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Domestic Pig Organs as Good Sources of Nutritionally Important Fatty Acids and Low Cholesterol Meat

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Abstract - The levels of fatty acids, phospholipids and zoosterols were determined in the organs of domestic pig consumed in Nigeria on dry weight basis. The organs analysed were liver, muscle and brain. Results showed crude fat varied from 2.85-4.36 g/100 g; SFA varied from 34.4 -39.9 % of total fatty acids, total unsaturated fatty acids (TUFA) varied from 60.1-65.6 %, PUFA ranged from 23.9-30.1 % and MUFA ranged from 35.5-37.7 %. PUFA/SFA range was 0.598- 0.873; EPSI range was 0.659-0.848; AA/DGLA was 6.22-20.2; *n*-6/n-3 was 0.285-0.481 and EPA/DHA was 0.079-0.472. Fatty acid as food would be provided by 0.743-1.366 g/100 g (SFA); 0.796-1.239 g/100 g (MUFA); 0.574 -0.817 g/100 g (PUFA) whereas TUFA would provide 1.60-2.06 g/100 g. In energy from fatty acids: SFA would produce 27.5-50.5 kJ/100 g (34.5-39.8 %); MUFA would produce 29.5-45.8 kJ/100 g (35.5-37.7 %); PUFA would produce 21.2-30.2 kJ/100 g (23.8-30.1 %) and TUFA would produce 50.7-76.2 kJ/100 g (60.0-65.4 %). Correlation coefficient (r_{xy}) showed that liver/muscle, muscle/brain, liver/brain were each significantly different from each other at $r = {}_{0.05}$. In the phospholipids, phosphatidylcholine was mostly concentrated in all the samples having a range of 223-307 mg/100 g (58.0-63.8 %) and liver/muscle, muscle/brain and liver/brain rxy were all significantly different at $r = {}_{0.05}$. Cholesterol was the only sterol with value greater than 0.00 mg/100 g or 99.996-99.997 %.

Keywords : *domestic pig organs, lipid profiles, low cholesterol.*

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Keywords : domestic pig organs, lipid profiles, low cholesterol.

I. Introduction

The estimated world pig population of 826 million (FAO, 1988) means there is approximately one pig for every six people in the world. Although pigs are numerically fewer than some other domestic species, more pig meat is produced than any other meat. A comparison of the main livestock species in the world in terms of numbers and meat production is shown thus: cattle (1253), buffalo (137) (million head) have meat output (000 metric tonnes per year) as 50 098 (for the two animals); sheep (1174), goats (521) (million head) have meat output of (8801) both animals; poultry (10050) (million head) have meat output of 11 495 whereas pigs (826) million head have meat output of 63 917 (000 metric tonnes per year (FAO, 1989).

The distribution of pigs throughout the world is not uniform. Nearly half the world's pig population is in Asia, with a further 30 per cent in Europe and the old USSR. In contrast, the population in large parts of the tropical and sub-tropical developing regions (e.g. Africa and Latin America) is relatively small. Nevertheless, the increase in the world pig population over the last decade is largely attributable to increases within the developing world which now constitutes some 60 per cent of the world population of pigs. It is noteworthy that the majority of the pigs in the developing world are located in one Asian country, namely China (Holness, 1991). Similarly, marked differences exist in the consumption patterns of pigmeat throughout the world. In some parts of Europe, annual per capita consumption of pigmeat is over 50 kg, and represents some 60 per cent of the total meat consumed. At the other end of the scale, in areas of the developing world, and particularly in Africa, estimated annual per capita consumption ranges from 1 to 3 kg, and forms less than 10 per cent of the total meat diet (Holness, 1991).

Every country has its own system of assessing the quality of the carcass and generally carcasses are graded according to a number of criteria. They include: conformation (shape of the carcass), degree of fatness (amount of fat as subcutaneous fat cover at a set position), lean content of the carcass (measurement of muscle depth in the carcass) and fat quality (carcasses that exhibit a soft and oily, rather than hard, fat cover will tend to be downgraded because they cannot be used for the higher-priced fresh meat of cured products trade) (Holness, 1991). The main products derivable from pig meat are: fresh meat, cured products (such as bacons and hams), and other processed products (such as sausages, pies, luncheon meats, hamburgers and meat pastes). Other pig products in addition to meat are: lard (pig fat), pig skin, bristles, intestines (used for sausage casings), offals (these are edible and the liver in particular is a delicacy), blood (sometimes processed into sausages and other delicacies for human consumption), slaughterhouse by-products (bones,

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blood and inedible meat tissue is converted into animal feeds) and hoofs (used for gelation and glue products) (Holness, 1991).

A pig is any of the animals in the genus *Sus*, within the Suidae family of even-toed ungulates. Pigs include the domestic pig, its ancestor the wild boar, and several other wild relatives. Young and small pigs are known as piglets (http://www.merriam-webster.com/dictionary/piglet). Pigs are omnivores and are highly social and intelligent animals (Angier, 2009). Scientific classification: Kingdom (Animalia), Phylum (Chordata), Class (Mammalia), Subclass (Theria), Infraclass (Eutheria), Order (Artiodactyla), Family (Suidae), Genus (*Sus* Linnaeus, 1758). The genus *Sus* is currently considered to have 10 living species and a number of extinct species known as fossils: among them is: *Sus scrofa domestica* Erxleben, 1777-Domestic pig (sometimes treated as a full species). The domestic pig (*Sus scrofa dometicus)* is usually given the scientific name *Sus scrofa*, although some authors call it *S. domesticus*, reserving *S. scrofa* for the wild boar.

Meat animals yield, besides their carcasses, a considerable amount of parts which are biologically and hygienically fit for human consumption. These by-products are very different from the point of view of structure, proximate composition or functional or sensory properties, but they can all be used for food. They are generally consumed either as main ingredients in traditional dishes or as ingredients in meat products (Fornias, 1996). Among by-products which are edible are the brains which are consumed as direct meat products. People are sceptical on the consumption of pig carcass and its offals because of the believe in its high level of fat particularly saturated fatty acids and cholesterol levels. There is hardly any chemical information on the meat of domestic pig. The purpose of the present report was to explore evidence relating to the lipid composition of the muscle, liver and brain of *Sus domesticus* as contributors to the availability of long-chain (LC), very-long-chain (VLC) fatty acids and low level of sterols when taken as protein food source.

II. Materials and Methods

a) Materials

Domestic pig (male) parts were purchased from the butchers based at Iworoko Ekiti, in Ekiti State, Nigeria. Iworoko Ekiti is less than 1.0 km north of the Ekiti State University, Ado-Ekiti. The samples were kept in freezer and brought to the laboratory within 30 min of purchase.

b) Sample Treatment

The samples were washed with distil water in the laboratory, cut into smaller bit and dried in the oven for 5 h at 60 °C. After drying, samples were ground to flour, sieved and kept in freezer (-4 °C) in McCartney bottles pending analyses.

c) Extraction of Lipid

0.25 g of each sample was weighed into the extraction thimble. 200 ml of petroleum ether (40-60 °C boiling range) was measured and then added to the dried 250 ml capacity flask. The covered porous thimble with the sample was placed in the condenser of the Soxhlet extractor arrangement that has been assembled (AOAC, 2005). The lipid was extracted for 5 h. The extraction flask with the oil was oven dried at 105 °C for 1 h. The flask containing the dried oil was cooled in the desiccator and the weight of the cooled flask with the dried oil was measured.

d) Preparation of methyl ester and analysis

50 mg of the extracted oil was saponified for 5 min at 95 °C with 3.4 ml of 0.5 M KOH in dry methanol. The mixture was neutralised by 0.7 MHCl. 3 ml of 14 % boron triflouride in methanol was added (AOAC, 2005). The mixture was heated for 5 min at 90 °C to achieve complete methylation process. The fatty acid methyl esters were thrice extracted from the mixture with redistilled n-hexane. The content was concentrated to 1 ml for analysis and 1µl was injected into the injection pot of the GC. The fatty acid methyl esters were analysed using an HP 5890 powered with HP gas chromatography (HP 5890 powered with HP ChemStation rev. A09.01 [1206] software [GMI, Inc, Minnesota, USA]) fitted with a flame ionization detector. Nitrogen was the carrier gas with a flow rate of 20-60 ml/min. The oven programme was: initial temperature at 60 °C, first ramping at 10 °C/min for 20 min, maintained for 4 min, second ramping at 15 °C/min for 4 min and maintained for 10 min. The injection temperature was 250 °C whilst the detector temperature was 320°C. A capillary column (30 m x 0.25 mm) packed with a polar compound (HP INNOWAX) with a diameter (0.25 µm) was used to separate the esters. Split injection type was used having a split ratio of 20:1. The peaks were identified by comparison with standard fatty acid methyl esters.

e) Sterol Analysis

Sterol was analysed as described by AOAC (2005). The aliquots of the extracted fat were added to the 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 had been added to ensure miscibility. Deionised water (3 ml) was added and 2 ml of hexane was added in extracting the non-saponifiable materials. Three extractions, each with 2 ml hexane, were carried out for 1 h, 30 min and 30 min respectively. The hexane was concentrated to 1 ml in the vial for gas chromatographic analysis and 1 µl was injected into injection pot of GC. The peaks were identified by comparison with standard sterols. The sterols were analysed using similar conditions as for fatty acid methyl ester analyses.

f) Phospholipids Analysis

Modified method of Raheja *et al.* (1973) was employed in the analysis of phospholipids. 0.01 g of the extracted fat was added to each test tube. To ensure complete dryness of the fat for phospholipids analysis, the solvent was completely removed by passing stream of nitrogen gas on the fat. 0.40 ml chloroform was added to the tube followed by the addition of 0.10 ml chromogenic solution. The tube was heated at 100 °C in water bath for 1 min 20 sec. The content was allowed to cool to the laboratory temperature and 5 ml hexane added and the tube shaken gently several times. the solvent and the aqueous layers were allowed to be separated. The hexane layer was recovered and concentrated to 1.0 ml for analysis. The phospholipids 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 pulse flame photometric detector. Nitrogen was used as the carrier gas with a flow rate of 20-60 ml/min. The oven programme was: initial temperature at 50 °C, whilst the detector temperature was 320 °C. A capillary column (30m x 0.25 mm) packed with a polar compound (HP) with a diameter (0.25 μm) was used to separate the phospholipids. Split injection type was used having a split ratio of 20:1. The peaks were identified by comparison with standard phospholipids.

g) Quality Assurance

Standard chromatograms were prepared for sterols, phospholipids and fatty acid methyl esters which were then compared with respective analytical results; calibration curves were prepared for all the standard mixtures and correlation coefficient determined for each fatty acid parameter, same for sterols and phospholipids. Correlation coefficient should be > 0.95 for the result to be acceptable. It was performed with Hewlett Packard Chemistry (HPCHEM) software (GMI, Inc 6511 Bunker Lake Blvd Ramsey, Minnesota, 55303, USA).

Further on quality assurance, fatty acid values were subjected to calculation of uncertainty interval percentage (UIP). Certified reference materials (CRMs) play a critical role in validating the accuracy of nutrient data. A range of food CRMs with assigned values and uncertainty intervals (UIs) for many nutrients are currently supplied by several organisations (Phillips *et al.*, 2007). The fatty acids whose UIs were available were evaluated in certified reference materials (CRMs): C16:0, C18:0, C16:1, C18:1, C18:2 and C18:3 (AOAC, 2005; Phillips *et al.*, 2007). Certified reference material was available for cholesterol but not any of the phospholipids (Phillips *et al.*, 2007).

h) Calculation of fatty acid as food per 100 g in sample

At the data source and reference database levels, values for individual fatty acids are usually expressed as percentages of total fatty acids. At the user database level, values per 100 g of food are required. A conversion factor derived from the proportion of the total lipid present as fatty acids is required for converting the percentages of total fatty acids to fatty acids per 100 g of food. Total lipid level (crude fat) was multiplied by conversion factors as follows: muscle (3.59 x 0.953 = 3.42 g/100 g), brain (4.36 x 0.561= 2.45 g/100 g) and liver (2.85 x 0.741 =2.11 g/100 g) (Anderson, 1976). For fatty acids, precision is best limited to 0.1 g/100 g of fatty acids (Greenfield and Southgate, 2003).

i) Statistical Analysis

Statistical analysis (Oloyo, 2001) was carried out to determine coefficient of variation in per cent (CV %), linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (Rc), coefficient of alienation (C_A) and index of forecasting efficiency (IFE). The r_{xy} was subjected to the table (critical) value at $r_{= 0.05}$ to see if significant differences existed in the values of fatty acids and phospholipids in the samples having a mapping of liver/muscle, muscle/brain and liver/brain. The cholesterol was subjected to chi-square (X^2) analysis as well setting the critical value at $\alpha \leq 0.05$.

III. Results and Discussion

Table 1 depicts the crude fat levels of the samples. Also shown are the true total fatty acids and the energy (kJ/100 g) of each sample. The liver had the least crude fat of 2.85 g/100 g whereas brain had the highest level of 4.36 g/100 g; the true total fatty acids and total energy followed this trend. The coefficient of variation per cent (CV %) was low showing the fat levels were generally close among the values. From Fornias (1996) the percentage fat levels of the samples: brain (9.2), liver (2.4), lean pork (5.9) with corresponding energy value (Cal) of: 127, 116 and 143. In the bull, the crude fat was 42.5 g/100 g (brain) and total fatty acid (23.8 g/100 g) whereas in the hen, brain crude fat was 45.2 g/100 g and true total fatty acid of 25.4 g/100 g (Adeyeye, 2012a). The low level of fat (and low energy) from pork is a benefit to the consumer. Although pork contains a high concentration of nutrients, lean pork is relatively low in calories and of the major meats only chicken has a lower calorific value as shown (Holness, 1991): number of calories per 85 g of lean: beef (228), lamb (221), liver (220), pork (206) and chicken (144). This allows for a higher intake of the energy-rich, bulkier foods to be enjoyed. These considerations particularly apply to consumers in the developed world, but there is an increasing trend for consumers in the developing world, especially in urban and peri-urban areas, to become more aware of the need to reduce fat in the human diet (Holness, 1991).

We have in Table 2 the various levels of saturated and monounsaturated fatty acids (SFA and MUFA). Short-chain (SC) fatty acids (C4-C6) had no good values in all the samples. Medium-chain (MC) fatty acids (C8-C12) were detected in the samples particularly in the muscle. The values were however low where present. Both liver and brain had values only for C12:0 whereas muscle had value for C8:0, C10:0and C12:0. The CV % in C8:0 and C10:0 were high at 173 whereas it was low in C12:0 with a value of 26.1. C8:0-C12:0 have antimicrobial properties, are absorbed directly for quick energy and contribute to the health of the immune system (Enig and Fallon, 2000). The long-chain (LC) fatty acids have from 14 to 18 carbon atoms and can be either saturated, monounsaturated or polyunsaturated.

The first member of LC is C14:0, it is a ubiquitous component of lipids in most living organisms but usually at levels of 1-2 % only. In the present samples it has values of 2.23-4.97 % with a CV % of 46.1. Nutmeg butter is 75 % trimyristin, the triglyceride of myristic acid. Besides nutmeg, myristic acid is also found in palm kernel oil, coconut oil, butter fat and is a minor component of many other animal fats (IUPAC, 2001). It is also found in spermaceti, the crystallized fraction of oil from the sperm whale. Myristic acid is also commonly added co-transnationally to the penultimate, nitrogen-terminus, glycine in receptor-associated kinases to confer the membrane localisation of the enzyme. The myristic acid has a sufficiently high hydrophobicity to become incorporated into fatty acyl core of the phospholipid bilayer of the plasma membrane of the eukaryotic cell. In this way, myristic acid acts as a lipid anchor in biomembranes. The ester isopropyl myristate is used in cosmetic and tropical medicinal preparations where good absorption through the skin is desired. Palmitic acid (16:0) is usually considered the most abundant SFA in nature, it is found in appreciable amounts in the lipids of animals, plants and lower organisms. It comprises 20-30 % of the lipids in most animal tissues and it is present in amounts that vary from 10 to 40 % in seed oils. The present results of 21.2-24.9 % are within the range of 20-30 % of the lipids in most animal tissues. The bull's head and chicken head brains contained no detectable level of C16:0 (Adeyeye, 2012a). Stearic acid (18:0) is the second most abundant SFA in nature, and again it is found in the lipids of most living organisms. In these samples (18:0) occupied the second highest position in the SFA with values of 7.70-10.4 % with a CV % of 16.1. In lipid of some commercial importance, it occurs in the highest concentrations in ruminant fats (milk and tallow) or in vegetable oils such as cocoa butter, and in industrially hydrogenated fats. It can comprise 80 % of the total fatty acids in ganliosides. The other SFAs present in minor levels were arachidic acid (C20:0, 0.026-1.93 %), behenic acid (C22:0, 0.019-0.043 %) and lignoceric acid (C24:0, 0.002-005 %). The total SFA of 34.4-39.9 could easily compare favourably with literature values; they are: 43 % (beef fat), 50 % (lamb fat), 37 % (pork fat), 33 % (chicken, meat and skin), 27 % (duck, meat and skin), 30 % (calf liver) (Bender, 1992); three different land snails consumed in Nigeria (37.5-49.8 %) (Adeyeye, 2012b); bush pig (*Potamochoerus larvatus*) having SFA values of 39.5-47.6 % (Adeyeye *et al.*, 2013).

Oleic acid [9*c*-18:1 or 18:1(*n*-9)] is by far the most abundant monoenoic fatty acid in plant and animal tissues, both in structural lipids and in depot fats. It is the highest concentrated MUFA in muscle (15.1%) but second in liver (12.0 %) and brain (10.0 %). Olive oil contains up to 78 % oleic acid, and it is believed to have especially valuable nutritional properties as part of the Mediterranean diet. It has a number of important biological properties, both in the free and esterified form. Oleic acid is the biosynthetic precursor of a family of fatty acid with the (*n*-9) terminal structure and with chain-lengths of 20-24 or more. Petroselinic acid (6*c*-18:1) occurs up to a level of 50 % or more in seed oils of Umbelliferae family, including carrot, parsley and coriander. In the present report, petroselinic acid occupied the highest position in the *cis*-18:1 FA in both liver (12.5 %) and brain (13.7 %) but second highest in muscle (8.64 %). Studies in vitro by Weber *et al.* (1995) revealed that triacylglycerols containing petroselinoyl [18:1(*n*-12)] moeties are hydrolysed by pancreatic lipase at much lower rates than other triacylglycerols. Consumption of coriander (*Coriandrum sativum*) oil, compared with the other oils, led to significantly greater liver weights. No significant differences were observed among the groups fed various levels of oleic acid in body weight, the weights of heart, liver, kidneys, spleen or testes, lipid content of heart, or total cholesterol, HDL cholesterol and triacyglycerol concentrations of blood plasma. Ingestion of coriander oil led to incorporation of 18:1 (*n*-12) into heart, liver and blood lipids and to a significant reduction in the concentration of arachidonic acid in the lipids of hearts, liver and blood with a concomitant increase in the concentration of linoleic acid compared with results for the other groups. The data show that petroselinic acid from dietary triacylglycerols is absorbed by rats as readily as oleic acid, but the former reduces the concentration of arachidonic acid in tissue lipids suggests [in view of earlier studies (Mohrhauer *et al.,* 1967)] petroselinic acid-mediated inhibition of arachidonic acid synthesis. Another MUFA of reasonable level is palmitoleic acid (C16:1 c-9) having values of 6.39-6.95 % and CV % of 4.37. C 16:1c-9 has strong antimicrobial properties and it is found almost exclusively in animal fats (Enig and Fallon, 2000). It is also found in rich amounts in macadamia nut, olive, canola and peanut oils. This monounsaturated fatty acid is beneficial in reducing bad cholesterol (LDL) and it behaves like a saturated and not as an unsaturated fatty acid in its effect on HDL

cholesterol (Nestel *et al*., 1994). It also reduces the fat deposition in blood vessels and reduces blood clot formation (Grundy, 1994). Gondoic acid [11-*cis*-eicosenoic acid (11-20:1 or 20:1(*n*-9)] is a common if minor constituent of animal tissues and fish oils, often accompanied by the 13-isomer. It is also found in rapeseed oil and seed oils of related species. Its value ranged from 4.15-4.87 % and CV % of 9.26 in the present samples. Erucic acid (C22:1 *cis*-13) is a fatty acid that is apparently responsible for a favourable response of persons with nervous system disorders (Christensen *et al*., 1988). The administration of erucic acid in the diet will reduce the serum levels and brain accumulation of very-long-chain of saturated fatty acids (such as C26:0) responsible for demyelination (Sargent *et al*., 1994; Rasmussen *et al*., 1994). The level of erucic acid in the present samples ranged from 1.19-1.46 % and CV % of 10.2.

Accumulation of certain long- chain fatty acids is associated with degerative diseases of the central nervous system, such as behenic acid (C22:0; 0.019-0.043 % in samples) but about1 % in beef fat [Whetsell *et al.,* 2003] and lignoceric acid (C24:0; 0.002-0.005 % in samples but about 1 % in beef fat) as well as that of the unsaturated members of C22 and C24 group (Whetsell *et al*., 2003). Accumulation occurs because enzymes needed to maintain turnover of those fatty acids are lacking (Lord and Braloley, 2001). Behenic acid has been detected to be a cholesterol-raising SFA factor in humans (Cater and Denke, 2001).

The total *trans*-MUFA concentration was very low and insignificant at 0.008-0.018 % with CV % of 44.1 whereas *cis*-MUFA total ranged from 35.5-36.2 % and CV % of 3.06.

In Table 3 were enumerated the various concentrations of PUFA *n*-6 and *n*-3 fatty acids. The Table contains both long-chain (LC) and very –long-chain (VLC) fatty acids (LC, 18 and VLC, 20-24) carbon atoms. The major important polyunsaturated fatty acids found in samples were linoleic acid (LA) (C18:2 *cis*-9, 12), arachidonic acid (AA) (C20: 4 *cis*-5, 8, 11, 14), alpha-linolenic acid (ALA) (C18:3 *cis* -9, 12, 15), eicosapentaenoic acid (EPA) (C20:5 *cis*-5, 8, 11, 14, 17) and docosahexaenoic acid (DHA) (C22:6 *cis*-4, 7, 10, 13, 16, 19). LA had values of 0.760-1.87 % and CV % of 47.1; AA had 2.21-6.79 % and CV % of 50.7; ALA had 0.024-0.629 % and CV % of 148; EPA had 1.55-4.96 % and CV % of 70.1 and DHA had 10.5-20.0 % with CV % of 32.1. Alpha-linolenic acid (C18:3) is classified as a short-chain omega-3 fatty acid and is also found in nuts and seeds. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are found predominantly in foods of marine origin and are classified as long-chain omega-3 fatty acids. LA is also found in corn, sunflower oil, safflower oil and soybeans whereas AA is found in brain, liver, glandular and egg lipids (both acids belong to the omega-6 family of fatty acids) (Whetsell *et al*., 2003).

The omega-3 fatty acids present in pastures, like the alpha-linolenic acid (C18:3), appear to have little direct value for human health. However, the human body can add 2 or 4 carbons to these 18-carbon chain fats to produce 20-or 22–carbon chain omega-3 fatty acid. Thus, alpha-linolenic acid (C18:3) is a pre-cursor for EPA (C20:5) and DHA (C22:6) fatty acids, which are important for human health. It has been suggested that alpha –linolenic acid has a beneficial effect on cardiovascular heart disease (Ascherio *et al*., 1999; Hu *et al.,* 1999). However, other studies reported no evidence of alpha-linolenic acid having a positive effect on cardiovascular heart disease (Renaud *and* Lanzmann-Petithory, 2002; Sanderson *et al*., 2002). Although alpha-linolenic acid supplementation causes an increase in the blood and plasma levels of alpha-linolenic acid, EPA and DPA, no benefit has shown on either risk factors for cardiovascular diseases or on secondary prevention of cardiovascular heart disease (Sanderson *et al*., 2002). The present results do not appreciate the essentiality of C18:3 since both EPA and DHA were already much in excess of the C18:3 in the primary samples.

For many years linoleic acid (C18:2; omega-6) was thought to be the preferable fatty acid for the diet because it was considered to be the most effective cholesterol-lowering fatty acid. However, despite an increase in linoleic acid intake (from about 4 % to 7 %), there has been a growing reservation about recommending its consumption, due to no proven long-term safety (Grundy, 1994). In humans, high supplemental intakes of linoleic fatty acid can lower good cholesterol concentration and may increase the risk for cholesterol gallstones. In addition, the presence of linoleic acid in bad cholesterol lipids makes them more prone to oxidation, which could promote atherosclerosis. Because of these detrimental effects, current recommendations have been moderated and now caution that intakes of this fatty acid should not exceed current concentrations (about 7 % of total energy intakes; present result is very much below this level) (Grundy, 1994). However, recent information from American Heart Association (Whetsell *et al*., 2003) indicates that linoleic acid has a noticeable effect on lowering cholesterol further than oleic and palmitic acids when plasma cholesterol levels are high (> 200 mg/dl). They suggest that a 10 % calorie intake in the form of polyunsaturated fats, linoleic acid achieves a maximal effect on cholesterol lowering. It also has been suggested (Iso *et al.,* 2002) that a higher intake of linoleic acid appear to protect against stroke, possibly through potential mechanism of decreased blood pressure, reduced platelet aggregation and enhance deformability of erythrocyte cells. Again high levels of

arachidonic acid might have reduced the essentiality of linoleic acid in the samples.

Linoleic acid and alpha-linolenic acid are plant fatty acids that can be transformed to CLA (conjugate linolenic acid) by bacteria in the rumen, hence rumenic acid (Kepler *et al*., 1966). They are the C18:2 *cis*-9, *trans*-11 (just one of the series). A lot of health benefits have been attributed to CLA (Kramer, 1998), this includes its behaviour as an antioxidant, it also reduces circulating cholesterol in mice (West *et al*., 1998). CLA in the samples was low at 0.011-0.090 % and CV % of 108.

It has been suggested that arachidonic acid (C20:4 *cis* -5, 8, 11, 14) is detrimental to human health (Barham *et al*., 2000). However, it promotes inflammation that is an important protective response when one is injured. It also forms the basis of anti-inflammatory prostaglandins that the body uses, to reduce inflammation (Fallon and Enig, 1996). The amount of arachidonic acid in beef is very low (less than 0.5 % of total fat); it is much higher in the domestic pig: 2.21- 6.79 % of total fatty acids.

Two other omega-3 fatty acids in the samples are DHA (C22:6) and EPA (C20:5), have been reported to have health benefits (Mantzioris *et al*., 2000). These omega-3 fatty acids have been shown to prevent cancer (Hardman, 2002), and cardiovascular disease (Simopoulos, 2002), as well as being therapeutic for arthritis (Kremer, 2000), autoimmune disease (Harbige and Fisher, 2001), inflammatory effects (Grimm *et al*., 2002) and depression (Puri *et al*., 2001). DHA is also important during pregnancy for infant and brain development (Horrocks and Yeo, 1999) and reduces the incidence of premature birth (Allen and Harris, 2001). EPA lowers blood cholesterol (Pal *et al*., 2002) and reduces blood clotting, allowing better blood circulation (Heller *et al*., 2002). The present samples have high levels of EPA and DHA with respective values of 1.55-4.96 % and 10.0-20.0 %. Thus, there is a benefit from the production of additional DHA and EPA by the body's elongation and desaturation of shorter chain fatty acids (C18:3 omega-3; 18:2 omega -6) in humans. Total PUFA in the samples ranged as 23.9-30.1 %; in the bull and hen brain it was 83.5-85.0 % (Adeyeye, 2012a); in three land snails it was 25.5-38.7 % (Adeyeye, 2012b); in the bush pig it was 18.9-23.1 % (Adeyeye *et al*., 2013).

Table 4 contains the summary of quality characteristics of the fatty acids profile. The relative values of PUFA in all the samples made them important in diet. The eicosanoids help regulate blood clot formation, blood pressure, blood lipid (including cholesterol) concentration, the immune response, the inflammation response to injury and infection and many other body functions (Whitney *et al*., 1994). A deficiency of *n*-6 fatty acids in the diet leads to skin lesions. A deficiency of *n*-3 fatty acids leads to subtle neurological and visual problems. Deficiencies in PUFA produce growth retardation, reproductive failure, skin abnormalities and kidney and liver disorders. However, people are rarely deficient in those fatty acids (Tapiero *et al*., 2002). The relative amounts of PUFA and SFA in oils is important in nutrition and health. The ratio of PUFA/SFA (PS ratio) is therefore important in determining the detrimental effects of dietary fats. The higher the P/Sratio the more nutritionally useful is the oil. This is because the severity of atherosclerosis is closely associated with the proportion of the total energy supplied by SFA and PUFA fats (Honatra, 1974). The present PUFA/SFA varied between 0.598-0.873 which were averagely normal. 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 reative compounds. Since they compete for the same enzymes and have different biological roles, the balance between the *n*-6 and *n*-3 FAs in the diet can be of considerable importance (WHO/FAO, 1994). The ratio of *n*-6 to *n*-3 or specifically LA to ALA in the diet should be between 5:1 and 10:1 (WHO/FAO. 1994) or 4-10 g of *n*-6 FAs to 1.0 g of *n*-3 FAs (Canadian Government Publishing Center, 1990). As LA is almost always present in foods, it tends to be relatively more abundant in animal tissues. This is supported in the present report as follows: C18:2 (*n*-6) ranged as 0.760-1.87 % whereas C18:3 (*n*-3) ranged as 0.024-0.629 %. In turn, these FAs are the biosynthetic precursors in animal systems of C20 and C22 PUFAs, with 3-6 double bonds, via sequential desaturation and chain-elongation steps (desaturases in animal tissues can only insert a double bond) (Berg *et al*., 2007). Looking at *n*-6/*n*-3 in Table 4, none of the samples fell within the expected ratio, we had 0.285:1 to 0.481:1 and in LA/ALA, we had 2.98:1 to 31.7:1 ratios. Both LA and ALA need adjustment from other food sources.

The relative proportion of MUFA/SFA is an important aspect of phospholipid compositions and changes to this ratio have been claimed to have effects on such disease states as cardiovascular disease, obesity, diabetes, neuropathological conditions and cancer. For example, they have been shown to have cyto-protective actions in pancreatic β-cells. *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 now recognised by nutritionists as being beneficial in the human diet (Adeyeye, 2012b). Present results gave values of MUFA/SFA as 0.908-1.07 (Table 4) which were good enough. A high ratio between AA and DGLA, as an indicator of Δ-5 desaturase activity, in the skeletal muscle phospholipids has been related to good insulin sensitivity; the AA/DGLA in the samples ranged as 6.22-20.2 (Table 4) which were good results. For the assessment of the essential PUFA status of an individual, the total amount of the various EFA and PUFA in plasma or erythrocyte phospholipids is a useful indicator (Hornstra, 1992). The following are further used

as additional status markers to reliably assess the functional PUFA status (Benatti *et al.*, 2004). The best known marker is Mead acid [trivial name for all-*cis*-icosa-5, 8, 11-trienoic acid (20:3*n*-9)]. The synthesis of this fatty acid is promoted if there are insufficient concentrations of LA and ALA to meet the need for the synthesis of long-chain PUFA. EPA and DHA inhibit Mead acid synthesis; the presence of Mead acid indicates a general shortage of all essential PUFA. The present results had ratios of EPA/DHA as 0.079-0.472 and no Mead acid was produced. Another suitable indicator of essential PUFA status is the essential PUFA status index (EPSI), which is the ratio between all essential PUFA (the sum of all *n*-3 and *n*-6 FAs) and all non-essential unsaturated FAs (the sum of all *n*-7 and *n*-9 FAs). The higher the EPSI status indexes the better the essential PUFA status. The present results had values of EPSI range of 0.659-0.948 which were all above average. Finally, 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 is a reliable indicator of the functional DHA status (Neuringer *et al.,* 1986). Hence the PUFA in the domestic pig samples cannot cause functional distress.

Table 5 contains the fatty acids distribution per 100 g sample as food. The values produced from SFA, MUFA and PUFA were consistently highest in the pig muscle than the corresponding two other samples. In the *n*-6 values were highest in AA > LA; in *n*-3 values were highest in DHA > EPA. The calculation accounted for all the total fatty acids as calculated by crude fat x the conversion factors for samples.

The National Institute of Health has published recommended daily intakes of FAs; specific recommendations included 650 mg of EPA and DHA, 2.22 g/day of ALA and 4.44 g/day of LA. However, the Institute of Medicine has recommended DRI (dietary reference intake) for LA at 12 to 17 and ALA at 1.1 to 1.6 g for adult women and men, respectively. Although seafood is the major dietary source of *n*-3 FAs, a recent fatty acid intake survey indicated that red meat also serves as a significant source of *n*-3 fatty acids for some population (Daley *et al.,* 2010); this had been aptly demonstrated in the pig samples.

The PUFA content of some selected foods for LA are (mg/100 g): beef (muscles only), 80; calf's kidney, 61; chicken (breast), 980; chicken (leg), 370; horse meat (average), 160; pork (muscle only), 110; turkey (breast), 180; turkey (leg), 750; veal (muscles only), 197. For ALA (mg/100 g): calf's kidney, 61; chicken (breast), 2.7; chicken (leg), 10; horse meat (average), 260; pork (muscle only), 25 and veal (muscles only), 9.1 (Souci *et al.*, 1990). The present level of LA and ALA are in good relationship with the literature values having values of 127-266 mg/100 g (linoleic acid) and 447-533 mg/100 g (alpha linolenic acid).

The energy in food is held in form of fat, carbohydrate, protein and alcohol. Each gram of fat contains approximately 9 kilocalories (37 kJ) (Royal Society, 1972). This value was used to calculate the energy levels of the various fat samples. The energy density in the samples due to fat ranged as 78.2-127 kJ/100 g (about 19.0-30.8 kcal/100 g) (Table 6). The 1990 Canadian RNI (Recommended Nutrient Intakes) included specific amounts for 3n-3 fatty acids and 2*n*-6 fatty acids. For *n*-3 FAs, the RNI is 0.5 % of total energy or 0.55 g/1000 kcal; for *n*-6 FAs, the RNI is 3 % of total energy or 3.3 g/1000 kcal (Whitney *et al.*, 1994). For energy contribution in the samples, the following was observed: liver (MUFA > SFA > PUFA), muscle (SFA > MUFA > PUFA), brain (MUFA > SFA > PUFA).

Remember, total energy contribution by the samples ranged from 78.2-127 kJ/100 g (about 19.0-30.8 kcal/100 g). For uptimum weight loss, reduce your overall fat/oil consumption to a sensible level. A level of 15-20 % of your total calories should come from fat-and the majority of that should be essential fatty acids. To determine how many grams of fats this translates into, you multiply your total daily calories by 15 % (20 % for the high-end of the range) and then divide by 9, which is the number of calories in a gram of fat. Here is an example: 2500 daily calories x 0.15 = 375/9 = 41.7 or 42 g of total fat per day- the bulk of which should be EFAs. It is known that 20 % energy from fat is consistent with good health. With 41.7 g of total fat per day, the pig that contains 2.11-3.42 g/100 g fatty acids will only be able to be a minor source of energy to its consumers.

The statistical analysis of the results in Table 4 is shown in Table 7. Results showed high positive and significant linear correlation coefficient (r_{xy}) (0.8060-0.9874) at $r_{=0.05}$ and *n*-2 degrees of freedom. The coefficient of determination (r_{xy}^2) values were also high (0.6500-0.9745) showing that 65.00-97.45 % of variance in liver/muscle (76.38 %), muscle/brain (65.00 %) and liver/brain (97.45 %). The linear regression (Rc) showed that for every unit increase in the liver fatty acid, there was a corresponding increase of 1.34 in the fatty acid of muscle; a unit increase in muscle resulted into 5.99 increase in brain fatty acid and a unit increase in liver resulted into 0.7475 increase in brain fatty acid. The coefficient of alienation (C_A) values ranged as 0.1585 (15.85 %)- 0.4860 (48.60 %) with corresponding high values of index of forecasting efficiency (IFE) with values of 0.5140 (51.40 %)-0.8415 (84.15 %). The IFE is actually a value of reduction of error of relationship between the compared paired samples; this meant that the error in the prediction of relationship was 48.6 % (liver/muscle), 35.0 % (muscle/brain) and 15.85 % (liver/brain). The implication of this was that any member of a pair in each group fatty acids could carry out adequately the functions of the other pair of its group.

The pig samples demonstrated close values of phospholipids with levels ranging from 352-529 mg/100 g at low CV % of 22.1 as shown in Table 8. Mammalian cell membranes contain more than a thousand different phospholipids. This large mixture of phospholipid species is primarily the result of the distinct fatty acyl chains esterified to the sn-1 and sn-2 positions of the glycerol backbone as well as the different polar head-groups attached to the sn-3 position of the glycerol backbone. The amounts of the various phospholipids in a membrane define the fluidity of the membrane and, consequently, the functions of the embedded proteins (Vance, 2008). Phosphatidylcholine is the most abundant phospholipid in mammalian cell membranes, comprising 40-50 % of total phospholipids. In the present results, phosphatidylcholine (lecithin) values ranged as 223-307 mg/100 g or 58.0 -63.8 %. The second most abundant mammalian membrane phospholipid is phosphatidylethanolamine (PE or cephalin) which comprises 20-50 % of total phospholipids. This is true in the present results with values ranging from 95.7-133 mg/100 g or 24.7-27.2 %. In the brain, ~ 45 % of total phospholipids are PE whereas in the liver only ~ 20 % of total phospholipids are PE (Vance, 2008). In the present report, PE in brain was 25.1 % and PE in liver was 27.2 %. Phosphatidylserine (PS) is a quantitatively minor membrane phospholipid that makes up 2-10 % of total phospholipids (Vance, 2008). PS came 4th in position among the phospholipids in all the samples and had values of 12.9-33.6 mg/100 g or 3.66-6.35 %. There is a strong metabolic inter-relationships among PS, PE and phosphatidylcholine (Vance, 2008). Additional relatively minor mammalian membrane phospholipids include phosphatidylinositol [PI, 3rd position, 17.4-37.2 mg/100 g (4.94-7.01 %)] and lysophophatidylcholine [5th position, 3.68-18.0 mg/100 g (1.05-3.40 %)].

Different types of mammalian cells and tissues have characteristic phospholipid compositions. For example, the brain is enriched in the two aminophospholipids PE and PS compared to other tissues (Vance, 2008). In the present results PE in brain to PE in muscle and liver had ratios of 1.39:1 and 1.39:1 respectively; in PS brain to PS muscle and liver, we had 2.24:1 (muscle) and 2.60:1 (liver). In the brain, and particularly in the retina (Ford *et al.*, 2007), the acyl chains of PS are highly enriched in docosahexaenoic acid (22:6*n*-3) (Kim, 2007). In human grey matter, 22:6*n*-3 accounts for > 36 % of the fatty acyl species of PS (Kim *et al.,* 2004). Since 22: 6*n*-3 appears to be essential for normal development and functioning of the nervous system (Mozzi*et al.,* 2003) it is likely that PS plays an important role in the nervous system and in vision (Kim, 2007).

Phospholipids were, for many years, thought to play primarily structural roles in biological membranes. A large number of recent studies have revealed, however, that these lipids mediate important regulatory functions in cells, partly because of their ability to be converted into key lipid second messengers such as diacylglycerol, inositol-1, 4, 5-trisphosphate (Berridge and Irvine, 1984; Nishizuka, 1986), lyso-phosphatidic acid and arachidonic acid.

The statistical analysis of the results in Table 8 is depicted in Table 9. These values were high in the pairwise comparisons: r_{xy} (0.9985-0.9996, all values significant), r_{xy}^2 (0.9971-0.9992), Rc (0.4936-13.5) and IFE (0.9459-0.9711 or 94.59-97.11 %); but the C_A was low (0.0289-0.0541 or 2.89-5.41 %).

In the analysis of sterols, only cholesterol had values greater 0.00 mg/100 g. Those outside the range of 0.00 mg/100 g were cholestanol, ergosterol, compesterol, stig-masterol, 5-avenasterol and sitosterol as shown in Table 10. The only major sterol of concern was cholesterol whose values ranged from 50.7-89.3 mg/100 g forming percentage range of 99.996-99.997 %. The CV % for cholesterol was 31.1. Cholesterol is a fatty compound involved in the transport of fat in the blood stream and is also part of the structure of cell membranes of tissues of the body. It is not a dietary essential since adequate amounts are synthesised in the body from other dietary ingredients. The body makes one-eighth to one-fourth teaspoons of pure cholesterol daily. Confusion has arisen between the terms blood cholesterol and dietary cholesterol. For most individuals dietary cholesterol has little or no effect on blood cholesterol because reduced synthesis in the body compensates for increased dietary intake (Bender, 1992). However, there are individuals who are sentive to dietary cholesterol (Reiser and Shorland, 1990) and most authorities advise a general reduction in cholesterol intake for everyone. The rise of cholesterol in the body can give a condition in which excessive cholesterol is deposited in artery walls called atherosclerosis. This condition blocks the blood flow to vital organs which can result in high blood pressure or stroke. Cholesterol in foods is not always bad, there are some types of cholesterol which are friendly to the heart and blood vessels. High-density lipoprotein is commonly called the “good” part of cholesterol. These lipoproteins help in the removal of cholesterol from the cells, which are then transported back to the liver where it is disintegrated and excreted as waste or broken down into parts (Cholesterol Advise. Net Understanding Cholesterol: What is Cholesterol and Causes High Cholesterol?).

Meat supplies about one third of the dietary cholesterol in many western diets with the remainder from eggs and dairy products. Since all these foods are valuable sources of nutrients there could be some nutritional risk in restricting their intake. Most authorities, but not all, recommend a reduction in dietary cholesterol to around 300 mg or less per day (Bender, 1992); this is more than the level in 100 g in the samples under

discussion. Some literature values of cholesterol are as shown (mg/100 g): fish (50-60), egg yolk (1260), meat and poultry (60-120), brain (2000-3000), liver (300-350) (Bender, 1992). Sheep brain contains 2200 mg/100 g cholesterol level (Paul and Southgate, 1978). Garcia *et al.* (2008) reported (cholesterol/100 g) 40.3 and 45.8 or 40300 and 45800 mg/100 g of tissue in pastured and grain-fed steers (castrated bulls), respectively ($p < 0.001$). Levels (mg/100 g) in bull brain was 874 and in hen brain it was 589 (Adeyeye, 2012a). In bush pig it ranged from 316-383 mg/100 g (Adeyeye *et al*; 2013).

Table 11 shows the uncertainty interval per cent (UIP) for fatty acids and cholesterol. Most of the literature UIP levels were correspondingly lower than the present results in most of the samples. The only exception was in C16:1 where critical UIP was 6.2 whereas sample UIPs ranged from 2.30-2.50. Beef-PorkFat Blend UIP information was used in comparing to the domestic pig values. The implication of the UIP values on the present result is that higher critical (table value) for fat/cholesterol than the present result values means that the new IUP in the sample result is higher than the critical table value. For example, UIP = (UI/value) x 100 in C16:0; we have 25.96 (0.3, 1.2): where 0.3 is UI, 25.96 is sample value and 1.2 is UIP; hence 0.3/25.96 x 100 = 1.2. On the other hand where standard value was less than experimental result, then experimental UIP is lower like in C16:1 (where standard sample value was 2.58). UIP determination is one of the ingredients to attest to the quality of the analytical determinations. Also the correlation determined for all the standards: fatty acids, phospholipids and sterols, all had values ranging as follows: 0.99833-0.99997 (fatty acids), 0.99909-0.99999 (phospholipids) and 0.99920-0.99994 (sterols); all the correlation values were greater than 0.95 which is the least critical correlation for acceptance of these types of analytical results. Both the correlation values and UIP values attested to the quality of the determinations.

IV. Conclusion

Sus scrofa domesticus organs (liver, muscle, brain) are sources of low level of fats which are mostly unsaturated which might not promote cardiovascular disease. The fatty acids are also high in the essential fatty acids particularly arachidonic and docosahexaenoic acids. All the samples were good sources of phospholipids and they all contain low cholesterol as the only major sterol. For people on low fat animal protein food source, the domestic pig is recommended as their animal protein choice.

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Table 1 : Crude fat, true total fatty acid and total energy levels of the different domestic pig organs

Parameters	Liver	Muscle	Brain	Mean	SD	CV%
Crude fat (g/100g)	2.85	3.59	4.36	3.60	0.76	21.0
True total fatty acids (g/100g)[a]	2.11	3.42	2.45	2.66	0.68	25.6
Total energy (kJ/100g)	105	133	161	133	28	21.1

[a]Liver (2.85x0.741); muscle (3.59 x 0.953); brain (4.36 x 0.561). SD = standard deviation.
CV% =coefficient of variation percent.

Table 2 : Saturated and monounsaturated fatty acid composition of the three different organs of domestic pig (% total fatty acid weight)

Fatty acid	Liver	Muscle	Brain	Mean	SD	CV%
Hexanoic acid (C6:0)	0.00	0.00	0.00	0.00	-	-
Octanoic acid (C8:0)	0.00	0.384	0.00	0.128	0.222	173
Decanoic acid (C10:0)	0.00	0.058	0.00	0.019	0.034	173
Lauric acid (C12:0)	0.264	0.425	0.294	0.328	0.086	26.1
Myristic acid (C14:0)	2.23	4.97	2.55	3.25	1.50	46.1
Palmitic acid (C16:0)	24.9	23.9	21.2	23.3	1.90	8.15
Stearic acid (C18:0)	7.70	8.21	10.4	8.76	1.41	16.1
Arachidic acid (C20:0)	0.046	1.93	0.026	0.669	1.10	164
Behenic acid (C22:0)	0.043	0.019	0.024	0.028	0.013	44.1
Lignoceric acid (C24:0)	0.005	0.002	0.003	0.004	0.002	44.1
Total SFA	35.1	39.9	34.4	36.5	2.97	8.13
Myristoleic acid (C14: 1*cis* - 9)	0.006	0.003	0.003	0.004	0.002	44.1
Palmitoleic acid (C16: 1 *cis* - 9)	6.81	6.95	6.39	6.72	0.294	4.37
Petroselinic acid (C18: 1 *cis* -6)	12.5	8.64	13.7	11.6	2.66	22.9
Oleic acid (C18: 1 *cis* - 9)	12.0	15.1	10.0	12.4	2.57	20.8
Gondoic acid (C20: 1 *cis* - 11)	4.87	4.19	4.15	4.40	0.408	9.26
Erucic acid (C22:1 *cis*-13)	1.46	1.32	1.19	1.32	0.135	10.2
Nervonic acid (C24:1 *cis*-15)	0.005	0.002	0.003	0.004	0.002	44.1
MUFA (*cis*)	37.7	36.2	35.5	36.5	1.11	3.05
Trans- Petroselinic acid (C18: 1 *trans-6*)	0.017	0.007	0.009	0.011	0.005	44.1
Elaidic acid (C18:1 *trans*-9)	0.00	0.001	0.001	0.0001	0.0004	44.1
Vaccenic acid (C18:1 *trans*-11)	0.00	0.00	0.00	-	-	-
MUFA (*trans*)	0.018	0.008	0.010	0.012	0.005	44.1
MUFA (total)	37.7	36.2	35.5	36.5	1.12	3.06

SFA = saturated fatty acid; MUFA = monounsaturated fatty acid.

Table 3 : PUFA *n*-6 and *n*-3 fatty acid composition of the three organs of domestic pig (% total fatty acids)

Fatty acid	Liver	Muscle	Brain	Mean	SD	CV%
Linoleic acid (LA) (C18: 2 *cis*-9,12)	1.05	1.87	0.760	1.23	0.578	47.1
Gamma- linolenic acid (C18:3 *cis*-6,9,12)	0.055	0.991	0.031	0.359	0.548	152
Eicosadienoic acid (C20: 2 *cis*-11,14)	0.007	2.07	0.004	0.692	1.19	172
Dihomo-γ-linolenic acid (C20:3 *cis*-8,11,14)	0.233	0.355	0.336	0.308	0.066	21.3
Arachidonic acid (AA) (C20:4 *cis*-5,8,11,14)	4.58	2.21	6.79	4.53	2.29	50.7
Docosadienoic acid (C22:2 *cis*-13,16)	0.088	0.175	0.349	0.204	0.133	65.3
***n*-6 PUFA (*cis*)**	6.01	7.67	8.27	7.32	1.17	16.0
Rumenic acid (C18:2 *cis*-9,*trans*-11)	0.019	0.090	0.011	0.040	0.043	108
***n*-6 PUFA (total)**	6.03	7.76	8.28	7.36	1.18	16.0
Alpha-linolenic acid (ALA)(C18:3 *cis*-9,12,15)	0.043	0.629	0.024	0.232	0.344	148
Eicosatrienoic acid (ETA)(C20:3 *cis*-11,14,17)	0.028	0.012	0.016	0.019	0.008	44.1
Timnodonic acid (EPA) (C20:5 *cis*-5,8,11,14,17)	1.55	4.96	1.72	2.74	1.92	70.1
Cervonic acid (DHA)(C22:6 *cis*-4,7,10,13,16,19)	19.5	10.5	20.0	16.7	5.35	32.1
Total *n*-3	21.1	16.1	21.8	19.7	3.11	15.8
n-6 +*n*-3 (total)	27.2	23.9	30.1	27.1	3.10	11.5

PUFA = polyunsaturated fatty acid.

Table 4 : Summary of quality characteristics of the fatty acids profile

Fatty acid	Liver	Muscle	Brain	Mean	SD	CV%
Total PUFA *n*-6	6.03	7.76	8.28	7.36	1.18	16.0
Total PUFA *n*-3	21.1	16.1	21.8	19.7	3.11	15.8
Total PUFA (*n*-3 + *n*-6)	27.2	23.9	30.1	27.1	3.10	11.5
MUFA total (*cis*)	37.7	36.2	35.5	36.5	1.11	3.05
MUFA total (*trans*)	0.018	0.008	0.010	0.012	0.005	44.1
MUFA total	37.7	36.2	35.5	36.5	1.12	3.06
SFA total	35.1	39.9	34.4	36.5	2.97	8.13
MUFA + PUFA	64.9	60.1	65.6	63.5	2.99	4.71
n-6/n-3	0.285	0.481	0.380	0.382	0.098	25.7
PUFA/SFA	0.773	0.598	0.873	0.748	0.139	18.6
MUFA/SFA	1.07	0.908	1.03	1.00	0.084	8.42
EPSI	0.721	0.659	0.848	0.743	0.096	13.0
AA/DGLA	19.6	6.22	20.2	15.3	7.90	51.5
LA/ALA	24.5	2.98	31.7	19.7	14.9	75.8
EPA/DHA	0.079	0.472	0.086	0.212	0.225	106
Ratio	1:1	1:1	1:1	-	-	-

EPSI = essential PUFA status index.

Table 5 : Fatty acid levels in the domestic pig per 100g liver, muscle and brain samples as food

Fatty acid	Liver	Muscle	Brain	Mean	SD	CV%
C6:0	-	-	-	-	-	-
C8:0	-	0.013	-	-	-	-
C10:0	-	0.002	-	-	-	-
C12:0	0.006	0.015	0.007	0.009	0.005	52.9
C14:0	0.047	0.170	0.062	0.093	0.067	72.2
C16:0	0.525	0.818	0.518	0.620	0.171	27.5
C18:0	0.163	0.281	0.253	0.232	0.062	26.5
C20:0	0.001	0.066	0.001	0.023	0.038	166
C22:0	0.001	0.001	0.001	0.001	0.00	-
C24:0	0.00	0.00	0.00	-	-	-
SFA	0.743	1.366	0.842	0.985	0.337	34.2
C14: 1(*cis* – 9)	0.00	0.00	0.00	-	-	-
C16: (1 *cis* – 9)	0.144	0.238	0.156	0.179	0.051	28.5
C18: (1 *cis* -6)	0.264	0.296	0.336	0.298	0.036	12.1
C18: (1 *cis* – 9)	0.254	0.517	0.245	0.339	0.155	45.6
C20: (1 *cis* – 11)	0.103	0.143	0.102	0.116	0.023	20.2
C22:0(1 *cis*-13)	0.031	0.045	0.029	0.035	0.009	24.9
C24:1(*cis*-15)	0.00	0.00	0.00	-	-	-
MUFA (*cis*)	0.796	1.239	0.868	0.968	0.238	24.6
C18: 1 (*trans*-6)	0.00	0.00	0.00	-	-	-
C18:1(*trans*-9)	0.00	0.00	0.00	-	-	-
C18:1 (*trans*-11)	0.00	0.00	0.00	-	-	-
MUFA (*trans*)	0.00	0.00	0.00	-	-	-
MUFA (total)	0.796	1.239	0.868	0.968	0.238	24.6
C18: 2 (*cis*-9,12)	0.022	0.064	0.019	0.035	0.025	71.9
C18:2 (*cis*-9,*trans*-11)	0.00	0.003	0.00	-	-	-
C18:3 (*cis*-6,9,12)	0.001	0.034	0.001	0.012	0.019	159
C20: 2 (*cis*-11,14)	0.00	0.071	0.00	-	-	-
C20:3 (*cis*-8,11,14)	0.005	0.012	0.008	0.008	0.004	42.1
C20:4 (*cis*-5,8,11,14)	0.097	0.076	0.166	0.113	0.047	41.7
C22:2 (*cis*-13,16)	0.002	0.006	0.009	0.006	0.004	62.0
C18:3 (*cis*-9,12,15)	0.001	0.023	0.001	0.008	0.012	152
C20:3 (c*is*-11,14,17)	0.001	0.00	0.00	-	-	-
C20:5 (*cis*-5,8,11,14,17)	0.033	0.170	0.042	0.082	0.077	93.8
C22:6 (*cis*-4,7,10,13,16,19)	0.412	0.359	0.490	0.421	0.065	15.6
PUFA (*n*-6, total)	0.127	0.266	0.203	0.199	0.070	35.0
PUFA (*n*-3, total)	0.447	0.551	0.533	0.511	0.056	11.0
PUFA (*n*-6+ *n*-3 total)	0.574	0.817	0.736	0.709	0.124	17.5
MUFA+ PUFA (total)	1.37	2.06	1.60	1.68	0.351	21.0
Total (SFA + MUFA+ PUFA)	2.11	3.42	2.45	2.66	0.685	25.7

Table 6 : Energy contribution (kJ/100g) of the domestic pig organs

Parameter	Liver	Muscle	Brain	Mean	SD	CV%
SFA	27.5 (35.2%)	50.5 (39.8%)	31.2 (34.5%)	36.4 (36.9%)	12.4	33.9
MUFA (*cis*)	29.5 (37.7%)	45.8 (36.1%)	32.1 (35.5%)	35.8 (36.3%)	8.76	24.5
MUFA (*trans*)	0.00	0.00	0.00	0.00	-	-
MUFA (total)	29.5 (37.7%)	45.8 (36.1%)	32.1 (35.5%)	35.8 (36.3%)	8.76	24.5
n-6 PUFA	4.70 (6.01%)	9.84 (7.75%)	7.51 (8.30%)	7.35 (7.45%)	2.57	35.0
n-3 PUFA	16.5 (21.1%)	20.4 (16.1%)	19.7 (21.8%)	18.9 (19.2%)	2.08	11.0
PUFA (total)	21.2 (27.1%)	30.2 (23.8%)	27.2 (30.1%)	26.2 (26.6%)	4.58	17.5
MUFA + PUFA	50.7 (64.8%)	76.2 (60.0%)	59.2 (65.4%)	62.0 (62.9%)	13.0	20.9
SFA +MUFA+ PUFA (TFAE)	78.2 (100%)	127 (100%)	90.5 (100%)	98.6(100%)	25.4	25.7

TFAE = total fatty acid energy in kJ/100g fat as food.

Table 7 : Statistical analysis of the results from Table 4

Statistics	Liver/Muscle	Muscle/Brain	Liver/Brain
Correlation coefficient (r_{xy})	0.874	0.806	0.9874
Coefficient of determination (r_{xy}^2)	0.7638	0.650	0.9745
Regression coefficient (R_c)	-1.34	5.99	0.7475
Mean of X	14.6	11.3	14.5
X± SD	14.5	14.5	14.6
Mean of Y	11.3	15.4	15.4
Y±SD	14.5	14.9	14.9
Coefficient of alienation (C_A)	0.486	0.350	0.1585
Index of forecasting efficiency (IFE)	0.514	0.650	0.8415
Remark	Significant	Significant	Significant

X is liver, muscle, liver
Y is muscle, brain, brain
as they pair in liver/muscle; muscle/brain; liver/brain.
SD = standard deviation.
Results significantly different at df 10 and $r_{=0.05}$ (with value of 0.576).

Table 8 : Phospholipids level (mg/100g) of the three organs of the domestic pig

Phospholipid	Liver	Muscle	Brain	Mean	SD	CV%
Cephalin (PE)	95.7 (27.2)	95.9 (24.7)	133 (25.1)	108 (25.5)	21.5	19.9
Lecithin	223 (63.4)	248 (63.8)	307 (58.0)	259 (61.2)	43.5	16.8
Ptd-L-Ser (PS)	12.9 (3.66)	15.0 (3.86)	33.6 (6.35)	20.5 (4.85)	11.4	55.5
Lysophosphatidylcholine	3.68 (1.05)	6.59 (1.69)	18.0 (3.40)	9.41 (2.22)	7.54	80.2
Ptd Ins (PI)	17.4 (4.94)	22.9 (5.89)	37.1 (7.01)	25.8 (6.10)	10.2	39.5
Total	352 (100)	389 (100)	529 (100)	423 (100)	93.4	22.1

PE = phosphatidylethanolamine;
Lecithin= phosphatidycholine;
PS = phosphatidylserine;
PI = phosphatidylinositol;
Values in parentheses are in percentages.

Table 9 : Statistical analysis of the results from Table 8

Statistics	Liver/Muscle	Muscle/Brain	Liver/Brain
r_{xv}	0.9985	0.9995	0.9996
r_{xv}^2	0.9971	0.9989	0.9992
R_c	0.4936	13.1	13.5
Mean of X	70.5	77.7	70.5
X ± SD	92.7	102	92.7
Mean of Y	77.7	106	106
Y ± SD	102	122	122
C_A	0.0541	0.0324	0.0289
IFE	0.9459	0.9676	0.9711
Remark	Significant	Significant	Significant

Results significantly different at df 3 and r = $_{0.05}$ (with value of 0.878).

Table 10 : Sterol levels (mg/100g) of the three different organs of the domestic pig

Sterol	Liver	Muscle	Brain	Mean	SD	CV%
Cholesterol*	50.73271 (99.996)	57.90563 (99.996)	89.27982 (99.997)	66.0	20.5	31.1
Cholestanol	4.92e-4	5.95e-4	5.76e-4	-	-	9.79
Ergosterol	5.66e-4	6.98e-4	6.81e-4	-	-	11.0
Campesterol	2.87e-4	2.81e-4	9.82e-4	-	-	77.9
Stig-masterol	5.24e-5	7.04e-5	6.54e-5	-	-	14.8
5-Avenasterol	4.60e-4	4.64e-4	4.62e-4	-	-	0.331
Sitosterol	7.41e-6	1.08e-5	8.73e-6	-	-	19.2
Total	50.73458	57.90775	89.2826	66.0	20.5	31.1

Values in parentheses are percentage values.

*Cholesterol subjected to chi-square (X^2) analysis showed no significant difference.

Table 11 : Uncertainty interval as percentage of analytical results

Parameter	UIP (table)+	UIP (Liver)	UIP (Muscle)	UIP (Brain)
Fatty acid:				
C16:0	1.2	1.2	1.26	1.42
C18:0	0.9	2.1	1.95	1.55
C16:1	6.2	2.35	2.30	2.50
C18:1	0.9	-	-	-
C18:1 (*cis* - 6)	-	2.88	4.17	2.62
C18:1 (*cis* - 9)	-	3.00	2.38	3.60
C18:2	2.4	-	-	-
C18:2 (*cis* -9, 12)	-	16.2	9.08	22.4
C18:3	16.3	-	-	-
C18:3 (*cis* - 9, 12, 15)	-	327	22.2	584
Sterol:				
Cholesterol	3.5	9.26	8.20	5.26

UIP = uncertainty interval percent

+UIP(table) = UIP adapted from Beef – Pork Fat Blend.