestibility in pigs fed T-1 to T-4 was 47.76, 46.01, 44.55 and 42.91, respectively and the differences were non-significant.

Table 11: Nutrient digestibility during finisher phase

Nutrients	**T-1**	**T-2**	**T-3**	**T-4**
Dry matter*	$79.21^{a}\pm2.02$	$78.10^{ab}\pm1.28$	$77.84^{ab}\pm1.16$	$74.03^{b}\pm2.70$
Organic matter*	$81.56^{a}\pm0.64$	$77.08^{b}\pm0.59$	$75.82^{b}\pm1.96$	$75.74^{b}\pm2.07$
Crude protein**	$82.3^{a}\pm1.34$	$76.76^{b}\pm0.99$	$71.35^{b}\pm1.89$	$65.02^{c}\pm2.76$
Crude fibre	47.76±4.20	46.01±3.1	44.55±3.90	42.91±4.64
Ether extract	81.18±1.72	79.53±1.91	79.47±0.32	76.91±1.14
Nitrogen free extract	86.47±0.87	83.56±0.59	84.28±2.13	85.87±1.29

^{abc} Values in a row not sharing common superscripts differ significantly ** P(<0.01), * P(<0.05)

The ether extract (EE) digestibility in pigs fed T-1 to T-4 was 81.18, 79.53, 79.47 and 76.91 per cent, respectively and the differences were non- significant. The nitrogen free extract (NFE) digestibility in pigs fed T-1 to T-4 was 86.47, 83.56, 84.28 and 85.87, respectively and the differences were non-significant.

4.10. Nitrogen utilization of pigs fed finisher rations

The nitrogen balance of pigs fed different finisher rations is presented in Table 12

The nitrogen intake (g/day) of pigs fed T-1 to T-4 was 44.03, 44.38, 38.66 and 38.67 % respectively and the differences among the ration were non- significant. The N excretion in faeces (g/day) of pigs fed T-1 to T-4 was 7.60, 9.47, 10.99 and 11.69, respectively and it was higher ($P<0.01$) in T-3 or T-4 fed pigs than in T-1 fed pigs. However, there was no significant difference between T-1 or T-2, T-2 or T-3 and T-3 or T-4 fed pigs. The N excretion in urine (g/day) of pigs fed T-1 to T-4 was 4.34, 5.73, 7.87 and 10.08, respectively and it was higher ($P<0.05$) in T-3 or T-4 fed pigs. Similarly, the pigs fed T-3 excreted significantly more ($P<0.01$) nitrogen through urine than T-1 or T-2 fed pigs. The total N excretion (g/day) of pigs fed T-1 to T-4 was 11.25, 15.20, 18.86 and 21.74, respectively and it was higher ($P<0.01$) in T-3 or T-4 fed pigs than in T-1 or T-2 fed pigs.

The N retention (g/day) of pigs fed T-1 to T-4 was 32.09, 29.22, 19.80 and 12.32, respectively and it was higher ($P<0.\ 01$) in T-1 fed pigs than in T-3 or T-4 fed pigs. There was no significant difference between T-1 and T-2 rations.

Table 12: Nitrogen balance (g/d) of pigs fed different finisher rations

Nitrogen balance	**T-1**	**T-2**	**T-3**	**T-4**
Daily feed intake (g/d)	1707.33±55.99	1694±90.78	1455.75±76.55	1449.52±76.55
N intake (g/d)	44.03±3.97	44.38±2.19	38.66±1.56	38.67±2.26
N excretion (g/day)				
Faeces**	7.60^{c}±0.77	9.47^{bc}±0.23	10.99^{ab}±0.73	11.69^{a}±0.69
Urine**	4.34^{c}±0.55	5.73^{c}±0.63	7.87^{b}±1.94	10.08^{a}±0.90
Total**	11.25^{b}±1.17	15.20^{b}±0.77	18.86^{a}±2.06	21.74^{a}±1.32
N retention				
g/day**	32.09^{a}±3.35^{a}	29.22^{a}±2.36	19.80^{b}±2.37	12.32^{c}±3.19
Per cent intake**	72.89^{a}±1.95	65.78^{b}±2.52	51.21^{c}±4.83	31.86^{d}±6.54
Per absorbed**	88.09^{a}±1.82	83.60^{a}±2.55	72.10^{b}±3.24	46.75^{c}±4.22

[abc] Values in a row not sharing common superscripts differ significantly ** P(<0.01)

N retention in T-2 fed pigs was significantly (P<0.01) higher than in T-3 or T-4 fed pigs and there was significant (P<0.01) difference between T-3 or T-4 fed pigs. The N retention expressed as per cent intake was 72.89, 65.78, 51.21 and 31.86, respectively in pigs fed T-1 to T-4 and the differences were significant (P<0.01). It was higher (P<0.01) in T-1 and T-2 than inT-3 or T-4 fed pigs but there was no significant difference between T-1 or T-2 fed pigs. The N retention expressed in terms of per absorbed was 88.09, 83.60, 72.10 and 46.75, respectively for T-1 to T-4 fed pigs and the differences were significant (P<0.01). N absorption in terms of per cent was significantly higher (P<0.01) in T-1or T-2 fed pigs than in T-3 and T-4 fed pigs. It was also significantly higher (P<0.01) in T-3 than in T-4 fed pigs.

4.11. Economics

The cost of feed on different finisher rations is presented in Table 13

The cost of the finisher rations was calculated based on the cost of individual feed ingredients. The cost of T-1 to T-4 rations with inclusion of sheanut cake at 0, 50, 75 and 100 per cent levels by replacing DORB was Rs.16.44, 15.49, 15.00 and 14.32 per kg respectively. The cost of feed/kg weight gain was Rs.60.07,77.41, 92.35 and 103.94 in pigs fed T-1 to T-4, respectively and the differences were significant (P<0.01). The cost of feed per kg weight gain was significantly lower (P<0.01)in pigs fed T-1 or T-2 than those fed T-3 or T-4 while it was not significantly different between T-3 or T-4 fed pigs.

Table 13: Economics of feeding different finisher rations

Particulars	T-1	T-2	T-3	T-4
Cost of feed /kg weight gain**	60.07^{c}±8.49	77.41^{b}±3.35	92.35^{ab}±2.06	103.94^{a}±6.8

^{abc} Values in a row not sharing common superscripts differ significantly ** P(<0.01).

4.12. Overall performance characteristics of pigs during 15-70 kg body weight

The overall growth performance (15-70 kg) of pigs fed different rations is presented in Table 14.

There was no significant difference among pigs fed T-1 to T-4 in the initial and final weights as well as body weight gain.

The number of days taken by the pigs to reach target weight of 70 kg were 149, 167, 197 and 248, respectively for the rations T-1 to T-4 and the differences were significant (P<0.01). Number of days taken to reach 70 kg was the highest in T-4 fed pigs and was the lowest in T-1 fed pigs. The pigs fed on T-4 ration had taken significantly higher (P<0.01) number of days than all other groups. Similarly T-3 ration pig fed pigs had taken significantly higher (P<0.01) number of days than T-1 or T-2 fed pigs while difference between T-1 and T-2 fed pigs was not significant.

The average daily gain (ADG) of pigs fed T-1 to T-4 was 379.6, 331.2, 282.5 and 220.4 gm, respectively and the differences were significant (P<0.01). The ADG was the highest in T-1 and the lowest in T-4 fed pigs. The ADG in pigs fed T-1 was significantly higher (P<0.01) than T-2, T-3 or T-4 fed pigs. The ADG of pigs fed T-

2 was significantly higher (P<0.01) than T-3 and T-4 fed pigs and whereas T-3 was significantly higher (P<0.01) than T-4 ration pigs.

The average daily feed consumption of the pigs fed rations (T-1 to T-4) was 1.29, 1.54, 1.60 and 1.42 kg, respectively. There was a significant difference (P<0.01) in average daily feed consumption between groups. Feed consumed by T-3 ration pigs was higher but was not significant with T-2 rations and these two rations were significantly higher (P<0.01) than T-1 and T-4 rations. T-1 and T-4 rations do not differ significantly.

The feed consumed / kg gain was 3.50, 4.67, 5.67 and 6.45, respectively for pigs fed rations T-1 to T-4 and the differences were significant (P<0.01). Feed consumed per kg gain was the highest (P<0.01) in T-4 rations and the lowest in T-1 fed pigs. Feed consumed per kg was in the order T-4 > T-3 > T-2 > T-1.

Table 14: Overall growth performance of pigs fed different experimental rations

Characteristics	**T-1**	**T-2**	**T-3**	**T-4**
Number of pigs	6	6	6	6
Initial body weight (kg)	15.08±0.28	15.46±0.10	15.22±0.34	15.62±0.09
Final body weight (kg)	70.68±0.29	70.57±0.27	70.57±0.20	70.01±0.12
Weight gain (kg)	55.6±0.53	55.10±0.31	55.35±0.34	54.39±0.14
No. of days**	149±8.86^{c}	167±3.85^{c}	197±4.78^{b}	248±5.75^{a}
Daily gain (g/d)**	379.63±23.31^{a}	331.19±7.88^{b}	282.52±7.09^{c}	220.37±5.29^{d}
Feed consumption (kg/d)**	1.29±0.06^{b}	1.54±0.03^{a}	1.60±0.04^{a}	1.42±0.06^{b}
Feed consumed / kg gain**	3.50±0.30^{d}	4.67±0.12^{c}	5.67±0.11^{b}	6.45±0.27^{a}

^{abcd} Values in a row not sharing common superscripts differ significantly ** P(<0.01), * P(<0.05)

4.13. Economics

The cost of feed/kg gain in pigs fed on different rations are presented in Table 15

Table 15: Economics of feeding different rations

Particulars	T-1	T-2	T-3	T-4
Cost of feed per Kg weight gain**	57.81±4.99[c]	73.15±1.97[b]	86.47±1.69[a]	94.11±3.83[a]

[abc] Values in a row not sharing common superscripts differ significantly ** P(<0.01)

The cost of ration/kg gain for T-1 to T-4 fed pigs was Rs.57.81, 73.15, 86.47 and 94.11, respectively and the differences were significant (P<0.01). The cost of ration per kg weight gain was highest in T-4 fed pigs and was lowest in T-1 ration. There was no significant difference between pigs T-3 or T-4 fed and these two rations were significantly higher (P<0.01) than T-1 and T-2 rations. T-2 ration was significantly higher (P<0.01) than T-1 ration.

4.14. Carcass Characteristics

Two pigs from each group were slaughtered at a target body weight of about 70 kg. The carcass characteristics of pigs fed different rations are presented in Tables 16 and 17.

There was no significant difference among the pigs fed different rations for the various carcass characteristics (Table 16) such as slaughter weight, average dressing percentage, carcass length, average back fat thickness and loin eye area. Though the differences were non-significant, the dressing per cent of pigs fed T-1 (78.40), T-2 (76.13) and T-3 (76.36) were higher as compared to that of pigs fed T-4 ration (72.60).

The yield of carcass cuts and meat:bone:fat ratio of pigs fed on different rations was not significantly different among the different groups .

Table 16: Carcass characteristics of pigs fed different rations

Characteristics	**T-1**	**T-2**	**T-3**	**T-4**
Slaughter weight (kg)	70.83±0.53	71.05±0.75	68.5±0.30	68.5±1.60
Dressing percentage	78.40±0.57	76.13±4.07	76.36±0.68	72.60±1.34
Carcass length (cm)	71±1.52	75.25±0.75	71.50±0.50	72.00±2.00
Back fat thickness (cm)	2.51±0.11	2.02±0.25	2.27±0.01	2.24±0.21
Loin eye area (cm^2)	24.25±1.84	24±2.25	24.37±0.12	19.00±1.25

Table 17: Yields of meat cuts and Meat: Bone: Fat ratio of pigs fed different rations

Per cent yield	**T-1**	**T-2**	**T-3**	**T-4**
Meat	23.94±1.37	26.02±2.97	23.97±0.12	20.36±0.70
Bone	11.63±0.68	10.73±0.18	10.15±0.65	11.55±1.04
Fat	16.98±1.62	15.17±0.57	14.93±0.68	15.34±0.67
Ham	11.83±1.60	10.11±2.66	10.89±0.77	12.70±0.02
Loin	11.90±0.51	11.68±1.32	10.70±0.16	10.01±0.55
Shoulder	10.58±1.28	8.14±0.44	7.07±0.06	7.22±0.60
Meat : Bone : Fat	2.39:1.16:1.69	2.6:1.07:1.51	2.39:1.01:1.49	2.03:1.15:1.53

4.15. Serum Biochemistry

The serum biochemical profile is presented in Table 18.

Table 18: Serum biochemical profile of crossbred pigs fed different rations

Parameter	T-1	T-2	T-3	T-4
SGOT (U/l)**	47.60±1.92[a]	41.55±3.34[a]	30.31±0.57[b]	25.87±0.28[b]
SGPT (U/l)**	62.19±6.13[a]	44.82±3.51[b]	21.33±0.43[c]	17.17±1.29[c]
Total Protein (mg/dl)	8.31±0.12	8.30±0.20	7.93±0.02	7.86±0.05
Total Cholesterol (g/dl)**	48.68±1.22[a]	40.97±0.76[b]	32.70±0.54[c]	30.59±0.60[c]

[abc] Values in a row not sharing common superscripts differ significantly ** P(<0.01)

The SGOT in serum of pigs fed different rations was within normal range and the values were 47.60, 41.55, 30.31 and 25.87 U/l for pigs fed T-1 to T-4 respectively. SGOT levels were highest (P<0.01) in T-1 fed pigs and were lowest in T-4 fed pigs. There was no significant difference between T-1 or T-2 fed pigs but these values were significantly higher (P<0.01) than in T-3 or T-4 ration fed pigs. There was no significant difference between T-3 and T-4 ration fed pigs.

The SGPT values of pigs fed different rations were within the normal range except in T-4 fed pigs and the values were 62.19, 44.82, 21.33 and 17.17 U/l in pigs fed T-1 to T-4, respectively. The SGPT values of pigs fed T-3 or T-4 were comparable but were significantly lower (P<0.01) in T-1 or T-2 fed pigs.

The serum protein levels were within the normal range in all the groups and there was no significant difference among the pigs fed different rations. The serum protein values were 8.31, 8.30, 7.93 and 7.86 mg/dl for pigs fed T-1 to T-4, rations respectively.

The total cholesterol in serum was within normal range in pigs fed T-1 or T-2 but less than the normal in T-3 or T-4 fed pigs and there was significant ($P<0.01$) difference among the groups and the values were 48.68, 40.97, 32.70 and 30.59 g/dl in T-1 to T-4 fed pigs respectively. Total cholesterol level in pigs fed T-1 was significantly higher ($P<0.01$) than in T-2 fed pigs. The values for pigs fed T-2 ration fed pigs were significantly higher ($P<0.01$) than T-3 or T-4 rations. There was no significant difference between T-3 and T-4 rations.

CHAPTER-5

Discussion

The search for alternate, low cost unconventional feed ingredients to economise livestock production is a continuous process since the feed cost represent more than 70 per cent of the total cost of pig production. Several attempts have been made in the past to use low cost unconventional feed ingredients in pig rations to reduce the cost of production. The results of present study on effect of inclusion of sheanut (*Vitellaria paradoxa*) cake at different levels in grower and finisher swine rations on growth, nutrient utilization and carcass characteristics is discussed together with the available literature.

5.1. Chemical composition of sheanut cake

The DM and NFE contents of SNC used in the present study were less than the mean values of previous reports (Table A) whereas the CP, EE, CF, TA values were higher than the mean values of earlier findings.

The tannin and saponin content of sheanut cake observed in the present study was 4.36 and 0.33 per cent, respectively. The tannin content was less than the mean value of earlier reports whereas the saponin content was comparable to the previous reports (Table D).

5.2. Ingredient and chemical composition of grower rations

The sheanut cake was included at 0 (T-1), 50 (T-2), 75 (T-3) and 100 (T-4) per cent levels by replacing DORB in the grower rations. All the rations were made iso- nitrogenous by adjusting the maize and soyabean meal levels. The CP content of grower rations T-1 to T-4 was 18.13, 18.29, 18.51 and 18.45 per cent, respectively. Since, the EE content of sheanut cake was higher than that in DORB, the EE content of the grower rations T-2 to T-4 was 3.06, 4.04 and 4.29 % respectively and was more than the value of 2.95 % in T-1 ration. The CF content of the grower rations increased as the level of SNC increased and the values were 8.81, 8.67, 9.12 and 9.9 per cent respectively for T-1 to T-4.

The total ash content (8.02, 7.86, 7.62 and 7.54) of the all grower rations decreased as the level of SNC increased in the rations. The NFE content of the rations were almost similar.

5.3. Cost of the grower rations

As the level of inclusion of SNC increased, the cost of the ration (Rs per kg) decreased from 16.66 (T-1) to 15.22 (T-4).

5.4. Performance of pigs during grower phase

The growth performance of the pigs during grower phase (Table 4) revealed no significant difference among the treatments in initial and final body weights, weight gain and feed consumption. However, the number of days taken to reach the final body weight of 35 kg was significantly increased ($P<0.01$) by 45, 35, 36 days in pigs fed T-2 to T-4, respectively than those fed T-1. This has led to a corresponding significant decrease ($P<0.01$) in the ADG by about 80, 137, 143 gm in pigs fed T-2 to T-4 respectively than those fed T-1 as the level of SNC increased. The feed consumed /kg gain increased significantly ($P<0.01$) by 0.8, 1.54, 1.73 kg due to SNC inclusion in T-2 to T-4 when compared to pigs fed control ration indicated that feed efficiency declined progressively beyond 50 % SNC inclusion.

The significant decrease in ADG and increase in feed/kg gain during grower phase might be attributed to the significant ($P<0.05$)decrease in DM and

CP digestibility particularly in T-3 and T-4 fed pigs when compared with pigs fed T-1. However, the OM, CF, EE and NFE digestibilities were not significantly different among the treatments.

Further the N balance study (Table 6) revealed that the N intake (g/day) significantly ($P<0.05$) decreased in pigs fed rations containing SNC i.e., T-2 to T-4 than those fed T-1 due to decrease in the feed intake. The decrease in N intake was 8.3, 36.3 and 48.1 per cent in T-2 to T-4 fed pigs, respectively than those fed T-1. However, no significant differences were observed in the N excretion g/day in faeces urine and the total N excreted among the treatments. The N retention expressed as g/day, as per cent intake or as per cent absorbed was comparable between T-1 and T-2 but was significantly ($P<0.05$) lower in T-3 or T-4 fed than in T-1 or T-2 fed pigs. The tannin, saponins and theobromine content in SNC might have caused poor feed intake, decrease in digestibilities of CP and DM and reduced N retention leading to poor growth performance. Several earlier reports (Cheeke 1971, Kendall and Leath 1976, Tung *et al.,* 1977, Cheeke *et al.,* 1978, Livingston 1977) attributed decreased feed intake to the saponins content in the diets of animals.

In the present study also the saponins content of diets gradually increased form 0.05 % in T-2 to 0.1 % in T-4. The tannin content of diets was 0.61. 0.92 and 1.3 % in T-2 to T-4 in the present study. Poor weight gain and inferior feed efficiency in pigs fed T-2 to T-4 might also be due to tannin content in SNC and it is in agreement with observations of (Armstrong *et al.,* 1974, Ahmed et *al.,* 1991, Trevino *et al.,* 1992, Iji *et al.,* 2004).

The decrease in DM and CP digestibilities in rations T-2 to T-4 might be attributed to the saponins (Ishaaya and Birk 1965, Cheeke 1971, Liener 1990, Long staff and McNab 1991), tannins (Salunkhe *et al.*, 1990, Livingston and McNab 1991, Schmidt *et al.,* 1994, Van Leeuwen *et al.*, 1995, Jansman *et al.,* 1995, Jeroch *et al.,* 1996, Salobir *et al.,* 1997, Farrell *et al.,* 1999, Salobir *et al.*,2005) and theobromine (Longstaff and McNab 1991) content of SNC.

The nitrogen retention (g/d) decreased (P<0.01) linearly as the level of SNC in the rations increased and significant difference was observed among the rations. The present results are similar to the earlier observations of Jansman *et al.,* (1993, 1995) Salobir *et al.*, (1997) who reported that tannins in the feed increase the excretion of endogenous protein.

5.5. Ingredient and chemical composition of finisher rations

The ingredient and chemical composition of finisher rations T-1 to T-4 were presented in Table 8 and 9. The sheanut cake was included at 0 (T-1), 50 (T-2), 75 (T-3) and 100 (T-4) per cent levels by replacing DORB in the grower rations. All the rations were made iso nitrogenous by adjusting the maize and soyabean meal levels. The CP content of grower rations T-1 to T-4 was 16.12, 16.39, 16.52 and 16.67 per cent, respectively. Since, the EE content of sheanut cake was higher than EE content of DORB, the EE content of the finisher rations, T-2 to T-4 increased linearly from 3.79 in T-1 to 4.54 (T-2), 5.50 (T-3) and 7.14 (T-4) per cent, respectively. The CF content of the finisher rations increased as the level of SNC increased and the values were 10.18, 11.80, 12.20 and 13.30 % respectively, for T-1 to T-4.

The total ash content of 7.59, 7.86 and 8.40% in T-2 to T-4, respectively was higher than in T-1 (7.01%). The NFE contents of the rations were 61.83, 58.51, 56.31 and 54.85 %.

5.6. Cost of finisher rations

As the level of inclusion of SNC increased in the finisher rations, the cost of the ration (Rs) per kg decreased and it was 16.40, 15.49, 15.00 and 14.32 for T-1 to T-4, respectively.

5.7. Performance of pigs during finisher phase

The growth performance of the pigs during grower phase (Table 10) revealed no significant difference among the treatments in initial and final body weights, and weight gain. However, the daily feed consumption was significantly ($P<0.01$) increased from T-1 to T-3 ration fed pigs but it was low in T-4 ration fed pigs. The number of days taken to reach 70 kg from 35 kg was also significantly increased ($P<0.01$) by 2, 11, 62 days in pigs fed T-2 to T-4, respectively than those fed T-1 ration. As the daily feed intake was less in T-4 fed pigs than in pigs fed other rations the number of days taken to reach the target body weight increased. The increase in number of days had led to a corresponding significant decrease ($P<0.01$) in the ADG by about 11, 61, 173 g in pigs fed T-2 to T-4 rations respectively than those fed T-1 ration. The feed consumed per kg gain significantly increased ($P<0.05$) by 1.39, 2.55, 3.65 kg due to SNC inclusion in T-2 to T-4 rations when compared to pigs fed control ration.

The significant decrease in ADG and increase in feed intake/kg gain during finisher phase might be attributed to the significant ($P<0.01$) decrease in the DM, OM and CP digestibility. However, there was no significant difference in the EE, CF and NFE digestibility among the treatments. The decrease in DM, OM and CP digestibilities in rations T-2 to T-4 might be attributed to the saponins (Ishaaya and Birk 1965, Cheeke 1971, Liener 1990, Long staff and McNab 1991), tannins (Salunkhe *et al.*, 1990, Livingston and McNab 1991, Schmidt *et al.*, 1994, Van Leeuwen *et al.*, 1995, Jansman *et al.*, 1995, Jeroch *et al.*, 1996, Salobir *et al.*, 1997, Farrell *et al.*, 1999, Salobir *et al.*,2005) and theobromine (Longstaff and McNab 1991) content of SNC.

The N balance study (Table 12) revealed that there was no significant difference in the N intake among the pigs fed rations containing different levels of SNC, although the intake was less N excretion through faeces was significantly increased (P<0.01) as the level of SNC increased in rations of pigs.

The N retention expressed as g/day, per cent intake or per cent absorbed was comparable between T-1 and T-2 but was significantly (P<0.05) lower in T-3 or T-4 fed pigs. The feed intake during metabolism trial was lower in T-2 to T-4 fed pigs than those fed T-1, although during the entire growth period the trend was reverse. The tannin, saponins and theobromine content in SNC might have caused poor feed intake. Several earlier reports (Cheeke 1971, Kendall and Leath 1976, Tung *et al.*, 1977, Cheeke *et al.*, 1978 and Livingston 1977) attributed decreased feed intake to the saponins content in the diets of animals. Poor weight gain and inferior feed efficiency in pigs fed T-2 to T-4 might also be due to tannin content in SNC and it is in agreement with earlier observations (Armstrong *et al.*, 1974, Ahmed et *al.*, 1991, Trevino *et al.*, 1992, Iji *et al.*, 2004).

In the present study also the saponin content of diets gradually increased with higher levels of SNC rations and the values were 0.04, 0.06 and 0.1 % in T-2 to T-4, respectively. The tannin content of diets was 0.61. 0.92 and 1.3 % in T-2 to T-4, respectively.

The nitrogen retention (g/d) decreased (P<0.01) linearly as the level of SNC in the rations increased. The present results are similar to the earlier observations of Jansman *et al.,* (1993, 1995) and Salobir *et al.,* (1997) who reported that tannins in the feed increases the excretion of endogenous protein. Further the CF content of rations increases with the inclusion of SNC and might have caused reduced nitrogen retention. The results are also in agreement with the earlier observations of Cunningham *et al.,* (1962), Ranjhan *et al.,* (1971), Srinivasa Rao *et al.,* (1989), Geetha Priya *et al.,* (2000) and Hongbari Ingtipi (2003), who reported reduced N retention with increased fibre levels in swine rations.

5.8. Overall performance of pigs

The overall performance i.e., from 15-70 kg revealed no significant differences in the initial and final body weights and in the body weight gain among treatments. The pigs fed on T-3 or T-4 had taken significantly (P<0.01)more number of days to attain the slaughter weight than those fed on T-1 or T-2 while there was no difference in T-1 or T-2 fed pigs. The ADG of T-4 ration fed pigs was significantly (P<0.01) lower as compared to T-1. The ADG was significantly lower (P<0.01) in pigs fed T-2 to T-3 i.e., rations containing SNC from those fed control ration (T-1). Similar to the earlier findings of Ishaaya and Birk (1965), Livingston *et al.,* (1977), who reported poor growth rate due to saponin content in the fed. The decreased ADG led to the increased number of days to reach the slaughter weight of 70 kg body weight. The ADG was lower by 48, 97 and 159 gm in pigs fed on T-2, T-3 or T-4 than those fed T-1, respectively. The average daily feed intake was significantly (P<0.05) higher in T-2 or T-3 fed pigs than those fed T-1 or T-4. The feed/kg gain was significantly higher

(P<0.01) in pigs fed rations containing SNC i.e., T-2 to T-4 from those fed T-1 and the values were higher by 1.11, 2.17 and 2.95 in T-2 to T-4 fed pigs than those fed T-1.

The cost of ration (Rs per kg gain) in pigs fed different rations from the start of the experiment (15 kg to the slaughter weight of 70 kg), was 57.81, 73.15, 86.47 and 94.11, respectively and it increased by 15.34, 28.66 and 36.30 in T-2, T-3 and T-4 fed pigs respectively than those fed T-1.

5.9. Carcass characteristics

There was no significant difference in slaughter weight, dressing percentage, carcass length, loin eye area and back fat thickness among the pigs fed experimental rations. Similarly earlier workers (Thomas and Anjaneya Prasad,1983; Srinivasa Rao *et al.,* 1989; Madhava Rao,2000 and Hongbari Engtipi,2003) also reported no significant differences in carcass characteristics in pigs fed rations containing unconventional feed ingredients like tamarind seed and molasses, groundnut haulms, guava pomace and red gram chuni, respectively.

The per cent yield in terms of total meat, ham, loin, shoulder, bone and fat were not influenced by the experimental rations . The meat, bone and fat ratios were 2.39:1.16:1.69, 2.6:1.07:1.51, 2.39:1.01:1.49 and 2.03:1.15:1.53 for pigs fed T-1 to T-4, respectively. Similar to the present findings, Geetha Priya *et al.,* (2000), Madhava Rao (2000) and Hongbari Engtipi (2003) reported no significant difference in per cent yields of total meat, ham, loin, shoulder and bone with crossbred pigs fed rations containing amaranthus whole plant meal, guava pomace and red gram chuni, respectively.

5.10. Serum Biochemistry

The SGOT, SGPT values were reduced (P<0.01) in T-3 or T-4 than in T-1 or T-2 fed pigs. However, in all treatments the SGOT values were within the normal range. SGPT value of T-4 ration fed pigs was less than the normal value which indicated that there was effect of SNC on the liver function. The serum protein levels were also in normal range and there was no significant difference between treatments though the values decrease linearly from T-1 to T-4 rations fed pigs. This is not in agreement with the findings of Olorede and Longe (1999) and Elemo *et al.,* (2011) who reported that the total protein levels in serum reduces with the inclusion of SNC.

The decrease in total cholesterol levels than the normal level in case of T-3 and T-4 ration fed pigs might be attributed to the saponins (Malinow *et al.,*1977) and the hypocholesteromic condition in these two ration fed pigs was similar with the findings of Atuahene *et al.,* (1998) and Olorede and Longe (1999).

5.11. Economics of inclusion of Sheanut cake in pig rations

The total feed consumption, cost of the rations, total gain in body weight and the total meat produced were taken into account while calculating the cost per kg live weight gain or kg pork produced. The cost per kg of the grower and finisher rations were Rs. 16.66, 15.96, 15.72, 15.22 and 16.40, 15.49, 15.00 and 14.32, respectively for T-1 to T-4 rations. From the start of the experiment (15 kg) till slaughter (70 kg), the total feed consumed for the rations T-1(grower+finisher), T-2(grower+finisher), T-3(grower+finisher) and T-4(grower+finisher)was 195.01, 257.83, 314.40 and 351.18 kg, respectively and the differences between the rations were significant (P<0.05). The total feed cost for the rations per kg weight gain was Rs. 57.81, 73.15, 86.47 and 94.11, respectively for rations T-1 to T-4 and the differences among the rations was significant($P<0.05$). Based on the results obtained in the present study it can be concluded that the performance of pigs during grower or finisher phase declined as inclusion level increased beyond 50%. Hence safe level of inclusion can be worked out by using SNC below 50% and it requires further studies to utilize sheanut cake as an alternate feed resource in swine feeding.

CHAPTER-6

6. SUMMARY

In a completely randomized design experiment, twenty four crossbred male pigs (15.35±0.11) of 75 per cent exotic inheritance were divided into 4 groups of 6 animals each to study the effect of inclusion of sheanut (*Vitellaria paradoxa*) cake on the growth performance, nutrient utilization and carcass characteristics.

Four isonitrogenous rations were formulated for pigs with 0(T-1), 50(T-2), 75 (T-3) and 100 % (T-4) inclusion of sheanut cake by replacing DORB. Maize and soyabean meal were the other feed ingredients used. The levels of maize and soyabean meal were adjusted to male the rations isonitrogenous. Each group of pigs was allotted to one of the rations at random and fed *ad libitum* till they attained 35 kg body weight. A digestion-cum-metabolism trial was conducted during the grower phase.

The number of days taken to reach 35 kg body weight were 93, 95, 105 and 156, respectively and the differences among the treatment were significant (P<0.01). As the days increased the ADG decreased significantly (P<0.01).The efficiency of feed utilization decreased linearly (P<0.01) with increased levels of sheanut cake in grower rations. The cost of the ration/ kg gain was Rs. 55.22, 65.75, 76.28 and 76.82, respectively, for T-1 to T-4 fed pigs and as the level of sheanut cake increased the cost of ration/kg gain increased linearly.

Uniform trend of reduction in the digestibilities of various organic nutrients (DM, OM, CP, CF and EE) was observed with the increased levels of sheanut cake in the rations and the differences among the rations were significant for OM and CP (P<0.01).

The nitrogen retention (g/day) for pigs fed T-1 to T-4 decreased significantly (P<0.01) as the inclusion level of sheanut cake increased. The N retention expressed as per cent of intake or per cent absorbed were also decreased significantly (P<0.01).

Whenever a pig attains a body weight of 35 kg it was shifted to its corresponding finisher ration (T-1 to T-4) and fed *ad libitum* till it attained a predetermined slaughter weight of 70 kg. A digestion-cum-metabolism trial was conducted in the finisher phase.

There was significant difference in the number of days to reach 70 kg body weight, ADG, feed consumption per day (P<0.01) and EFU (P<0.05). The cost of the feed per kg gain (Rs) were 60.07, 77.41, 92.35 and 103.94 respectively for T-1 to T-4 rations and the cost increased significantly (P<0.01) as the level of sheanut cake increased in the diets.

The digestibility of DM, OM (P<0.05) and CP (P<0.01) decreased significantly with increased level of sheanut cake in the finisher rations. A linear decrease was observed without any significant difference in the digestibility of CF and EE in pigs fed finisher rations containing sheanut cake.

The nitrogen excretion (g/day) in faeces, urine and total N excretion decreased (P<0.01) significantly as level of inclusion of sheanut cake increased in finisher rations. The N retention (g/day), N retention expressed as per cent intake or per cent of absorbed were also decreased significantly (P<0.01).

The number of days taken to reach from 15 to 70 kg body weight in pigs fed T-4 (248) was significantly (P<0.01) higher as compared to T-1 (149). The differences were non-significant for pigs fed T-1 and T-2. The average daily feed consumption of pigs fed T-3 (1.60) was highest (P<0.01) than T-1(1.29).

The ADG (g) between 15 and 70 kg in pigs fed T-1 (380) was significantly higher ($P<0.01$) than those fed T-4 (220), T-3 (283) and T-2 (331). The efficiency of feed utilization (feed/gain) in the pigs fed T-1 to T-4 was decreased significantly ($P<0.01$).

No significant difference was observed in the average dressing percentage, back fat thickness (cm) and loin eye area (cm^2) between different treatment groups.

Based on the present investigation with pigs from 15 to 70 kg live weight it can be concluded that the performance of pigs during grower or finisher phase declined as inclusion level increased beyond 50%. Hence safe level of inclusion can be worked out by using SNC below 50% and it requires further studies to utilize sheanut cake as an alternate feed resource in swine feeding.

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Fig no. 9 Two splits of carcass

Fig no.10Measurement of carcass length

Fig no.11Measurement of backfat thickness

Fig no.12Loin-eye area

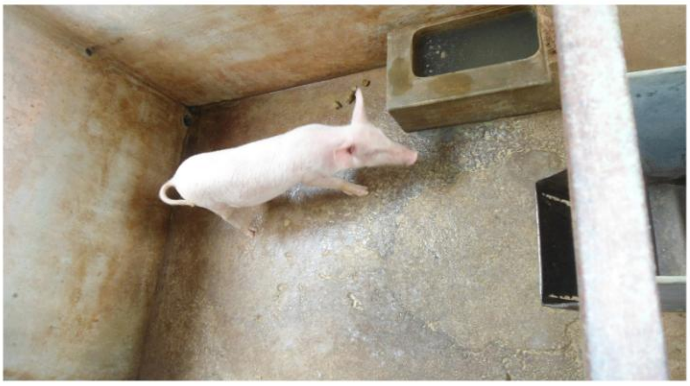

Fig No.6 **Experiemental animal in covered area of the pen**

Fig No.7 **Experiemental animal under metabolic trial**

Fig No.8 **Measurement of body weight of the experimental animal with electronic weighing balance**

Fig No.1 Sheanut tree

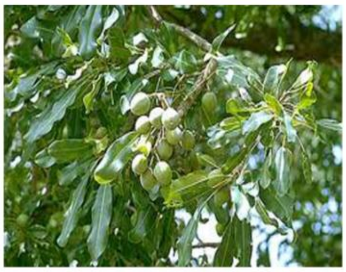

Fig No.2 Sheanut tree with friuts

Fig No. 3 Sheanut fruit

Fig No. 4 Sheanuts

Fig No. 5 Sheanut cake