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## Lipid composition of the brains of she-goat and castrated goat consumed in Ekiti State, Nigeria

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### Abstract

The levels of fatty acids, phospholipids and sterols were determined in the brains of she-goat and castrated goat found in Ekiti State, Nigeria by gas chromatography. Results showed that the crude fat levels were 9.98 and 10.2 % in the brains of she-goat and castrated goat respectively. The fatty acid composition of she-goat and castrated goat brain shows that the SFA was 40.6 and 42.7 %, MUFA was 37.1 and 38.7 % and PUFA was 20.9 and 22.3% respectively. The other parameters of she-goat and castrated goat brain were found: PUFA/SFA, 0.490 and 0.548; MUFA/SFA, 0.869 and 0.953; *n*-6/*n*-3, 0.775 and 11.7; LA/ALA, 0.876 and 28.0; AA/DGLA, 6.05 and 17.4; EPA/DHA, 1.00 and 5.89 and EPSI (PUFA/MUFA), 0.564 and 0.575 respectively. Phospholipids were present in she-goat and castrated goat with a value range of 2365 and 3047 mg/100g respectively. Among the sterols, only cholesterol was of any significant level with values of 1353 mg/100g (she-goat brain) and 1355 mg/100g (castrated goat brain). Linear correlation at  $\alpha = 0.05$ ,  $df = n-1$  showed that no significant difference exists between the crude fats, phospholipids and sterols except in the fatty acids parameters.

**Keywords:** Goat brain; Lipid composition; Fatty acid; Phospholipid; Sterol; Gas chromatograph

### Introduction

The domestic goat (*Capra aegagrus hircus*) is a subspecies of goat domesticated from wild goat of Southwest Asia and Eastern Europe. The goat is a member of the family Bovidae and is closely related to the sheep as both are in the goat-antelope subfamily Caprinae. There are over 300 distinct breeds of goat (Hirst, 2008). Goats are one of the oldest domesticated species, and have been used for their milk, meat, hair, and skin in most parts of the world. In 2011, there were more than 924 million live goats around the globe, according to the UN Food and Agriculture Organization (Anonymous, 1988). Norman (Norman, 1991) noted from several references that goats are concentrated in the drier regions of Brazil and Nigeria as well as in southern Africa. There are virtually no religious or culture taboos on the eating of goat meat; with the result that goat are readily available to societies in which eating beef, pork, or other meat types are prohibited. In many parts of the world goat is preferred to mutton and commands a better price (Casey, 1992).

Meat protein has a digestibility coefficient of 97% giving ingested meat heat combustion of 17.8 kJ (Gopalan *et al.*, 1971). The average biological value of goat meat reported by Mitra and Mitra (1945), based on feeding trials with rats fed at 10% level of protein was 60.4% which was slightly lower than the 68.6% of beef. The nutrient value of muscle lies in the extent to which the protein and specifically the indispensable amino acid requirements of humans are satisfied. Pellet and Young (Pellet and Young, 1990)

proposed that dietary protein quality should be determined in terms of two standards: that which is needed for infants, and for persons older than 2 years. The analyses of goat muscle are presented in terms of the later group. A greater intramuscular fat content which occurs at heavier masses and in older animals would decrease the relative content of other nutrients (Casey and Naude, 1984).

In many developing countries, meat animals are frequently slaughtered only for the carcass, whereas a number of byproducts which can be obtained quite easily could help to improve the supply of low cost, high protein foods for people. As regards the utilization of edible slaughter byproducts, most studies have concentrated on protein extraction, involving costly processing techniques of little or no practical interest to developing countries. Good profits can be achieved, however by utilizing byproducts as ingredients in meat production (Fornias, 1996). Meat animals yield, besides their carcass, a considerable amount of parts which are biologically and hygienically fit for human consumption. These byproducts are very different from the view of structure, proximate composition, functional or sensory properties, but they can all be used as food. They are generally consumed either as main ingredients in meat products (Adeyeye, 2013). Among byproducts which are edible is the brain which is consumed as direct meat products. A considerable literature has been published on the health benefits of fish, oil rich fish and fish oils and their constituent

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long chain *n*-3 PUFA. Adeyeye (Adeyeye, 2012) reported on the long-chain (*n*-6) and *n*-3 polyunsaturated fatty acids and other lipids in the brains of bull and hen. There is hardly any information on the lipid composition of brains of goat. The purpose of this paper therefore is to explore evidence relating to the lipid composition of the brains of she-goat and castrated goat as contributors to the availability of nutritionally valuable fatty acids when used as food.

## Materials and methods

### *Sample collection and treatment*

The brains of goats (she and castrated) were collected from butchers who daily slaughter goats for the meat from the slaughter house based in Ado- Ekiti. The brains were collected into clean glass Petri- dishes, covered and dried in air oven at a temperature between 60°C and 80°C for about 5 hours. After drying, the brains were made into fine powder and packed in airtight plastic sample bottles and kept in freezer (-4°C) for analysis.

### *Determination of ether extract*

An aliquot (0.25 g) of each sample was weighed in an extraction thimble and 200 ml of petroleum ether (40-60 °C boiling range) was added. The covered porous thimble containing the sample was extracted for 5 h using a Soxhlet extractor. The extraction flask was removed from the heating mantle when it was almost free of petroleum ether, oven dried at 105 °C for 1 h, cooled in a desiccator and the weight of dried oil was determined.

### *Preparation of fatty acid methyl esters and analysis*

A 50 mg aliquot of the dried oil was saponified for 5 min at 95 °C with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralized by 0.7 M HCl and 3 ml of 14 % boron trifluoride in methanol was added. The mixture was heated for 5 min at 90 °C to achieve complete methylation. The fatty acid methyl esters were thrice extracted from the mixture with redistilled *n*-hexane and concentrated to 1 ml for analysis. The fatty acid methyl esters were analysed using an HP 5890 powered with HP gas chromatograph [HP 5890 powered with HP ChemStation rev A09.01 (1206) software (GMI, Inc., Minnesota, USA)] fitted with a flame ionization detector. Nitrogen was used as the carrier gas with a flow rate of 20-60 ml/min. The oven programme was: initial temperature at 60 °C, ramping at 10 °C /min for 20 min, held for 4 min, with a second ramping at 15 °C /min for 4 min and held for 10 min. The injection temperature was 250 °C and the detector was 320°C. A polar (HPINNOWAX) capillary column (30 m x 0.25 mm x 0.25 µm) was used to separate the esters. A split injection was used with a split ratio of 20:1. The peaks were identified by their relative retention time compared with known standards.

### *Sterol analysis*

Aliquots of the dried oil were added to screw-capped test tubes. The sample was saponified at 95°C for 30 min, using 3 ml of 10 % KOH in ethanol, to which 0.20 ml of benzene was added to ensure miscibility. Deionised water (3 ml) was added and 2 ml of hexane was used in extracting the nonsaponifiable materials. Three extractions, each with 2 ml of hexane, were carried out for 1 h, 30 min and 30 min respectively, to achieve complete extraction of the sterols. Hexane was concentrated to 1 ml for gas chromatographic analysis. Other procedures followed as in the analysis for fatty acid methyl esters.

### *Phospholipid analysis*

By using a modified method of Raheja and Co-workers (Raheja *et al.*, (1973) 0.01 g of the dried oil was added to test tubes. Any remaining solvent was removed by passing a stream of nitrogen gas over the oil. Then 0.40 ml of chloroform was added, followed by addition of 0.10 ml of the chromogenic solution. The tube was heated to 100 °C in a water bath for 1 min 20 sec., cooled to room temperature, 5 ml of hexane was added and the tube was shaken gently several times. After separation of the solvent and aqueous layers, the hexane layer was recovered and concentrated to 1.0 ml for analysis. Analysis was performed using the gas chromatograph with a polar (HP5) capillary column (30 m x 0.25 mm x 0.25 µm). The oven programme was: initially at 50 °C ramping at 10 °C /min for 20 min, held for 4 min, a second ramping at 15 °C /min for 4 min and held for 5 min. The injection temperature was 250 °C, and the detector temperature was 320 °C. As previously described, a split injection type was used having a split ratio of 20: 1. Peaks were identified by comparison with known standards.

## Results and discussion

Table I depicts total lipid and calculated total fatty acid levels on dry weight basis of brains of she-goat (G1) and castrated goat (I3). The values of total lipids between the two samples were very close with the CV% of 1.54. The total fat of 9.98 and 10.2 g were comparably lower than the value in duck's meat and skin (43%), chicken's meat and skin (18.0%), beef fat (67%), lamb fat (72%) and pork fat (71%) (Bender, 1992); brains of bull and hen (42.5% and 45.2%) (Adeyeye, 2012) but comparably close to the value reported for the fat of cattle brain (10.6%) wet weight with 77.6% water content and also comparably lower than the level reported for sheep brain (38.1%) and pig brain ( 42.6%) (Fornias, 1996). Table II shows the level of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids in the two brain samples. In both samples the brain SFAs C2:0, C3:0, C4:0, C5:0, C6:0, C8:0, C10:0 and C12:0 recorded were 0.00 %. Similar observations have also been made in respect of the brains of bull and hen except that C14:0, C16:0, C18:0 and C20:0 were not at 0.0% level

**Table I. Crude fat, total fatty acids (%) and energy (kJ/100g) of she-goat (G1) and castrated goat (I3)**

Samples	G1	I3	Mean	SD	CV %
Crude fat	9.98	10.2	10.1	0.156	1.54
Total fatty acid*	7.98	8.16	8.07	0.124	1.54
Energy kJ/100g	295	302	299	4.60	1.54

(Adeyeye, 2012). Among the MUFA, both samples had 0.0% value for C18:1 (*trans*-11). The highest concentrated SFA in the two samples (brains of she-goat and castrated goat) was C16:0 with values of 23.0 % and 23.3 %, followed by C18:0 with values of 14.5% and 14.4%. The levels of these two SFAs were comparably close to the levels reported for the testes of bull, bucks and African giant pouch rats (Adeyeye, 2013). The levels of C22:0 (0.510 and 0.469 %) and C24:0 (0.063 and 0.058 %) obtained in the present work were comparably lower than the levels reported for the brains of bulls and hen ( Adeyeye, 2012). C22:0 and C24:0 have not been implicated in enhancing the level of low density lipoprotein (LDL) cholesterol unlike myristic acid (C14:0) and palmitic (C16:0) acids (Grundy, 1994). The MUFA levels were contributed by C14:1(*cis*-9), C16:1 (*cis*-9), C18:1 (*cis*-6), C18:1 (*cis*-9); C20:1(*cis*-11), C22:1 (*cis*-13) and C24:1 (*cis*-15). Their total values were C14:1 (0.181 - 0.167 %), C16:1 (4.57 – 4.99 %), C18:1 (16.7 – 14.9 %), C18:1 *cis*-9 (14.4 – 17.7), C20:1 (0.693 - 0.521 %), C22:1 (0.175 – 0.161 %) and C24:1 (0.063 – 0.058 %). Although the CV % values were low in both SFA and MUFA showing homogeneity of the results, a close observation would show that the values in the brains of she-goat were correspondingly higher than in the brain of castrated goat. Some literature SFA values were (% total fat): 6.11 and 6.54% ( brains of bull and hen) (Adeyeye, 2012); beef fat (43%), lamb fat (50%), pork fat (37%), chicken's meat and skin (33%), duck meat and skin (27%) calf liver (30%), with corresponding MUFA values of 48%, 39%; 41%, 42%, 54% and 54% ( Bender, 1992). SFA of testes of bull (48.0%), buck (45.1%) and pouch rat (27.0%) with corresponding MUFA values of 38.6%, 39.9% and 55.6% respectively (Adeyeye, 2013); all these SFA and MUFA values were closely comparable to the present SFA and MUFA levels of the brains of she-goat and castrated goat (SFA: 42.7 and 40.6 %; MUFA: 37.1 and 38.7 %). These values on the other hand were much higher than the levels reported for the brains of bull and hen (Adeyeye, 2012). Also in Table II, polyunsaturated fatty acids (PUFA) were depicted (consisting of *n*-6 and *n*-3 in the samples). Among the *n*-6 family, C20:4 *n*-6, (*cis*) (arachidonic acid AA) was the most concentrated in both samples with value

range of 5.87- 1.88 % with a CV % of 72.8. Whilst total PUFA *n*-6 was 9.14 % in the she-goat brain, it was 20.5% in the brain of castrated goat with a CV% of 54.1. These values were comparably lower than that reported for the brains of bull and hen (39.0 and 35.4 %) (Adeyeye, 2012) but comparably higher than the levels reported for the testes of bull, bucks and giant pouch rats (Adeyeye, 2013). C18:2 (*n*-6 *cis*, *trans* -linoleic acid, conjugated linoleic acid, CLA) has a value of 0.233% (she-goat brain) and 0.214% (castrated goat brain) with CV% of 6.01 Table II. One of the factors that affect the total lipid found in serving of meat is highly dependent upon the feeding regimen (Daley *et al.*, 2010). CLA is a constituent of ruminant animals and exists as a general mixture of conjugated isomers of linoleic acid (LA). The (*cis*-9, *trans* -11, CLA isomer (rumenic acid or RA) accounts for up to 80-90 % of the total CLA in ruminant products (Daley *et al.*, 2010). Naturally occurring CLAs originate from two sources: bacterial isomerization and /or biohydrogenation of PUFA in the rumen and desaturation of *trans* fatty acids in the adipose tissue and mammary gland (Grinary *et al.*, 2000, Sebart *et al.*, 1999). Microbial biohydrogenation of LA and  $\alpha$ -LA by anaerobic rumen bacterium *Butyrivibrio fibrisolvens* is highly dependent on rumen pH. Grain consumption decreases rumen pH thereby reducing *B. fibrisolvens* activity, conversely grass based diets provide for a more favourable rumen environment for subsequent bacterial synthesis (Daley *et al.*, 2010). Rumen pH might help explain apparent differences in CLA content between grain (mostly for the birds e.g hen), and grass (mostly for herd)-finished products. CLA has been shown in action to reduce carcinogenesis, atherosclerosis and onset of diabetes (Adeyeye, 2012). Considering the *n*-3 PUFA group, C22:6, (docosahexadienoic acid, DHA) has the higher levels in the brain of she-goat with a value of 10.7 % whereas the value in castrated goat was 0.00%. The total PUFA from literatures were: 85.0 (brain of hen) and 83.5 % (brian of bull) (Adeyeye, 2012), beef fat (40 %), lamb fat (5 %), pork fat (15 %), chicken's meat and skin (19 %), duck meat and skin (12 %) and calf liver (26 %) (Bender, 1992). Whilst the levels in the present results were comparably higher (total PUFA, 20.9

**Table II. Fatty acids composition (%) of the brains of she-goat (G1) and castrated goat (I3) as well as their food and energy values**

Fatty acids	% values		As food values		Energy in kJ /100g	
	G1	I3	G1	I3	G1	I3
C14:0	4.09	1.83	0.33	0.15	12.1	5.54
C16:0	23.0	23.3	1.8	1.905	67.9	70.5
C18:0	14.5	14.4	1.2	1.177	42.8	43.6
C20:0	0.553	0.509	0.044	0.042	1.63	1.54
C22:0	0.510	0.469	0.041	0.038	1.51	1.42
C24:0	0.063	0.058	0.005	0.005	0.19	0.175
TotalSFA	42.7	40.6	3.4	3.32	126	123
C14:1( <i>cis</i> -9)	0.181	0.167	0.014	0.014	0.53	0.505
C16:1( <i>cis</i> -9)	4.67	4.99	0.37	0.408	13.8	15.1
C18:1( <i>cis</i> -6)	16.7	14.9	1.3	1.22	49.3	45.1
C18:1( <i>cis</i> -9)	14.2	17.7	1.1	1.45	41.9	53.5
C20:1 ( <i>cis</i> -11)	0.69	0.521	0.055	0.043	2.05	1.58
C22:1( <i>cis</i> -13)	0.18	0.161	0.014	0.013	0.52	0.49
C24:1( <i>cis</i> -15)	0.06	0.058	0.005	0.005	0.19	0.18
Total MUFA <i>cis</i>	36.7	38.5	2.9	3.15	108	116
C18:1( <i>trans</i> 6)	0.199	0.183	0.016	0.015	0.59	0.554
C18:1( <i>trans</i> 9)	0.02	0.017	0.002	0.001	0.06	0.051
C18:1( <i>trans</i> 11)	0.00	0.00	0.00	0.00	0.00	0.00
Total MUFA <i>trans</i>	0.219	0.200	0.017	0.016	0.65	0.605
MUFA <i>total</i>	36.9	38.7	2.9	3.16	109	117
C20:2( <i>cis</i> -11,14)	0.078	0.072	0.006	0.006	0.23	0.218
C20:5( <i>cis</i> -5,8,11,14,17)	0.37	0.058	0.030	0.005	1.10	0.175
C22:6( <i>cis</i> -4,7,10,13,16,19)	10.7	0.000	0.85	0.00	31.6	0
Total( <i>n</i> -3)	11.1	0.13	0.89	0.01	32.9	0.39
C18:2( <i>cis</i> -9,12)	0.61	14.6	0.05	1.19	1.79	44.2
C18: 2( <i>trans</i> 9,11)	0.23	0.214	0.019	0.017	0.69	0.65
C18:3( <i>cis</i> -6,9,12)	0.82	0.853	0.066	0.070	2.43	2.58
C18:3( <i>cis</i> -9,12, 15)	0.56	0.921	0.045	0.075	1.65	2.79
C20:3( <i>cis</i> -8,11,14)	0.65	1.620	0.05	0.132	1.91	4.90
C20:3( <i>cis</i> -11,14,17)	0.338	0.311	0.027	0.025	1.00	0.94
C20:4( <i>cis</i> -5,8,11,14)	5.87	1.88	0.47	0.15	17.3	5.69
C22:2( <i>cis</i> -13,16)	0.06	0.058	0.005	0.005	0.19	0.18
Total( <i>n</i> -6)	9.14	20.5	0.7	1.67	27.0	61.9
PUFA <i>total</i>	20.2	22.3	1.6	1.823	59.7	67.5
Grand <i>total</i>	99.80	99.9	8.0	8.168	295	302

% and 22.3 % respectively) than others, it was favourably comparable to chicken's meat and skin (19 %) and calf liver (26 %) (Bender, 1992). DHA is required in a large amount by the human brain, low DHA levels have been associated with low brain serotonin levels, which are connected to an increased tendency for depression and suicide. Several

studies have established a correlation between low levels of *n*-3 fatty acids and depression. High consumption of *n*-3 FAs is typically associated with a lower incidence of depression, a decreased prevalence of age-related memory loss and a lower risk of developing Alzheimer disease (Laugharne, 1996).

Casey and Co-workers (Casey and Van Niekerk, 1985) and Casey and Co-workers (Casey *et al.*, 1988) have reported that the profile of the long chain fatty acids of goat meat showed oleic acid (C18:1) to be the most abundant with palmitic (C16:0) and stearic acid (C18:0) being relatively high. Nutritional influences on the fatty acid profile of ruminants are less than monogastric animals. It would appear however, that nutrition could cause subtle changes in ruminants including goats (Casey *et al.*, 1985). PUFA (*n*-3 and *n*-6) are essential, that is human must consume them in the diet, the two groups compete for the same metabolic enzymes, thus the *n*-6: *n*-3 ratio will significantly influence the ratio of the ensuing eicosanoids (hormones) (like prostaglandins, leukotrienes, thromboxanes, *e.t.c.*) and will alter the body's metabolic function (Hooper *et al.*, 2006). Generally, grass-fed animals accumulate more *n*-3 than do grain-fed animals which accumulate relatively more *n*-6. Metabolites of *n*-6 are significantly more inflammatory especially arachidonic acid (AA) than those of *n*-3. This requires that *n*-3 and *n*-6 are consumed in balanced proportion: healthy ratios of *n*-6/*n*-3 range from 1:1 to 4:1. The samples under consideration have the *n*-6/*n*-3 ratio of 0.775:1 (she-goat brain) and 11.7:1 (brain of castrated goat). Typical western diets provide ratios of between 10:1 and 20:1, that is dramatically skewed toward *n*-6 (Ruxton *et al.*, 2005). The ratios of *n*-6/*n*-3 in the present samples are fairly comparable to some ratios provided in the literatures. Here are some of the ratios provided for some common oils: canola 2:1, soybean 7:1, olive 3-13:1, sunflower (no *n*-3), flax 1:3, cotton seed (almost no *n*-3), peanut (no *n*-3), corn oil 46:1, brain of bull 0.2:1, brain of hen 0.125:1 (Adeyeye, 2012).

The relative amounts of PUFA and SFA in dietary fat/oil is important in nutrition and health. The ratio of PUFA/SFA (P/S ratio) is therefore important in determining the detrimental effects of dietary fats. The higher the P/S ratio the more nutritionally useful is the dietary fat/oil. This is because the severity of atherosclerosis is closely associated with the proportion of the total energy supplied by SFAs and PUFAs (Honatra, 1974). The present PUFA/SFA levels were: 0.490 (she-goat brain) and 0.575 (castrated goat brain). These ratios were low but comparable to the values reported for the brains of bull (0.274) and buck (0.329) (Adeyeye, 2013). From several *in-vivo* and *in-vitro* studies with different animal species it is well known that ALA, LA and oleic acid (C18:1, *n*-9) compete for the same  $\alpha$  - desaturase in the metabolic cascade. Dietary studies on rats and other animals have shown that ALA is a strong suppressor of *n*-6 fatty acids metabolism, whereas 10 times as much LA is required to give an equal suppression of *n*-3 metabolism (Holman, 1998). The *n*-6 and *n*-3 FAs have critical roles in the membrane structure (Kinsella, 1990) and as precursors of eicosanoids, which are potent and highly reactive compounds. Since they compete for the same enzymes and have different biological roles, the

balance between the *n*-6 and *n*-3 FAs in diet can be of considerable importance (Anonymous, 1994). The ratio of *n*-6 to *n*-3 or specifically LA to ALA in the diet should be 5:1 and 10:1 (WHO/FAO, 1994) or 4-10 g of *n*-6 FAs to 1.0 g of *n*-3 FAs. As LA is almost always present in food it tends to be relatively more abundant in animal tissues. This is supported in the present report as follows from LA/ALA ratios which were: 0.876:1 (she-goat brain) and 28:1 in castrated goat brain. The implication of this is that whilst it would be easy for the body to synthesis AA (C20:4 (*n*-6)) from (C18:2(*n*-6)), it may be difficult to synthesize the *n*-3 PUFA series especially eicosapentaenoic acid (20:5 (*n*-3) or EPA) because of the low level of C18:3 (*n*-3) and so the diet must be enhanced in this PUFA. The relative proportion of MUFA/SFA is an important aspect of phospholipid composition and changes to this ratio have been claimed to have effects on such disease states as cardiovascular disease, obesity, diabetes, neuropathological conditions and cancer (Adeyeye, 2013). The MUFA/SFA levels in the samples were 0.869 (she-goat brain) and 0.953 (castrated goat brain) which were better than in PUFA/SFA levels (0.490 and 0.505 respectively). For example, MUFA/SFA has been shown to have cytoprotective actions in pancreatic  $\beta$ -cell. *Cis*-monoenoic acids have desirable physical properties for membrane lipids in that they are liquid at body temperature, yet are relatively resistant to oxidation. They are recognized by nutritionists as being beneficial in the human diet.

Several clinical studies show that insulin resistance is related to fatty acid composition (Borkman *et al.*, 1993; Storen *et al.*, 2007). Insulin resistance is characterized by specific changes of the composition of fatty acids in the serum lipids and in skeletal muscle membranes. Impaired insulin sensitivity is associated with high proportions of palmitic acid (16:0) and low levels of linoleic acid in serum. In addition, there are apparent changes of FA desaturase activities suggesting an increased activity of the  $\Delta$ -9 desaturase. Experimental studies have indicated that insulin activates the  $\Delta$ -9 and  $\Delta$ -6 desaturases. In experimental diabetes and in spontaneously diabetes rats, there are reduced activities of  $\Delta$ -9,  $\Delta$ -6, and  $\Delta$ -5 liver microtonal desaturases, which are restored after insulin treatment (Mimouni and Poisson, 1992). Moreover, *in-vitro* studies, evidenced that an increased unsaturation and a decreased ratio of *n*-6/*n*-3 FAs in the muscle membrane are compatible with an increased membrane fluidity, findings that have been linked to the presence of an increased insulin receptors and an increased insulin binding (Ginsberg *et al.*, 1982). The AA /DGLA values of 17.4 (she-goat brain) and 6.05 (castrated goat brain), which were all favourable to high AA/DGLA ratio leading to good insulin sensitivity. These FAs can be essential PUFA status makers: the best known maker is mead acid (C20:3, *n*-9). The synthesis of this FA is promoted if there are insufficient concentrations of LA and ALA to meet the need for the synthesis of long-chain PUFA.

**Table III. Phospholipids (mg/100g) contents of the brains of she-goat (G1) and castrated goat (I3)**

Phospholipids	G1	I3	Mean	SD	CV %
Phosphatidylethanolamine (PE)	521	357	439	116	26.4
Phosphatidylcholine (PC)	849	1320	1085	333	30.7
Phosphatidylserine (PS)	447	797	622	247	39.8
Lysophosphatidylcholine	6.84	9.49	8.17	1.87	22.9
Phosphatidylinositol (PI)	548	572	560	17.0	3.0
Total	2365	3047	2706	482	17.8

EPA and DHA inhibit mead acid synthesis; the presence of mead acid indicates a general shortage of all essential PUFA. Another indicator of essential PUFA status is the essential PUFA status index (EPSI), which is the ratio between all essential PUFA (the sum of *n*-3 and *n*-6 fatty acids) and all non-essential unsaturated fatty acids (the sum of all *n*-7 and *n*-9 fatty acids). The higher the EPSI the better the essential PUFA status. The EPSI values in the brains of she-goat and castrated goat were 0.564 and 0.575 respectively. These values were higher compared with what was reported for testes of bull, bucks and giant pouch rats (Adeyeye, 2012). If there is a functional shortage of DHA, the body starts to synthesize the most comparable long-chain PUFA of the *n*-6 family, osbond acid (C22:5, *n*-6) therefore under steady state conditions, the ratio between DHA and osbond acid (all *cis*-4, 7, 10, 13, 16) is a reliable indicator of the functional DHA status (Neuringer *et al.*, 1986). In the present report interestingly, the ratios of EPA/DHA were: 5.89:1 (she-goat brain) and 1.00:1 (castrated goat brain).

Table II also shows the fatty acid distribution of she-goat and castrated goat brains as food. The values produced from SFA and MUFA were consistently higher than the levels produced by PUFAs in both the she-goat and castrated goat brains. The major contributions among the SFAs come from C16:0 and C18:0 with values in g/100g ranging between 1.84-1.91 (C16:0) and 1.16-1.18 (C18:0) for she-goat and castrated goats brains respectively whereas among the MUFAs, the major contributors were (18:1 *cis* -6) and (18:1(*cis*-9)). However, the total contributions from PUFA were 1.67 (she-goat brain) and 1.82 (castrated goat brain).

The energy contributions from fatty acids are shown in Table II where SFA was the major contributor with values of 126 kJ/100g (she-goat brain) and 123 kJ/100g (castrated goat brain) followed by MUFA which contributed 109 kJ/100g (she-goat brain) and 116 kJ/100g (castrated goat brain) and then PUFA group being the least contributors: 61.9 kJ/100g (she-goat brain) and 67.5 kJ/100g (castrated goat brain). The trend in energy contributions from these fatty acids group is SFA > MUFA > PUFA.

Table III shows the levels of various phospholipids in the sample. Phospholipids are not essential nutrients: they are just another lipid and as such, contribute 9 kcal/g of energy. Minor contributor to the phospholipids level was lysophosphatidylcholine that contribute less than 10 mg/100g in each of the brain samples. The actual values being: 6.84 mg/100g (she-goat brain) and 9.49 mg/100g (castrated goat brain). These values amount to 0.289 and 0.311% of the total phospholipid respectively. The total phospholipids level ranged between 2365 and 3047 mg/100g for she-goat and castrated goat brains respectively showing the brains of these animals to be high in phospholipids content. The highest phospholipid was lecithin (phosphatidylcholine) with values of 849 mg/100g in she-goat brain and 1320 mg/100g in castrated goat brain. This was followed by phosphatidylinositol in the she-goat brain [548 mg/100g (23.2 %)] and phosphatidylserine in the castrated goat brain (797 mg/100g) or 26.2%. The levels of phospholipids in the present study was better than the levels reported for the brains of bull, buck and hen (Adeyeye, 2013). Phosphatidylcholine plays a role in membrane-mediated cell signaling and PCTP (Phosphatidylcholine Transfer Protein) activation of other enzymes (Kanno *et al.*, 2007). At birth and throughout

**Table IV. Sterols (mg/100g) contents of the brains of she-goat (G1) and castrated goat (I3)**

Sterol	G3	I3	Mean	SD	CV %
Cholesterol	1353	1355	1354	1.41	0.104
Cholestanol	4.09e -4	2.66 e -4	3.38 e -4	1.01 e -4	30.0
Ergosterol	2.90 e -4	1.71 e -3	1.00 e -3	1.00 e -3	100
Campesterol	5.04e -3	5.14 e -4	2.78 e -3	3.20 e -3	115
Stigmasterol	1.66 e -3	1.64 e -3	1.65 e -3	1.41 e -3	0.857
5- Avenasterol	8.85 e -3	8.85 e -3	8.85 e -3	0.00	0.00
Sitosterol	6.40 e -3	6.39 e -3	6.40 e -3	7.07e -6	0.111
Total	1353	1355	1354	1.43	0.105

**Table V. Statistical analysis of the results**

Group of parameters	$r_{xy}$	$r_{xy}^2$	CA(%)	IFE(%)	TV	$\bar{X}$	$\bar{Y}$	Remark
Crude fat, total fatty acids and energy (G3/I3)	1.000	1.000	0.00	100	-	104	107	NS
fatty acids parameters (G1/I3)	0.7965	0.6344	60.5	39.5	0.48	3.84	6.98	S
Phospholipids (G1/I3)	0.9816	0.9634	19.1	80.9	0.95	789	1017	NS
Sterols (G1/I3)	1.000	1.000	0.00	100	0.81	338	338	NS

TV= table value at  $\alpha = 0.05$ ,  $n-1=2$ , CA=coefficient of alienation, IFE=index of forecasting efficiency

infancy, phosphatidylcholine concentrations are high (as high as 90 % of the cell membrane), but it is slowly depleted to as low as 10 % of the cellular membrane in the elderly. As is such, some researchers in the fields of health and nutrition have begun to recommend daily supplementation of phosphatidylcholine as a way of slowing down senescence (Mci – Chu *et al.*, 2001) and improving brain functioning and memory capacity (Chung *et al.*, 1995). In addition to the increased caloric burden of a diet rich in fats like phosphatidylcholine, a recent report has linked the microbial catabolites of phosphatidylcholine with increased atherosclerosis through the production of choline, trimethylamine oxide and betaine (Wang *et al.*, 2011). Phosphatidylethanolamine is found in all living cells, although in human physiology it is found particularly in nervous tissue such as the white matter of brain, nerves, neural tissue and in spinal cord. The US Food and Drug Administration (USFDA) have stated that consumption of

phosphatidylserine (PS) may reduce the risk of cognitive dysfunction in the elderly (Adeyeye and Oyarekua, 2011). Phosphatidylserine (Ptd-L-Ser or PS) is a phospholipid component, usually kept on the inner leaflet, the cytosolic side, of cell membranes by an enzyme called flippase. Early studies of PS distilled the chemical from bovine brain. Because of concerns about Bovine Spongiform Encephalopathy, however, modern studies and commercially available products are made from soybeans. Preliminary studies indicate that the soyproduct is at least as effective as that of bovine origin (Blockland *et al.*, 1999; Crook and Klatz, 1998). PS has been demonstrated to speed up recovery, prevent muscle soreness, improve well-being, and might possess ergogenic properties in athletes involved in cycling, weight training and endurance running. Soy-PS, in a dose dependent manner (400 mg), has been reported to be an effective supplement for combating exercise-induced stress by blunting the exercise induced increase in cortisol levels

(Jäger *et al.*, 2007). PS supplementation promotes a desirable hormonal balance for athletes and might attenuate the physiological deterioration that accompanies overtraining and/or overstretching (Starks *et al.*, 2008). In recent studies, PS has been shown to enhance mood in a cohort of young people during mental stress and to improve accuracy during tee-off by increasing the stress resistance of golfers (Hirayama *et al.*, 2006). First pilot studies indicate that PS supplementation might be beneficial for children with attention-deficit hyperactivity disorder (Vaisman *et al.*, 2008). Traditionally, PS supplements were derived from bovine cortex (BC-PS); however, due to the potential transfer of infectious diseases, soy-derived PS (S-PS) has been established as a safe alternative. Soy-derived PS is generally recognized as safe (GRAS) and is a safer nutritional supplement for older persons if taken up to a dosage of 200 mg three times daily (Jorissen *et al.*, 2002).

The sterol results in Table IV showed the values to be high for cholesterol in both of the samples with values 1353 and 1355 mg/100 g representing percentage levels of 99.99 - 99.99 % making other types of sterols very irrelevant. Along with SFA, cholesterol in the cell membrane gives our cells necessary stiffness and stability. This is why serum cholesterol levels may go down temporarily when we replace SFA with polyunsaturated oils in the diets (Jones, 1997). Cholesterol acts as precursor to vital corticosteroids, hormones that help us deal with stress and protect the body against heart disease and cancer and to the sex hormones like androgen, testosterone, estrogen and progesterone. Cholesterol is a precursor to vitamin D, a very important fat-soluble vitamin needed for healthy bones and nervous system, proper growth, mineral metabolism, muscle tone, insulin production, reproduction and immune system function. The bile salts are made from cholesterol. Bile is vital for digestion and assimilation of fats in the diet. Recent research shows that cholesterol also acts as an antioxidant (Cranton and Frackelton, 1984). This is the likely explanation for the fact that cholesterol levels go up with age. As an antioxidant, cholesterol protects us against free radical damage that leads to heart disease and cancer. Cholesterol is needed for proper function of serotonin receptors in the brain (Engelberg, 1992). Serotonin is in the body's natural "feel-good" chemical, low cholesterol levels have been linked to aggressive and violent behaviour, depression and suicidal tendencies. Mother's milk is especially rich in cholesterol and contains a special enzyme that helps the baby utilize the nutrient. Babies and children need cholesterol-rich foods throughout their growing years to ensure proper development of the brain and nervous system. Dietary cholesterol plays an important role in maintaining the health of the intestinal wall (Alfi-Slater and Aftergood, 1980). This is why low cholesterol vegetarian diets can lead to leaky gut syndrome and other intestinal disorders. Cholesterol levels in

literature from many animal protein sources were either lower or higher than the she-goat and castrated goat cholesterol levels. Values in mg/100 g were: fish (50-60), egg yolk (1260), meat and poultry (60-120), brain (2000-3000), liver (300-350) (Bender, 1992). Others were lean rabbit, (71), sheep brain (2200), ox liver (270), sheep (430), pig (260) and calf (370) (Paul and Southgate, 1978). Most authorities, but not all, recommend a reduction in dietary cholesterol to around 300 mg or less per day (Bender, 1992). The cholesterol levels in the two samples (1353 and 1355 mg/100g) fell far above this value.

#### Statistical analysis

Statistically, in Table VIII, the linear correlation at  $\alpha = 0.05$ ,  $df: n-1$  showed that no significant difference existed between the crude fats, phospholipids and sterols except in the fatty acids parameters. The IFE (%) was highest for crude fat and sterols at 100, 80.9 for phospholipids and least for fatty acids parameters at 39.5 % making it to have the highest degree of coefficient of alienation ( $C_A$ ) at 60.5 %. The high values of IFE in crude fat, sterols and phospholipids make the comparison of the two brains easy unlike in the fatty acids because of the IFE values.

#### Conclusion

The findings of this study showed that the crude fat levels were of slight unequal distribution, but fairly low, 9.98 and 10.2 %. The SFA was lower (42.7 % and 40.6 %) than the total unsaturated fatty acids in both of the two brain samples (58.0% and 61.0%); thereby making the fats good for human health. The proportion of cholesterol neutral stearic FA (C18:0) was about equal with 14.5% (she-goat) and 14.4 % (castrated goat). The cholesterol-elevating SFAs such as myristic (C14:0) and palmitic (C16:0) were 4.09 % and 23.0 % (she-goat); and 1.83 % and 23.3% (castrated goat). The phospholipids were generally high (2365 mg/100g and 3047 mg/100g) and will promote the good health of its consumers. The cholesterol was the only sterol of significance and was generally higher (1353 mg/100g and 1355mg/100g) than the recommended daily intake of 300 mg per day. On the whole, the brains would serve as good animal by-products in dietary fat sources.

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