LIPIDOMICS OF BLOOD AND ORGANS OF RATS FED DIETS SUPPLEMENTED WITH DIFFERENT EDIBLE OILS

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ABSTRACT

Studies were carried out to compare the effects of different edible oils (olive, turkey, palm, groundnut and soya) on lipidomics of blood and organs of rats. Thirty-six male albino rats divided into six groups (n = 6) were fed compounded diets without oil (control) and with different oils (10%) each ad libitum for twenty-eight days. Lipid profiles of tissues (blood, brain, heart and liver) and Hydroxymethylglutaryl CoA (HMG CoA) reductase activity in brain and liver were determined. All edible oil-containing diets (especially groundnut and soya oils) significantly reduced (p<0.05) weight gain and daily growth rate. Condition factor was significantly decreased (p<0.05) only in groundnut and increased in turkey oil fed groups compared with other diets. Different lipidomic patterns were elicited by the different oils compared with control. Significant decreases (p<0.05) were observed in level of cholesterol in plasma (olive and turkey oils) and heart (all oil diets) while increases were observed in HDL (olive, groundnut and soya oils), VLDL-LDL (olive, turkey and palm oils), RBC (all oil diets except olive oil group), brain (groundnut and soya oils) and liver (olive and turkey oils). HMG-CoA reductase activity significantly increased in liver of olive, soya and palm oil fed groups and brain (all oil diets) but decreased in liver of groundnut oil group. Triacylglycerol level significantly increased (p<0.05) in plasma and RBC of palm oil group, HDL (turkey oil) and VLDL-LDL (olive, turkey and palm oils) while it decreased in plasma (groundnut and soya oils), brain (all oil diets) and heart (palm and groundnut oils). Phospholipid levels increased significantly (p<0.05) in RBC (all oil diets except the olive), plasma and VLDL-LDL (all oil diets), brain (soya bean oil) and heart (turkey oil). The results indicated that olive, groundnut and soya bean oils are more beneficial to health compared with palm and turkey oils which may predispose to cardiovascular disease.

Keywords: Edible oils, Lipidomic patterns, Lipid profiles, Cholesterol, Triacylglycerol, Phospholipid Plasma, Red blood cells, Lipoproteins, Heart, Brain, Liver

INTRODUCTION

Oils from the seeds of some plants and animal fats are the sources of edible oils. They are the main constituent of various diets. They are good sources of energy and nutrients, especially essential fatty acids (Odeomelam, 2005; Kurban *et al.,* 2007; Akubugwo *et al.,* 2008; Imafidon

and Okunrobo, 2012). They also serve as a requirement for the absorption of fat-soluble vitamins. Plants such as soya beans, olive, oil palm and groundnut to mention a few, are good sources from which edible oils are obtained (Parwez, 2011). They are composed of triacylglycerols which contain saturated, mono- and polyunsaturated fatty acids (Nkafamiya *et al.*, 2010; Musa *et al.*, 2012). Also found in them is cholesterol (Behrman and Venkat, 2005; Okpuzor *et al.,* 2009). Behrman and Venkat (2005) reported that about 5% cholesterol is present in vegetable oils. They reported that it is a major constituent of chloroplasts, seeds and leaf surfaces. This report was confirmed by Okpuzor *et al.* (2009) when a quantity of cholesterol was estimated in a number of vegetable oils they worked with even when the manufacturers were silent about it.

When these fatty acids are liberated from the triacylglycerols during digestion, they either are re-esterified in the mucosal cells to triglyceride again, used for generation of energy through β-oxidation, for membrane lipid synthesis or for cell signaling (Kolawole *et al.,* 2013). Dietary intake plays a role in nutrition and health, and oils have been reported to affect lipid composition generally (Romon *et al.,* 1995; Celebi and Utlu, 2006). The amount and type of oil contained in a diet have long been linked with risk of Coronary Heart Disease (CHD) (Ighosotu and Tonukari, 2010). There is an increasing rate of cardiovascular disease (CVD) in developing countries and while dealing with this, there is still the problem of poor nutrition (WHF, 2015) and this has prompted the research interest in edible oils. Oils that contain saturated fatty acids have been reported to increase blood cholesterol levels, and consequently increase the risk of CVD (Sundram *et al.,* 1995; Murray *et al.*, 2003; WHF, 2015) while the oils that contain unsaturated fatty acids, while being protective, are easily oxidized thereby increasing the amount of peroxidation products in the liver (Ide *et al.,* 1978; Slater, 1972). Diets high in saturated fat have been reported to cause 31% of CHD and 11% of stroke worldwide (WHF, 2015). The oils especially rich in linoleic and α-linolenic acids are reported to increase HDL-

cholesterol (good cholesterol) and decrease LDL-cholesterol (bad cholesterol) and lowers risk and predisposition to CVD (Arterburn *et al.,* 2008), while higher intake of oleic acid decreases LDL-cholesterol but does not affect HDL-cholesterol levels (Lawton *et al.*, 2000; Przybylski and McDonald, 1995). Several studies also indicated that diets rich in oleic acid decrease the development of atherosclerosis and lower serum cholesterol by reducing oxidative stress and inflammatory mediators while promoting antioxidant defense. The reverse is however the case for saturated fatty acid-containing oils.

Soya and olive oils are pale yellow oils. While soya oil contains about 60% polyunsaturated fatty acids followed by almost 25% monounsaturated fatty acids, olive oil contains almost 70% monounsaturated fatty acids followed by 14% saturated fatty acids. Groundnut oil, on the other hand, contains about 59% monounsaturated, 30% polyunsaturated and 20% saturated fatty acids (Imafidon and Okunrobo, 2012). Turkey oil and palm oil are almost in the same category, in that they both contain approximately the same amount of monounsaturated fatty acids (40%) followed by the saturated fatty acid content. However, palm oil contains almost two folds of saturated fatty acids present in turkey oil. Polyunsaturated fatty acids are however more in turkey oil than palm oil. These edible oils also contain phenolic compounds like flavonoids, terpenoids and lignans that can serve as antioxidants and anticancer substances (Edem and Akpanabiatu, 2006). For example, palm oil is known to be rich in antioxidants particularly β-carotene and vitamin E (Edem and Akpanabiatu, 2006). Antioxidants contained in edible oils have been discovered to play beneficial roles by blocking oxidative damage which has an implication in atherosclerosis (Ide *et al.*, 1978). Justyna and Waldemar (2011) reported that olive oil contains the highest amount of phenolic compounds which improve taste and aroma (bitter, tart) of fats and also quench free radicals. Several studies have been carried out on the effects of some of these oils in plasma/serum (Ibegbulem and Chikezie, 2012; Nna *et al.*, 2014) and some selected organs like the brain (Kurban *et al.,*

2007), liver (de Sousa *et al.,* 2002) especially in relation to high fat diets or diseased conditions. Since dietary lipids have play a role in health and there is a paucity of the effects of these oils on lipid metabolism under normal conditions, this study sought to investigate and compare the effects of notable edible oils in diets on the lipidomics of rat tissues.

MATERIALS AND METHODS

Animals and Experimental Design: Thirty six male albino rats of average weight (60g) were purchased and kept in plastic cages in the animal house with temperature 22°C with a 12 hour light : dark cycle in the Department. The standard guideline of the Committee on care and use of experimental animal resources was followed. They were acclimatized for two weeks and separated into six groups with six rats each. Their feed was compounded according to Zûlet *et al.* (1999) composition. The oils (olive, turkey, palm, groundnut and soya) were obtained from local supermarkets in Abeokuta. To allow for the inclusion of edible oil, the quantity of corn starch was reduced by l0 grams. The diets were then fed to the rats for 28 days with fresh water *ad libitum.* All experimental protocols complied with the NIH guidelines (NRC, 1985). The composition of feed is shown in Table 1.

Sacrifice of Animals: The weight of the rats was monitored for 28 days and the mathematical model of Cateliér *et al.* (2006) was used to evaluate daily growth rate and condition factor thus: Daily growth rate = ([(M_f – M_i] / M_i] × 100) / n, and Condition factor = (M_f / BL^3) × 100, where, M_f is final mass of animal in g, M_i is initial mass of animal in g, n is the number of feeding days and BL is the body length in cm.

Blood and Organ Collection: After twenty-eight days, blood was collected with syringes containing heparin into heparinized tubes at the end of each stage of treatment. Blood samples were separated into plasma and RBC and stored in Eppendorf tubes for further analyses while the RBC were washed thrice with ice-cold physiological saline solution before using for analysis. The brain, heart and liver were excised, trimmed of connective tissues and rinsed in ice-cold physiological saline solution. They were then blotted dry, weighed and stored at -20°C until analysis.

Table 1: Composition of diets (g/100g) (Zulet *et al.*, 1999)

Feed Composition	Control	Olive Oil	Turkey Oil
Corn starch	52.2	42.2	42.2
Skimmed Milk	43.8	43.8	43.8
Premix	4.0	4.0	4.0
Oil	——	10.0	10.0
	Palm Oil	**Groundnut Oil**	**Soya Oil**
Corn starch	42.2	42.2	42.2
Skimmed Milk	43.8	43.8	43.8
Premix	4.0	4.0	4.0
Oil	10.0	10.0	10.0

Premix (per g) contains: Cobalt (0.08mg), Copper (1.2mg), Iodine (0.4mg), Iron (8.4mg), Manganese (16mg), selenium (0.08mg), Zinc (12.4mg), antioxidant (0.5mg), Choline Chloride (70mg), Folic acid (0.2mg), Biotin H_2 (0.1mg), vitamin B_{12} (0.004mg), vitamin B_6 (0.8mg), vitamin E (2.8mg), vitamin K_3 (0.6mg), vitamin D_3 (600i.u) and vitamin A (3200 i.u). Skimmed milk contains 28% protein.

Biochemical Analyses: Plasma concentrations of cholesterol, triacylglycerol and phospholipid were determined using the Cypress diagnostic kits. HDL-cholesterol, triacylglycerol and phospholipids were determined in plasma with the same diagnostic kits after very low density lipoproteins and low density lipoproteins (VLDL-LDL) were precipitated using the method described by Gidez *et al.* (1982). RBC lipids were extracted using chloroform-isopropanol (7:11, v/v) described by Rose and Oklander (1965). For cholesterol determination, 0.1 ml of the extract was evaporated to dryness at 60°C and 20µl of Triton X-100/chloroform mixture (1:1, v/v) was added to the dried extract and evaporated again.

Cholesterol kit reagent (1.0 ml) was added, mixed and incubated for 30 minutes before reading the absorbance in a spectrophotometer.

Triacylglycerol concentration was determined by evaporating to dryness 0.1ml of the extract and adding 0.1 ml of 97% ethanol to re-suspend the dried lipid. To this, 1 ml of the

triacylglycerol kit reagent was added, mixed and incubated for 30 minutes before the absorbance reading was taken. For phospholipids' determination in the RBC, 0.1ml of the extract was evaporated and 1ml of the phospholipid kit reagent was added, mixed and incubated for 30 minutes before taking absorbance. For the organ lipid profiles, lipids were extracted from brain, heart and liver as described by Folch *et al.* (1957). Homogenate of the organs (10%) was prepared in choloroform-methanol (2:1) mixture. The homogenates were then spun at 4000 rpm for 10 minutes in a centrifuge and the supernatants containing the lipids were removed into clean Eppendorf tubes. After washing with 0.05M KCl, 0.1 ml each of the chloroform-methanol extract were used for the determination of cholesterol, triacylglycerol and phospholipids after being evaporated to dryness at $60^{o}C$. The lipid profiles were determined in aliquots of the extracts as described for RBC above.

Determination of HMG-CoA reductase Activity: The activity of 3-hydroxy-3-methyl-glutaryl-CoA (HMG CoA) reductase in the liver and brain was determined using the method described by Rao and Ramakrishnan (1975) by estimating the ratio of HMG CoA: mevalonic acid as an index of the enzyme activity. Briefly, homogenates (10% w/v) were prepared in saline arsenate solution (1g/l). Equal volumes of fresh 10% (w/v) homogenate and dilute perchloric acid (50ml/l) were mixed together, allowed to stand for 5 minutes and centrifuged at 2000 rpm for 10 minutes. Then, 1 ml of the filtrate was treated with 0.5ml of freshly prepared hydroxylamine reagent (alkaline hydroxylamine in the case of HMG-CoA and neutral hydroxylamine in the case of mevalonate), mixed and after 5 minutes, 1.5ml of ferric chloride reagent was added and shaken. The absorbances were read after 10 minutes at 540nm versus a similarly treated saline/ arsenate blank.

Statistical analysis: Results are expressed as mean ± S.E.M. One way analysis of variance (ANOVA) followed by Tukey's Test was used to analyze the results with $p < 0.05$ considered significant.

RESULTS

The effect of edible oils on weight gain of the rats indicated that the edible oil groups exhibited significantly lower ($p < 0.05$) body weights when compared with control group (Figure 1). Among the edible oil groups, significantly lower ($p < 0.05$) body weights were observed in the groundnut and soya oil fed groups (8.33 ± 2.47g and 3.00 ± 1.00g, respectively).
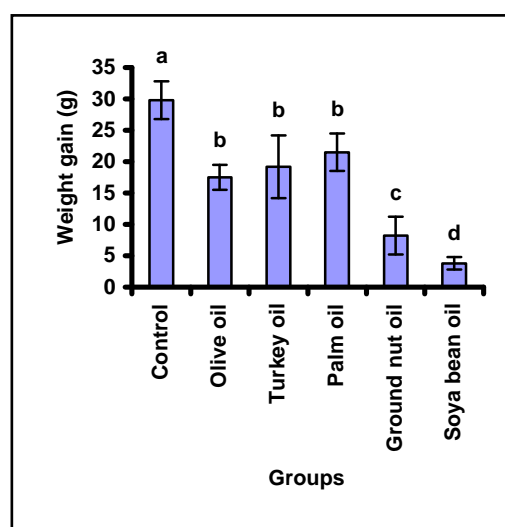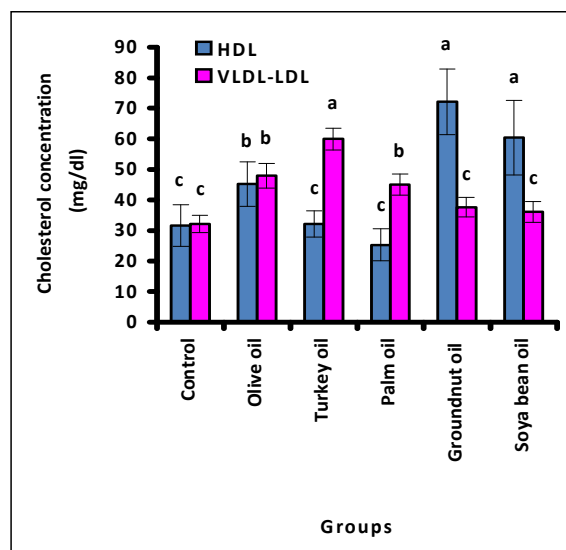

Figure 1: Effect of edible oils on weight gain of the animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

Significantly lower ($p < 0.05$) daily growth rates were observed in the groundnut oil and soya oil fed groups (0.48 ± 0.16 and 0.18 ± 0.07, respectively) when compared with the control (2.35 ± 0.49) and the other edible oil fed groups (Figure 2).
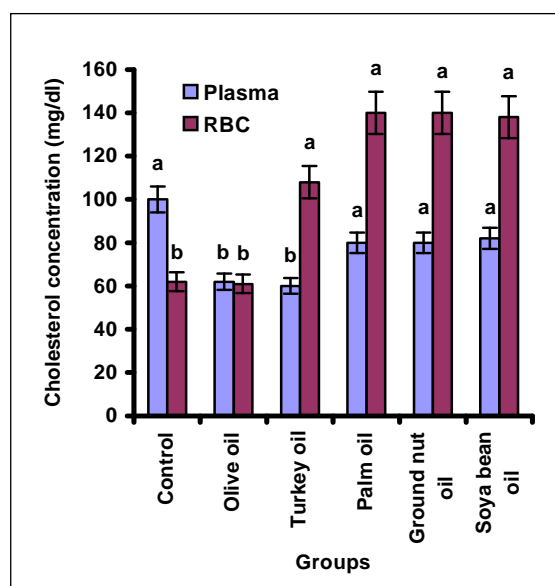
The turkey oil fed group exhibited a significantly higher ($p < 0.05$) mean condition factor of $0.47 ± 0.02g/cm^3$. The other oil fed groups; olive oil, palm oil and soya oil had insignificant ($p > 0.05$) mean condition factors of 0.41, 0.39 and $0.38g/cm^3$, respectively which were not different from the control ($0.39g/cm^3$) (Figure 2).
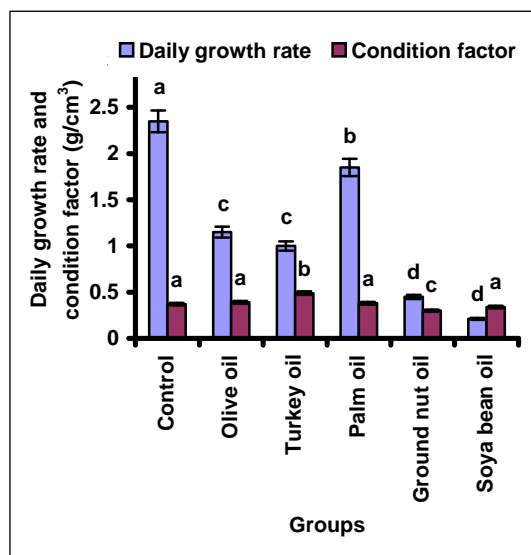
Figure 2: Daily growth rate and condition factor of animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05
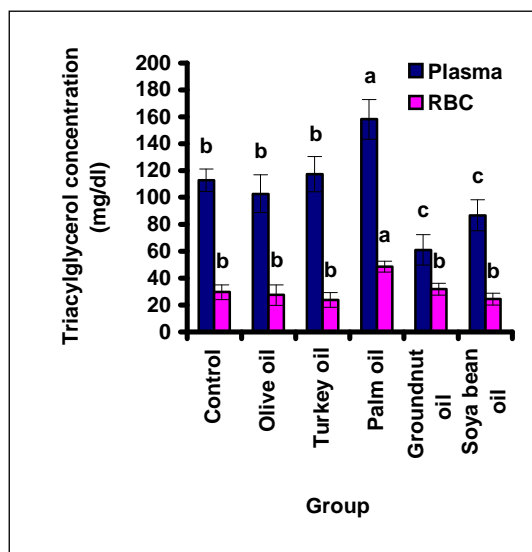

Figure 3: Effect of different edible oils on concentrations of cholesterol in the plasma and RBC. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

The effect of different edible oils on concentration of cholesterol in the plasma, HDL, VLDL-LDL and RBC are shown in Figures 3 and 4. Palm oil, groundnut oil and soya oil fed groups had significantly (p<0.05) higher values of plasma cholesterol than the olive and turkey oil fed groups though not significantly (p>0.05) different from the control.

Figure 4: Effect of different edible oils on concentrations of cholesterol in the HDL and VLDL-LDL. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

Cholesterol concentration was significantly reduced (p<0.05) by olive and turkey oils by 36% and 41% compared with control. The level of HDL-cholesterol was significantly increased in the olive, groundnut and soya oil groups by 43, 128 and 91% when compared with the control and other edible oil groups. On the other hand, VLDL-LDL-cholesterol was not significantly (p>0.05) affected by groundnut and soya oils compared with control.

Turkey oil fed group had the highest VLDL-LDL-cholesterol concentration followed by olive oil and then palm oil when compared with control and other edible oil fed groups. Turkey oil, palm oil, groundnut oil and soya oil groups exhibited significant higher (p<0.05) values for RBC-cholesterol when compared with control and olive oil groups.

The effects of edible oils on the level of triacylglycerol in the plasma, HDL, VLDL-LDL and RBC indicated that the palm oil fed group exhibited significantly higher (p<0.05) values of plasma and RBC triacylglycerol (40% and 64%, respectively) compared with control unlike the other edible oil fed groups which elicited below 4% and 8% increase, respectively (Figures 5). The levels observed in the plasma were in the order; palm oil > turkey oil > olive oil > soya oil > groundnut oil.
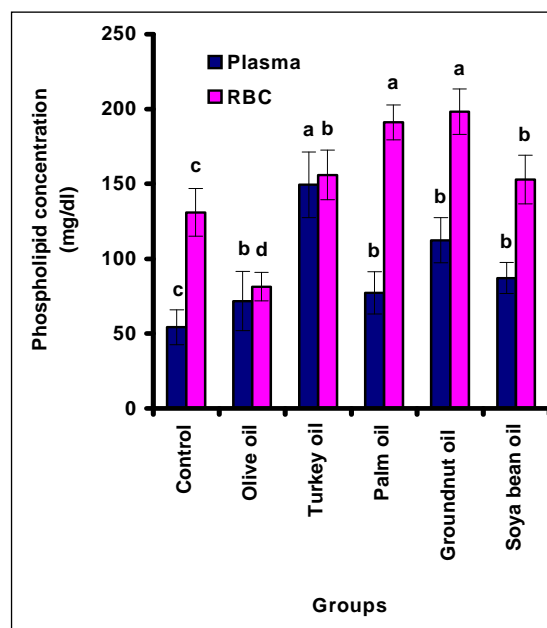
Figure 5: Effects of edible oils on the concentrations of triacylglycerol in the plasma and RBC. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05.
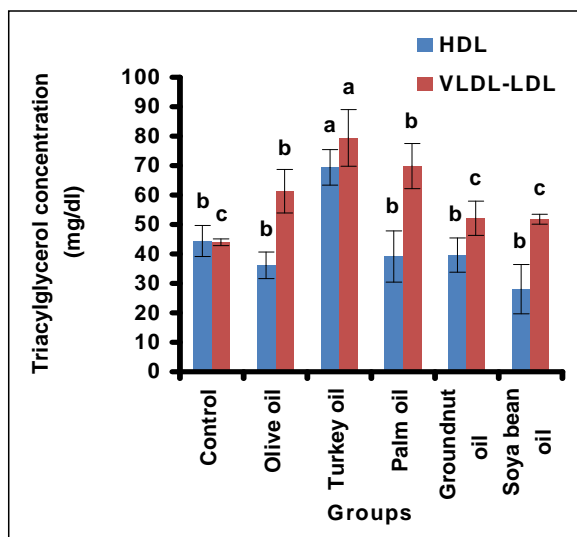
Figure 6: Effects of edible oils on the concentrations of triacylglycerol in the HDL and VLDL-LDL. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

While palm oil and olive oil retained their order of effects as obtained in plasma for the RBC, the case was different for the other oils. Unlike the other edible oil fed groups, turkey oil exhibited the highest significant increases of 56% and 81% for HDL and VLDL-LDL triacylglycerol concentrations respectively compared with the control (Figure 6).
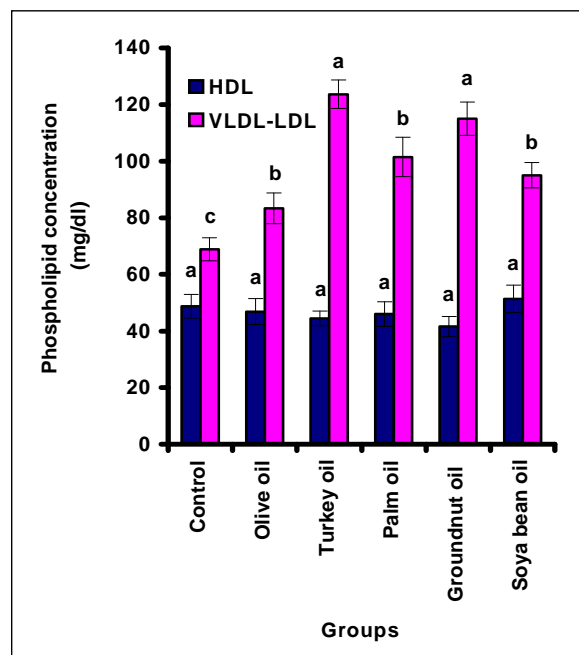

Figures 7: Effect of edible oils in the phospholipids level of the plasma and RBC. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

The oils elicited an increase in VLDL-LDL triacylglycerol concentration with the groundnut and soya oils having the same effect of 18% increase compared with control (Figure 6).

Figures 7 and 8 depict the effects of edible oils in the phospholipid levels in plasma, RBC, VLDL-LDL and HDL. All the oils significantly increased plasma and VLDL-LDL phospholipid levels compared with the control. The highest percent increase in plasma and VLDL-LDL phospholipids was observed in the turkey oil group (175% and 80%, respectively) while the least was observed in the olive oil group (32% and 21% respectively). On the other hand, soya oil group showed a significant increase in HDL phospholipids when compared with control while the rest resulted in decreased level of phospholipid. The least value (41.63 ± 3.54 mg/dl) in HDL was obtained for the groundnut oil fed group. The groundnut oil as well as palm oil fed groups had significantly increased values of RBC phospholipid level while olive oil fed group had a significantly decreased value compared with control.
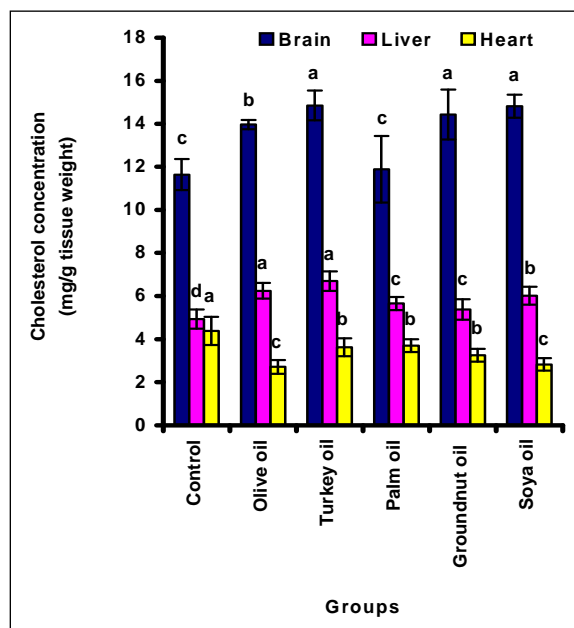
Figure 9 shows the effect of edible oils on the level of cholesterol in the hepatic, brain and cardiac cholesterol.

Figures 8: Effect of edible oils in the phospholipids level in the HDL and VLDL-LDL. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05
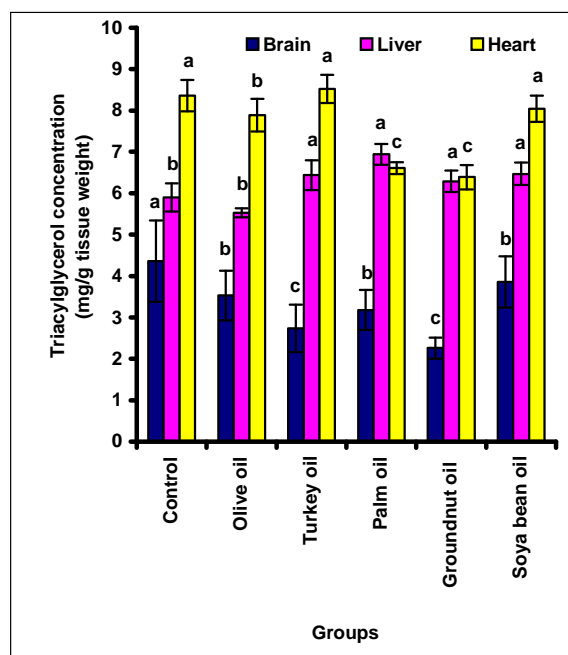
Figure 10: Effect of edible oils on hepatic, brain and cardiac triacylglycerol concentration in animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05
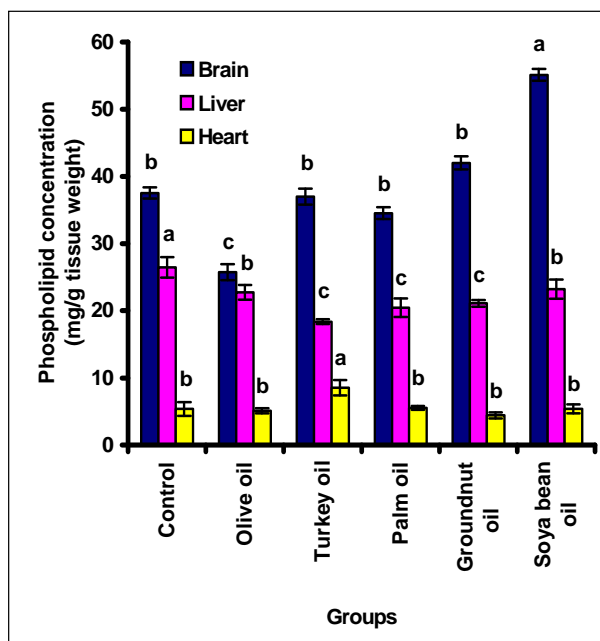

Figure 9: Effect of edible oils on hepatic, brain and cardiac level of cholesterol in animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05

The levels of brain cholesterol were significantly decreased (p<0.05) in the groundnut oil and soya oil group when compared with the control and other edible oil groups.

The decrease was by 36 and 37%, respectively compared with control. The highest cholesterol level of 20% over control was observed in the olive oil group. The levels of hepatic cholesterol were significantly higher (p<0.05) in the olive oil and turkey oil groups when compared with the control and the other edible oil groups. The highest level (36%) of increase was observed in the groundnut oil group while the least level (8%) was exhibited in the turkey oil group. Cardiac cholesterol level was highest in the control with the olive oil group having the greatest decreased concentration of 38%.

Brain, hepatic and cardiac triacylglycerol concentrations are shown in figure 10. Significantly lower values of brain triacylglycerol were observed in the edible oil groups compared with control. The concentration decreased by 11 − 48%. The least levels were observed in the turkey and groundnut oil groups. No significant difference (p>0.05) was observed in hepatic triacylglycerol level among the groups. The palm oil and groundnut oil groups showed the least significant concentrations of cardiac triacylglycerol when compared with the control and other edible oil groups.

Figure 11: Effect of edible oils on hepatic, brain and cardiac phospholipid concentration in animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05
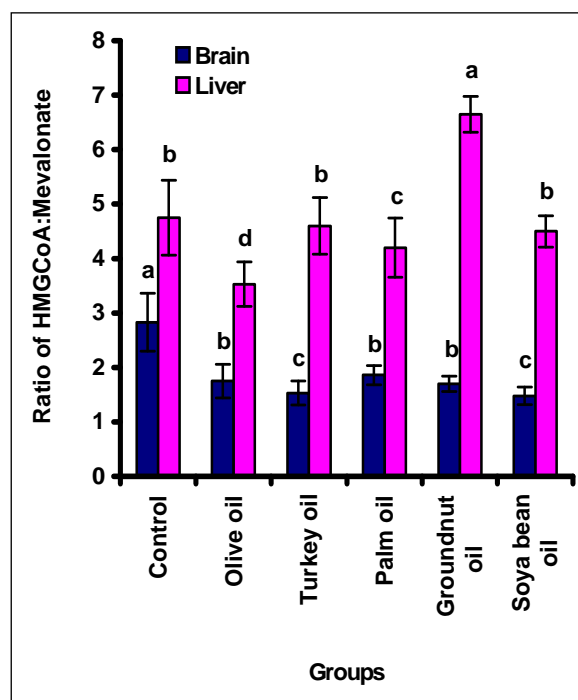
Figure 12: Effect of edible oils on the activity of HMG-CoA reductase in the brain and the liver of animals. Each bar represents the mean ± S.E.M. of 6 rats. Bars with different alphabets are significantly different at p<0.05.

Hepatic, cardiac and brain phospholipid levels are shown in Figure 11. The concentration of brain phospholipid observed in the olive oil group was significant lower when compared with control and other oil groups. Concentration of hepatic phospholipids was significantly decreased (p<0.05) in the edible oil groups compared with control. Phospholipidosis was observed in the heart of only the turkey oil group while no significant difference (p>0.05) was observed among the others and control.

Figure 12 shows the ratio of HMG-CoA : mevalonate as an index of the activity of HMG-CoA reductase in the brain and liver. Groundnut oil down-regulated the activity of the hepatic HMG-CoA reductase by 40% compared with control while the other edible oils except turkey up-regulated the activity of the enzyme, On the other hand, HMG-CoA activity in the brain was increased significantly (p<0.05) by all the edible oils. A higher level of cholesterogenesis resulted in the turkey and soya followed by the other oil groups.

DISCUSSION

The findings from this study demonstrated that there were significant oil diet-related changes in the lipidomics of tissues which could have significant metabolic effects in animals. It is a known fact that dietary oil intake plays a role in nutrition and health (Romon *et al.,* 1995; Celebi and Utlu, 2006; Arterburn *et al.,* 2008; Ighosotu and Tonukari, 2010). They have an impact on total body fat composition and by extension lipid metabolism (Oluba *et al.,* 2011). Several studies have revealed hypercholesterolemic properties of saturated fatty acids and cholesterol in relation to lipoprotein patterns and increasing cholesterol levels (Enos *et al.,* 2013).

From the results, average weight gain and daily growth rate of the rats fed the different edible oils were significantly reduced compared with control. This is in agreement with the results of Oluba *et al.* (2011), Ibegbulem and Chikezie (2012) and Kolawole *et al.* (2013). The least average weight gain and daily growth rate were observed in the groups fed with groundnut and soya bean oils. The highly significant decrease in weight gain and daily growth rate may be due to low total body fat contents (Oluba *et al.,* 2011) and the unavailability of nutrients for the synthesis of

building blocks. Also, it could be attributed to the channeling of energy generated to the brain for the maintenance of intracellular homeostasis (Kolawole *et al.,* 2013).

Incorporation of the oils reduced daily feed intake (data not shown). This is in accordance with the report of Church and Pond (1988). They reported that when energy content of diet is increased, feed consumption decreases. The edible oils must have increased the energy contents of the diets hence the decrease in body weight gain which could have been due to decreased feed consumption. These oils contain in good moderation, monounsaturated and polyunsaturated fatty acids which have been demonstrated to be both hypocholesterolemic and hypotriglyceridemic thereby reducing body weight (Bhargara *et al.,* 2012). Condition factor is observed to be least in the soya bean oil group followed by groundnut oil group and highest in the turkey oil group. This agrees with the results of Kolawole *et al.* (2013). Condition factor is a relationship between length and weight of animals and is a measure of the health of animals (Nash *et al.,* 2006). It reflects physical and biological circumstances and fluctuations by interaction among feeding condition and physiological factors (Le Cren, 1951). It also indicates the changes in food reserves. From the results of this study, animals fed soya bean oil had the least food reserve followed by groundnut oil group, while the turkey oil group had the highest food reserve and was more robust than the animals fed soya bean and groundnut oils. Datta *et al.* (2013) reported similar finding in *Channa punctata* under different feeding regimes.

The findings of this study also indicate that different edible oils elicited different degrees of tissue dyslipidemia. The dyslipidemia was characterized by down-regulation and up-regulation of different lipids by the edible oils in various compartments. Compared to the control rats, the dyslipidemia was characterized by hypocholesterolemia, decreased cholesterol levels in heart, decreased level of triacylglycerol and phospholipids in brain and liver respectively. The reverse was the order in VLDL-LDL, RBC (except olive oil group), brain and hepatic

cholesterol (as shown by the decreased HMG-CoA : mevalonate ratio, an index of HMG-CoA reductase activity), VLDL-LDL triacylglycerol, plasma, VLDL-LDL and RBC (except olive oil group) phospholipids are increased. For the remaining parameters, the edible oils had different effects on them.

The oils were observed to affect triacylglycerol levels differently. While the level increased significantly in the palm oil-fed group, it decreased significantly in the groundnut and soya oil-fed groups. Though, concentrations of free fatty acids in plasma were not determined, under normal circumstances, when a diet rich in oil is ingested, the oil is digested into glycerol and fatty acids. These fatty acids are then re-esterified in the mucosal epithelial cells of the intestine to triacylglycerol. These are micellarized in chylomicrons and transported to the adipose tissue, heart and muscle (80%) and liver (20%) where they are either stored or used to generate energy via beta oxidation (Murray *et al.,* 2003). However, the liver also has active enzyme systems for synthesizing and oxidizing fatty acids and for synthesis of triacylglycerols and phospholipids. From the results of this study, plasma triacylglycerol concentration was increased only in the palm oil-fed group but not having any significant increase in the liver compared to the other edible oils. This corroborates the findings of de Sousa *et al.* (2002), Kochikuzhyil *et al.* (2010), Ibegbulem and Chikezie (2012) and Nna *et al.* (2014) but disagrees with the findings of Oluba *et al.* (2011) and Kolawole *et al.* (2013). The difference could be adduced to the design of the study. While they determined the effect of feeding of palm oil rich diet to rats fed protein rich diet and 20% of the oil respectively, this study fed 10% oil and normal rat diet. Phospholipids were increased in plasma, VLDL-LDL and RBC by all the edible diets. These indicate that probably, the diet generated a high level of circulating free fatty acids which favoured synthesis of triacylglycerols in the adipose tissue and major phospholipids in the blood probably by up-regulating the enzymes involved in the synthesis of these lipids. It could have also favoured synthesis of triacylglycerol in the liver since a significantly increased VLDL-

LDL content of triacylglycerol was observed in the edible oil groups except groundnut and soya oil groups. VLDL is the lipoprotein that transports endogenously synthesized triacylglycerol from the liver (Murray *et al.,* 2003). The results also showed that in well fed state, these edible oils in diets do not cause accumulation in the organs but rather cause significant decreases in organs especially brain. This result is however, in disagreement with Kurban *et al.* (2007) that reported an increased level of triacylglycerol in the brain of rats fed diet oils.

The RBC lipid composition is becoming of great interest. This is because the etiology of many diseases has been traced down to RBC dyslipidemia (Allen and Manning, 1994). The RBC lipids are usually replenished by an exchange with the plasma lipids (Nikolic *et al.,* 2007). Any lipid soluble substance can facilitate this exchange since the membrane of RBC is basically made up of lipids. From the results of this study, the effects of the edible oils on plasma triacylglycerol are also relayed in the RBC indicating that there is a relationship between the two. Since equilibrium was not attained between them, it could be that the RBC lipids are pooled from other source like the liver through VLDL-LDL.

Plasma cholesterol was significantly decreased by the olive and turkey edible oil diets and not affected by the other diets while cholesterol level was significantly increased in VLDL-LDL and HDL compartments of the edible oil groups (except turkey and palm oil groups for HDL) and RBC content was increased significantly by the oil diets except olive oil diet. These findings agree to some extent with those of Oluba *et al.* (2011). The findings of this study indicated that palm oil diet lowered plasma cholesterol but not significantly. This could be due to the type of diet given in this study. Cholesterol levels increased also in the organs (not significantly) except in the heart. In lipid metabolism, rate of absorption of acylglycerols differ according to lipid composition of ingested diets. Positive associations between LDL-cholesterol and cholesteryl ester transfer protein activity were found in animals fed saturated fat. This was accounted for by diet-induced down-

regulation of LDL receptor activity through the inhibition of cleavage of the protein and sterol regulatory element binding protein (Lars *et al.,* 2007). Data exist that show the ability of dietary fatty acids to increase LDL-cholesterol in both animals and humans, and how monounsaturated and saturated fatty acids influence lipid profiles (Lars *et al.,* 2007; Kolawole *et al.,* 2013). In this study, palm and turkey oils had the highest levels of saturated fatty acids and effected least increases in HDL-cholesterol and highest levels of LDL-cholesterol. Groundnut oil as well as soya oil is rich in unsaturated fatty acids. Groundnut oil is rich in oleic acid which increases HDL-cholesterol. On the other hand, saturated fat intake increases LDL-cholesterol and decreases HDL-cholesterol (Mensink and Katan, 1992). The groups fed with groundnut oil and soya oil has the highest value of HDL-cholesterol and lowest value of LDL-cholesterol when compared with the control and other edible oil groups. Groundnut oil is highly effectively is lowering blood cholesterol, primarily LDL-cholesterol as it contains a good proportion of linoleic acid (33.4%) which probably favours the synthesis of LDL receptors on the liver and other tissue cells that will take up LDL and increase the process of reverse cholesterol transport especially from the heart to the liver for catabolism (Cedomila *et al.,* 2001; Murray *et al.,* 2003). Palm oil which is rich in saturated fatty acids incited a hypocholesterolemic effect which was however not significant. This could be due to its high content of the antioxidant, tocotrienols. Karaji-Bani *et al.* (2006) demonstrated that tocotrienols inhibit cholesterol synthesis *in vivo*, thus enhancing the transport of cholesterol to the liver.

Due to blood brain barrier, circulating lipoproteins cannot reach the brain except for the small HDL particles (Kersten, 2014). The astrocytes of the brain have been suggested to be responsible for the transfer of lipids within the brain (Wang and Eckel, 2014). Cholesterogenesis is observed in the brain and liver though not significantly. The edible oils do not contain cholesterol, so the increase observed in the groundnut oil diet group may be due to activation of HMG-CoA reductase and the

rate limiting enzyme in cholesterol synthesis (Sawada *et al.,* 2005). The mechanism of the oils being able to do this is not yet understood, but it could be due to changes in the quantity of enzyme protein which is relatively slow compared to the rapid changes that occur from phosphorylation-dephosphorylation of the enzyme (Kennelly and Rodwell, 1985). Consistent with this, is the observed little increases which were not altogether significant.

Phospholipidosis, which is a storage disorder arising from accumulation of abnormal quantities of phospholipids is observed only in the brain and heart of the groups fed soya and turkey oils respectively. Oils being lipids, among other factors may alter the metabolism of cells and result in phospholipidosis. There are four major concepts that have been proposed for the mechanism of induction of the disorder (Sawada *et al.,* 2005). Two of these might be involved here; these two edible oils may in one way or the other through the enhancement of cholesterogenesis and free fatty acid availability cause the synthesis and therefore the accumulation of phospholipids in the heart and brain (Sawadi *et al.,* 2005).

Conclusion: The results of this present study imply that the consumption of palm oil and turkey oil could predispose to the risk of cardiovascular disease since they elicited an elevation of LVLDL-LDL-cholesterol and lowered HDL-cholesterol, while soya and groundnut oils would not since they effected a decrease in the level of cholesterol and triacylglycerol in the plasma while increasing the level of HDL-cholesterol. This implies that, soya, groundnut and olive could be more beneficial in nutrition and health than palm and turkey oils.

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