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COMPARATIVE STUDIES ON THE PROXIMATE AND LIPID CONTENTS IN PROCESSED FISH SESAME AND PIGEON PEA FLOURS

[1]Oyarekua, M.A. [2]Adeoye, A.O. [3]Ojo, O.I. [1]Amao, B & [1]Alo V.
[1]Department of Food Science and Technology, Federal University Oye-Ekiti, Oye-Ekiti, Nigeria,
[2]Department of Biochemistry, Federal University Oye-Ekiti, Oye-Ekiti, Nigeria,
[3] Department of Chemical Sciences,
Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Nigeria
Corresponding Author's email: mojisola.oyarekua@fuoye.edu.ng

Abstract
A balanced ratio among classes of fatty acids is necessary to obtain a healthy diet. This study assessed the nutritional and fatty acids content in fish, pigeon pea, and sesame oil. Standard analyses were done for contents of proximate, fatty acids, phospholipids, and sterols for all the oils. Results showed that pigeon pea flour had the lowest percentage of crude fat, crude protein, and crude fiber compared to sesame seed and fish (boiled and dried) flours. Linoleic acid was higher in seed oils than in fish samples while oleic acid was higher in fish samples than in seed oils. Eicosanoic acid and docosahexaenoic acid were not detected in seed oils but in fish oil. Palmitic acid was the most abundant in all the samples. Dried tilapia fish oil had the highest total saturated fatty acids composition. The ratio of Linoleic to linolenic (n6/n3) was higher in the seeds than in fish oils. Total phospholipid composition was higher in the seed oils than in the fish oils. Sistosterol was more abundant in pigeon seeds oils than in fish oil while cholesterol was more abundant in fish oils. The results of this study showed that pigeon pea and sesame seed oils could be beneficial to our health.

Keywords: fish, sesame; pigeon pea; fatty acids; sterols; nutrition

Introduction

Sesame *(Sesamum indicum L.)* is an ancient oil seed crop called Gingelly, Simsim, Till. Nigeria is one of the major producing countries (Musa et al. 2019**)**. Sesame seed is important in human nutrition because they are used for the extraction of oil and the rest are used for edible purposes. The oil extracted from the seed can be processed into sesame butte which is similar to peanut butter. Also**,** the oil is used widely in some injectable drug formulations (Wara, 2011**)**. The lignans such as sesamin, episesamin, sesaminol and sesamolin are major constituents of sesame oil (Gokbulut, 2010). Sesame seed has higher oil content (around 50%) than most of the known oil seeds (Hwang et al, 2021). The seed has 40-60 percent of oil with almost equal levels of oleic (about 41%) linoleic acid (about 43%) and some palmitic acid (about 9%) and stearic acid (about 6%) (Gunstone, 1999**)**. The dominant saturated acids were palmitic (up to 8.58%) and stearic (up to 5.44%) (Nzikou et al. 2009). Based on the USDA's Food Composition Database (USDA, 2018); 5mL of sesame oil contains in gram carbohydrate 0, protein 0, fat 13.5, saturated fat 1.9, monosaturated fat 5.4, polysaturated 5.6. Omega-3 40.5mg, omega-6 5576 mg, a small amount of vitamins E and K, and no minerals. Sesame oil does not necessarily require refining to make it edible. However, some manufacturers use a solvent-extraction process for less time, effort, and money. Unrefined sesame oil has a light and nutty flavor, and it can be yellow to amber or

dark brown. On the other hand, refined sesame oil has no real flavor, and it has a light yellow color similar to other vegetable oils.

Numerous randomized trials show that sesame oil lowers triglyceride levels and raises HDL. Sesame oil displayed significantly better oxidative stability than soybean oil. In microwave treatment tests, large amounts of volatile aldehyde compounds develop in sesame oil with just 3-4 minutes of exposure. These findings show that sesame oil might not be one of the better cooking oils. Thus high-heat temperatures might not be desirable for the use of sesame oil.

Sesame oil has an imbalance of omega-6 to omega-3 contents. Therefore, regular consumption of large amounts of sesame oil may create an imbalance between omega-6 and omega-3. The recommended n-6/n-3 fatty acid ratio in human nutrition is 5:1 (Ghanzali et al. 2020).

While the n-6/n-3 fatty acid ratio should be 1:1 or above (WHO 2008); additionally, a high level of omega-6 largely inhibits the conversion and absorption of plant sources of omega-3 (ALA) (Wara, 2011).

The n-3 polyunsaturated fatty acids (PUFA) have been reported to alter cell growth by modulating cell replication, interfering with the components of the cell cycle, or increasing cell death through necrosis or apoptosis (Liput et al. 2021).

Pigeon pea (*Cajanus cajan*) is cultivated widely in southwest Nigeria, it is one of the most drought-tolerant and widely grown legumes in tropical and subtropical regions. It has been underutilized due to its tough texture giving it long cookability, fuel, and time consumption, and most importantly lack of nutritional education on its potential (Oyarekua, 2011). According to Ade-Omowaye et al. (2015); in mature and immature pigeon peas seeds, palmitic acid is the predominant saturated fatty acid, accounting for 15 to 25 percent, 20 to 40 percent, and 26 to 30 percent of neutral lipids, glycol-lipids, and phospholipids, respectively observed that linoleic acid was the most abundant polyunsaturated fatty acid in pigeon pea, while caprylic, lauric, oleic, and eicosanoid acids were only found in trace amounts.

Fish are the most important sources of these omega-3 fatty acids; fatty fish, such as sardines, mackerel, anchovies, and some salmon species, are rich in EPA and DHA. Lipid composition by implication fatty acid of fish depends on the aquatic environment, seasonal changes, migration, sexual maturity and spawning period, species, feeding habits, and whether reared in aquaculture or grown in natural habitats (Memon, 2010).

Fish contain significant amounts of n-3 fatty acids. Thus essential fatty acids (EFAs) need to be obtained through food intake. Sources of n-6 fatty acid and, especially, linoleic acid (LA) sources are seed oils, and arachidonic acid (AA); the main n-3 alpha-linolenic acid (ALA) source is meat. Even though EPA and DHA are critical in human health, their consumption can be relatively low, from inadequate consumption of fish and fish products **(**Williamson et al. 2008). According to (Hagstrup, 2011); a weekly consumption of 300 g of fatty fish or a daily 200 mg EPA and DHA intake is reported to be sufficient. Catfish (*Clarias gariepinus*) is a diverse group of ray-finned fish. Catfish have been widely introduced around the world because they are potamodromous, which means they migrate within streams and rivers.They are very adaptive to extreme environmental conditions and can live in P^H range of 6.5-8.0. The optimal temperature for growth is 28-30^oC (Memon, 2010).

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Methodology

Determination of ash content

Ash content was determined using AOAC, (2010) method. 5g of powdered sample was weighed into an empty pre-weighed porcelain crucible. This was transferred into the muffle furnace set at 550^0C and left to ash for about 5 hours. After ashing, the sample turned white, then the crucible and its content were cooled in a desiccator. The crucible with the sample was weighed and the percentage of ash was calculated as:

$$\% \text{ Ash content} = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100 \quad \ldots (1)$$

The Weight of the ash is determined by removing the weight of the crucible from the weight of the crucible and ash.

Determination of moisture content

Moisture content was determined using AOAC, (2010) method. 3g of powdered sample was weighed using an analytical balance (Denver instrument company, TR-2102) into pre-weighed Petri dishes. The weighed samples were put into the pre-set oven (Fisher scientific iso temp Oven, model 655F, (Chicago, USA) at 105^0C for 3 hours. After oven drying the samples were cooled in a desiccator to room temperature, weighed, recorded, then returned to the oven at 105°C for 30min and then weighed until a constant weight was obtained for each sample. The differences in weight between each petri-dish and dried residue were recorded as the percentage of the initial sample.

$$\% \text{ Moisture content} = \frac{Weight\ of\ sample\ before\ drying - Weight\ of\ sample\ after\ drying}{Weight\ of\ sample\ after\ drying} \times 100 \quad \ldots\ldots (2)$$

Determination of crude fat

Crude fat was determined by the AOAC (2010) method using the soxhlet apparatus (Sunbim, India). Approximately 5g of the ground sample was placed into a thimble which was placed inside the Soxhlet extractor and n-hexane will be poured into a pre-weighed round bottom flask and extracted with n-hexane. The extraction was carried out for about 6 hours. The solvent was removed from the extracted oil by distillation. The oil in the flask was further dried in a hot-air oven at 90ºC for 30 minutes to remove residual organic solvent and moisture. This was cooled in a desiccator and flask and its content was weighed. The fat content was calculated as:

$$\% \text{ Fat content} = \frac{(Weight\ of\ flask+fat) - Weight\ of\ empty\ flask}{Sample\ weight} \times 100 \quad \ldots\ldots (3)$$

Determination of the crude fiber

Then crude fiber was determined by AOAC (2010) using 2g of sample. About 200 ml of 1.25 % (*w/v*) dilute sulphuric acid was added and the flask was placed on a hot plate and allowed to boil for 30 min. The content was filtered using filter paper (Whatman No.1) and the residue on the filter paper was washed with 50-70 mL of distilled water. The washed residue was then transferred back into the flask and about 200 ml 1.25 % (w/v) NaOH was added and allow to boil for 30 min. The content was then filtered as described earlier and the residue obtained was washed with distilled water and then filtered again using filter paper (Whatman No.1). The residue was transferred to an ashing dish and allowed to dry at 130 ^{0}C for 2 hr, cool in a desiccator and weighed. This was then ashed at 550 ^{0}C inside the muffle furnace chamber (Carbolite AAF1100, United Kingdom) for 30 min, cooled, and reweighed. The ash obtained was then subtracted from the residue and the difference was expressed as a percentage of

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the starting material as shown in the equation below:

$$\% \text{ Fiber} = \frac{(\text{Weight of crucible+sample after drying}) - (\text{weight of crucible+sample after ashing})}{\text{Weight of sample}} \times 100$$

…… (4)

Determination of carbohydrates

Carbohydrate was determined by subtracting the addition of other proximate chemical components from 100. % Carbohydrate content = 100 - (Moisture + Fat + Crude Fibre + Ash + Crude Protein) ……..…..(4)

Soxhlet Extraction Method

Fatty Acid Methyl Esther Analysis

Using the method of Tapsell et al. (2009); about 50mg of the extracted fat content of each sample was saponified (esterified) for five minutes at 95^0C with 3.4 ml of 0.5M KOH in dry methanol. The mixture was neutralized by using 0.7M HCL. 3ml of 14% boron trifluoride in methanol was added. The mixture was heated for 5 minutes at the temperature of 90^0C to achieve a complete methylation process. The fatty acid methyl esters (FAME) were thrice extracted from the mixture with redistilled n-hexane. The content was concentrated to 1ml for gas chromatography analysis and 1 µ1 was injected into the injection port of GC. The gas chromatography conditions of analysis are attached in the analysis printout.

Sterol Analysis

Sterol analysis was carried out by following the modified AOAC (2010). The aliquot of the extracted oil was added to the screw-capped test tubes. The sample was saponified at 95^0C for 30 minutes, by using 3 ml of 10% KOH in ethanol, to which 0.20ml of benzene had been added to ensure miscibility. Deionized water (3ml) was added and 2ml of hexane was used in extracting the non-saponifiable materials. Three extractions, each with 2ml of hexane, were carried out for 1 hour, 30, minutes, and 30 minutes respectively, to achieve complete extraction of the sterols. The hexane was concentrated to 1 ml in the vial for gas chromatography analysis and 1 µl was injected into the injection port of GC.

Phospholipids Analysis

The modified method of Raheja et al. (1973) was employed in the analysis of the extracted oil phospholipids content. About 0.01g of the extracted fat was added to the test tubes. To ensure complete dryness of the oil for phospholipids analysis, the solvent was completely removed by passing a stream of nitrogen gas on the oil. 0.40ml of chloroform was added to the content of the tube and it was left in the water bath at 100^0C for about 1 minute 20 seconds. The content was allowed to cool to the laboratory temperature and 5 ml of hexane was added and the tube with its content was shaken gently several times. The solvent and the aqueous layers were allowed to separate. The hexane layer was recovered and allowed to concentrate to 1.0 ml for gas chromatography analysis using a pulse flame photometric detector.

Statistical Analysis

The analysis was carried out in duplicates and the results for the duplicates was expressed as mean ± SD. the SPSS 17.0 for windows computer software package was used for the analysis of variance (ANOVA) and the correlation coefficient was used.

Results

Table 1 showed the proximate composition of the percentage flour composition of pigeon pea, sesame seed, and tilapia fish (boiled and dried). The pigeon pea flour had the highest percentage of moisture

content while the sesame seed flour had the lowest percentage of moisture content when compared with the boiled and dried fish flour. The percentage moisture content of both the boiled and dried fish flour are not significantly ($p > 0.05$) different from each other while the percentage ash content of both the boiled and dried fish flour are not significantly different from each other but significantly ($p < 0.05$) higher than that of pigeon pea and sesame seed flour. The percentage of crude fat in sesame seed flour was significantly higher ($p<0.05$) than in pigeon pea and fish (boiled and dried) flour. However, the pigeon pea flour had the lowest percentage of crude fat, crude protein, and crude fiber when compared to sesame seed and fish (boiled and dried) flour. Dried tilapia fish flour had the highest percentage of crude protein and crude fiber. Sesame seed flour was observed to have the least percentage of crude protein while pigeon pea flour had the least percentage of crude fiber content. From the results, the percentage of carbohydrates in pigeon pea flour was significantly ($p < 0.05$) higher than the sesame seed flour and fish (boiled and dried) flour. Dried tilapia fish flour had the lowest percentage of carbohydrates.

The percentage of fatty acids composition in pigeon pea, sesame oil, and tilapia fish oil is presented in Table 2. The results revealed the presence of linoleic acid being the most abundant in pigeon pea and sesame seed oil while oleic acid was found the most abundant in both the boiled and dried tilapia fish oil. Caprylic acid, capric acid, and lauric acid were not detected in the pigeon pea and sesame seed oil as well as the boiled and dried tilapia fish oil. Erucic acid was found in small amounts in pigeon pea and sesame seed oil according to Suen, (2020); erucic acid is safe if taken in low content however erucic acid was not present in tilapia fish oil. Eicosanoic acid and docosahexaenoic acid are also not found in pigeon peas and sesame seed oil but are present in boiled and dried tilapia fish oil.Table 3 showed the percentage of saturated fatty acids composition in pigeon pea, sesame oil, and tilapia fish oil. From the results, palmitic acid was observed to be the most abundant in pigeon pea, sesame seed oil, and in both boiled and dried tilapia fish oil. Caprylic acid, capric acid, and lauric acid were not found in the pigeon pea and sesame seed oil as well as the boiled and dried tilapia fish oil. Dried tilapia fish oil had the highest total saturated fatty acids composition.

The percentage of unsaturated fatty acids composition in pigeon pea, sesame oil, and tilapia fish oil is presented in Table 4. Linoleic acid, a poly-unsaturated fatty was found in abundance in pigeon pea and sesame seed oil while oleic acid, a mono-unsaturated fatty acid was found in abundance in boiled and dried tilapia fish oil. Pigeon pea oil had the highest total unsaturated fatty acids composition. The phospholipid composition of pigeon pea and sesame seed oil as well as tilapia fish oil is presented in Table 5.

Phosphatidylethanolamine

Phosphatidylcholine and phosphatidylinositol were found in higher amounts among other phospholipids in pigeon pea and sesame seed oil with phosphatidylcholine being the most abundant. The amount of phosphatidyl ethanolamine and phosphatidylcholine was observed to be higher in both boiled and dried tilapia fish oil with phosphatidylethanolamine being the most abundant in tilapia fish oil. From the results, sphingomyelin was not found in both boiled and dried fish oil. The total phospholipid composition in pigeon pea and sesame seed oil was higher than the boiled and dried tilapia fish oil. The total phospholipid composition; of 887.81, 829.32,

349.76, and 317.68 are found in sesame seed oil, pigeon pea oil, dried fish oil, and boiled fish oil respectively.

Table 6 showed the sterol composition in pigeon pea, sesame oil, and tilapia fish oil. Sistosterol was found in abundance in pigeon pea and sesame seed oil while cholesterol was found in abundance in both boiled and dried tilapia fish oil. The total sterol composition in pigeon pea oil, sesame seed oil, boiled tilapia fish oil, and dried tilapia fish oil are (mg/100g) 126.76, 136.30, 83.42, and 91.93 respectively.

Discussion

Sesame seed is widely used in food and nutraceutical industries in many countries because of its protein, high oil, and antioxidant contents. It has the potential to prevent a range of disorders such as hypertension, hypercholesterolemia, cancer and aging, chronic renal failure, and neurodegenerative diseases. It is also useful in the management of oxidative stress-associated diseases such as atherosclerosis, diabetes mellitus, obesity (Nakano et al. 2002).

Pigeon pea seeds are a source of protein and energy as they are rich in protein and carbohydrates, and relatively poor in crude fibre (Oshodi 1993). The nutritional components of pigeon pea are considered crucial for human nutrition. Several studies have reported that consumption of pigeon pea is associated with a lower risk of several diseases (Singh & Basu, 2012).

From the results of this study, it was observed that the pigeon pea flour had the highest percentage moisture content while the sesame seed flour had the lowest percentage moisture content when compared with the boiled and dried fish flour. Different food materials have different capacity for absorbing and retaining moisture.

The low moisture content seen in sesame seed flour revealed that flour has good storage ability. However, the percentage moisture content of pigeon pea obtained in this study was lower than the findings of Abdel-Tawwab et al. (2010). This must be due to the type of species of pigeon pea used in this study. On the contrary, the percentage ash content of both the boiled and dried fish flour was significantly higher than the pigeon pea and sesame seed flour. Pigeon pea flour had the lowest percentage of crude fat, crude protein, and crude fiber when compared to sesame seed and fish (boiled and dried) flour. The results of this study showed that tilapia fish flour (both boiled and dried) had more than double the percentage of crude fiber found in sesame seed flour Abdel-Tawwab et al. (2010) reported that pigeon pea is low in crude fiber. Moreover, the results of this study revealed that the percentage of crude protein content in tilapia fish flour was significantly higher than in sesame seed and pigeon pea flours.

The percentage fatty acid composition of the oil from pigeon pea and sesame seed indicates that linoleic and oleic acid were present in large amount. The value of linoleic (46.30%) and oleic acid (44.67%) in pigeon pea oil were more than twice the value of palmitic acid (14.98%) but the amount of linoleic and oleic acid in sesame seed oil was almost double the amount of palmitic acid (17.58%). However, oleic acid was present in high amount in both boiled (41.06%) and dried tilapia fish oil (38.94%). It was observed that caprylic acid, capric acid and lauric acid were not detectable or they are at trace levels in pigeon pea and sesame seed oil as well as the boiled and dried tilapia fish oil. From the findings of this study, eicosanoic and docosahexanoic acids which are critical in human health were not detectable in pigeon pea and sesame seed oil but present in the boiled and dried tilapia fish

oil. Deficiency of eicosanoic and decosahexanoic acid can result in attention deficit hyperactivity in children (Burgess et al. 2000). It was also observed that, erucic acid was found in small amount in pigeon pea and sesame seed oil but not detected in tilapia fish oil. The observation from the results of this study is in consonant with the report of Elleuch et al. (2007), who reported that the fatty acids present in sesame oil are oleic acid, linoleic acid, palmitic acid, stearic acid, and trace amounts of α-linolenic acid which together comprises of about 96% of total fatty acids. Linoleic improves insulin sensitivity and blood pressure according to Jandacek, (2017); while oleic supports heart health by reducing total LDL cholesterol, reduces inflammation, blood sugar control, and mental health (Sales-Campos et al. 2013).

Foods of plant and animal origin are known to provide a complex mixture of natural substances with antioxidative effects. Such antioxidant activity appears to be closely related to the prevention of degenerative diseases such as cancer, cardiovascular diseases, atherosclerosis, and the process of ageing. The antioxidant and oxidative stability of sesame oil is attributed to its endogenous antioxidant lignans such as sesamolin, sesamin, and sesamol, along with tocopherol. From the previous studies, it was reported that sesame lignans, sesame seed, and oil also contain other important biologically active compounds such as vitamin E especially γ‑tocopherol (Williamson etal.2008). From this study, palmitic was the most abundant saturated fatty acid in dried tilapia fish oil, boiled tilapia fish oil, sesame seed oil, and pigeon pea oil are 34.03%, 29.53%, 21.68%, and 18.46% respectively. This observation is in agreement with the findings of Nzikou et al. (2009); who reported that the dominant saturated fatty acids in sesame oil were palmitic and stearic acid. Palmitic acid maintains membrane phospholipids and there should be an optimal intake of it in a certain ratio with unsaturated fatty acids especially PUFA of n-6 and n-3. The detrimental effect of palmitic acid therefore may be related to the excessive imbalance of dietary Palmitic acid/ PUFA ratio (Carta et al. 2017). In addition, the total percentage of unsaturated fatty acids mainly linoleic and oleic acids in pigeon pea oil, sesame seed oil, boiled, and dried tilapia fish are 81.54%, 78.32%, 70.47%, and 65.97%. Omega-3 fatty acids (alpha-linolenic, eicosapentaenoic acid, and docosahexaenoic acid) have been shown to decrease the level of pro-atherosclerotic biomarkers. Alpha-linolenic acid is found in naturally occurring foods, such as nuts, whereas eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are both found in fish (Singh et al. 2016). EPA and DHA are essential fatty acids that are not synthesized by humans but are obtained through dietary sources (Singh et al. 2016). From this study, docosahexanoic acid was found in both the boiled and dried tilapia fish oil but not found in pigeon pea and sesame seed oil. High levels of mono-unsaturated and poly-unsaturated fatty acids have been reported to increase the quality of oil for human consumption. The poly-unsaturated fatty is known to have anti-inflammatory, anti‑thrombotic, hypolipidemic, and vasodilatory properties. Also, high levels of linoleic acid reduce blood cholesterol and play a vital role in preventing atherosclerosis.

Phospholipids play a significant role in food manufacturing and are currently used in a broad range of food products such as instant drinks, dairy products, baked goods, chocolate, and margarine (Singh et al. 2016**)**. Phospholipids are mainly known for their role as building blocks for cell membranes due to their dual hydrophilic and hydrophobic

properties. They play an important part in the formation of lipoproteins, which transport lipids to tissues through the bloodstream in addition to their role in cellular structure and function (Lu and Nielsen, 2011**)**. From the results, phosphatidylethanolamine, phosphatidylcholine, and phosphatidylinositol were found in higher amounts in pigeon pea and sesame seed oil with phosphatidylcholine being the most predominant while the amount of phosphatidylethanolamine and phosphatidylcholine was observed to be higher in both boiled and dried tilapia fish oil. Previous research has shown that phosphatidylcholine is most predominant phospholipid in marine sources and phosphatidylethanolamine was shown to be the second most abundant. Phosphatidylinositol, phosphatidylserine, lysophosphatidylcholine (lyso-PC), and sphingomyelin are found in smaller amounts in marine sources (Lu and Nielsen, 2011**)**. It has been shown that phospholipids have beneficial nutritional effects, and emulsifying properties, and also serve as supplementation of n-3 fatty acids in functional food (Singh et al. 2016).

Plants possess bioactive compounds that have a wide range of biological activities in animals and humans, such as anti-oxidative (Van-Rensburg et al. 2000), antibacterial (Zhao et al. 2005), inflammatory (Bouic 2002) and anti-cancerous (Awad and Fink, 2000).

Different groups of phytosterols include sitosterol, campesterol, stigmasterol, etc. From the results of this study, sistosterol was found to be predominant in pigeon pea and sesame seed oil while cholesterol was found in abundance in both boiled and dried tilapia fish oil. A previous study revealed that pigeon pea is a good source of saponins that have been implicated in the control of high cholesterol level (Aja, 2015).

In terms of the ratio of n-6 to n-3 as shown in Table 7; the ratio was highest in sesame oil followed by pigeon pea oil, then boiled fish and the lowest was in dried fish. All these ratios were higher than the 1:1 recommended by the (WHO, 2008).

Table 8 revealed the study on the ratio of LA/DHA, LA/ARA, and ARA/DHA. The ratio of boiled fish oil and dried fish oil of LA/DHA were ideal to the less than 10 recommended by (Al-Taan et al.2013)**;** while the ratio of ARA/DHA in the two fish samples was significantly ($p0<0.5$) lower than the ratio in pigeon and sesame seed oils. According to Ghanzali et al. (2020), the ratio of ARA/DHA should be low thus the fish samples might be desirable in terms of their ratios in ARA/DHA.

Calculation of Standard Conversion from Crude Fat to Fatty Acids Acids (Greenfield and Southgate 2003)

= Crude Fat Value (Y) X 0.90 = Xg/100g

Value to Phospholipid and Sterols = Y-X = Z/100g (Phospholipids & Strols) ……. (5)

For Legumes: There is No Standard Value for Converting Crude Fat in Legume to Fatty Acids. Assuming the Value for Nuts (0.956) is taken as the Standard

Conclusion

The results of this study showed that tilapia fish flour (both boiled and dried) had enhanced crude fiber and crude protein than sesame and pigeon pea seeds.

Linoleic which improves insulin sensitivity and blood pressure and oleic which supports heart health, were more abundant in sesame and pigeon oil than in boiled and dried fish. Eicosanoic and docosahexanoic acids were present only in boiled and dried tilapia fish oil but not in sesame and pigeon oil. Phosphatidylethanolamine.

Phosphatidylcholine, and phosphatidylinositol

were found in higher amounts in pigeon pea and sesame seed oil while phosphatidylethanolamine and phosphatidylcholine were observed to be higher in both boiled and dried tilapia fish oil. Sistosterol content was more in pigeon pea and sesame seed oil while cholesterol was more enhanced in both boiled and dried tilapia fish oil. The ratio of boiled fish oil and dried fish oil of LA/DHA were ideal for the recommended ratio. The ratio of ARA/DHA in the two fish samples was lower than the ratio in pigeon and sesame seed oils thus the fish samples might be desirable in terms of their ratios in ARA/DHA.

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Table 1: Proximate Composition of Samples

Sample	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Protein (%)	Crude Fibre (%)	Carbohydrate (%)
Pigeon pea	10.35 ± 0.23^{a}	3.21 ± 0.01^{a}	7.70 ± 0.16^{a}	19.63 ± 0.57^{a}	0.05 ± 0.01^{a}	59.08 ± 0.18^{a}
Sesame seed	5.00 ± 0.01^{c}	6.41 ± 0.22^{b}	29.01 ± 0.68^{b}	23.89 ± 0.35^{b}	5.09 ± 0.33^{b}	30.60 ± 0.23^{b}
Boiled Tilapia fish	8.30 ± 0.01^{b}	15.70 ± 0.01^{c}	15.00 ± 0.01^{c}	37.20 ± 0.01^{c}	10.80 ± 0.01^{c}	11.00 ± 0.01^{c}
Dried Tilapia fish	9.00 ± 0.01^{b}	14.60 ± 0.01^{c}	18.90 ± 0.01^{cd}	41.80 ± 0.01^{d}	12.90 ± 0.01^{c}	4.64 ± 0.01^{d}

Values in superscripts were significantly different

Table 2: Percentage fatty acids composition

Fatty Acids	Pigeon pea oil	Sesame seed oil	Boiled Tilapia fish oil	Dried Tilapia fish oil
Caprylic acid	0.00	0.00	0.00	0.00
Capric acid	0.00	0.00	0.00	0.00
Lauric acid	0.00	0.00	0.00	0.00
Myristic acid	0.194	0.415	3.30	4.18
Pamitic acid	14.98	17.58	22.30	25.20
Palmiloleic acid	0.146	0.141	7.90	7.10
Margaric acid	0.025	0.24	0.86	0.81
Stearic acid	3.07	3.469	1.45	2.30
Oleic acid	31.30	30.17	41.06	38.94
Linoleic acid	46.30	44.67	14.66	14.00
Linolenic acid	3.60	3.16	1.38	1.36

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Arachidic acid	0.014	0.130	0.480	0.450
Arachidonic acid	0.077	0.075	0.610	0.610
Eichosanoic acid	-	-	1.56	1.42
Behemic acid	0.086	0.083	0.630	0.610
Erucic acid	0.093	0.90	-	-
Docosahexanoic acid	-	-	3.09	2.70
Lignoceric acid	0.089	0.086	0.46	0.45
TOTAL	100	100	100	100

Table 3: Percentage saturated fatty acids composition

Fatty Acids	Pigeon pea oil	Sesame seed oil	Boiled Tilapia fish oil	Dried Tilapia fish oil
Caprylic acid (C8:0)	0.000000	0.000000	0.0000	0.0000
Capric acid (C10:0)	0.000000	0.000000	0.0000	0.0000
Lauric acid (C12:0)	0.000000	0.000000	0.0000	0.0000
Myristic acid (C14:0)	0.194368	0.415227	3.329807	4.181657
Palmitic acid (C16:0)	14.982795	17.584106	22.306746	25.211099
Margaric acid (C17:0)	0.025238	0.024352	0.861383	0.810467
Stearic acid (C18:0)	3.071558	3.469977	1.451900	2.300391
Arachidic acid (C20:0)	0.014295	0.013793	0.484460	0.458491
Behenic acid (C22:0) id	0.086874	0.083826	0.631711	0.614584
Docosahexaenoic (C22:0)	-	-	-	-
Lignoceric acid (C24:0)	0.089352	0.086217	0.466289	0.455671
TOTAL	18.46448	21.677498	29.532296	34.03236

Table 4: Percentage unsaturated fatty acids composition

	Pigeon pea oil	Sesame seed oil	Boiled Tilapia fish oil	Dried Tilapia fish oil
MONO-UNSATURATED				
Palmitoleic acid (C16:1)	0.146196	0.141067	7.932039	7.172960
Oleic acid (C18:1)	31.267666	30.170630	41.064556	38.979294
Erucic acid (C22:1)	0.093952	0.090655	0.137720	0.135233
Eicosenoic acid (C20:1)	-	-	1.567986	1.426852
POLY-UNSATURATED				
Linoleic acid (C18:2)	46.301713	44.677203	14.664453	14.004926
Linolenic acid (C18:3)	0.077936	0.075202	1.387293	1.363136
Arachidonic acid (C20:4)	3.648057	3.167745	0.618048	0.607264
Docosahexanoic acid (C22:6)	-	-	3.095611	2.277975
Total USFA	81.53552	78.322502	70.467706	65.96764

Table 5: Phospholipid compositions

Phospholipid	Pigeon pea oil (mg/100g)	Sesame seed oil (mg/100g)	Boiled Tilapia fish oil (mg/100g)	Dried Tilapia fish oil (mg/100g)
Phosphatidylethanolamine	212.77	220.19	190.30	206.19
Phosphatidylcholine	363.91	381.44	123.89	139.59
Phosphatidylserine	9.93	14.25	1.672	1.84

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Lysophosphatidylcholine	6.23	6.75	1.697	2.00
Sphingomyelin	2.44	3.33	-	-
Phosphatidylinositol	226.62	255.35	1.83	2.12
Phosphatic acid	9.85	9.72	2.04	2.08
TOTAL	829.32	887.81	317.68	349.76

Table 6: Sterol compositions

Sterol	Pigeon pea oil (mg/100g)	Sesame seed oil (mg/100g)	Boiled Tilapia fish oil (mg/100g)	Dried Tilapia fish oil (mg/100g)
Cholesterol	9.32	1.66	83.40	97.90
Cholestanol	4.65	4.68	5.60	7.84
Ergosterol	2.02	2.57	1.88	6.17
Campesterol	14.00	14.80	8.44	9.98
Stigmasterol	8.59	8.96	2.88	2.20
5-Avenasterol	2.32	3.08	3.01	1.00
Sistosterol	101.85	109.40	3.56	2.49
TOTAL	126.76	136.30	83.42	91.93

Table 7. Ratio of Linoleic n-6 to Linolenic n-3

Sample	**Linoleic (n-6)**	**Linolenic (n-3)**	**Ratio 6/n3**
Sesame	44.67	3.16	14.13
Pigeon pea	46.30	3.60	12.86
Boiled fish	14.66	1.38	10.62
Dried fish	14.00	1.36	10.29

Table 8. Ratio of LA/DHA, LA/ARA and ARA/DHA

Fatty acids ratios	Pigeon pea seed oil	Sesame seed oil	Boiled fish oil	Dried fish oil
LA/DHA	NA	NA	4.74	6.74
LA/ARA	12.69	14.14	23.73	23.06
ARA/DHA	3.65	3.17	0.20	0.27

Table 9 Calculation of Standard Conversion from Crude Fat to Fatty Acids

Parameter	Pigeon pea oil	Sesame oil	Boiled Tilapia oil	Dried Tilapia oil
Standard value	0.956	0.956	0.70	0.70
Value of crude fatty acid	7.7 g/100g	29.01 g/100g	29.01 g/100g	15.00g/100g
Value of fatty acids	93.6128 g/100g	99.83 g/100gg	99.74 g/100g	100.13g/100g
Value of phospholipids and sterols	7.3612 g/100g	27.73 g/100g	10.50 g/100g	13.23 g/100g