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Growth Performance of Weaned Male Albino Rats Fed on Processed Atlantic Horse Mackerel (Trachurus trachurus)

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Abstract
Trachurus trachurus is a table fish, locally called *kote* in south-west Nigeria. Fish processing (like poaching and smoking) generates reactive di-carbonyl compounds & poly-aromatic hydrocarbons that affect its digestibility. Study determined the effect of processing methods on growth performance of weaned male albino rats reared on Atlantic horse mackerel (*Trachurus trachurus*). Chemical analyses were carried out on processed fillet; skin, head & bone (SHB) diets under standard conditions. 40 weaned male albino rats were fed with processed fillet or SHB diets for 14 days to assess protein digestibility via: feed intake, weight gain, feed efficiency ratio (FER), feed conversion ratio (FCR), water intake & faecal output. Animals fed on coal smoked fillet diet had the best growth, in terms of weight gained, FCR & FER respectively; followed by the wood smoked SHB diet ($p<0.001$) compared to the positive control. The best results were obtained from animals fed the smoked fillet / SHB. The SHB could be a significant source of valuable ingredients for animal feeds & human consumption.
Keywords: Processing methods; Growth performance**;** Feed Efficiency Ratio; Feed Conversion Ratio; *Trachurus trachurus*, Agricultural waste / Discards

1. INTRODUCTION

Proteins contribute to the key body functions, including blood clotting, fluid balance, production of hormones and enzymes, vision, and cell growth and repair (Wardlaw & Insel, 1996). Protein is a source of essential amino acids needed mostly for tissue synthesis, maintenance and repair (Young et al, 2001). Fish is a very good source of animal protein with little or no religious rejection, giving it an advantage over pork or beef (FOS, 1990; Olatunde, 1998; Omojowo, 2009).

Fish is a very important source of animal protein in the diet of man. It is widely consumed in many parts of the world not only for both its high quality protein and low saturated fat content. It contains essential n-3 polyunsaturated fatty acids that are known to support good health, lower the risk of heart diseases in adults and are important for neuro-development in infants and young (Uauy et al. 2003; Marimuthu et al, 2011). In recent years, fish lipids have also assumed great nutritional significance, because of their high polyunsaturated fatty acid levels. Fish are also considered very rich source of minerals and vitamins. The total content of minerals in the raw flesh of fish and invertebrates is in the range of 0.6–1.5% of wet weight. Mineral components such as sodium, potassium, magnesium, calcium, iron, phosphorus and iodine are important for human nutrition (Sikorski et al. 1990). The contents of Na, K, Ca, Mg and P are up to 1 mg/100 g, whereas those of Fe, Zn and I are less than 1 mg/100 g (Kietzmann et al. 1969).

Fish dietary intake provides about 60% of the total animal protein consumed in West Africa (Saisithi, 1994). Although fish are nutritious and rich in protein, they are highly perishable (Olafsdottir et al, 1997; Okeyo et al, 2009). At death enzymes in the flesh and gut of the fish that were previously involved in metabolism catalyze autolytic reactions, in which various compounds decompose. Fish spoilage can be delayed by many processes, including temperature, pH, and smoke, which eliminate, or reduce, microbial growth, enzyme activity, oxidation or insect infestation (Camire et al, 1990). Processing methods like heat application may denature protein; disrupt the food matrix thus resulting in lower essential amino acid bioavailability, reduced digestibility and protein quality (Mensa-Wilmot et al 2001; Patterson et al, 2001).

In Nigeria, kote fish is rarely eaten raw and it is usually processed by various cooking methods, such as boiling, grilling, baking, and frying, before consumption. Cooking is a means of processing food, without which many foods would be unfit for human consumption. Raw foods such as meat, fish and eggs, may harbour food poisoning bacteria, which if consumed are likely to cause illness (Belitz and Grosc, 1994). Most cooking methods if performed properly will heat foods to over 70^{o}C, so applying such a temperature for a carefully calculated time period prevents many food borne illnesses. Many foods contain proteins, such as meat, fish, eggs, vegetables, nuts and pulses (Belitz and Grosc, 1994; Vaclavik and Christian, 2007). During cooking, heat causes the proteins to vibrate violently, which results in the breakage of the weak hydrogen bonds holding the amino

acid strands in place. Ultimately, the protein unravels to re-take its initial form of amino acid strands (Vaclavik and Christian, 2007).

The denaturation of protein molecules in foods usually causes a substantial change to the texture of the product. In addition overcooking of some baked and fried foods causes acrylamide and heterocyclic amines (HCAs). HCAs are known as cancer causing (Zheng et al, 1998; *Vitaglione and Fogliano 2004*). Many people feel that it is important to cook food well in order to avoid bacterial infection. These same people do not realize that cooking meat, poultry, or fish at high temperatures for long periods of time can also be dangerous to health. Acrylamide is cancer causing in animals (Zheng et al, 1998).

The higher the temperature that food is cooked, the longer it stays in the gut and the more difficult it becomes for the digestive mechanisms to digest it (Francis & Pottenger 1939). This makes it more difficult for the food to absorb and function at a cellular level where it needs to work. When the food can not function in the cells, the cells can become deficient and/or toxic which leads to deficiency and toxicity of the whole body making the body less able to function optimally (Warshaw et al, 1974; Simon Martin, 1995).

Also, fish preservation methods often times involves removal of the head, viscera and other parts of fish, which may have either negative or positive effect on the total nutritive values of the fish (Saliu, 2008; Johnson et al, 2010). The effect of fish processing methods on growth is important especially in food science, particularly for developing foods with targeted nutritional value in animal husbandry. Nevertheless, there remains paucity of scientific information on the effect of different processing methods (poached, wood and charcoal smoked) on the growth performance of *Trachurus trachurus* (fillet and SHB) in weaned male wistar rats. Present study, therefore evaluated the effect of processing methods on the digestibility and bioavailability of processed *kote* fillet and SHB. The fillet and SHB were the protein source in compounded feed using rat bioassay of feed conversion ratio (FCR) and feed efficiency ratio (FER).

2. MATERIALS AND METHODS

2.1 Sample processing

The mean length and weight of *Trachurus trachurus* were; 30.52 ± 0.22 cm and 197.66 ± 3.67g respectively. Freshly harvested fish from the wild sea were purchased from two major fish distributors in Oja Ipata, Ilorin, packed in ice polystyrene boxes were transported to the laboratory within 30 min. The fish was thoroughly washed and drained, placed on wire gauze and cooked by poaching or smoking (firewood or charcoal). Poaching of the fish was done according to the method described by (The Economic Research Service of the USDA, (USDA), 2006) modified by Larsen (2012). The procedure was followed without addition of any ingredient. *T. trachurus* weighing 7 kg was hot smoked using either firewood or charcoal in Altona smoke kiln as described by FAO/UN (2007). The smoking time, temperature and ambient conditions were monitored during the smoking operation. Smoking was terminated when fish was properly dried to an average moisture content of 10.41±0.02%, after 8 hours. The fish was turned at intervals and the smoked or poached fish samples kept in cane woven baskets, under laboratory conditions with no preservative, left to cool and subsequently packaged in low density and high-density polyethylene bags respectively, sealed then stored at 8^{o}C until required for further use.

2.2 Rat diets formulation

Yellow maize (*Zea mays*) was purchased from Alice market, South Africa. The maize was soaked in warm water and changed daily for four days to soften the outer coat in preparation for milling. The corn was dried at 40^{o}C to constant weight using the Prolab Electrical Oven and milled to smooth powder using Polymix Dispersion and mixing Technology Kinemation Switzerland Blender. The animal diets were formulated following the protocol of Food and Agricultural Organization (Food and Agricultural Organization /

World Health Organization (FAO/WHO), 1991). The gross and chemical compositions of control and test diets formulated are shown in Table 1. A protein-free diet served as a negative control whereas the processed fish varieties (fillet and SHB) served as protein source in the experimental diets. All the diets for the experiment provided a minimum of 10% protein. Soy bean meal and groundnut cake were used as the protein source in the positive control. Both diets contained equal amounts of DL-methionine, sucrose, wheat meal, vitamin mix and mineral mix.

2.3 Proximate analysis of formulated diets

Raw and processed fish samples were oven dried to constant weight at 60^{o}C, fish fillet was separated from its skin, head and bones (SHB). Fish fillet or SHB was grounded to powder using a monillex kitchen blender for protein concentrate. The feed samples were analyzed for moisture and ash content (Association of Official Analytical Chemists (AOAC), 2002). Total crude fat was determined using the Soxhlet extraction method according to AOAC (2002) as modified by Reinik et al, (2007). The crude fiber content was estimated by acid-base digestion method as described by Association of Official Analytical Chemists (AOAC) (2002). Crude

protein content was determined by the Kjeldahl method (Association of Official Analytical Chemists (AOAC), 1984). Percentage nitrogen was calculated using the equation Y= 0.026x - 0.003 and R^2= 0.974 obtained from the calibration curve after nitrogen content determination (Figure 1) (Okalebo et al, 2006). Crude protein was estimated by multiplying the nitrogen value by the converting factor of 6.25.

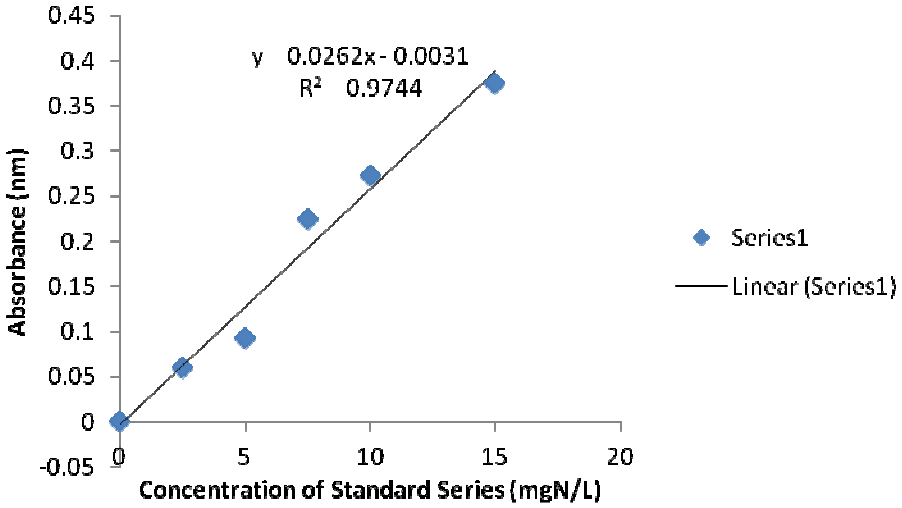

Figure 1: Graph Showing Calibration Curve Used for the Calculation of Nitrogen Content

2.4 Experimental animals

A total of 40 male weaned wistar albino rats weighing between 30 and 40 g were obtained from the animal house of Central Analytical Laboratory, University of Fort Hare. The animals were kept in clean Plexiglas cages and maintained at a controlled temperature 24°C with a 12 hour light-dark cycle and relative humidity of 45-50%. They were fed with formulated diets or standard rat feed with water *ad-libitum* for 12 days. All animal experiments were conducted under NIH guidelines for care and use of laboratory animals after approval of animal ethics committee of the University of Fort Hare, South Africa.

2.5 Animal experimental design

Animals were randomly distributed into eight treatment groups with mean weight differing within ±2.00g: Group I: animal administered soya bean-groundnut cake meal (positive control). Group II: animals received basal diet (zero protein or negative control). Group III: animals received poached fillet diet. Group IV: animals treated with coal smoked fillet diet. Group V: animals fed with wood smoked fillet diet. Group VI: animals fed with poached SHB diet. Group VII: animals received coal smoked SHB diet. Group VIII: animals administered with wood smoked SHB diet for 12 days. Individual weights of the rats were taken prior to commencement of the experiment and afterwards on 4 day interval. Feed and water intake of rats were measured on a daily basis, while the cages were cleaned on 4th day, by which time the rat faces were collected. At the end of the experimental period, growth performance parameters: voluntary feed intake, water intake, weight gained, feed efficiency ratio (FER), protein efficiency ratio (PER) and feed conversion ratio (FCR) were recorded.

2.6 Determination of growth performance parameters

The feacal output was determined after collecting feces from rats in each group at 4 day interval, dried in an air circulating oven at 60°C for 24 hour, cooled and weighed. At the end of 12 days, the faecal weight was obtained and divided by the number of rats within each group. Feed Conversion Ratio (FCR) was determined by measuring the amount of feed consumed per unit weight gained whereas feed efficiency ratio (FER) was determined as the ratio of body weight gained per unit of feed consumed over a period of time.

2.7 Determination of feacal nitrogen content (FNC)

Total nitrogen content was assessed by micro-Kjeldahl modified method of Okalebo et al. (2002). A known weight (0.5 g) of the feacal sample was mixed with 12 ml of (9 ml Conc. Nitric acid + 3 ml Conc. HCl) digestion mixture. The resulting mixture was digested using Buchi 425 digester from Switzerland for 1 hour until clear solution was observed. The mixture was allowed to cool and then made up to 50 ml with distilled water. The resulting solution was left to stand in the dark for 2 hours for full color development, and then absorbance was measured at 650 nm. A calibration curve was plotted and used to read off the nitrogen concentration of the

solution. Percentage nitrogen was calculated using the equation Y= 0.026x - 0.003 and R^2= 0.974 from the calibration curve at various concentration of the standards.

2.8 Statistical analysis

The data from all the analyses were collected and statistically analyzed and expressed as the mean ± standard error (s.e.) (n=3), the significant differences between means were compared for each group of rats using the least significant difference test after ANOVA for one-way classified data. SPSS 14.0 (SPSS, 2005) statistical tool was used to analyze data obtained. Results were considered statistically significant at a level of $p < 0.05$, chosen as the minimum for significance with Duncan's multiple range test (Duncan, 1955).

3. RESULTS

3.1 Proximate analysis of experimental diets

The data on the proximate analysis of formulated diets is presented in Table 1. The crude protein content was significantly high ($p < 0.001$) whereas crude fat content was highest ($p < 0.001$) in the WSCF as compared with the positive control diet. All formulated diets had sufficient nutrients required for growth and development of experimental animals.

3.2 Growth performance of animal fed with formulated diets

Growth response of rats fed with test and control diets are presented in Table 2. The results showed that rats fed CSKFBD had the highest weight gain (5.73g) in the fillet. The processing methods investigated increase the feed conversion ratio (FCR) of rats fed with *T. trachurus* diets compared to those in the soy bean-groundnut meal diet in decreasing order of magnitude CSKFD > WSKFD > PSKFD > S-GBD > ZPD. It is an indication of better utilization of the experimental feed compared to those fed with the control meals. The same trend observed in the FCR was repeated in the feed efficiency ratios (FER). Water intake, did not follow a particular pattern, however rats fed with the CSKFBD (308.08±7.41ml) had the highest ($p<0.001$).

Table 2 showed weight gain by the treated rats with highest value from WSHBBD (8.13g) followed by SHBBD in relation to the control diets. The significant increase ($p<0.05$) in the feed conversion ratio (FCR) of rats fed with processed SHB diets compared favourably to those treated with soy bean meal diet in the following magnitude of decreasing order; WSHBBD > CSHBBD > PSHBBD > S-GBD > ZPD. Similar trend observed in FCR was repeated in the feed efficiency ratio (FER) for rats fed with the SHB diets. The water intake however, did not follow a particular pattern though the rats fed with the PSHBBD (522.49 ± 4.37ml) rats respectively.

Overall the water intake and feacal output followed the same trend in animals fed on both control and experimental diets; while rats fed with the experimental diets had the least water intake and feacal output compared to those in the control groups, except for rats in the PSHB group. Feacal nitrogen levels of rats fed on the test and control diets are shown in Figures 2 and 3 respectively. Rats fed with processed test diet, showed lower ($p < 0.05$) feacal nitrogen content compared to the positive control.

Table 1: Gross and proximate composition (%) of experimental (fillet and SHB) based diets

Parameters	Protein	Fat	Ash	Crude fibre	Moisture	CHO
γS-GBD	13.76±4.91^{a}	2.15±0.01^{c}	3.17±0.17^{d}	8.43±0.01^{d}	46.67±0.17^{a}	28.19±0.96^{b}
†S-GBD	13.76±4.91^{a}	2.15±0.01^{c}	3.17±0.17^{d}	8.43±0.01^{d}	46.67±0.17^{a}	28.19±0.96^{b}
γZPD	11.52±4.35^{c}	2.86±0.03^{b}	3.17±0.17^{d}	8.30±0.10^{d}	47.50±0.50^{a}	24.28±1.12^{c}
†ZPD	11.52±4.35^{c}	2.86±0.03^{b}	3.17±0.17^{d}	8.30±0.10^{d}	47.50±0.50^{a}	24.28±1.12^{c}
CSKFBD	14.62±2.23^{a}	3.24±0.08^{b}	5.50±0.29^{b}	6.36±0.01^{c}	38.17±1.42^{c}	32.11±0.81^{a}
CSHBBD	10.44±3.32^{d}	5.03±0.08^{a}	7.67±0.44^{a}	19.06±0.03^{b}	40.17±1.09^{b}	17.63±1.92^{e}
WSKFBD	12.43±3.24^{a}	3.45±0.09^{b}	6.17±0.17^{b}	13.18±0.02^{c}	47.00±1.00^{a}	17.77±0.97^{e}
WSHBBD	12.68±3.28^{a}	5.62±0.26^{a}	4.5±0.00^{c}	18.90±0.03^{b}	46.17±0.33^{a}	12.13±0.78f^{e}
PKFBD	14.66±1.01^{a}	3.05±0.01^{b}	3.5±0.00^{d}	7.85±0.09^{d}	46.50±0.00^{a}	24.44±0.21^{c}
PSHBBD	14.25±2.45^{a}	3.69±0.02^{b}	8.17±0.33^{a}	24.82±0.01^{a}	29.00±3.00^{d}	20.07±0.82^{d}

*Data= Mean ± SEM, n=3. Values with different superscripts within a column are significantly different ($p < 0.05$). CSKFBD: charcoal smoked *kote* fillet meal based diet; WSKFBD: wood smoked *kote* fillet meal based diet; PKFBD: poached *kote* fillet meal based diet; CSHBBD: charcoal smoked *kote* SHB meal based diet; WSHBBD: wood smoked *kote* SHB meal based diet; PSHBBD: poached *kote* SHB meal based diet S-GBD: Soy bean & Groundnut cake meal based diet (Positive control); ZPD: Zero protein diet (Negative control).† stands for SHB group and γ stands for fillet fed group; CHO stands for carbohydrate.

Table 2: Growth performance parameters of rats fed experimental diets after 12 days of feed trials

Fish diets	Initial weight (g)	Final weight (g)	Weight gain (g)	Feed intake (g)	FCR	FER	Faecal output	Water intake (ml)
γS-GBD	44.79±0.95^{b}	55.14±0.3^{c}	10.3±0.17^{e}	245.95±7.33^{c}	27.76±1.94^{d}	0.01±0.00^{b}	10.44±1.07^{c}	277.25±1.44^{c}
†S-GBD	44.79±0.95^{b}	55.14±0.31^{c}	10.3±0.17^{e}	245.95±7.33^{c}	27.76±1.94^{d}	0.01±0.00^{b}	10.44±1.07^{c}	277.25±1.44^{c}
γZPD	41.15±0.80c^{b}	42.11±0.86^{d}	0.19±0.03^{f}	314.49±12.81^{b}	331.04±27.00^{e}	0.00±0.00^{c}	7.36±1.29^{d}	203.32±1.44^{d}
†ZPD	41.15±0.80^{c}	42.11±0.86^{d}	0.19±0.03^{f}	314.49±12.8^{b}	331.04±27.00^{e}	0.00±0.00^{c}	7.36±1.29^{d}	203.32±1.44^{d}
CSKFBD	40.92±2.16^{d}	69.57±4.77^{a}	28.6±0.86^{c}	282.07±10.44^{b}	9.85±0.51^{a}	0.02±0.01^{a}	9.76±1.01^{a}	308.08±7.41^{b}
CSHBBD	59.59±12.8^{a}	95.0±15.87^{a}	36.6±0.44^{b}	348.00±3.6^{b}	9.80±1.50^{a}	0.02±0.00^{a}	16.44±4.87^{b}	359.59±7.51^{b}
WSKFBD	41.88±5.31^{c}	60.09±8.35^{b}	18.2±0.76^{d}	245.18±8.37^{c}	13.47±0.49^{c}	0.02±0.01^{a}	8.95±0.64^{b}	246.91±1.67^{c}
WSHBBD	64.85±9.35^{a}	105.4±4.77^{a}	40.6±0.70^{a}	350.68±4.24^{b}	8.63±0.34^{a}	0.02±0.01^{a}	16.84±3.86^{b}	354.88±6.00^{b}
PKFBD	40.67±7.63^{b}	57.53±7.44^{c}	16.9±0.41^{c}	247.02±12.42^{c}	14.61±1.02^{c}	0.01±0.01^{b}	10.17±1.96^{c}	271.11±3.01^{c}
PSHBBD	62.09±7.30^{a}	101.6±16.5^{a}	39.5±1.58^{a}	445.59±19.77^{a}	11.25±0.49^{b}	0.01±0.00^{b}	26.24±5.69^{a}	522.49±4.37^{a}

*Data= Mean ± SEM, n=3. Values with different superscripts within the column are significantly different ($p < 0.05$). CSKFBD: charcoal smoked *kote* fillet meal based diet; WSKFBD: wood smoked *kote* fillet meal based diet; PKFBD: poached *kote* fillet meal based diet; CSHBBD: charcoal smoked *kote* SHB meal based diet; WSHBBD: wood smoked *kote* SHB meal based diet; PSHBBD: poached *kote* SHB meal based diet; S-GBD: Soy bean & Groundnut cake meal based diet (Positive control); ZPD: Zero protein diet (Negative control); FCR: Feed conversion ratio; FER: Feed efficiency ratio.

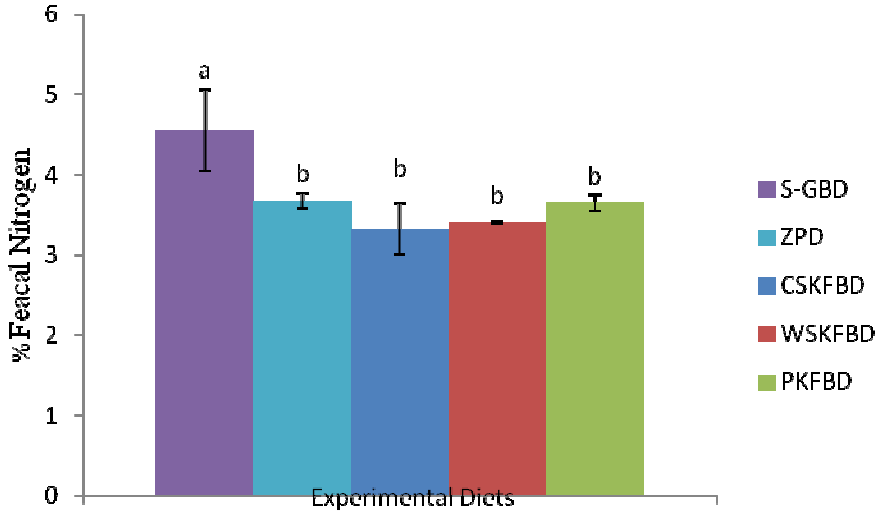

Figure 2: Feacal nitrogen contents of rats fed fish fillet based diets

*Values are means of 3 determinations ± SEM. N = 3. Bars with the same colour but different letters are significantly different ($p < 0.05$). CSKFBD = coal smoked *kote* fillet meal based diet, WSKFBD= wood smoked *kote* fillet meal based diet, PKFBD= poached *kote* fillet meal based diet; S-GBD: Soy bean & Groundnut cake meal based diet (Positive control); ZPD: Zero protein diet (Negative control)

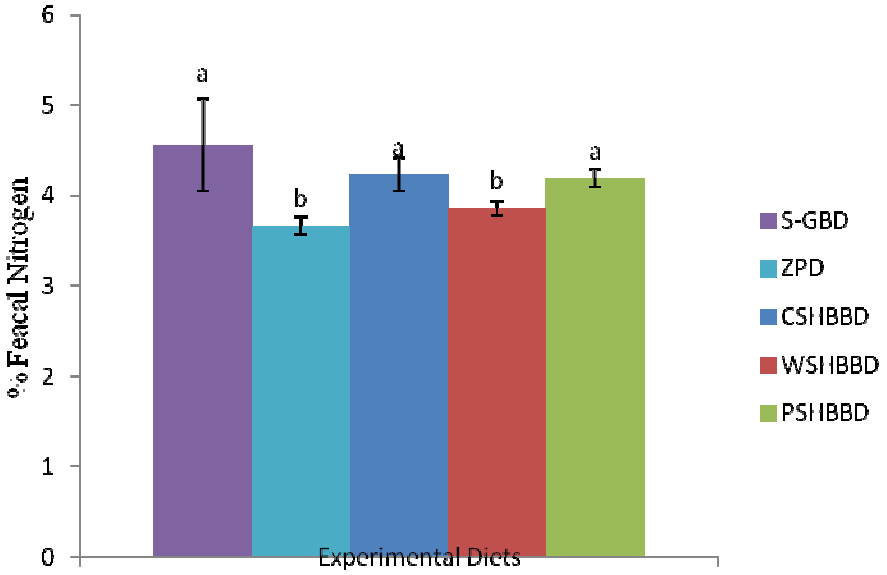

Figure 3: Feacal nitrogen contents of rats fed fish SHB based diets

*Values are means of 3 determinations ± SEM. Bars with the same colour but different letters are significantly different ($p < 0.05$). CSHBBD = coal smoked *kote* SHB meal based diet; WSHBBD= wood smoked *kote* SHB meal based diet; PSHBBD= poached *kote* SHB meal based diet; Soy bean & Groundnut cake meal based diet (Positive control); ZPD: Zero protein diet (Negative control)

4. DISCUSSION

The growth performance of animals fed on test and controls diets revealed that the initial body weight (g) of rats fed with test and controls diets at the start of the experimental study were homogenous. At the end of the 14 days feed trial period, all rats fed with the fillet and SHB meal based diets increased ($p < 0.05$) in body weight compared to those in the positive control group, furthermore, rats fed with the CSCFBD had the highest weight gained (5.73g) in the fillet and WSHBBD (8.13g) in the SHB groups. Whereas the significantly lowest ($p < 0.05$) weight gain of 0.19g was achieved by rats fed with the ZPD (negative control) diet.

Feed intake and weight gain of rats fed with test and controls diets in order of significantly decreasing ($p<0.05$) magnitude were; ZPD > CSKFBD > PKFBD > WSKFBD = S-GBD and CSKFBD > WSKFBD > PKFBD > S-GBD in the fillet meal based diet group. This affirms our earlier observation that the body weight gain of animals in this study was not a reflection of feed intake; because the rats fed with negative control meal based diet, consumed the highest amount of feed but gained the least ($p < 0.05$) weight compared to the other groups respectively.

However, growth rate / net weight gain of rats correlated with the dietary protein consumption irrespective of dietary lipid content. It is therefore clear from present investigation that the lesser ($p < 0.01$) weight gain of the negative control group was as a result of the significantly lesser ($p < 0.01$) amount of protein in their diet, even though they consumed the highest ($p < 0.001$) amount of feed. Whereas animals that fed on the smoked fillet diets recorded superior ($p < 0.05$) growth rates compared to those in the control groups. This lends further credence to the reports of De Silva, (1990) & Alais and Linden (1999) that proteins are essential parts of the animals' diet, since they cannot synthesize all the amino acids, they must obtain these essential amino acids from food.

Additionally, the significantly improved ($p < 0.05$) state of animals fed with the experimental diets compared to those in the positive control group may be because, fish species contain proteolytic enzymes that are majorly involved in the process of protein degradation, although they can also be applied in a large extent to the study of carbohydrate and lipid digestion (Alarcón et al, 1997). The enzymes in fish muscles are responsible for hydrolyzing muscle protein, leading to softness of the meat. Thus the presence of active enzymes in the fish muscle can be advantageous for processing, because these enzymes remain active at 65^0C (Cordova-Murueta et al, 2007) and partially hydrolyzed protein are more easily assimilated by the digestive system of marine organisms and other animals (Hardy, 1991; Cahu et al, 1999; Clemente, 2000; Cordova-Murueta & Garcıa-Carreno, 2002). Therefore in addition to the earlier points raised, the presence of proteases in the fish could be responsible for the speedy degradation of the processed fish diets in the rats compared to those in the positive

control.

Feed Conversion Ratio (FCR) is a measure of how well an animal converts feed intake (feed usage) into live weight. The improvement observed by FCR and FER in the rats fed with either WSHBD or CSHBD and CSHBBD respectively could be linked to the increased absorptive capacity of the small intestine (McDonald et al, 2002). The obtained data on FCR for rats fed with the fillet diets concurred with the findings of Leonard et al.(1979) & Onu et al, (2006). The FCR data recorded in the present study might have improved availability and absorption of nutrients in these animals. FER of rats fed with the control diets confirmed the reports of Cho et al, (2008); who suggested that animal protein (casein) could be replaced by plant protein especially combined soybean-groundnut cake in growing animals without adverse effects on growth performance and feed utilization parameters. It could be inferred that proper combination of plant proteins may provide similar benefits as animal protein. This observation agrees with the report of Schneeman and Gallaher (1980) &Gomes et al (1999) for rainbow trout in growing pigs.

Fecal output (F.O) was inversely proportional to the weight gained in rats fed with the fillet diets, but directly proportional to those fed SHB meal based diets. The crude fiber content of these experimental diets could be responsible for the direct opposite observed in animal treated groups with either fillet or SHB diets. This observation corresponds with the finding of Schneeman and Gallaher Schneeman and Gallaher (1980). Fleming and Lee (1983); Lopez-Guisa et al (1988) and Nishina et al (1991) who reported that additions of insoluble, un-degradable sources of fiber such as cellulose, oat hulls, wheat bran, and corn bran to rat diets at concentrations up to 20% do not affect growth.

This is because the non-fermentable crude fiber sources dilute the nutrient density of the diet and thus reduce feed intake. On the contrary, the crude fiber in the SHB diets supported growth and development in the rats fed with SHB diets. Water is an essential nutrient, without which animal or man life cannot survive. It is known to aid food digestion. The water intake of experimental rats was directly proportional to the weight gained observed in animals fed with experimental diets. Protein and carbohydrates digestion to usable and absorbable forms has been demonstrated to depend absolutely on water as part of the biochemical reaction (McKinzie, 2009).

5. CONCLUSION

It can be concluded that the growth indices of rats fed with the test and control diets, indicated that rats fed on the coal smoked fillet diet had the best ($p < 0.001$) growth in terms of weight gain, FCR and FER; followed by the wood smoked SHB diet was best ($p < 0.001$) compared to the positive control. Thus, foods processed from the SHB could serve as a nutritive low cost food that would help increase the importance of wastes which if left uncared may cause pollution to the environment. Due to the high cost of protein concentrate and fish meal used in animal feeds, the SHB often regarded as agricultural waste / discards could be converted to nourishable feeds.

6. ACKNOWLEDGEMENT

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7. REFERENCE

Alais C. and Linden G. (1997) Food Biochemistry. Spen. Publisher, Inc., Gaithersbury, Maryland. 1999; 119 - 129Alarcón, FJ, Moyano, FJ and Díaz, M. Studies on Digestive Enzymes in Fish: Characterization and Practical Applications. In: Tacon AGJ (ed), Basurco B. (ed). Feeding Tomorrow's Fish. Zaragora: CIHEAM. Cashier Options Mediterraneennes. 22: 113 - 121

Association of Official Analytical Chemists (AOAC). (2002) Official Methods of Analysis. 17th edn Washington DC. Association of Official Analytical Chemists.

Association of Official Analytical Chemists (1984) 14. ed. Arlington. 1141

Belitz H. D. and Grosch W. (1999). Food Chemistry. Springer

Cahu C. L., Zambonino Infante J. L., Quazuguel P. & Le Gall M. M. (1999) Protein Hydrolysate Vs. Fish Meal in Compound Diets for 10-day Old Sea Bass Dicentrachus Labrax Larvae. Aquaculture. 171, 109–119

Camire M. E., Camire A., Krumhar, K. (1990) Chemical and Nutritional Changes in Foods During Extrusion. Food Sci Nutr. Rev. 29:35–56

Cho S. H. et al. (2008) Effect of Casein Substitution With Fishmeal, Soybean Meal and Crustacean Meal In The Diet of the Abalone (Haliotis discus hannai) Ino. Aquaculture Nutr. 14: 61 - 66.

Clemente A. (2000)Enzymatic Protein Hydrolysate in Human Nutrition. Trends in Food Science and Technology. 11; 254 -262

Cordova-Murueta J., & Garcıa-Carreno F. (2002) Nutritive Value of Squid and Hydrolyzed Protein Supplement in Shrimp Feed. Aquaculture. 210, 371–384.

Cordova-Murueta J., Marıa de Los Angeles Navarrete del Toro and Fernando Garcıa Carreno, et al. (2007) Concentrates of Fish Protein from By-Catch Species Produced by Various Drying Processes. Food

Chemistry. 100: 705–711
De Silva S. S., Shim K. F. and Khim Ong A.(1990) An Evaluation of the Method used in Digestibility Estimation of a Dietary Ingredient and Comparisons on External and Internal Markers and Time of Faeces Collection in Digestibility Studies in the Fish Oreochomis aureus (Steindachner). Reproduction, Nutrition, Development. 30: 215-226.
Duncan, D.B. (1955) Multiple Range and Multiple F-test Biometrics. 11:1 – 5
FAO/UN. (2007) State of the World's Forests 2007. Food and Agriculture Organization of the United Nations Rome, 2007. http://www.fao.org/docrep/009/a0773e/a0773e00.htm.
FAO/WHO. (1988) Protein Quality Evaluation Report of Joint FAO/WHO Expert Consultation, Food and Agriculture Organization of the United Nations, FAO Food and Nutrition Paper, Rome Italy. 1991; (51): 247
Fibre Sources in Rats. J. Nutr. 118, 953–962.
Fleming S. E. and Lee B. (1983) Growth Performance and Intestinal Transit Time of Rats Fed Purified and Natural Dietary Fibers. J. Nutr. 113:592 - 601
FOS - Federal Office of Statistics. (1990) Nigerian Fish Production by Sectors. Lagos Nigerian Government Printers, Nigeria. 40
Francis M., Pottenger, Jr., (1939) "Heat Labile Factors Necessary for the Proper Growth and Development of Cats." Journal of Laboratory and Clinical Medicine. 25 (6);238-240
Gomes E. F., Rema P. and Kaushik S. (1995a) Replacement of Fishmeal by Plant Proteins in the Diet of Rainbow trout (*Oncorhynchus mykiss*) Digestibility and Growth Performance. Aquaculture. 130: 177-186
Gomes E. F., Rema P. and Kaushik S. (1995b) Replacement of Fishmeal by Plant Proteins in Diets for Rainbow trout (Oncorhynchus Mykiss): Effect of the Quality of the Fishmeal Based Control Diets on Digestibility and Nutrient Balances. Water Science and Technology. 31: 205 - 211.
Hardy R. W. (1991) Fish Hydrolysate: Production and use in Aquaculture Feeds. In D. M. Akiyama & R. K. H. Tan (Eds.), Proceedings of the Aquaculture Feed Processing and Nutrition Workshop. Thailand: American Soybean Association. 109–115
Johnson W. E., Leek J. T., Scharpf R., Corrada-Bravo H., Simcha D., Langmead B, Geman D., Baggerly K.,
Irizarry R. A. (2010) Tackling the Widespread and Critical Impact of Batch Effects in High-Throughput Data. Nature Reviews Genetics. 11, 733–739
Kietzmann U., Priebe K., Rakou D., Reichstein K. (1969) Seefisch als Lebensmittel. Berlin: Paul Parey Verlag Hamburg. 63–79
Larsen (2012). Aspects of Physical and Chemical Alternatives to Proteins during Food processing- Some Implication for Nutrition. Bri. J. of Nutri.108: S288 – S297
Leonard A. M., Lossi J. A., Hintz H. F. & Warmer R. G. (1979) Animal Nutrition 7th ed. Tata McGrawhi Publishers. 356-368
Lopez-Guisa J. M., Harned M. C., Dubielzig R., Rao S. C., Marlett J. A. (2002) Processed Oat Hulls as Potential Dietary McDonald, TT, Biancheri, P, Sarra, M et al. What's the Next Best Cytokine Target in IBD? Inflamm Bowel Dis. 18 (11): 2180 – 2189
Marimuthu K., Thilaga M., Kathiresan S., Xavier R., and Mas R. H. M. H. (2011) Effect of Different Cooking Methods on Proximate and Mineral Composition of Striped Snakehead Fish (*Channa striatus,* Bloch) J Food Sci Technol. 49(3): 373–377
McKinzie, Steve. (2009) A Response from Steve McKinzie," Against the Grain. 21 (6): 23. http://docs.lib.purdue.edu/atg/vol21/iss6/23
Mensa-Wilmot Yvonne, Phillips R. D., Hargrove J. L. (2001) Protein Quality Evaluation of Cowpea-Based Extrusion Cooked Cereal/Legume Weaning Mixtures. Nutrition Research. 2001; 21: 849–857
Nishina P. M., Schneeman B. O. and Freedland R. A. (1991) Effects of Dietary Fibers on Nonfasting Plasma
Lipoprotein Levels in Rats. J. Nutr. 121: 431 – 442.
Okalebo J. R., Gathua K. W. and Woomer P. L. (2002) Laboratory Methods of Soil and Plant Analysis: A Working Manual. 2nd edition, 128
Okalebo J. R., Othieno C. O., Woomer P. L., Karanja N. K., Semoka J. R. M., Bekunda M. A., Mugendi D. N., Muasya R. M., Bationo A., Mukhwana E. J. (2006) Available Technologies to Replenish Soil Fertility in East Africa, Nutr. Cycle. Agroecosys.76: 153-170
Okeyo G. O., Lokuruka M. N. I. and Matofari J. W. (2009) Nutritional composition and shelf life of the lake Victoria Nile Perch (*Lates niloticus*) stored in ice. African Journal of Food Agriculture Nutrition and Development. 9(3): 901-919
Olafsdottir G., Martinsdottir E., Oehlenschlager J., Dalgaard P., Jensen B., Undeland I., Mackie I. M., Henehan G. and Nielsen J. (1997) Methods to Evaluate Fish Freshness in Research and Industry. Trends Food Sci. Technol. 8: 258 - 265

Olatunde A.A. (1998) Approaches to the Study of Fisheries Biology in Nigeria Inland Waters. Proceedings of International Conference of two decades of research In Lake Kainji. 338- 541

Omojowo F. S. I., Garba L. and Ihuahi J. A. (2009) Comparative Assessment of Potassium Sorbate and Sodium Metabisulphite on the Safety and Shelf Life of Smoked Catfish. Nature and Science. 7(10):10 – 17

Onu P. N., Nwakpa P. E. and Chukwu L. O. (2001) Performance of Broiler Chicks (Gallus domesticus) Fed Maize Offal-Based Diets Supplemented with Roxazyme G enzyme. Int. J. Poult. Sci. 2006; 5: 607-610.

Patterson, J. Canning of Smoked Brown Mussel, Perna Indica. Phuket Marine Biological Centre Special Publication. 25(1):219–220

Reinik M., Tamme T., Roasto M., Juhkam K., Tenno T., Kiis A. (2007) Polycyclic Aromatic Hydrocarbons (PAHs) In Meat Products and Estimated PAH Intake by Children and the General Population in Estonia. Food Addit Contam. 24(4):429-37

Saisithi P. (1994) Traditional Fermented Fish: Fish Sauce Production. In: AM Martin, Editor. Fisheries Processing Biotechnological Application. London: Chapman & Hall. 111 – 131

Saliu J. K. (2008) Effect of Smoking and Frozen Storage on the Nutrient Composition of some African Fish. Adv. Nat. Appl. Sci. 2(1): 16-20

Schneeman B. O. and Gallaher D. (1980) Changes in Small Intestinal Digestive Enzyme Activity and Bile Acids with Dietary Cellulose in Rats. J. Nutr. 110: 584 – 590

Sikorski Z. E., Lolakowska A., Pan B. S. (1990) The nutritive composition of the major groups of marine food organisms. In: Sikorski ZE, editor. Resources Nutritional Composition and Preservation. Boca Raton: CRC Press-Inc. 30–52

Simon Martin, (1995) "Intestinal Permeability," BioMed Newsletter 11, May, 1995

Statistical Package for Social Sciences for Windows (SPSS) 14.0. (2005) Computer Program, MS. For Windows, Version 14 .00, SPSS Inc., USA. Release 14.0. http://www. Spss.com.

Uauy R., Hoffman D. R., Mena P., Llanos A., Birch E. E. (2003) Term infant studies of DHA and ARA supplementation on neurodevelopment: Results of randomized controlled trials. J Pediatr. 143 (4):17–25. doi: 10.1067/S0022-3476(03)00398-6. [PubMed] [Cross Ref]

USDA (*The Economic Research Service of the USDA*). (2006) Global Food Markets: Briefing Rooms. http://www.ers.usda.gov/Briefing/.

Vaclavik V.A. and Christian, E.W. (2007). Essentials of Food Science. Springer

Vitaglione P. and Fogliano V. (2004). Use of antioxidants to minimize the human health risk associated to mutagenic / carcinogenic heterocyclic amines in food. Journal of Chromatography B 802:189-199

Wardlaw G. M. & Insel P. M. (1996) Perspectives in Nutrition. Third Edition. New York, NY: WCB/McGraw-Hill.

Warshaw A. L., Walker W. A., and Isselbacher K. J. (1974) "Protein Uptake by the Intestine: Evidence for Absorption of Intact Macromolecules. Gastroenterology. 66:987

Young L. J., Lim M., Gingrich B., Insel T. R. (2001) Cellular Mechanisms of Social Attachment. Horm Behave. In Press.

Zheng W., et al. (1998) Report: "Well-done Meat Intake and the Risk of Breast Cancer,." Journal of the National Cancer Institute. 90(22):1724-1729 http://articles.mercola.com/sites/articles/archive/2002/05/29/over-cooking.aspx

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