Original Research Article

Stomach Environment, Serum Metabolites and Microbial Cells of Goats Fed Condemned Engine Oil as Option for Waste Oil Management

Abstract

The experiment was carried out with the objective of developing and adaptive rumen microbial ecology towards the breakdown of different of different oils as enshrined on this work, for bioremediation on waste oil. The study was conducted in Michael Okpara University Teaching and Research Farms. The diets contained T1 = 0% oil, T2 = 5.5% palm oil (PO), T3 = 5.5% condemned engine oil (CEO), and T4 = 5.5% palm kernel oil (PKO), sawdust, poultry litter, palm kernel cake and 5% ruminant concentrate mixed were used to balance the diets in a completely randomized design. 40 unsexed Sokoto red goats aged between 6 to 7 months were divided into 4 treatments of 5 replicates, in a completely randomized design (CRD) and housed in 0.5 by 0.75m^2 floor space pens. Fed for a period of 52 days. The results were separated according to the parameters of microbial cells count, serum metabolites, stomach ecology and growth rate. The investigation revealed that microbial load counts, average dry matter of stomach compartment, serum metabolites and growth rate were significantly ($p<0.01$) influenced by treatments. Recticulo-rumen microbial load counts declined with goats fed diets supplemented with condemned engine oil. This shows that microbial community of rumen fed different oils were greatly affected. The microorganisms may become adaptive and genetically improve into oil eating microbes, when advance procedures are carried out. It can be concluded that, long time inclusion of condemned engine oil in the diets of goats, the recticulo-rumen microbes would redesign its enzymatic feeding mechanism to feed on condemned engine oil.

Key words: Environment, Goats, Microbes, Oils, Wastes, Management

1. INTRODUCTION

Resorting to making waste management a competitive feed for farm animal production, in the bid to encourage these nations to clean up and create environmental friendliness. The waste segregation and recycling might be an 'old hat' in most countries, but in Nigeria, where cities are growing exponentially, negligence, administrative mismanagement and lack of infrastructure have resulted in open dumping in towns and cities nationwide. The Life-enzyme and Fine Chemical Research (Waste Management, Recycling and Utilization) has estimated that, by the year 2040, waste generation across Nigerian's cities will triple as well as the human pollution, which will increase in unaffordable and unfriendly environment, and wastes disposal can be as in making it as part of formulated animal feed (Agida *et al.*, 2021; Anigbogu *et al*., 2020 and Anigbogu, 2014).

Nigeria generates about 96.36 million tons of Municipal Solid Waste (MSW), which is about 4/5 of the country's total municipal organic waste (MOW) of which 7.709 million tons is waste papers (WP), which is 8% of the total MOW generated in the year 2012. In the future, it will be important and of great benefit that, Nigerian's municipality governments take more responsibility for the safety in disposal of its waste nationwide. Though, the implementation of the Municipal Waste Management rules and collection has been poor and needed to be improved. The idea of handling municipal solid waste (MSW) management by processing into farm animal feeds came to the interest of most animal scientist. Oil and grease are considered hazardous pollutants, particularly in the aquatic environments and can completely damage the ecology of the aquatic ecosystems (Bala, *et al.,* 2015). The pollution of the soil and water bodies by petroleum products is a huge environmental concern worldwide (Carson *et al.*, 2003). The fate of petroleum products found in the soil and water bodies depend solely on the soil microbial community, as degradation cannot take place without these hydrocarbonoclastic organisms, which established that microorganisms depend on the availability of nutrients for survival (Dombrowski and Baker, 2016). The growth rate of oil degrading bacteria on contaminated ecology is often restricted by the accessibility of nutrients like nitrogen and phosphorus (Bragg *et al*., 1993; Lee *et al.*, 1993; Venosa *et al.*, 1996). These nutrients are the basic building blocks of life and to create the enabling environment for necessary enzyme producers by the microorganisms and to break down the hydrocarbon compounds (Adeleye, *et al.*, 2018).

ls of different kinds are being produced in every day markets and activities in great quantities, either inform of waste products or in normal processing method (Gohl, 1981). At the same time, the conversional market for fat has been increasing, largely because of the high utilization of oils by the industries and as human needs, or as farm animal feeds. Hence, oil is availed at a high cost for feeding farm animals, and are added to feeds to enrich the energy value of the ration to levels unattainable with other ingredients. Pure oil (lard and tallow) is often the cheapest available energy sources. The economy benefits on the inclusion of oil or fat in rations is often encouraged by the cost of oil itself, improved growth rate and better productivities (Mayard *et al*., 2005). It will be noted that, the addition of oil will permit the inclusion of low-energy and low-cost feed materials in rations for animal husbandry. It was observed that, fatty acids from saturated, unsaturated as well as polysaturated are essential components of oils in farm animal feeding system and were noted as part of the animal integral feeding system (Gohl, 1981). Oil helps in the incensement and in palatability of the diets, and elimination of dustiness in compounded feeds and wears on pelleting diets (Wan zahari and Alimon, 2014).

Thailand Palm tree (*Elais guineensis*) is a tropical tree crop native to West Africa especially Nigeria. Palm tree can also be found in countries like, Malaysia, Indonesia, Papau New Guinea, Ivory Coast, Colombia, India and Brazil (Murphy *et al.*, 2021). Two types of oil extracted from palm fruits: are red palm oil (RPO) from the edible mesocarp and palm kernel oil from the hard endocarp seeds after separating it from the hard shell. The two oil is use for cooking and for other traditional health benefits for humans and domestic animals alike. Red palm oil, contains triglycerides (TAGs), vitamin E, carotenoids (500-700ppm), tocopherols and tocotrienols (600-1200ppm), phytosterols, phospholipids, free fatty acids (FFAs), lipid oxidation and gums (Mba *et al.*, 2015; Souganidis *et al.*, 2013; Obibuzor *et al.*, 2012; Edem, 2002; and Sambanthanmarthi *et al.*, 2000). The fatty acids composition of palm oil; lauric acid (12:0) 0.2%, myristic acid ((14:0) 1.1%, palmitic acid (16:0) 44.0%, stearic acid (18:0) 4.5%, oleic acid (18:1) 39.2%, linoleic acid (18:2) 10.2%, linolenic acid (18:3) 0.4%, arachidic acid (20:0) 0.1%, total saturated fatty acids (TSFAs) 49.9%, total monounsaturated fatty acids (TMUSFAs) 39.2%, and total polyunsaturated fatty acids (TPUFAs) 10.5% (Edem, 2015). Palm kernel oil fatty acids composition; caproic acid (6:0) 0.2%, caprylic acid (8:0) 3.3%, capric acid (10:0) 3.5% lauric acid (12:0) 47.8%, myristic acid (14:0) 16.3%, palmitic acid (16:0) 8.5%, stearic acid (18:0) 2.4%, oleic acid (18:1) 15.4%, linoleic acid (18:2) 2.4%, arachidic acid (20:0) 0.1%, total saturated fatty acids (TSFAs) 82.1%, total monosaturated fatty acids (TMUFAs) 15.4% and total polyunsaturated fatty acids (TPUSFAs) 2.4% (Edem, 2015).

Condemned engine oil (spent engine oil or used crankcase oil) is derived from a complex mixture of low and high (C_{15}-C_{50}) molecular aliphatic and aromatic hydrocarbons, lubrication additives, metals and some organic and inorganic compounds. Its chemical composition varies due to; crude oil origin, distillation or refining processes, engine type used for lubrication, the gasoline combustion products, additives used on both the fuel and with the original oil, and the length of time of usage in the engine. The condemned engine oil is found to have, 78-80% weight/weight aliphatic hydrocarbon (primary alkanes and cycloalkanes with 1-6 rings); 11-15% monoaromatic hydrocarbons; 2-5% diaromatic hydrocarbons, and 4-8% polyaromatic hydrocarbons (Vasquez-Duhalt, 1989). Lubrication additives are 20% of which consist primarily; zinc diaryl, molybdenum disulphide, zinc dithiophosphate, metal soaps, organometallic compounds; detergents and dispersants constitute 2-15% of the additives based on the manufacturer’s specifications (Vasquez-Duhalt, 1989). As a result of the oil additives, the condemned engine oil has inclusively the following minerals; zinc, barium, phosphorus, some chlorine and bromine compounds (Soleimani et al., 2018).

Based on the findings of Gohl (1981), studies had shown that, it is possible to decrease the amount of excrement in the farm animal system, to less than one half by adding about 7% fat to feed the farm animals, thereby minimizing waste disposal problems. For these reasons it may be necessary to add pure oils in some compounded rations, thus this study, especially in ruminant rations, as an alternative waste management and as part of formulated feed for goats (Anigbogu, 2014).

2. MATERIALS AND METHODS

2.1 Chemical analyses

The dry matter and ash were determined by conventional gravimetric as adopted by Jennische and Larsson (1990); while the crude fat was determined as described by Anonymous (1984). Total nitrogen content was determined by dry combustion at 14^0C with a CNS 2000 from LECO Equipment Corporation. Volatile fatty acids and ethanol were determined by HPLC using an ion-exchange Colum (Aminex HPX-87H, 300^o,7.8mm, Bio-Rad, Richmond, CA, USA) at 35^0C. Gross energy was determined by using an automatic bomb calorimeter (LECO AC 300) (Swedish standard 187182). The pH was measured in the water phase after shaking a sample-water mixture with the volume/volume ratio 1:2. Analysis of most elements, other than carbon and nitrogen, were done with an inductively coupled plasma emission spectrometer (JY 50 P, Instrument S.A; Division Jobin-Yvon, Longjumean, France) after wet ashing with a mixture of concentrated perchloric and nitiric acids (Frank, 1976; Frank and Petersson, 1983), while wet ashing was done with nitric acid (Anonymous, 1993) was also tested.

2.2 Experimental animals and diets

Forty Red Sokoto goats between the ages of 6 - 7 months with average weight of about 8.01kg were used for the study. They were housed on a floor space of 0.5 - 0.75 square meters, with 4 - 5 linear inches feeding space on well ventilated, cemented, floored pens. To prevent the accumulation of excreta and wetness of the pens, the pens were spread with wood shaven as bedding material, and the goats quarantined for 3 weeks to observe their health condition, and treated against helminthes and ectoparasites using IVOMEC during which they were fed the experimental rations (Anigbogu *et al.,* 2009b). The diets consist of T1 = 0% oil, T2 = 5.5% Palm oil (PO), T3 = 5.5% Condemned engine oil (CEO), and T4= 5.5% Palm kernel oil (PKO). Sawdust, poultry litter, palm kernel cake, 5% ruminant concentrated mixed were used to balance the diets as shown in Table 1.

Table 1. Experimental diets with or without condemned engine oil fed to the goats.

Feed composition	T_A No Oils	T_B Palm Oil	T_C Palm Kernel Oil	T_D Condemned Engine Oil
Sawdust	42.5	40	40	40
Poultry Litter	23	20	20	20
Palm Kernel Cake	34	34	34	34
Palm Oil	-	5.5	-	-
Palm Kernel Oil	-	-	5.5	-
Condemned Engine Oil	-	-	-	5.5
5% Ruminant Concentrate	0.50	0.50	0.50	0.50

2.3 Feeding and water procedure

The 40 goats were divided into 4 treatment groups according to their initial body weight and were assigned to 4 diets in a Complete Randomized Design. To avoid selective intake of the diets, weighed quantities of the diets were offered daily, separately at 7.30am and 4.30pm, respectively. Water was given *ad libitum*. The initial weights of the goats were measured at the beginning of the experiment and subsequently at weekly intervals. All data gathered were recorded and diets offered were adjusted depending on the weights of the goats without altering the diets.

2.4 Data collection and experimental designs

Feed intake was measured daily, while the mean weight gain, feed intake and efficiency of feed utilization were calculated at the end of the study based on (Anigbogu, 2011). Completely Randomized Design (CRD) of 4 treatments and 5 replicates, where 2 goats/replicates were adopted for the experimental study according to (Gomez and Gomez, 2005). Parameters measured include; weight gain, feed intake, efficiency of feed utilization, economic benefit of diets, serum and stomach metabolites, stomach dry matter and microbial cell load. The initial live weights of goats were determined by weighing them individually at the commencement of the experiment and at weekly interval till the end of the study.

2.4.1 Data determination

Average daily weight gain = Final weight - Initial weight ÷ Total number of days

Average daily feed intake = Total feed intake ÷ Total number of days

Feed conversion ratio = Feed Intake ÷ Weight gain

2.5 Microbial cell count

The pour-plate method as described by (Harrigan and McCane, 1987) was used to determine the rumen microbial load. Three animals from each of the treatment were stunned, and rumen content collected (Chesson *et al*., 1983). One gram of each sample was suspended into 9ml of sterile distilled water in a McCartney bottle to give 0.1 (one tenth) dilution. Serial dilutions were made up to 1/10 and each dilute of the samples were plated under duplicate using pour plating techniques. This was done by transferring 1ml from each McCartney bottle into 2 different dishes, and then pour about 15ml of the nutrient agar media on each sample. Incubation of microorganisms was done in an incubator for 48 hours at 37°C. After which the colonies appearing on the agar plates were counted using a tally counter and hand lens. The average colony obtained from the countable duplicate plate was expressed as colony forming unit per gram (cfu/g).

2.6 Statistical analysis

All data gathered at the end of the studies were analyzed using the analysis of variance (ANOVA) of Complete Randomized Design (CRD) (Steel and Torrie, 2000). The mean separation for significant effect was done using Duncan's New Multiple Range Test where significant occurred (Gomez and Gomez, 2005).

3. Results and Discussions

The performance characteristics of the experimental goats were stated as in Tables 2, 3, 4, 5, and 6, respectively; they include the growth data, stomach and serum metabolites, average dry matter of the stomach compartments, and microbial loads of the reticulum-rumen.

Body weight change

The Table 2 shows the body weight change of the goats fed with or without condemned engine oil as part of formulated diets showed (*P*<0.01). The best value was noted among the goats fed diet T1 (2.00 kg) then followed by T2, where the goats fed T4 and T3 diets had the least values of -1.25 kg and -1.50 kg, respectively. The values as noted in T4 and T3 diets were as the result of the inclusion of oils of high levels of saturated fatty acids which are related to hydrocarbons as part of formulated diets. This is similar to the reported of (Maynard *et al.,* 2020), who revealed that, saturated oils have high levels of lauric acids and of poor composition of unsaturated and polyunsaturated fatty acids in fatty acid profile data, which can result to poor growth in farm animal productivity.

Average feed intake

The average feed intake was found (*P*<0.05) as in Table 2 among the goats fed the different diets with or without condemned engine oil as part of the formulated diets, while the T1 had the highest value (4.10 kg), followed by T2 and T4, respectively, where the lowest value of 3.15 kg was found among the goats fed the T3 diet. This revelation on the poor feed intake as noted in the T3 could be as a result of the inclusion of the condemned engine oil with high level of hydrocarbon and low level of unsaturated and polysaturated fatty acids as part of formulated diet. These facts could further be justified as a result of the poor palatability of the oil, which resulted to low feed intake by the goats. The poor digestibility of the T3 diet in question could also be a factor that led to slow movement of the feed within the digestive chamber of the goats, that resulted to poor feed intake. This was as previously noted by (Chanjula *et. al.,* 2018) in a related work where poor quality feeds were observed as factor on low feed intake in the nutrition of farm animals.

Average feed conversion ratio

As in Table 2, the average feed conversion ratio of the goats fed with or without condemned engine oil differed (*P*<0.01). The best value was observed in T1 (2.05) as revealed among the goats fed the diets, and was followed by T2, while poor results were obtained among the goats fed diets T4 and T3, respectively. This finding could be as a result of the poor feed intake and poor metabolism of the feeds, which contributed to the poor grow of the goats. These suggested factors contributed to poor feed conversion ratio as in this study could be as a result of the poor fat and carbohydrate metabolism. The better feed conversion ratio as obtained among the goats fed the T1 and T2 diets without the saturated oils as in diets T3 and T4 could be as a result of better energy yield that helped to improve the microbial metabolic activities in the reticulo-rumen of the goats (Chanjula *et. al.,* 2018). It is agreeable in this study that, the high quality fatty acids dominated the rations as in the T1 and T2 diets, as against diets T3 and T4, respectively.

Table 2. Growth data of goats fed with or without condemned engine oil.

Parameter	T1 0% Oil	T2 5%Palm oil	T3 5% CEO	T4 5% PKO	Significant
Ave. initial body weight (kg)	8.00	8.50	8.50	8.00	Ns
Ave. final body weight (kg)	10.00[a]	9.00[b]	7.00[c]	7.75[c]	**
Ave. body weight changes (kg)	2.00[a]	1.00[b]	-1.50[c]	-1.25[d]	**
Ave. feed intake (kg)	4.10[a]	3.70[ab]	3.15[c]	3.50[b]	*
Ave. feed conversion ratio	2.05[b]	3.70[a]	-2.10[d]	-2.80[c]	**

(*P*<0.01=**, *P*<0.05=*), CEO = Condemned Engine Oil, PKO = Palm Kernel Oil

Stomach pH metabolite

The stomach pH metabolites among the goats fed with or without condemned engine oil as part of formulated diets showed (*P*<0.05) as in Table 3. The highest value was noted among the goats fed T1 diet (6.70) then followed by T2, where the goats fed T4 and T3 diets had the least values of 6.00 and 5.70, respectively. These values recorded were as the result of the inclusion of the oils with high levels of saturated fatty acids as part of the formulated diets for the goats as in palm kernel and condemned engine oils respectively. This is similar to the reported of (Maynard *et al.,* 2010) who noted that these oils have high levels of lauric acids and of low or non-composition of unsaturated fatty acids in their fatty acid profiles data which lead to the increased level of the pH in the stomach environment of the goats, as in this study.

Average total volatile fatty acids (TVFA)

The average total volatile fatty acids were found (*P*<0.01) as in Table 3 among the goats fed the different diets with or without condemned engine oil as part of the formulated diets, while the T1 had the highest value (226.12Mmol/L), which was followed by T2 and T4, respectively as in the Table 3, where the lowest value of 146.13Mmol/L was revealed among the goats fed the T3 diet. This record on the lower TVFA as noted in the T3 could be as a result of the inclusion of the condemned engine oil with high level of hydrocarbon and low level of unsaturated fatty acids as part of the formulated diet in the nutrition of the goats. This is as previously reported by (Machmueller *et. al.,* 1998) in related work where poor quality oils with poor level of unsaturated fatty acids were used as part of formulated diets for farm animals.

Stomach sodium metabolite

The level of stomach sodium metabolite was observed (*P*<0.05) among the goats fed with or without condemned engine oil as part of the formulated diets as noted in Table 3. Though, the T3 fed goats had the lowest value (117.13mM) of stomach sodium metabolite, which was followed by those fed the T4 and T2 diets, respectively. While the goats fed diet T1 had the highest value. This value of the stomach sodium metabolite as noted among the goats fed the T3 diet helped to lower the stomach sodium metabolite pH to higher acidic level when compared to other treatments. This was expected and helped to affect the action of the ruminal microbial cells as in T3 diet. This resulted to poor microbial cell loads, and in agreement to the works of (Nangia and Sharma, 1994; Yang *et al*., 2004). The lower stomach sodium metabolite value recorded in T1 and T2 diets revealed that, it takes the goats on good quality oil base diet to standardize the stomach pH. This helps to low the stomach sodium metabolites for better performance and to create good stomach environment for high microbial activities within the ruminal vats. While the goats on the T3 diet with poor quality fatty acids had poor results. This revelation is in line with the observation made by (Hutjens, 1992; Wallace, 1994) in similar studies.

Stomach potassium metabolite

There were significant (*P*<0.01) differences on the stomach potassium metabolite as noted in Table 3 on goats fed diets with or without condemned engine oils, where the highest value was noted among the goats fed the T1 diet, then followed on the T2 and T4, respectively, while the lowest value was observed in the T3. The high stomach potassium values as found in the T1 and T2 resulted to the improved metabolic activities in the goats' ruminal fluids; this helped to increase the microbial cells in the ruminal vats. This is to say that, the improved stomach potassium metabolite resulted to increase in the microbial cells within the stomach environment of the goats. Further, it was observed that, the lesser the quality in essential fatty acids in the diet consumed by the goats, the decrease in the microbial cell load in the ruminal vats system, and the lesser the stomach potassium metabolite, this was as observed by (Van Soest, 1994).

Stomach chlorine metabolite

The Table 3 shows the stomach chlorine metabolite among the goats fed with or without condemned engine oil as part of formulated diets, which revealed (*P*<0.01). While the T1 diet fed goats had the highest value, then followed by the T2 and the T4 respectively, while the poorest value was observed on the T3. This low stomach chlorine metabolite value as found in T3 was expected to help improve the ruminal environment for an increase microbial cells production. This is contrary with the observations made in this study of (Atikah *et al.,*2018), where a high microbial cell load was found in a similar work.

The observation could be an indication that, growth of microbial cell is inconsistent in an unfavorable condition and costly in the absence of essential fatty acids from quality oil or feed (Wan Zahari and Alimon, 2014). So, essential fatty acids are needed in diets for goats for good performance. Diets containing quality oils were observed to maintain better environment to obtain a measure of microbial cells as found in this study (Mavromichalis, 2015).

Total stomach nitrogen (N) metabolite

As shown in Table 3, the total stomach nitrogen metabolite revealed (P<0.01) among the treatments fed with or without condemned engine oil. While the T3 had the lowest value, where the best total stomach N metabolite value was observed in T1 diet as well as in T2, respectively, then followed by the T4. This lower total stomach N metabolite value as noted in the T3 diet resulted to the poor level in the microbial activities which in turn coursed the poor microbial cell load in the ruminal environment. Based on the results of (Chanjula *et al.*, 2010), who observed that, total stomach N metabolite helps to improve the life span of the living cell activities and their general performances as well as in the microbial cells themselves. It was observed that N is the index of protein composition and the observations made in this study are in line with the works of (Atikah, *et al*., 2018).

Stomach fat metabolite

The high stomach fat metabolite as noted in T3 (2.12mM) was (P<0.01) among the goats fed with or without condemned engine oil, where the poorest was found on the goats fed diet T1, then followed by these of T2 and T4, respectively. It was observed that, this low level of stomach fat metabolite has a positive effect in the ruminal microbial environment, which resulted to better metabolic activities in the ruminal vats, that lead to very high microbial cell production in the fermentation environment of the goats (Anonymous, 2018). This was as revealed among the goats in the T1 and T2 which is in conferment with the observation made by (Atikah *et al*., 2018) in a similar study. The result of the stomach fat metabolite as observed in this study with or without condemned engine oil could be an indication that, metabolism is inconsistent and poor in the present of hydrocarbons and other poor quality fats as a component of feed. So, quality fats or oils are needed as part of formulated ration to get the same proportion of metabolic action and improved ruminal environment, for increased microbial cells activities and for better productivities. All other diets containing oils or without oil but with essential fatty acids in the diet were observed to improve rumen environment that helped to obtain a measure of increased microbial cells as in this study (Boggs *et al.*, 1987; Fereira *et al.*, 2012).

Table 3. Stomach metabolites of goats fed with or without condemned engine oil.

Parameters	T1 0% Oil	T2 5%Palm oil	T3 5% CFO	T4 5% PKC	Significant
pH	6.70^{a}	6.40^{ab}	5.70^{c}	6.00^{bc}	Ns
TVFA (Mmol/L)	226.12^{a}	201.70^{b}	146.13^{c}	192.23^{b}	**
Sodium (mM)	137.12^{a}	129.10^{ab}	117.12^{b}	120.32^{b}	s*
Potassium (mM)	123.24^{b}	199.21^{a}	99.91^{c}	116.19^{b}	**
Chlorine (mM)	68.10^{a}	61.19^{b}	50.41^{c}	58.72^{b}	**
Total N (mg/100ml)	56.10^{a}	50.41^{b}	43.92^{c}	46.11^{bc}	**
Total fat (mg/100ml)	0.67^{c}	0.88^{b}	2.12^{a}	0.95^{b}	**

(*P*<0.01=**, *P*<0.05=*); CEO = Condemned Engine Oil, PKO = Palm kernel Oil, TVFA = Total Volatile Fatty Acids.

Serum urea metabolite

As in the Table 4, the serum urea metabolite was significant (*P*< 0.01) among the goats fed diets with or without condemned engine oil, though the T3 goats fed diet had the lowest value followed by the T4 fed goats. While the highest were generally noted on the T1 and T2 fed goats, respectively; which is in agreement with the observations made by (Seephueak *et al*., 2011) as also noted by (Hutjan, 1991) in similar report.

Serum creatinine metabolite

The serum creatinine metabolite of the goats fed with or without condemned engine oil differed (*P*<0.01) as shown in Table 4. The highst value was noted in T1 as revealed on the goats fed the diet, then followed by T2 and T4 diets, respectively, where the lowest serum creatinine metabolite was obtained in T3 and was as a result of poor fat and carbohydrate metabolism that resulted to poor energy availability (Abubakr *et al.*, 2015; Jouany and Morgavi, 2007). The poor functional protein as noted in this study is as a result of the poor fat and carbohydrate metabolism. The high serum creatinine metabolite as obtained among the goats fed the T1 and T2 diets with or without condemned engine oil or oils with high levels of saturated fatty acids inclusion, resulted to better energy yield that helped to improve the microbial activities. It is agreeable in this study that, the high quality fatty acids dominated rations as in the T1 and T2 diets, and as part of the goats formulated rations showed good results (Wan Zahari and Alimon, 2014). The low creatinine value that is noted in T3 fed goats, was as a result of poor protein intake, poor fiber and fat metabolisms.

Serum glucose metabolite

The Table 4 shows that the serum glucose metabolite of the goats fed with or without condemned engine oil differed (*P*<0.01) among the treatment diets. The best value was observed in T1 (2.84Mmol/L) as found among the goats fed the diet, then followed by T2 and T4 diets, respectively, while the lowest serum glucose metabolite as obtained in T3 (2.01Mmol/L) was as a result of poor fat and carbohydrate digestion, which resulted to poor energy metabolism. This high serum glucose metabolite as obtained among the goats fed T1 and T2 diets without condemned engine oil or oils with high levels of saturated fatty acids inclusion, resulted to better energy yield that help to increased microbial performance. It is agreeable on this study that, the high-quality fatty acids dominated the rations as in T1 and T2 diets fed goats, as revealed in the study of (Yang *et al.,* 2004; Mavronmichalis, 2015)

Serum protein metabolite

The serum protein metabolite for the goats fed diets with or without condemned engine oil as found in Table 4 were (*P*<0.01) among the treatment groups. The poorest values of 50.17Mmol/L and 63.17Mmol/L were recorded on the T3 and T4 diets fed goats, respectively. This is as a result of poor quality essential fatty acids present in the diets as a result of the saturated fatty acids present. While higher levels of serum protein metabolite were found in T1 and T2 diets fed goats without condemned engine oil or oils with high composition of saturated fatty acids as part of formulated diets. The best serum protein metabolite values as noted among the diets fed goats could be as a result of better metabolism of the carbohydrates and fats that resulted to better glucose yield, which helped to high productivity of the microbial cells in the ruminal chambers, the weigh house of the beneficial microbial organism. This is in line with and comparable to the studies of (Jori *et al.,* 1995; Fayenuwo *et al.,* 2003) in a similar work.

Serum fat metabolite

The Table 4 showed that, the serum fat metabolite differed (*P*<0.01) among the goats fed diets with or without condemned engine oil, values were lower among the goats fed diet T3, followed by those fed diet T4, while T2 diet fed goats had the highest value. The higher value as obtained among the goats fed diet T2 on palm oil-based diet, with quality essential fatty acids was as a result of better metabolism as noted in this study (Atikah *et al.*, 2018; Abubakr *et al*., 2015), which is as a result of including palm oil with low level of saturated and considerable levels of unsaturated fatty acids, as part of formulated diet, which contributed to high metabolism among the goats in T2 diet. It has high palmistic acid as observed in the study of (Abubakr *et al.,* 2015).

Table 4. Serum metabolites of goats fed with or without condemned engine oil.

Parameters	T1 0% Oil	T2 5%Palm oil	T3 5% CEO	T4 5% PKO	Significant
Urea (Mmol/L)	2.99^{a}	2.61^{b}	2.01^{c}	2.41^{b}	**
Creatinine (Mmol/L)	89.26^{a}	86.15^{c}	69.14^{b}	76.21^{b}	*
Glucose (Mmol/L)	2.84^{a}	2.61^{a}	2.01^{b}	2.42^{a}	**
Protein (Mmol/L)	68.17^{a}	65.19^{a}	50.17^{c}	59.13^{a}	**
Fat (Mmol/L)	1.96^{c}	2.60^{a}	0.81^{d}	2.10^{b}	**

($P<0.01$=**, $P<0.05$=*), CEO = Condemned Engine Oil, PKO = Palm kernel Oil.

Reticulum-rumen dry matter (RDM)

There was ($P<0.01$) on the reticulum-rumen dry matter of goats fed with or without condemned engine oil-based diets as in the Table 5. The value was high among the goats fed T3 diet, which was followed by T4 and T2 respectively, where the lowest was noted in the T1 diet fed goats. The best value as obtained in T1 diet fed goats without oil could be an indication of efficient utilization of the diet, that resulted to higher serum and stomach metabolites in the goat' physiological system. That is to say that, the diet had efficient metabolism than in the other treatments, where oils were made part of the formulated rations, and is in line with the finding of (Hujtens, 1991; Machmueller *et al.*, 1998; Anigbogu, 2011).

Omasum dry matter (ODM)

As observed in the Table 5, the omasum dry matter showed ($P<0.01$) among the goats fed with or without condemned engine oil as part of formulated diets. The findings were in similar pattern as noted in the reticulum-rumen dry matter as previously discussed. The T3 had the highest value as revealed on the goats fed the condemned engine oil, then followed by the goats fed diets T4 and T2, respectively, while the goats placed on diet T1 had the list value. The higher values as noted among the goats fed with oils as part of the formulated diets showed poor metabolism, when compared to the diets when oils were made part of the formulated diets. This agreed with the finding of (Maynard *et al*., 2005; Abubakr *et al.*, 2015), who proved that, oil can be an inhibiting factor in the metabolic activities in the reticulum-rumun of the ruminant animals, on the formation of microbial cells, due to the poor activities of the microbes. Though, goats needed low intake oil to meet their energy needs and for better metabolism (Abubakr *et al.,* 2015; Anonymous, 2018).

Abomasums dry matter (ADM)

There was (*P*<0.01) on the abomasum dry matter as noted in Table 5 among the goats fed with or without condemned engine oils as part of the formulated diets. Where the T1 had the list value, followed by the T2 and T4 fed goats, respectively. The T3 had the highest value (12.17). The best abomasum dry matter was found on T1 which was as a result of better metabolic activities found among the goats fed diet without oil. This helped the reticulum-rumen microbes to adhered properly to the feed particles, for proper metabolism in the rumen environment, due to the low oil found in the diet. The lesser the quantity of oil in the ruminant diets consumed, the improved in the reticulum-rumen environment and the better the metabolic action of the diet (Anigbogu and Adekule-Agbale, 2013; Anigbogu and Ezekwem, 2013). The list values as observed among the goats fed oils base diets, might be further as a result of the inclusion of oils in the diets; which inhibited the microbial actions of microorganisms in the ruminal system. This is among the contributory factors that lead to retard the ability of the goats to metabolize the diets and convert the feed into products, because of the high fats present in the diets that resulted to poor metabolism. Furthermore, the growth of the microbial cells was stagnant among goats fed oils as part of the formulated diets as revealed by (Machmuller, *et al.*, 1998)

Table 5. Average dry matter of stomach compartment of goats fed with or without condemned engine oil (%).

Parameters	T1 0% Oil	T2 5%Palm oil	T3 5% CEO	T4 5% PKO	Significant
Reticulo-rumen	9.98[c]	11.83[b]	13.91[a]	12.10[b]	**
Omasum	17.64[c]	20.19[b]	24.12[a]	21.09[b]	**
Abomasum	7.17[c]	9.45[b]	12.16[a]	9.67[b]	

(*P*<0.01=**, *P*<0.05=*), CEO = Condemned Engine Oil, PKO = Palm kernel Oil

Reticulum-rumen bacteria load

The average reticulum-rumen bacteria load was found (*P*<0.01) among the goats fed with or without condemned engine oils as part of the formulated diets, while the poorest results was found on T3, then followed by the T4 and T2, respectively in Table 5. The goats fed the T1 diet had the best value at $1.6x10^9$ as shown in Table 6. The record on the lower reticulum-rumen bacteria as noted among the goats fed the T3 diet could be as a result of the inclusion of the condemned engine oil as part of the compounded diet. Condemned engine oil has a low but poor composition of the essential fatty acids as compared to palm oil as a dietary feed (Doreau and Chillard, 1997). It was noted to be dietary poor as feed material for livestock. This is as previously reported by (Boggs *et al.,* 1987) in a related study. The supplementation of the condemned engine oil as feed has resulted to the poor ruminal pH and ruminal metabolites as observed in this study, which actually resulted to the poor microbial activity in the vat.

Reticulum-rumen protozoa load

The reticulum-rumen protozoa load of goats fed with or without condemned engine oil was observed (P<0.01) as in Table 6, where the T3 showed the lowest value at $7.2x10^{7}$, then followed by the goats fed T4 diet, while the highest was observed among the goats fed T1 diet, then followed by those fed T2. The best value as recorded in T1 and T2, respectively was as of the absent of the lower quality fatty acids in the diet when compared to the T3 and T4, as shown in this study. It takes the goats on poor quality and a low quantity diet to record good performance, while the goats fed the none treated oil feed showed better result than those with the inclusion of oil as part of the formulated ration. This result is in line with the observation made by (Hutjens, 1991; Wallace, 1994) in similar studies.

Reticulum-rumen fungi load

As in table 6, there was (P<0.01) observed among the goats fed diets with and without condemned engine oil as part of formulated diets. The highest value was obtained among the goats fed T1 ($3.9x10^{4}$), then followed by the T2 and T4 diets respectively, where the poorest was found in T3. The higher values recorded as in the T1, T2 and T4 diets could be as a result of the none inclusion of hydrocarbon feed materials in these diets, which was toxic and inhibited the functions of microbial activities in the reticulum-rumen, the warehouse of the microbial functions. These performances noted in this work supported the report by (Salem *et al.*, 2000) oil feed additives were added as part of the formulated feed in the diets of goats.

Table 6. Microbial cell loads of the reticulo-rumen of goats fed with or without condemned engine oil.

Parameters	T1 0% Oil	T2 5%Palm oil	T3 5% CEO	T4 5% PKO	Significant
Bacteria	$1.6x10^{9a}$	$1.5x10^{9b}$	$1.1x10^{9c}$	$1.3x10^{9b}$	**
Protozoa	$9.8x10^{7a}$	$9.4x10^{7ab}$	$7.2x10^{7c}$	$8.6x10^{7b}$	**
Fungi	$3.9x10^{4a}$	$2.8x10^{4a}$	$2.1x10^{4c}$	$2.6x10^{4b}$	

(P<0.01=**, P<0.05=*), CEO = Condemned Engine Oil, PKO = Palm kernel Oil

Conclusion

Growth performance, pH, total volatile fatty acids, mineral and serum metabolites, and microbial cell loads were adversely affected by condemned engine oil. The palm oil reported no adverse effect. Regarding the effects observed on the animals fed diets containing the different oils (red palm oil, palm kernel oil and condemned or spent engine oil), red palm oil and palm kernel oil were found to have favoured all parameters obtained. Palm oil and palm kernel oil do not contain toxic substances, capable of reducing the rumen microbial activities by hampering the reproductive potency, and symbiotic maintenance of its ecology and physiological functions. It can be concluded that, long time inclusion of condemned engine oil in the diets of goats, the recticulo-rumen microbes would redesign its enzymatic feeding mechanism to feed on condemned engine oil.

ETHICAL APPROVAL

Animal ethics and welfare committee approval was taken to carry out this study.

DISCLAIMER:

Authors have declared that no competing interest exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do no not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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