DOI: https://dx.doi.org/10.4314/gjpas.v31i3.12

global journal OF PURE AND APPLIED SCIENCES VOL. 31, 2025: 559-571
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CHEMICAL COMPOSITION AND FEEDING VALUE OF SANDBOX (*Hura crepitans*) SEED MEAL AS AN ALTERNATIVE PLANT PROTEIN SOURCE FOR RABBITS IN SOUTHERN NIGERIA

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(Received 8 March 2025; Revision Accepted 2 April 2025)

ABSTRACT

The chemical composition and feeding value of sandbox seed meal (SBSM) were evaluated in this study. The mature pods were harvested from sandbox trees and broken to obtain the seeds. The seeds were sun dried to constant weight before milling and the oil was extracted. The final samples were subjected to chemical analyses. Sixty cross bred weaned rabbits of mixed sexes between the ages of 7 and 8 weeks old, with mean body weight (933.66±2.53g) were used in the determination of the feeding value of SBSM. Five experimental diets were formulated where SBSM replaced soybean meal at 0, 25, 50, 75 and 100 % for T_1, T_2, T_3, T_4 and T_5, respectively. The feeding trial lasted for 60 days. At the end, 6 rabbits per treatment were sacrificed for carcass evaluation. All data obtained were subjected to one way analysis of variance. Result showed the proximate composition of SBSM as 90.75 % dry matter, 26.88 % ether extract, 5.02 % ash, 24.41 % crude protein,11.49 % crude fibre and 33.20 % nitrogen free extracts. The anti-nutrients were 19.10 mg/g oxalate, 1.67 mg/g tannins, 3.45 mg/g alkaloids, 6.44 mg/g saponins, 0.20 mg/g flavonoids, 2.56 mg/g cyanogenic glucosides and 1.05 mg/g trypsin inhibitors. The fatty acids were linoleic acid (10.03%), oleic acid (7.48%, stearic acid (4.62%), linolenic acid (4.49%), palmitoleic acid (2.44%), lauric acid (0.21%) and palmitic acid (1.00%). The mineral composition showed potassium (189.51 mg/g), calcium (7.45 mg/g), sodium (5.08 mg/g), zinc (1.94 mg/g), iron (6.95 mg/g), copper (0.86 mg/g) and phosphorus (0.41 mg/g); while vitamins A, E, K, C and D were 405.72 IU, 0.87, 0.41, 0.03 and 1.80 mg/100g, respectively. Growth performance parameters showed significant ($p<0.05$) effect on final weight, daily weight gain, daily feed intake and FCR, respectively. Carcass characteristics showed significant ($p<0.05$) effect in the relative weight of the thigh, back cut and rack. The study concluded that sandbox seed meal is rich in nutrients and moderate in anti-nutrients. Therefore, can serve as a good alternative plant protein. Sandbox seed meal can conveniently replace soybean meal up to 75 % without adverse effects on performance of rabbits.

KEYWORDS: Carcass, performance, protein, phytochemicals, rabbit

INTRODUCTION

The urgent need to increase livestock production as a means of alleviating the overwhelming shortage of animal protein is very vital to humanity (Mamphogoro *et al*., 2024). The demand for protein of animal origin in Nigeria is greater than the supply, there is therefore acute shortage of animal protein in the diets of many Nigerians, demanding that efforts should be directed to livestock that are prolific and have short gestation interval such as rabbits (Ibitoye *et al*., 2010).

The domestic rabbit when compared with other livestock is characterized by early sexual maturity, high prolificacy, relatively short gestation period, short generation interval, high productive potential, rapid growth, good ability to utilize forages and fibrous plant materials and agricultural by-products (Oke *et al*., 2016). It is also more efficient in feed conversion, low cost per breeding female and high profitability for small-scale system of production in backyards (Okon *et al*., 2007).

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Rabbit meat is nearly white, fine grained, palatable, mild flavoured, high in good quality protein content, low in fat and caloric contents, contains a higher percent of minerals than other meat types, nearly of the same nutritive value as beef and comparable to that of broiler chicken, of good meat-to-bone ratio and is acceptable to the general consumers in most countries of the world (Nsa *et al*., 2020).

Feed insufficiency is due to stiff competition with need for human food, particularly for the fast growing and prolific monogastric species and for concentrates mixtures in ruminants (Oso *et al*., 2009). The livestock sector is a significant contributor to the livelihoods of the world's poor and is the fastest-growing field of agricultural output worldwide (Akash *et al*., 2022); hence the prices of various feed ingredients in recent years have risen to the extent that the cost per unit feed is now very high making rabbit production more expensive and its products inaccessible. This high cost of feed coupled with the neglect of possible alternative and cheap feed ingredients are among important factors militating against increased commercial rabbit production in Nigeria. However, these have encouraged the utilization of alternative feed resources that are less competed for by humans, readily available and cheap. These can partly substitute the conventional feedstuffs in rabbits and other livestock diets. Out of many options advocated to finding lasting solutions to current high cost of conventional feedstuffs is the replacement of the conventional with non-conventional feedstuffs in rabbit diets (Nsa *et al*., 2020). A number of alternative feed stuffs aimed at lowering the cost of feeds had been severally evaluated at various stages of rabbit production. Many agricultural by-products and indigenous forages in Nigeria had been evaluated and found to be good substitutes for conventional feed stuffs; furthermore, rabbits adapt well in household production due to their low investment and labour costs. As herbivores, rabbits do not compete with humans for food, making this a sustainable practice (Ahmad *et al*., 2018).

Sandbox (*Hura crepitans*), also known as the dynamite tree, is a species of flowering plants that belongs to the *Euphorbiaceae* family. It is native to South America and is commonly found in countries such as Brazil, Nigeria, Guyana and Venezuela (Abdulkadir *et al*., 2003). The tree is so named from the sound made when its fruit capsules explode, which is similar to the sound of dynamite blast. The tree can grow up to 30 m tall and has a distinctive appearance with its large, rounded crown and long slender trunk. The leaves are glossy and dark green in colour and are about 25 – 40 cm long. The tree produces small green flowers that are followed by large, woody fruit capsules that are up to 30 cm long (Vogel, 2013). These fruit capsules contain many seeds and are dispersed through explosive dehiscence, which is the process of capsule walls breaking open to release the seeds.

Sandbox tree has a number of traditional uses and is considered to be a valuable resource in many South American communities. The wood is hard and durable, making it suitable for use in construction, furniture, and tool-making. The sap of the tree is useful in traditional medicine as it is believed to have anti-inflammatory and pain-relieving effects (Fowomola, 2006).

However, despite its diverse uses; the sandbox tree is considered to be an invasive species in many parts of the world. The tree's explosive fruit capsules can cause damage to property and are considered to be a safety hazard. It has a fast growth rate and ability to outcompete native plants also makes it a threat to the ecosystem (Fowomola and Akindahunsi, 2008). The high cost of conventional vegetable protein sources mainly groundnut (*Arachis hypogea*) and soybean meal (*Glycine max*) has largely contributed to the existing high prices of monogastric animals in Nigeria (FAO, 2015). To improve the production and consumption in Nigeria, where per caput animal protein intake is much below recommended levels, there is need to source for readily available, high quality alternative protein sources that are cheaper and capable of reducing the production cost of feeds. This problem could be solved through utilizing the little known or neglected tropical plants available in Nigeria such as sandbox (*Hura crepitans*). There are under-utilized but may possess as much agronomic and nutritional potentials as the conventionally used legumes, more especially as humans do not commonly consume them.

Sandbox has promising seeds with high crude protein and oil contents (Abdulkadir *et al*.,2003). The tree (*Hura*) is shady with a thorny trunk commonly found along roadsides in towns and villages. The woody segmented fruit shape is like that of garden egg, and when dry, bursts releasing several flattened circular seeds of about 18-20 mm in diameter (Keay, 2010). The dry matter content of the seed (91-95 %) is quite comparable to those of the conventional feedstuffs, a good indicator of its high storage life, that is devoid of mould growth (Nsa and Archibong, 2019). The ether extract of the seed ranges from 38.95-51.24 %. These seeds are found to be moderate in crude protein and rich in carbohydrate and minerals most especially Na, K, Ca, and trace amounts of Mg, Fe, and Zn (Esonu *et al*., 2014). In terms of the essential amino acids content of the seeds, arginine has the highest value followed by leucine (Yaakugh, 2001). Notwithstanding, the seed is known to have some anti-nutritional factors such as saponin, phytate and hemagglutinins.

This study therefore evaluated the chemical composition (proximate, anti-nutrients, minerals, fatty acids and vitamins) as well as the feeding value (growth performance and carcass characteristics) of sandbox seed meal as a potential plant protein source to replace soybean meal in rabbit diets.

MATERIALS AND METHODS

Study location and collection of Sandbox seeds

In this study, the chemical analysis was carried out at the Central laboratory of the Faculty of Agriculture; while the animal feeding trial was carried out at the Teaching and Research Farm, University of Calabar, Calabar, Nigeria. The study site (Calabar) is located at latitude 4°57′ N of the equator and longitude 8°19′ E of the Greenwich meridian, with a land mass of 233.2 sq miles (604 km^2). The average annual rainfall is 1830 mm and average daily temperature is 24.30°C (77°F), respectively and a relative humidity between 70 and 80 % (NiMet, 2024).

Mature sandbox (*Hura crepitans)* seeds were harvested from sandbox trees within the University of Calabar premises (Abraham Ordia Stadium). The pods were broken with hammer to remove the seeds. The seeds were subsequently sun - dried to constant weight for 7 days to prevent spoilage or sprouting out. Oil was extracted from the seeds through mechanical means as described by Nsa *et al.* (2020). Thereafter, the seeds were milled with a hammer mill to obtain sandbox seed meal (SBSM) and stored for determination of chemical composition and diet formulation, respectively.

Chemical analyses

Determination of proximate composition

The proximate analysis of the SBSM samples and experimental diets was carried out using the methods of AOAC (2023). The dry matter, crude protein, ether extract, ash, crude fibre and nitrogen-free extract were determined.

Determination of mineral composition

The Atomic Absorption Spectrometer (AAS) (model 703 Perkin Elmes, Norwalk, CT, USA) was used in the determining calcium, copper, zinc and iron. Sodium and potassium were determined using a flame photometer (Sherwood flame photometer 410, Sherwood Scientific Ltd., Cambridge, UK), while phosphorus concentration was measured using the Vanadomolydate method (AOAC, 2023).

Phytochemical screening (anti – nutrients)

The phytochemical determination of anti- nutrients (cyanogenic glycosides, tannins, oxalate, and alkaloids) was carried out using the methods described by Harborne (1973) and AOAC (2023). The phytate content was determined by the anion-exchange method as described by AOAC (2000), using phosphate as the standard. Trypsin activity was monitored using the method of Prokopet and Unlewonick (2002), while saponins were determined using spectrometric method and the total flavonoids and alkaloids were determined according to the methods outlined by Harborne (1973).

Fatty acid determination

The compositions of both essential and non-essential fatty acids in the SBSM were determined using the chemical titration method; the fat and oil were dissolved in hot neutralized ethanol or diethyl ether using phenolphthalein as an end-point indicator.

Determination of vitamin composition

The vitamins composition of SBSM was assayed using the High - Performance Liquid Chromatography (HPLC) method as described by Zhang *et al*. (2018).

Housing of rabbits

The rabbits were housed in concrete cages with wire mesh floor, measuring 65 × 65 × 65 cm^3 and raised 20 cm from ground level. The cages and entire rabbitry unit were thoroughly washed with disinfectant (Izal) and detergent and were allowed to dry for seven days before the animals arrived. Concrete watering and feeding troughs were placed in each cage. The rabbit cages were housed in a well-ventilated building with half walls and asbestos roofing sheets.

Experimental diets

Five experimental diets were formulated and sandbox seed meal (SBSM) replaced soybean meal at 0, 25, 50, 75 and 100 % for T_1, T_2, T_3, T_4 and T_5, respectively. The gross composition of experimental diets is presented in Table 1. The proximate analyses of the test ingredient and experimental diets were carried out according to the methods of AOAC (2023).

Experimental animals, and management

Sixty growing crossbred weaned rabbits (mixed sexes) between the ages 7 and 8 weeks old, with a mean body weight of 933.66±2.53g were used in this study. The rabbits were obtained from a standard commercial rabbitry in Calabar, Cross River State. The rabbits were intensively managed in concrete cages with wire mesh floor in a standard rabbitry. The feeding trial lasted for 60 days.

Experimental design

The rabbits were randomly assigned to different dietary treatments after weight and sex equalization in a Completely Randomized Design (CRD) experiment. Each experimental group/ dietary treatment comprised twelve (12) rabbits (6 buck and 6 does) and each rabbit served as a replicate. The experimental model used was as follows: $Y_{ij} = \mu + T_i + E_{ij}$

Where: Y_{ij}= Observed value

μ= overall mean value

T_i= Random treatment effect

E_{ij}= Random residual error

Data collection

Feed intake (g/day)

The quantity of feed fed to rabbits was measured and recorded on a daily basis and the left over was subtracted from the quantity fed the previous day to determine the quantity consumed by each rabbit.

Feed intake = Quantity of feed served – Quantity of left over feed.

The average feed intake was thereafter divided by number of days to get the daily feed intake.

$$\text{Average daily feed intake (g/day)} = \frac{\text{Mean total intake (g)}}{\text{Number of days of feed intake (7 days)}}$$

Body weight gain

Initial body weight of rabbits per replicate was taken at beginning of the study and subsequently on a weekly basis. A top loader weighing scale was used to determine the weight of the rabbits.

$$\text{Average Daily Weight Gain (g/day)} = \frac{\text{Mean final body weight – Mean initial body weight (g)}}{\text{Number of days (7 days)}}$$

Feed conversion ratio (FCR)

Feed conversion ratio is the total amount of feed consumed by the animal and divided by the amount of weight gain.

$$\text{FCR} = \frac{\text{Total feed intake}}{\text{Total weight gain}}$$

Carcass evaluation

At the end of the feeding trial, 6 rabbits per treatment whose individual weight was equal or close to the mean weight (three bucks and three does) per treatment were selected for carcass evaluation. Prior to slaughter, the rabbits were starved of feed for 12 hours with ample supply of drinking water. The animals were weighed and slaughtered by severing the jugular and carotid veins as described by Aduku and Olukosi (1990). Live weight was determined and each animal was eviscerated with all the viscerals removed *intoto,* thereafter the dressed carcasses were singed. Carcass weight was determined prior to further dissection into different cuts (head, neck, shoulder, thigh, loin, forelimb, hindlimb, rack and back cut).

Statistical analysis

All data collected were subjected to one way analysis of variance (ANOVA) for CRD (Steel and Torrie, 1980). Significant means were separated using Duncan's New multiple Range Test of GenStat Release 8.1 software package (GenStat, 2021).

RESULTS AND DISCUSSION

Chemical composition of sandbox seed meal

The result of the chemical composition of sandbox seed meal is presented in Tables 2 and 3, respectively. The results showed that the proximate composition, vitamins, minerals, anti-nutrients as well as the fatty acids are present in sandbox seed meal. In terms of proximate composition, the dry matter content was 90.75±0.03 %, while the crude protein, crude fibre, fat, ash, nitrogen free extracts were 24.41±0.01 %, 11.49±0.08 %, 26.88±0.02 %, 5.02±0.01 % and 33.20±0.05 %, respectively. Vitamins were vitamins A, E, C, K and D with values of 405.72 IU, 0.871 mg/g, 0.41 mg/g, 0.03mg/g, 1.80 mg/g, respectively. Vitamin A had the highest value (405.72 IU), followed by vitamin D (1.80 mg/g) and the least was vitamin C (0.03 mg/g). Minerals were potassium, sodium, calcium, zinc, iron, copper and phosphorus, of which potassium recorded the highest value (189.51 mg/kg) and phosphorus was the least (0.41 mg/kg). The anti-nutritional factors were oxalates, tannins, alkaloids, saponin, flavonoid, cyanogenic, glucoside and trypsin inhibitors. Oxalate recorded the highest value (19.10 mg/g). The fatty acids composition (Table 3) in sandbox seed meal were linolenic acid (C48:2), oleic acid (C18:1), stearic acid (C18;0) palmitoleic acid (C18:3), lauric acid (C12:0) and palmitic acid (C16:0). The values were 10.03±0.01, 7.48±0.01, 4.62±0.02, 4.59±0.01, 2.44±0.02, 0.21±0.07 and 1.00±0.01 %, of which linoleic acid recorded the highest value (10.03±0.01 %) and the least was lauric acid (0.21±0.07 %). The crude protein content of sandbox seed meal (24.41±0.01 %) in this study was lower than 31.99 % reported by Udoh *et al.* (2007) for raw sandbox seed meal. This value was closed to the crude protein contents reported by Ologhobo *et al*. (2002) for rubber seed meal (27.53 %), kidney bean (22.46 %), lima bean (22.53 %) and pigeon pea (22.46 %). It was also lower than the crude protein value of cowpea (27.86 %) reported by Hashium and Idris (2017). Sandbox seed meal is high in crude fibre (11.45±0.08 %) than most leguminous seeds. Fibre is important in the diets of farm animals. It acts as a diluent. Its absence in diets leads to incidence of a wide range of diseases such as colon diverticulitis, obesity, coronary artery problem and diarrhoea (Oke *et al*., 2016). Some level of fibre is also necessary for proper bowel movement. The high fat content (26.88±0.02 %) makes SBSM a good energy source (Nsa *et al*., 2020). The ash content (5.02 %), seems to be moderate when compared to other leguminous seeds, and the dry matter content (90.75%), was higher when compared to leguminous seed meals as reported by Oyenuga (2002).

Sandbox seed meal (SBSM) appears to be low in most minerals, except for potassium which was fairly higher. The calcium and phosphorus values however, were comparable to what was reported for soybean meal by Aduku (2012) and cowpea (Oke *et al*., 2015). However, the problem of low mineral content could be solved by using other mineral sources like proprietary mineral premixes. The vitamins content in sandbox seed meal seems to be low, except vitamin A which had highest amount.

The problem of low vitamin contents can also be handled by supplementing vitamin premix.

The levels of some anti-nutritional factors in sandbox seed meal showed that oxalates (19.10 mg/g) were higher than those of other edible seeds as reported by Inuwa *et al.* (2011). Oxalates reduce bio-availability of calcium and zinc and affect calcium and magnesium metabolism. They react with protein to form complexes which have an inhibitory effect in peptide digestion (Inuwa *et al*., 2011).

The tannin content of sandbox seed meal was (1.67 mg/g). This value seems to be low when compared to 3.45 mg/g of *Elaeis guineensis* seed meal (Boyd and Boyed, 2008). Tannins are believed to play a role in plant nutrient availability by inhibiting enzymes produced by invading pathogens and protein in the damaged plant tissues (Odoh *et al*., 2007). Tannins also interfere with digestion by displacing anti-trypsin and amylase enzymes (Etuk, 2000). The alkaloid content of SBSM was 3.46 mg/g. These factors are particularly effective at inhibiting neuromuscular function, the results of this inhibition in animals are the clinical signs of intoxication such as muscle weakness, failure of voluntary muscular coordination, bloating, difficult in respiration and even death (Green *et al*., 2013). Cyanogenic glycosides content of SBSM was 2.56 mg/g. This level was moderate when compared to other oil seeds. The lethal dose of cyanide has been reported to be 35 mg/g and above (EPSA, 2016). Saponin content of sandbox seed meal (SBSM) was 6.44 mg/100g. Saponin had a moderate value when compared to cowpea (Oke *et al*., 2016). Flavonoid value of SBSM was 0.20 mg/100g. The flavonoid value was the lowest among all the anti-nutrients present in sandbox seed meal compared to *Arachis hypogaea* seed oil (Erdman, 2009). The flavonoids are a group of polyphenolic compounds that include tannins. These compounds chelate metals such as iron and zinc and reduce the absorption of these nutrients, and thereby inhibiting digestive enzymes and may also precipitate proteins (Ologbodo *et al*.,2013). Trypsin inhibitors content of SBSM was 1.05 mg/g. The amount present in sandbox seed meal was lower than the amount present in lima bean (5900 g) as stated by Ologhobo *et al.* (2013) and cowpea (521 g) by Oke *et al.* (2016). Trypsin inhibitors prevent the digestion of protein which leads to indigestible compounds in the body.

The levels of fatty acids in sandbox seed meal (SBSM) showed that linoleic acid (C48:2) content was 10.03±0.01 %. The value was lower compared to soybean meal (52.2 %) which makes the fat content of SBSM low as reported by Primomo *et al.* (200). Oleic acid (C18:1) content was 7.48±0.01 %. This level of oleic acid was moderate when compared to oil seeds such as soybean meal which have the value of 21.50 % as reported by Cahoon *et al.* (2007). Stearic acid (C18:0) content of SBSM was 4.62±0.02 %. This value was moderate and of the same value with soybean seed meal as reported by Burgal *et al.* (2018). The production of fatty acid in seed meal is for nutritional improvement of feeds. Linolenic acid (C18:3) value of SBSM was 4.59±0.01 % and a closed value to soybean seed meal as stated by Danaei *et al.* (2009). Linolenic and linoleic acids are unsaturated fatty acids and deficiency can cause loss of hair (alopecia), susceptibility to infection, poor wound healing and circulatory problems (Fowomola *et al*., 2007). Palmitoleic acid (C16:1) value of SBSM was 2.44±0.02 %.

This value was higher than the value for sandbox seed meal reported by Oyeleke *et al.* (2012) for palmitoleic acid (1.211±0.013 %). Palmitoleic acid is one of the common omega-7 fatty acids which regulate different metabolic processes such as increase in insulin sensitivity in muscles and deficiency can cause low-birth weight, cystic fibrosis and gastro-intestinal abnormalities with diarrhoea (Astudilo *et al*., 2018). Lauric acid (C12:0) had the value 0.21±0.07 %. This amount was higher when compared to sandbox seed meal (1.310±0.01 %) as reported by Oyeleke *et al.* (2012) and was low compared to the value (14.436 %) of lauric acid in soybean oil and groundnut oil (14.567 %) as reported by Sodamade *et al.* (2013). Gregorio (2005) reported that lauric acid has the highest content of fatty acid found in groundnut. Palmitic acid (C16.0) was 1.00±0.01 %. This value seems to be lower when compared to soybean oil (3.456 %) and groundnut oil (4.755 %) as reported by Gillian *et al.* (2008). Palmitic acid is one of the most common saturated acids found in butter, cheese, milk, animals and plants; it is also an antioxidant.

Growth performance characteristics of rabbits fed sandbox seed meal - based diets

The growth performance characteristics of rabbits fed sandbox seed meal (SBSM) based-diets are summarized in Table 4. There were significant differences (p<0.05) between treatments in final weight gain, daily weight gain, daily feed intake and feed conversion ratio. The final weight gain (1624.00 g/rabbit) for treatment 4 with 75 % SBSM replacement level, was the highest compared to other dietary treatments. The average daily weight gain recorded a fluctuating trend with treatment 4 recording highest value (12.84 g/rabbit) and T_5 (100 % SBSM) the least value (6.47 g/rabbit). The daily feed intake increases gradually up to treatment 4 with 75% replacement level of SBSM and dropped at 100% level. The feed conversion ratio was best (4.07) in dietary treatment 4 with 75% replacement level compared to the control and other groups.

There were significant differences (p<0.05) in all growth parameters. Ozeudu *et al.* (2015) who fed sandbox seed meal also reported a significant effect (p<0.05) on the feed intake and body weight gain but had no significant effect (p>0.05) on the feed conversion ratio.

Parameters recorded an increasing trend for the daily feed intake (DFI), except treatment 5 (41.73g/rabbit) with replacement level of 100% of SBSM. Daily weight gain (DWG) and final weight gain (FWG) had a fluctuating trend; implying that increased weight was as a result of increased dietary replacement of soybean bean meal with sandbox seed meal (SBSM). This was in agreement with the report by Iyeghe-Erakpotobor *et al.* (2007) who stated that rabbits increased body weight when fed diets containing plant protein sources and forages.

The daily feed intake range increased marginally with increasing replacement levels of SBSM, the increased intake indicated that animals increased feed intake to meet up energy requirements which was in agreement with the reports of Lebas (2013); Iyeghe-Erakpotobor and Nwagu (2014) that monogastric animals are expected to consume less of high energy diets in an attempt not to overshoot their energy requirement favourably. The range of feed conversion ratio compared with the range (4 - 6) reported by Ozeudu *et al.* (2015). Treatment 4 (75% SBSM) had the best FCR (4.07) in this study. Adeyemo *et al*. (2014) stated that animals perform better with feed mixture of concentrate and forages; hence the reason for increase value of growth parameters as the sandbox seed meal replacement levels increased. However, Iyeghe-Erakpotobor *et al*. (2007) reported that nature of feed, age of the animal, difference in feed ingredients and environmental factors can also affect feed conversion ratio of an animal.

Carcass characteristics of rabbits fed Sandbox seed meal - based diets

The result of carcass characteristics of rabbits fed sandbox seed meal - based diets is presented in Table 5. The live weight, dressed weight and dressing percentage recorded significant (p<0.05) differences between dietary treatments. The dressed weight was highest in treatment 2 (25 % level) (1103.30 g/rabbit), while treatment 3 (50 % replacement level) had the least value (801.70 g/rabbit). Treatment 3 recorded the lowest for dressing percentage (50.01 %) and treatment 5 recorded the highest (76.93 %). The relative weight of parts/ cuts recorded significant differences (p<0.05) between dietary treatments for nearly all parameters, except the neck, forelimb/shoulder and loin cuts. The significant effect, indicated that the SBSM had effects on these carcass parameters. Fanimo *et al.* (2007) and Akinmoladun *et al.* (2018) who fed bamboo leaves as replacement for *Tridax procumbens,* respectively reported a similar trend. The live weight, dressed weight and dressing percentage recorded undulating pattern as SBSM replacement levels increased. The range of live weight (1300.70-1801.70 g/rabbit) was higher than (1733-1980 g/rabbit) reported by Haruna and Muhammad (2018) who fed diets containing yam peels. Akinmoladun *et al.* (2018) who fed bamboo leaves as replacement for *Tridax procumbens* had higher value (1733-1980 g/rabbit). The dressed weight range (801.70-1103.30 g/rabbit), was closed to the range (497.00-1164.9 g/rabbit) reported by Akinmutimi and Obioha (2010) who fed globe amaranth leaf meal to rabbits.

The dressing percentage recorded an undulating trend, the range (50.01-76.93 %), obtained in this study was lower when compared with the range (62-67 %) reported by Ozung *et al.* (2011) who fed cassava peel meal - based diets to rabbits and similar to the range (65-52 %) reported by Maidala *et al.* (2016).

Differences in dressing percentage occurred because the head, skin, and feet of rabbits contribute about 3 -10 %, respectively to the dressing percentage (Maidala *et al.*, 2016). Increased trend recorded for live weight, and dressed weight indicated the positive effect of diets in which Oteku and Igene (2006) reported that increased in carcass parameters may be as result of increased in age of the animal or effects of diets. The relative weight of back cut (11.20 - 18.05 % LW) was lower than (31.12 - 31.64 % LW) reported by Akinmutimi and Obioha (2010). The loin range (3.12-5.56 %LW) and tail range (0.16 - 0.44 %LW) were lower than the range (6.43 - 6.66 %LW) reported by Akinmutimi and Obioha (2010), and the head range (7.90 - 6.46 %LW), hind limb/thigh range (11.28 - 17.29 %LW) were higher than (9.01 - 22.32 %LW) reported by Maidala *et al.* (2016) who fed soybean meal to rabbits. Variations may be ascribed to age and environmental factors (Oteku and Igene, 2006).

Visceral organs of rabbits fed sandbox seed meal - based diets

The result of visceral organs for rabbits fed sandbox seed meal - based diets is presented in Table 6. The visceral organs recorded significant differences (p<0.05) for the pancreas, ileum, caecum and total GIT. The lungs, liver, adrenal gland, kidney, spleen, oesophagus, duodenum and jejunum recorded no significance (p>0.05) differences between treatments. The linear measurements of GIT recorded an undulating trend for all parameters. There were significant (p<0.05) differences in all parameters, except jejunum and Total GIT length. Jejunum length recorded the highest value in treatment 2 with 25 % replacement of SBSM (23.03 cm) and lowest in treatment 3 with 50 % replacement of SBSM (15.01 cm). An undulating pattern was recorded for all parameters as dietary SBSM replacement levels increased. The non-significant effect on some parameters, implied that the anti-nutrients in SBSM were within a tolerable range. Fluctuating pattern indicated that the anti-nutritional factors in sandbox seed meal were within a tolerable range as such no adverse effect was noticed on any of the organs.

The liver is the storage location for fat-soluble vitamins and handles cholesterol homeostasis, the lungs serve as gas exchange called respiration, the kidneys remove wastes and extra fluid from the body. Non-significant (p>0.05) effect showed that SBSM has no adverse effect on the visceral organs.

CONCLUSION

This study has revealed that the under - exploited seeds of sandbox trees can be useful products for animal diet formulation, and can serve as alternative plant protein source. Sandbox seed meal is rich in nutrients and moderate in anti-nutritional factors. Hence, within the present experimental conditions, this study concluded that sandbox seed meal can replace soybean meal in diets for rabbits up to 75 % level without adverse effects on growth performance and carcass characteristics as well as internal organs of rabbits.

RECOMMENDATION

Based on the outcome of this study, it is recommended that sandbox seed meal could be used as feed ingredient for rabbits as it could successfully replace soybean meal. However, replacement level of 75 % maximum is ideal and recommended as it promotes growth and carcass characteristics of rabbits. Above this level sandbox seed meal might have adverse effect on the animals.

ACKNOWLEDGEMENTS

The authors of this study are highly grateful to the Management of the University of Calabar, Calabar, Nigeria, especially the Vice Chancellor, Director of Academic Planning (DAP), Director of Research & Development, Staff of the Research Directorate and the Tertiary Education Trust Fund (TETFUND), Abuja, Nigeria for providing the enabling platform and funding of the research work via the 2018/2020 (Merged) TETFUND Intervention of Institutional Based Research (IBR) Grant.

DECLARATION OF COMPETING OR CONFLICT OF INTEREST

The authors declare that there is no competing or conflict of interest in this work.

Table 1: Gross composition of experimental diets

Ingredient	T_1	T_2	T_3	T_4	T_5
	Level of SBSM as replacement for SBM				
	0%	25%	50%	75%	100%
Yellow maize	50.00	50.00	50.00	50.00	50.00
Soybean meal	18.00	13.50	9.00	4.50	0.00
Sandbox seed meal	0.00	4.50	9.00	13.50	18.00
Wheat offal	15.25	15.25	15.25	15.25	15.25
Rice husk	12.25	12.25	12.25	12.25	12.25
Bone meal	2.00	2.00	2.00	2.00	2.00
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
*Premix (vit. /min)	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Sucrose	0.25	0.25	0.25	0.25	0.25
Palm oil	1.25	1.25	1.25	1.25	1.25
Total	100%	100%	100%	100%	100%
Calculated nutrient composition:					
% Crude protein	14.33	14.37	14.41	14.45	14.49
% Crude fibre	7.71	7.63	7.55	7.48	7.40
ME (Kcal/Kg)	2918.99	2771.78	2624.58	2477.37	2330.16
Determined/analyzed values:					
% Crude protein	15.03	15.12	15.35	15.41	15.54
% Crude fibre	8.25	8.11	8.09	8.03	8.01

*Gross Composition of Bio-Super Premix per Kg:
*Vitamin A- 15000,000IU: Vitamin D3 -300,000IU: Vitamin E- 400mg; Vitamin K3 -100mg
Vitamin B2- 400mg, Vitamin B12 - 200mg; Nicotinamide - 2,000mg; Calcium D -Pantothenic acid 800g, Choline Chloride – 40,000mg; Ferrous sulphate – 2,000mg; Manganese sulphate – 5,000mg; Copper sulphate – 80mg; Zinc oxide – 3000mg.
Cobalt sulphate – 10mg; Potassium iodide – 120mg;
DL-Methionine 10,000mg and Antioxidant – 18,000mg.
The premix was manufactured by Bio – Phamachemic Company, H.C.M City, Vietnam

Table 2: Chemical composition of sandbox (*Hura crepitans*) seed meal

Parameter	Composition
Proximate composition (%):	
Dry matter	90.75 ± 0.03
Crude protein	24.41 ± 0.01
Crude fibre	11.49 ± 0.08
Fat	26.88 ± 0.02
Ash	5.02 ± 0.01
Nitrogen free extract	33.20 ± 0.05
Minerals:	
Potassium (K) (mg/g)	18.51 ± 0.18
Calcium (Ca) (mg/g)	7.45 ± 0.03
Sodium (Na) (mg/kg)	5.08 ± 0.01
Zinc (Zn) (mg/g)	1.94 ± 0.01
Iron (Fe) (mg/g)	6.95 ± 0.04
Copper (Cu) (mg/g)	0.86 ± 0.01
Phosphorus (P) (mg/g)	0.41 ± 0.05
Vitamins:	
Vitamin A	405.72
Vitamin E	0.871
Vitamin K	0.41
Vitamin C	0.03
Vitamin D	1.80
Anti-nutritional factors (mg/g):	
Oxalate	19.10
Tannins	1.67
Alkaloid	3.46
Saponin	6.44
Flavonoid	0.20
Cyanogenic glucoside	2.56
Trypsin inhibitor	1.05

Each mean value was obtained from triplicate determinations using standard laboratory methods

Table 3: Fatty acid composition of sandbox (*Hura crepitans*) seed meal

Parameter (%)	Value ± S. D
Linoleic acid (C48:2)	10.03 ± 0.01
Oleic acid (C 18:1)	7.48 ± 0.01
Stearic acid (C18:0)	4.62 ± 0.02
Linolenic acid (C 18:3)	4.59 ± 0.01
Palmitoleic acid (C 16:1)	2.44 ± 0.02
Lauric acid (C12:0)	2.04 ± 0.01
Palmitic (C16:0)	1.00±0.01

Each mean value was obtained from triplicate determinations using standard laboratory methods

Table 4: Growth performance characteristics of rabbits fed sandbox seed meal – based diets

Parameter	T_1 0%	T_2 25%	T_3 50%	T_4 75%	T_5 100%	SEM
Number of rabbits / diets	12	12	12	12	12	
Av. Initial weight (g/rabbit)	933.33	950.00	950.00	908.33	916.66	2.53
Av. Final weight (g/rabbit)	1398.33^{b}	1438.67^{ab}	1265.33^{b}	1624.00^{a}	1276.33^{b}	9.04
Av. Daily weight gain (g/rabbit)	8.30^{b}	8.75^{b}	5.48^{d}	12.84^{a}	6.47^{c}	0.20
Av. Daily feed intake (g/rabbit)	42.71^{b}	44.98^{b}	52.07^{a}	52.30^{a}	41.73^{b}	0.41
FCR	5.15^{b}	5.14^{b}	9.50^{a}	4.07^{d}	6.45^{c}	0.25

$^{a, b, ab ...d}$ Means along the same row with different superscripts are significantly different ($p<0.05$)
DWG: Daily weight gain
DFI: Daily feed intake
FCR: Feed conversion ratio
SEM: Standard Error of Mean
Av: Average

Table 5: Carcass characteristics of rabbits fed sandbox seed meal - based diets

Parameter	T_1 0%	T_2 25%	T_3 50%	T_4 75%	T_5 100%	SEM
Live weight (g/rabbit)	1801.70^{a}	1603.30^{b}	1601.70^{b}	1735.70^{a}	1300.70^{c}	2.32
Dressed weight (g/rabbit)	1001.70^{a}	1103.30^{a}	801.70^{b}	903.30^{c}	1101.70^{a}	2.47
Dressing Percentage (%)	55.57^{c}	68.74^{b}	50.01^{c}	51.94^{c}	76.93^{a}	0.01
Relative weight of parts/cuts (% live weight)						
Head	7.87^{b}	9.20^{a}	6.46^{b}	7.42^{b}	7.90^{b}	0.01
Neck	1.48	1.89	1.45	1.09	1.83	9.06
Forelimb/ Shoulder	8.07	8.94	8.58	6.16	0.13	0.13
Hindlimb/ Thigh	15.37^{a}	17.29^{a}	13.96^{b}	13.38^{b}	11.28^{b}	0.01
Back cut	18.05^{b}	23.46^{a}	14.47^{b}	16.10^{b}	11.20^{c}	0.02
Rack	8.39^{b}	11.54^{a}	8.18^{b}	8.45^{b}	5.33^{c}	0.01
Loin	5.18	5.56	4.55	5.16	3.12	0.02
Tail	0.38^{a}	0.26^{b}	0.44^{a}	0.25^{b}	0.16^{c}	0.01

$^{a,b,c...}$ Means on the same row with different superscripts are significantly different ($p<0.05$)
S.E.M: Standard Error of Mean

Table 6: Visceral organs of rabbits fed sandbox seed meal - based diets

Parameter (% LW)	T_1 0%	T_2 25%	T_3 50%	T_4 75%	T_5 100%	SEM
Liver	2.46	2.74	2.34	1.97	1.70	1.00
Lungs	0.65	0.63	0.42	0.52	0.62	9.42
Adrenal gland	0.07	0.30	0.04	0.05	0.05	0.11
Kidney	0.57	0.50	0.57	0.45	0.62	1.00
Spleen	0.07	0.30	0.07	0.30	0.03	0.15
Pancreas	0.53^{b}	1.05^{a}	0.26^{c}	0.66^{b}	0.39^{c}	0.01
Oesophagus	0.27	0.10	0.56	0.15	0.20	0.11
Duodenum	0.28	0.37	0.19	0.22	0.18	0.01
Jejunum	0.27	0.29	0.24	0.23	0.26	3.38
Ileum	1.97^{b}	1.69^{b}	2.14^{a}	2.32^{a}	1.66^{b}	0.01
Caecum	5.52^{b}	6.80^{b}	4.69^{b}	6.70^{b}	9.42^{a}	0.01
Total GIT	14.72^{b}	16.01^{b}	13.49^{c}	12.45^{c}	18.79^{a}	0.01
Visceral fat	1.12	3.65	0.94	2.06	0.63	0.01
Stomach + Content	2.85^{c}	4.13^{a}	2.99^{c}	3.25^{a}	3.56^{a}	0.01
Linear measurements (cm):						
Oesophagus	21.51^{a}	10.51^{b}	10.01^{b}	12.01^{b}	7.01^{c}	0.01
Stomach	14.51^{b}	14.01^{b}	16.03^{a}	13.01^{b}	16.03^{a}	0.02
Duodenum	25.01^{a}	24.01^{a}	14.03^{b}	16.01^{b}	15.03^{b}	0.02
Jejunum	21.51	23.03	15.01	17.03	22.01	0.02
Ileum	177.03^{b}	160.02^{b}	176.03^{b}	267.02^{a}	147.03^{b}	0.02
Colon	84.52^{b}	89.03^{b}	102.22^{b}	108.03^{a}	95.52^{b}	0.02
Caecum	33.01^{b}	32.01^{b}	35.01^{b}	41.01^{a}	36.01^{b}	0.01
Appendix	12.01^{b}	10.51^{b}	9.53^{a}	18.01^{b}	8.51^{a}	0.02
Total GIT Length	377.09	363.13	367.86	480.12	340.14	0.02

[a,b,c]Means on the same the row with different superscripts are significantly different ($p<0.05$)
S.E.M: Standard Error of Mean

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