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FATTY ACID COMPOSITION OF DIFFERENT COMMERCIALLY SOLD VEGETABLE OILS WITHIN SOUTHERN KADUNA, KADUNA STATE, NIGERIA

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Abstract

Most of the edible vegetable oils in southern Kaduna are locally processed and are available in a large commercial quantity with little known about their fatty acid (FA) content. The aim of this work was to investigate the fatty acid content of these oils and their potential impact on human health**.** Six commonly used edible vegetable oil samples sold in various Southern Kaduna markets were analyzed for different fatty acids content using gas chromatography-mass spectrometry (GC-MS). The result of the analysis showed differences in the contents of saturated fatty acids (SFAs), monounsaturated (MUFAs), and polyunsaturated (PUFAs). Coconut oil and kernel oil showed high content of SFAs

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Vegetable oil, Fatty acids, Gas Chromatography, Health indices.

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(86.21% and 78.76%) respectively, while olive oil and peanut oil displayed significant amounts of MUFAs (75.40% and 47.62%) respectively due to high content of oleic acid (C18:1). Soybean oil with 58.06% of linoleic acid (C18:2) showed the highest total PUFA content of 65.23%. The Health Risk Index (HRI) was evaluated to assessed the impact associated with the overall intake of fatty acids in vegetable oils. The HRI were 1.78 (peanut), 0.04 (kernel), 0.23 (palm), 0.2(coconut), 4.05(soybean) and olive (0.71). Thus, soybean oil, peanut oil and olive oil have the optimum PUFA:SFA ratio according to FAO/WHO recommendations. Hence, they are recommended for mass consumption. The health promotion index (HPI) was also evaluated to assessed the content of certain essential fatty acids in various oils which have specific health benefits. The results of HPI investigation showed that only Soybean oil contains the balanced ω-6: ω-3 fatty acid ratio of 8.1 than others.

INTRODUCTION

Edible vegetable oils and fats are biological mixtures derived from plants sources, consisting of naturally occurring esters formed through esterification of saturated fatty acids (myristic, palmitic, stearic acids) and unsaturated fatty acids (oleic, linoleic, linolenic acids) with glycerol [1,2]. The composition of the fatty acids within triacylglycerols significantly impacts the physicochemical properties of these vegetable oils [3,6]. Fatty acids can be categorized into three main classes: saturated (SFAs), monounsaturated (MUFAs) and polyunsaturated fatty acids (PUFAs). Furthermore, the unsaturated ones are further subdivided into series commonly referred as omega(ω), with ω-9 classified as nonessential for humans, while ω-3 and ω-6 are designated as essential fatty acids since they cannot be synthesized by mammals and must thus be acquired through dietary intake. [4,8]. The predominant fatty acids found in vegetable oils and fats include both saturated and unsaturated compounds with straight aliphatic chains. An even number of carbon atoms, from 16 to 18, with a single carboxyl group, is the most common.

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Edible vegetable oils are among the main components of human diet and account for significant amount of average caloric intake. Vegetable oils play vital roles in food products and they act as carriers of fat-soluble vitamins (A, D, E, and K). These vitamins are crucial for various bodily functions, including vision, immune function, bone health, and blood coagulation They also provide an essential linoleic and linolenic acid, responsible for growth [9]. Apart from the caloric and nutritional value, fats enhance the taste, acceptability and palatability of foods. The lipid components enhance and release the flavours and aroma of other food components.

The ratio of unsaturated to saturated fatty acids in edible oils and fats is very important for human nutrition. While high levels of saturated fatty acids are desirable to increase oil stability, on the other hand nutritionally they become undesirable, because high levels of saturated fatty acids are frequently considered to have influence in increasing the concentration of low-density lipoproteins (LDL), affecting the ratio of LDL to HDL (high density lipoproteins), promoting clothing and vascular smooth muscle proliferation [5]. Diet with increasing intake of linoleic and linolenic acids increase HDL-cholesterol and decreases LDL-cholesterol (bad cholesterol), while higher intake of oleic acid decreases LDL-cholesterol, but does not affect HDL cholesterol levels [15].

Majority of the vegetable oils in Southern Kaduna markets are non-branded. There are various health related issues that are linked to fatty acids consumption in diets including diabetes and cardiovascular disease (CVD) [10, 12]. A high intake of saturated fatty acids (SFA) has been associated with an increased risk of cardiovascular events. Thus, reducing the dietary content of SFA is emphasized in CVD prevention [13]. The risk of diabetes is inversely associated with a higher intake of polyunsaturated fatty acid (PUFA), but no associations have been found with monounsaturated fatty acid (MUFA) or SFA [14].

There is no regulatory basis for control of fatty acid composition in vegetable oil in Nigeria. However, due to increasing awareness of the health implications

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of high cholesterol in diets, most people now prefer to purchase cholesterol-free vegetable oils [16]. FAO/WHO have recommendations for consumption of fats and fatty acids in human diet. The World health organization also recommends an ideal intake ratio of PUFA to SFA as 0.7 to 1 and ω-6 to ω-3 fatty acids as 5 to 10 [20].

To date, there is no comprehensive overview of studies in this area comparing the various health effects of edible vegetable oils, this motivated the drive for this study. We aim to determine the FA composition of different commercially sold edible vegetables oils in Southern Kaduna and also to investigate the nutritional benefits of consuming these oils with their associated health effect.

Study Area

Kaduna State is located in North-west Nigeria. Southern part of Kaduna lies within the Guinea Savanna Agro-ecological Zone of Nigeria, covering approximately 24,536km2 and monthly temperature is 28°C, while the mean atmospheric relative humidity is about 63% [37]. The climate and soil condition of southern part of Kaduna allow producers to grow various oilseeds that can be used to process vegetable oil in a large commercial quantity.

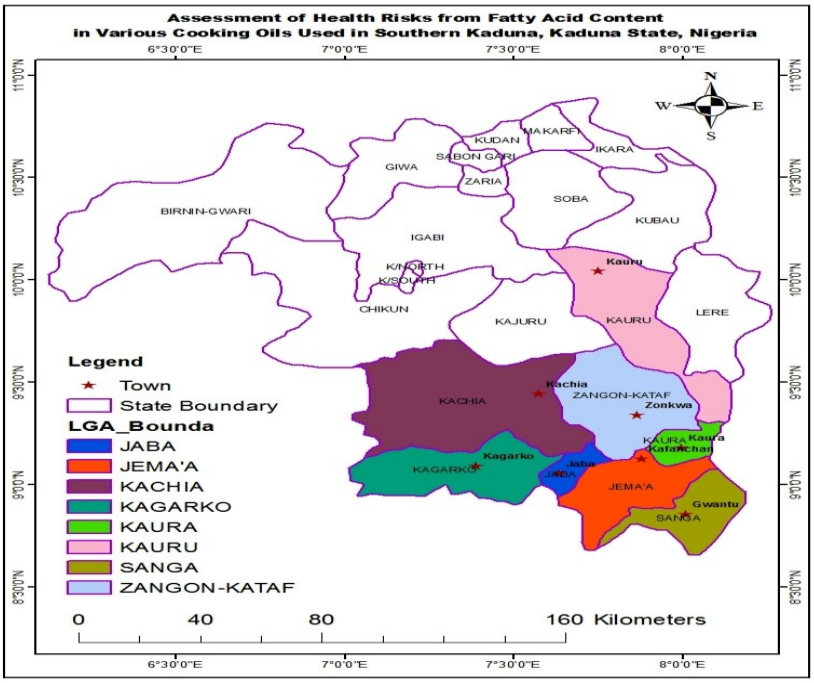

Fig 1: Map showing the various Local Government Areas in of Southern Kaduna

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Materials and Method

Reagents used

All chemicals, reagents and solvents were of analytical grade purchased from Yokel's Int'l Jos, Plateau State, Nigeria.

Collection of fats and oils

Before the commencement of this study, a market survey of various edible vegetable oils was carried out in various Local Government Areas of Southern Kaduna, Kaduna State. Six commonly used vegetable oils were identified which include; coconut oil, palm kernel oil, soybean oil, palm oil, peanut oils, and olive oils. Five samples of each of these commonly used vegetable oils were later purchased directly from oil processors, making a total of 30 samples. The samples were stored in opaque plastic vessels with a capacity of four litres (4L) at room temperature in the Chemistry laboratory of KSCOE Gidan Waya until it was required for analysis.

Preparation of Fatty Acid Methyl Esters (FAMEs)

Prior to the analysis of FA composition, esterification of the oil samples was carried out to convert the FA in the vegetable oil to FAMEs according to Japan Oil Chemist's Society (JOCS) Standard Method 2.4.1.3 [17]. A total of 50 mg of oil was dissolved ino.8 ml of hexane, and 0.2 ml sodium methoxide was added. The mixture was vortexed for 1 minute for the hydrolysis process and derivatization reactions to take place. The clear supernatant upper layer of the solution was transferred into a 2 ml capped vial before GC-MS analysis. Standard FAME of 37 compounds (C4 to C24) was purchased from (Supelco, Sigma-Aldrich, Bellefonte, PA).

Determination of fatty acid composition

Analysis of various oil samples for fatty acid composition was carried out using the ISQ7000 Single Quadrupole GC-MS System. 1µL of the supernatant was

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injected into the chromatographic column and peaks were recorded for their respective retention times and areas by the data processor unit of the TRACE 1310GC directly coupled to the ISQ7000 mass spectrometer system. The ionization voltage and ion source were set at 72ev and 240°C respectively. Chromatographic separation was performed on a 260M141P column) 30m length, 0.22mm internal diameter, 0.25µm film thickness). The oven temperature of the GC was programmed from 80°C, increased at 15°C/min to 280°C. Helium was used as carrier gas with a flow rate of 1.4mL/min and the split ratio as 1:10. the run time of one injection was 55 minutes. The analysis was conducted at three injection replications with randomized order of oil samples. The FAME peaks were identified by comparing their retention time with certified 37-component FAME Mix reference standards (Supelco, Sigma-Aldrich, USA). The percentage of fatty acid was calculated based on the peak area ratios of a fatty acid species to the total peak area of all the fatty acids [18].

Health risk index (HRI) determination

Health risk analysis was carried out to assessed the risk associated with the consumption of the oils such as cardiovascular health. The health effect of fatty acid intake through vegetable oil consumption was estimated based on health risk index (HRI). [25, 26]. The health risk index in this study is the ratio of PUFA to SFA of a particular oil sample. It was estimated using equation (1) as shown below:

$$\text{HRI} = \frac{PUFA\ \%}{SFA\%} \qquad (1)$$

The lower the HRI (SFA>PUFA) the more the adverse effect of consuming the oil. Several studies indicate that higher value of HRI means a smaller deposition of lipids in the body [7, 23]. The values of HRI of tested oils are shown in Fig 3.

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Determination of health promotion index (HPI)

The HPI was used as an index to evaluate the nutritional value of dietary fat that has particular relevance on human health. Essential fatty acids include: Linoleic acid (LA; C18:2ω- 6) and α-linolenic (ALA; C18:3ω-3). The HPI in this study was evaluated as the ratio of ω- 6 to ω-3 expressed as;

$$HPI = \frac{\omega - 6}{\omega - 3} \quad (2)$$

Higher HPI promote the pathogenesis of many diseases, such as cardiovascular disease, cancer, inflammatory, and autoimmune diseases, whereas lower HPI is necessary to reduce the various effects caused by high HPI due to significant amount of ω-3 PUFA [36].

Statistical Data Analysis

The data obtained from the experiment was subjected to analysis using statistical software, SPSS (Statistical Package for Social Sciences) version 24.0. Tests for significance in variations were conducted by one-way analysis of variance (ANOVA) and the means were compared using Tukey test. Variations were considered significant at $p < 0.05$.

Results and Discussion

Analysis of fatty acid composition

The FA profiles of the six vegetable oil samples obtained from the GC-MS test are shown in Table 1 and Table 2. Every FAME component was identified by the retention times and chromatograms in standard mix (Fig.2). The precision was validated by repeating the process two times with a solution of the standard mix.

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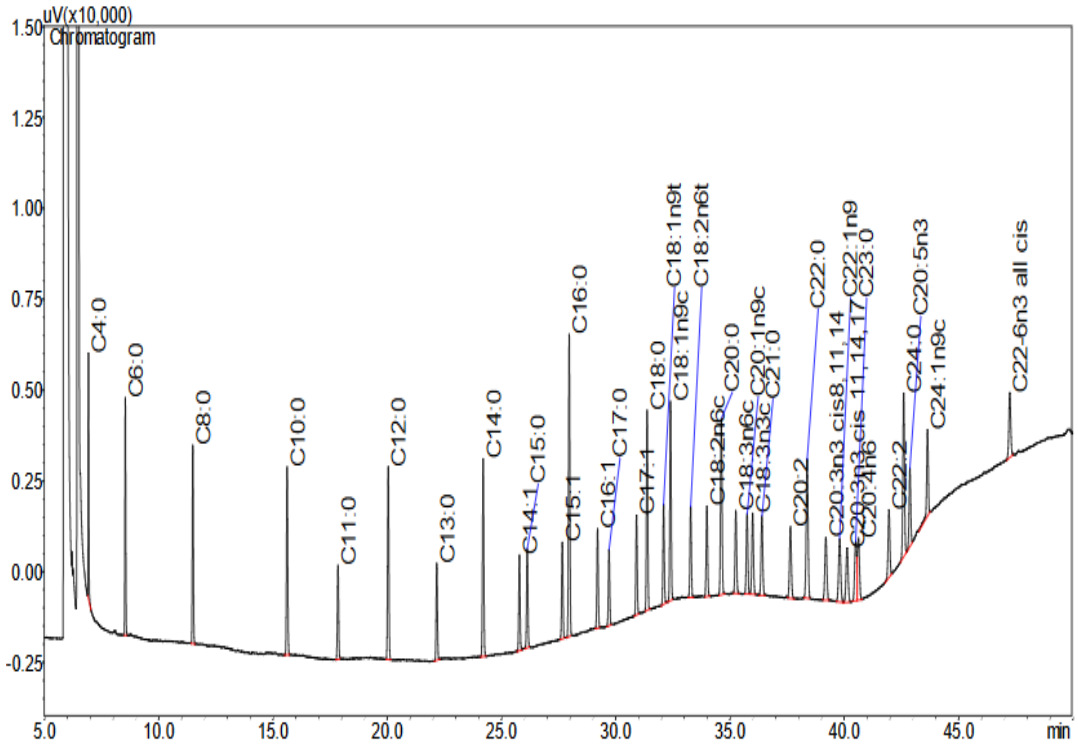

Fig 2: Chromatogram of 37-component FAME mix standard analyzed on 260M141P Column. The column's temperature was programmed as: 80° C (4min); 80° C /min

Table 1: Saturated Fatty acid composition of vegetable oil samples (in g FA/100g oil)

Oil	$C_{8.0}$	$C_{10.0}$	$C_{12.0}$	$C_{14.0}$	$C_{16.0}$	$C_{17.0}$	$C_{18.0}$	$C_{20.0}$	$C_{22.0}$	$C_{24.0}$	Total
Peanut	nd	nd	nd	0.02	8.92	0.09	2.24	1.11	3.20	1.54	17.12
Kernel	3.02	2.99	44.89	15.7	9.74	nd	2.06	0.14	nd	0.21	78.76
Palm	nd	nd	nd	1.84	43.0	0.12	4.82	0.25	0.57	0.02	50.62
Coconut	6.01	5.13	42.14	18.32	10.42	nd	4.12	0.07	nd	nd	86.21
Soybean	nd	nd	nd	0.09	9.43	0.18	5.32	0.19	0.67	0.24	16.12
Olive	nd	nd	nd	nd	8.54	3.47	0.29	0.38	0.12	0.09	12.89

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Values are mean of two measurements (n = 2). nd= not detected
$C_{8:0}$ = caprílic; $C_{10:0}$ = capric; $C_{12:0}$ = lauric; $C_{14:0}$ = miristic; C16:0 = palmitic; $C_{17:0}$ = margaric; $C_{18:0}$ = stearic; $C_{20:0}$ = arachnidic; $C_{22:0}$ = behenic; $C_{24:0}$ = lignoceric.

Table 1 showed fatty acid profile of SFAs for 6 different edible vegetable oil samples obtained from the GC-MS analysis. Palmitic acid (C16.0) and stearic acid (C18.0) are the major SFAs found in all vegetable oils samples while kernel oil and coconut oil displayed great amount of lauric acid (C12:0) as their major saturated fatty acids. These findings were similar with those of Zambiazi et al. [19]. Palmitic acid (C16:0) was predominant acid in palm oil 43.00%. The content of myristic acid (C14:0) in peanut oil, soybean oil and palm oil were low, ranging from 0.02% for peanut to 1.84% for palm oil. The presence of caprylic acid (C8:0), capric acid (C10:0) and lauric acid (C12:0) were found only in kernel and coconut oils. Low content of arachidic acid (C20:0) was found in all samples of vegetable oils within the range of 0.07% for coconut oil to 0.39% for soybean oil. Peanut oil showed the highest long chain SFA content, comprising 5.85% of behenic (C22:0), arachnidic (C20:0) and lignoceric(C24:0) FA. These findings are very close to the results presented by Zambiazi et al. [19], where total content of these three SFA was found to be 6.18%. Besides lauric acid which is the major SFA, another short chain SFA as caprylic acid (C8:0), capric acid (C10:0), myristic acid (C14:0), palmitic acid (C16:0), stearic acid (C18:0) and arachnidic (C20:0) were also present in both palm kernel oil and coconut oil. Because of a high content of short chain FAs these oils are used in chemical industry for manufacturing of detergents and soaps [16].

Table 2: Unsaturated Fatty acid composition of vegetable oil samples (g FA/100g oil)

Oil	$C_{16.1}$	$C_{17.1}$	$C_{18.1}$	$C_{18.2}$	$C_{18.3}$	$C_{20.1}$	$C_{20.2}$	$C_{22.1}$	$C_{22.2}$	$C_{24.1}$	MUFA	PUFA
Peanut	0.08	0.03	47.62	30.32	0.18	1.22	nd	0.09	nd	nd	49.09	30.48
Kernel	nd	nd	14.87	2.87	nd	0.14	nd	nd	nd	0.19	15,2	2.87
Palm	nd	0.05	37.61	10.85	0.83	0.14	nd	nd	nd	nd	37.8	11.68
Coconut	nd	nd	7.03	1.63	nd	0.4	nd	nd	nd	nd	7.07	1.63
Soybean	0.04	0.06	22.06	58.06	7.17	0.24	nd	nd	nd	nd	22.4	65.23
Olive	0.47	0.22	75.07	8.32	0.58	0.64	nd	nd	0.19	nd	75.4	9.09

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Values are mean of two measurements (n = 2). nd= Not detected
C16:1 = palmitoleic; C17:1 = miristoleic; C18:1 = oleic; C18:2 = linoleic; C18:3 = linolenic; C20:1 = gadoleic; C20:2 =eicosadienoic; C22:1 = erucic; C22:2 = docosodienoic; C24:1 = nervonic.

Table 2 presented the result of unsaturated fatty acid obtained from the GC-MS analysis. Soybean oil showed high PUFA content (58.06%) with the predominant presence of linoleic acid(C18:2). Soybean oil also showed presence of linolenic(C18:3) acid (7.17%) which is considered adequate for giving ω-3 source [13]. The Greek letter ω(omega) is used to designate the last carbon of the chain, opposite to the functional carboxylic group. Based on this nomenclature, the PUFAs are denominated as ω-3 when the first double bond is placed between C3 and C4, in relation to the carbon omega (C - ω); ω-6 when the first double bond is placed between C6 and C7, in relation to C – ω and ω-9 when the first double bond is placed between C9 and C10, in relation to C-ω [11].

Analysis of FA composition in this study also showed that the predominant MUFA in olive oil and peanut oil was oleic acid (75.07% and 47.62% respectively). Olive oil is nutritionally considered one of the best salad vegetable oil due to the highest MUFA content (65% -83 %), [21]. The lowest content of unsaturated FA was found in coconut oil with a total unsaturated fatty acid content of 8.7%. These findings were in line with the literature data [22].

Studies have shown that olive oil offers protection against heart disease by controlling LDL-cholesterol levels (bad cholesterol) while raising HDL levels [31]. This study shows that soybean is an important source of edible oil. Soybean oil is a good source of both linoleic and linolenic acids, which are essential for humans. More than 50% of the fat in soybean oil is linoleic acid, while about 7% of the total fat is linolenic [35].

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Health risk index (HRI) determination

After the determination of the FAs composition of all the oil samples, the various fatty acids analyzed were grouped into saturated (SFAs), monounsaturated (MUFAs), and polyunsaturated (PUFAs) fatty acids, and their respective calculation formulae were:

SFAs = C8:0 + C10:0 + C12:0 + C14:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 + C24:0 (3)

MUFAs = C16:1 + C17:1 + C18:1 + C20:1 + C22:1 + C24:1 (4)

PUFAs = C18:2+ C18:3 + C20:2 + C22:2 (5)

The health risk index (HRI) was evaluated as the ratio of PUFA to SFA as expressed in equation (2).

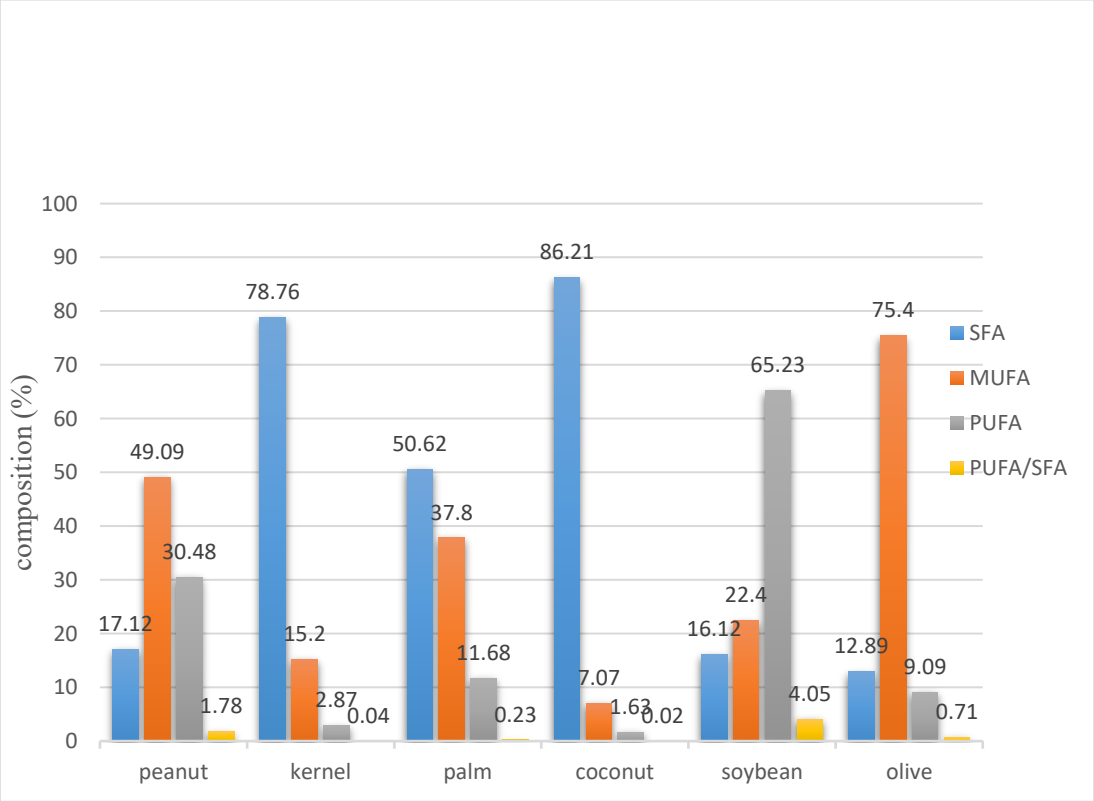

Fig. 3 **Composition of SFA, MUFA, PUFA and PUFA:SFA ratios**

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The different classes of FAs evaluated are shown in Fig. 3. The highest content of total PUFA was found in soybean oil (65.23%) followed by peanut oil (30.4%) and palm oil (11.68%). The lowest content of PUFA was found in coconut fat (1.63%).

It is known that the too much consumption of saturated fatty acids results to an increase in the plasmatic cholesterol and obesity [32]. On the other hand, the consumption of polyunsaturated (PUFAs) and monounsaturated fatty acids (MUFAs) has been recommended to improve the lipidic profile in relation to the saturated fatty acids [33]. However, other studies [34] indicates that rich diets in PUFA are not excepted of negative effects, having been demonstrated that those fatty acids may provoke an increase in the LDL-cholesterol oxidation and reduction of the HDL-cholesterol levels.

The health risk index (HRI) which gives the relationship between PUFAs and SFAs of the tested oils were shown in Fig. 3. These values are important parameters for determination of nutritional value of certain oils. Oils and fats with high values of HRI are considered to have nutritional value. Several studies indicated that higher value of HRI means a smaller deposition of lipids in the body [7]. The higher value for HRI was found in soybean oil (4.05) and the lowest in coconut oil (0.02) and kernel oil (0.04). These results are in line with the data obtained from previous studies [19, 21]. Peanut oil has the closet HRI of 1.79 as recommended by FAO/WHO [39]. The high HRI value in soybean oil indicates high PUFA than SFA content which is associated with the impact on human health therefore, soybean oil and peanut oil are recommended for mass consumption.

Health promotion index (HPI)

Health benefits may be achieved by lowering dietary ω-6: ω-3 FA ratio [28]. Lowering dietary ratio of ω-6: ω-3 fatty acids has been found to significantly reduce cardiovascular and metabolic risks regardless of the source of ω -3 fatty acids [29].

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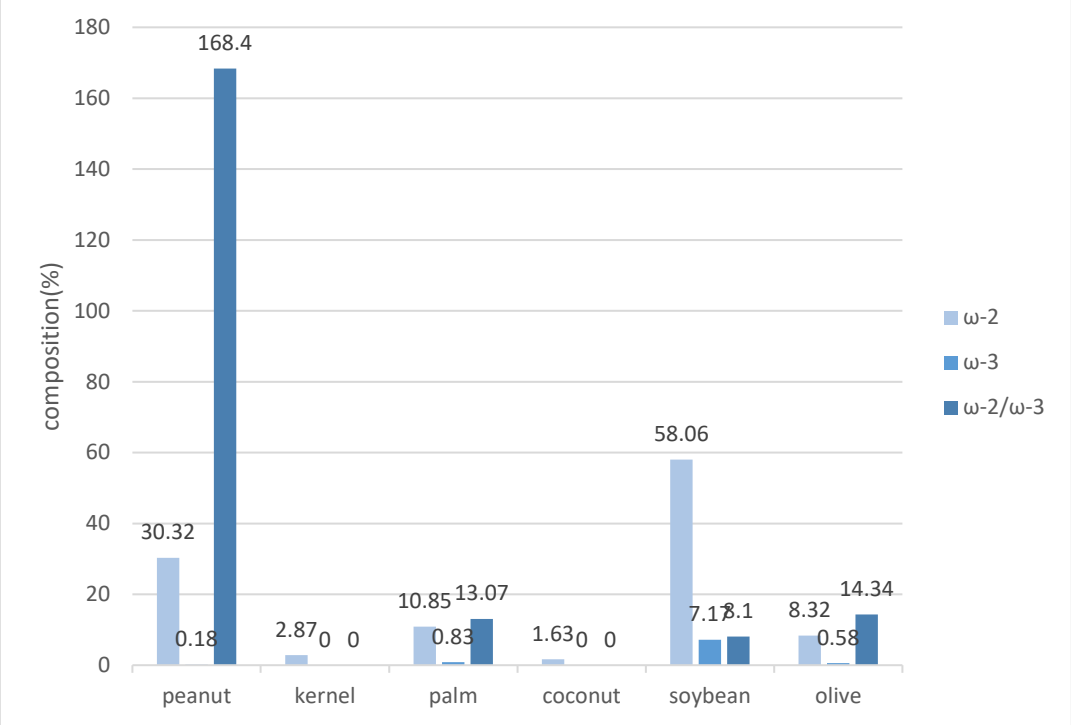

Fig 4: Essential fatty acids ω-6, ω-3 and their ratios

Figure 4 showed the essential fatty acid content (ω-6 and ω-3) of the various oil samples and the ratios of ω-6 to ω-3. ω-6 and ω-3 are considered essential FAs because they cannot be synthesized by the human body [30]. These two classes of EFA are not interconvertible, are metabolically and functionally distinct, and often have important opposing physiological functions [40]. Diets must be balanced in the omega-6 and omega-3 fatty acids so as to maintain a healthy EFAs intake. This balance can best be accomplished by decreasing the intake of oils rich in omega-6 fatty acids and increasing the intake of oils rich in omega-3. However, Increased ω-3 consumption has been shown to have protective effects on a whole host of diverse conditions from arteriosclerosis to inflammatory, autoimmune diseases, prevention and treatment of a great number of human diseases such as heart diseases [27,15]. Soybean oil was the richest vegetable oil in ω-3 fatty acid with 7.17% of linolenic acid (C18:3) while only trace or no ω-3 was found in the other oils. Although, higher content of

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linolenic acid makes it unsuitable for human consumption due to increase in oxidation reaction of oil that may likely occur [14].

The World Health Organization recommended the ratio of linoleic acid (C18:2 ω -6) to alpha linolenic acid (C18:3 ω-3) as 5-10% in the diet [20]. Only soybean oil with C18:2 (58.06%) and C18:3(7.17%) oil provided the optimal closest ratio of Omega-6 to Omega-3 ratio of 8.10% (Fig. 4). The remaining oils had either very high or low omega-6 to omega-3 ratio. Excessive amounts of Omega-6 PUFAs and very high Omega-6/Omega-3 ratios promote the pathogenesis of many diseases, including cardiovascular diseases, cancer, inflammatory diseases and autoimmune diseases [24].

Conclusion

The analysis of the six different vegetable oils commonly sold and consumed in southern Kaduna revealed eight different fatty acids present in varying proportion. The SFAs identified were caprylic ($C_{8:0}$), capric ($C_{10:0}$), lauric ($C_{12:0}$), miristic ($C_{14:0}$), palmitic ($C_{16:0}$), margaric($C_{17:0}$), stearic ($C_{18:0}$), arachnidic ($C_{20:0}$), behenic ($C_{22:0}$), lignoceric ($C_{24:0}$) acids, while Unsaturated FAs include the MUFA palmitoleic ($C_{16:1}$), miristoleic ($C_{17:1}$), oleic($C_{18:1}$), gadoleic ($C_{20:1}$), erucic($C_{22:1}$), nervonic ($C_{24:1}$) and the PUFAs linoleic ($C_{18:2}$), linolenic($C_{18:3}$) and docosodienoic ($C_{22.2}$) acids. The percentage distribution of unsaturated fatty acids was observed to be higher than the saturated fatty acids. The monounsaturated fatty acid oleic ($C_{18:1}$) largely contributed to the high percentage of unsaturated fatty acids in the olive oil, peanut and palm oil samples. Coconut oil and kernel oils were observed to have high total saturated fatty acids than the other oil samples. Peanut oil possessed the closest recommended HRI value while soybean oil displayed the highest HRI due to high PUFA than SFA. This makes them generally the most suitable edible oils for mass consumption. Also, the PUFA ratio of ω-6 to ω-3 which gives the HPI index as evaluated showed that soybean oil has the closest recommended ratio of ω-6 to ω-3 according to FAO/WHO.

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Author Contributions

Writing-original draft, Conceptualization. **Dariya, A., Confidence, M. K.** Methodology, formal analysis. **Dariya, A. Confidence M.K., Blessing, N.** Investigation. **Dariya, A., Confidence, M.K.** writing—review and editing, **Dariya, A., Confidence, M.K., Blessing, N.**

Data availability statement

The data that supported the findings can be made available upon reasonable request

Conflicts of Interest: The authors declared no conflict of interest.

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