Research article

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Physicochemical characteristics and fatty acid composition of ginger (*Zingiber Officinale*) and garlic (*Allium Sativum*) oils cultivated in the north-central region of Nigeria

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Abstract

Background and objective: Garlic (*Allium sativum)* and ginger (*Zingiber officinale)*, as cooking spice, are popular medicinal plants for treating various ailments and disorders. These plants contain many polyunsaturated fatty acids and other bioactive metabolites. This study aims to evaluate physicochemical properties, fatty acid profile, and quality parameters of the oil extracted from *Allium sativum and Zingiber officinale.*

Materials and methods: Fresh *Allium sativum* and *Zingiber officinale* were purchased from a local market in Lafia local government, Nasarawa state, Nigeria. The samples were cleaned to remove foreign particles, sun-dried, and the oil was extracted by steam distillation. Physicochemical parameters of the extracted oil including peroxide value (PV), iodine value (IV), acid value (AV), saponification value (SV), unsaponifiable matter (USM), specific gravity (SG), and refractive index (RI) were determined using standard analytical methods, and fatty acid profile was determined by using gas chromatograph.

Results and conclusion: Physical properties of the extracted oil from *Allium sativum* and *Zingiber officinale* were in the range of 0.90-0.97 at 15 ^oC for SG, and 1.49-1.50 at 40 ^oC for RI. The chemical parameters ranged from 2.42 to 2.61 meq/kg for PV, 105.64 to 116.20 mg I_2/g for IV, 2.60 to 4.52 mg KOH/g for AV, 182.15 to 191.22 mg KOH/g for SV, and 1.02 to 1.11 mg KOH/g for USM. In gas chromatography, 13 and 16 fatty acids were identified in *Allium sativum* oil and *Zingiber officinale* oil, respectively. Linoleic acid (25.81-52.20%), oleic acid (20.77-24.06%), and palmitic acid (19.75-20.52%) were the main fatty acids in both samples. The quality parameters including ratio of polyunsaturated/saturated fatty acids (0.64-2.43), ratio of hypocholesterolemic/hypercholesterolemic fatty acids (2.03-3.87), atherogenicity index (0.27-0.91), and thrombogenicity index (0.50-0.80) were within the acceptable range. The fatty acid profile and the quality parameters of the oil samples imply their medicinal and flavoring strength, and candidate them for extended use in food, drug, and cosmetics industries.

Keywords: Atherogenicity index, Fatty acid, Garlic, Ginger, Thrombogenicity index

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1. Introduction

Vegetable oil is of main sources of bioactive compounds particularly polyunsaturated fatty acids (PUFA), which offers several health benefits. The fatty acids are necessary for biological functions including metabolism, regulation of inflammation, and energy homeostasis. Development of the retina, the nervous system, and fetal growth depends on fatty acids [1,2]. For instance, linoleic acid is necessary for synthesis of prostaglandins and maintaining the water permeability barrier of the skin. In addition, arachidonic acid is critically essential for development and optimal performance of the nervous system, the brain, the cognitive function, the skeletal muscles, and the immune system [3,4]. The oil extracted from vegetables and spices is rich of monounsaturated fatty acids (MUFA) and PUFA [5]. Some spices belonging to Allium and Zingiber genera such as garlic and ginger, respectively, are popular among a lot of cultures as potent preventive and curative herbal medicine.

Allium sativum, known as garlic, is a member of Alliaceae family. It has been introduced as a beneficial spice, additive, and medicinal plant for treatment of various ailments and disorders. It is consumed either raw (fresh leaves or dried cloves) or processed (oil, extract, and powder), and has various chemical and bioactive ingredients [6]. Traditionally, garlic is used in treatment and management of arthritis, worm infestations, heart disease, and fatigue, as well as better digestion to prevent diarrhea and increase stamina [7-9].

Zingiber officinale, known as ginger, is a member of Zingiberaceae family. It is used as a cooking spice, condiment, and herbal remedy. Due to its flavor, ginger is used preferably for its medicinal properties rather than cooking spice by the Romans and the Greeks. It has been used in folk medicine in Africa, Asia, and Arabic countries as a carminative and anti-flatulent herb, and also to treat cold, headache, nausea, stomach upset, diarrhea, digestion disorders, arthritis, rheumatoid, and muscular discomfort [10,11].

Fatty acid composition of garlic and ginger has been studied by several scientists. However, geography, planting condition, environmental factors, and method of extraction affect the proportion of flavor to aromatic compounds, fatty acid profile, and the bioactive compounds in the plants [12,13]. Therefore, we aimed to analyze nutritional composition of the oil extracted from garlic and ginger cultivated in the north-central region of Nigeria. Specifically, the current work evaluates physicochemical characteristics and fatty acid composition of ginger oil and garlic oil produced in Lafia, Nasarawa state, Nigeria. Moreover, health promotion aspects including ratio of polyunsaturated/saturated fatty acids (PUFA/SFA), ratio of hypocholesterolemic/hypercholesterolemic fatty acids (h/H index), atherogenicity index (AI), and thrombogenicity index (TI) were investigated for both oils.

2. Materials and methods

2.1. Sample collection and preparation

Fresh *A. sativum* and *Z. officinale* were purchased from a local market in Lafia local government, Nasarawa state, Nigeria in February 2020. The samples were thoroughly cleaned with tap water to remove sand and other foreign particles, and taxonomically identified in the Department of Plant Science and Biotechnology, Federal University of Lafia, Nigeria. *T*he cleaned samples were cut into pieces, sun-dried, and ground into powder with a Kenwood food blender. Powder of both samples was separately kept at -4 ºC until analysis.

2.2. Oil extraction

Steam distillation technique was used to extract the oil of samples. About 100 g of garlic and ginger powder was soaked in water for 2 h, and steam-distilled further in a Clevenger-type apparatus for 8 h. This procedure was repeated six times [14]. The oil was separated by gravity, dried over anhydrous sodium sulphate, filtered, and stored at 4 ºC up to analysis.

2.3. Physicochemical characteristics of the extracted oil

Physicochemical parameters of the extracted oils including peroxide value (PV), iodine value (IV), acid value (AV), saponification value (SV), unsaponifiable matter (USM), specific gravity (SG), and refractive index (RI) were determined according to the American Oil Chemists Society (AOCS) methods [15].

2.4. Fatty acid profile

The fatty acids in the oil extracted from each sample was esterified by the method described by Aremu et al. [16]. Accordingly, 50 mg of the extracted oil was saponified with 3.4 ml of KOH solution in methanol (0.5 M) at 95 ºC for 5 min. The mixture was neutralized by HCl (0.7 M), followed by addition of 3 ml of boron trifluoride solution in methanol (14%). The final mixture was heated at 90 ºC for 5 min to complete methylation. The fatty acid methyl esters were analyzed by HP 6890 gas chromatograph (Bionics Scientific Technologies Ltd., India) equipped with a flame ionization detector. Nitrogen was used as carrier gas. A polar (HP INNO Wax) capillary column (30 m × 0.53 mm × 0.25 μm) was used for separation of fatty acids. Initial temperature of the column was set at 250 ºC, then increased at the rate of 5 ºC/min to reach a final temperature of 310 ºC. Injector and detector temperatures were 310 ºC and 350 ºC, respectively. Peaks of the fatty acid methyl esters were recognized by comparing their retention times with standard fatty acid methyl esters. Quantitative evaluation was carried out by calculation of peak areas. A recovery of 0.96 was achieved by using a heptadecanoic ester.

2.5. Health promotion properties

To find out the possible effectiveness of the oil in health promotion, proportion of beneficial fatty acids to the other fatty acids was calculated. For this, ratio of PUFA/SFA, h/H index (equation 1) [17,18], AI (equation 2), and TI (equation 3) [19,20] are presented.

$$h/H = \frac{C18{:}1\omega9 + C18{:}2\omega6 + C20{:}4\omega6 + C18{:}3\omega3 + C20{:}5\omega3 + C22{:}5\omega3 + C22{:}6\omega3}{C14{:}0+C16{:}0} \quad \text{Equation 1}$$

$$AI = \frac{C12{:}0 + 4(C14{:}0) + C16{:}0}{\Sigma MUFA + \Sigma\omega6 + \Sigma\omega3} \quad \text{Equation 2}$$

$$TI = \frac{C14{:}0 + C16{:}0 + C18{:}0}{0.5(\Sigma MUFA) + 0.5(\Sigma\omega6) + 3(\Sigma\omega3) + (\Sigma\omega3/\Sigma\omega6)} \quad \text{Equation 3}$$

Where, C12:0 = lauric acid; C14:0 = myristic acid; C16:0 = palmitic acid; C18:0 = stearic acid; C18:1ω9 = oleic acid; C18:2ω6 = linoleic acid; C18:3ω3 = linolenic acid; C20:4ω6 = arachidonic acid; C20:5ω3 = eicosapentaenoic acid; C22:5ω3 = docosapentaenoic acid; C22:6ω3 = docosahexaenoic acid; MUFA monounsaturated fatty acids.

3. Results and discussion

3.1. Physicochemical characteristics of *A. sativum* oil and *Z. officinale oil*

Physicochemical characteristics of the oil extracted from *A. sativum* and *Z. officinale* are presented in Table 1. PV of 2.42 and 2.61 were determined for garlic and ginger oils, respectively. PV is commonly used as an indicator of lipid oxidation. Oil with high PV causes adverse effects such as triggering inflammatory and cardiovascular diseases by increasing reactive oxygen species and secondary oxidation products. Furthermore, high PV indicates that the oil has a short shelf life and is not appropriate for human consumption [21]. The World Health Organization/Food and Agriculture Organization has determined maximum level of 10 milli equivalent of oxygen/kg of oil for PV. Accordingly, both samples in our study were appropriate for culinary use.

Table 1- Physicochemical characteristics of ginger and garlic oil

Parameter	Garlic	Ginger	Mean	SD	CV (%)
Peroxide value (meq/kg)	2.42	2.61	2.52	0.13	5.16
Iodine value (mg I_2/g)	116.20	105.64	110.92	7.47	6.73
Acid value (mg KOH/g)	2.60	4.52	3.56	1.36	38.20
Saponification value (mg KOH/g)	182.15	191.22	186.68	6.41	3.43
Unsaponifiable matter (mg KOH/g)	1.02	1.11	1.07	0.06	5.61
Specific gravity at 15 ºC	0.97	0.90	0.94	0.06	6.45
Refractive index at 40 ºC	1.50	1.49	1.50	0.01	0.67

Indeed, the low PV of both *A. sativum* and *Z. officinale* oil samples was associated with their strong antioxidant and free radical scavenging activities as reported by Danwilai et al. [22], Jang et al. [23], Ansary et al. [7], Farhat et al. [24], and Mustafa and Chin [25]. PV of our samples was lower than those reported for oil of ginger (148.60 meq/kg), cinnamon (234.15 meq/kg), and garlic (247.12 meq/kg) collected from Ilorin (Nigeria) by Francilia et al. [26].

Oil with iodine values less than 100 g/100g is classified as non-drying oil [27]. Thus, all the oil samples in this study are drying oil (IV = 116.20 for garlic oil, and IV = 105.64 for ginger oil). The higher IV of garlic oil suggests that it contains more unsaturated fatty acids than ginger oil.

AV of oil is a measure of its free fatty acids, and is an important factor in determination of its quality. Low AV of oil indicates that it is stable during time, and against rancidity and peroxidation. On the other hand, high AV in oil suggests that the oil may not be suitable for cooking purposes, but may be useful in production of paint, liquid soap, and shampoo. AV of both oil samples were within the acceptable range of ≤ 10 for edible oil [28].

SV is a measure of oxidation during storage and indicator of oil's deterioration. In combination with AV, SV provides information about quantity, type of glycerides, and mean weight of fatty acids in oil. SV of our samples showed that both garlic and ginger oil contained long-chain fatty acids (C18 and C16) predominantly, which had SV between 168 to 196 mg KOH/g [29].

USM of the samples ranged from 1.02 mg KOH/g to 1.11 mg KOH/g for garlic and ginger oil, respectively. USM contains a variable mixture of hydrocarbons, aldehydes, ketones, alcohols, sterols, pigments, and fat-soluble vitamins, which may occur naturally or may be formed during processing and/or degradation of fat. In some cases, USM of edible oils is used to characterize and authenticate the products [30].

SG and RI of the oil samples were 0.97 and 1.50 for garlic oil, and 0.90 and 1.49 for ginger oil, respectively. SG and RI are used in quality control to assess the oil's purity. RI of oil is directly proportional to degree of unsaturation and conjugation.

3.2. Fatty acid profile

Fatty acid composition of the oil extracted from garlic and ginger is presented in Table 2. The results indicated that unsaturated fatty acids of linoleic and oleic acid were predominant in both samples. Linoleic acid was the most abundant with concentration of 52.20% and 25.81% in garlic and ginger oil, respectively, followed by oleic acid (24.06% and 20.77% in garlic and ginger oil, respectively). Maric et al. [31] reported linoleic acid (49.15-55.49%) as the most abundant fatty acid in raspberry seed oil. Similarly, linoleic was the dominant fatty acid in a hydro-distilled extracted ginger oil at concentration of 23.92% [32]. Linoleic acid content of garlic oil in our study is comparable with its concentration in garlic oil of Greece (53.60%) [33], cashew nut kernel (57.21%) [16], and harms seed (47.95%) [34].

Palmitic acid was the third most concentrated fatty acid, with 19.75% and 20.52% in garlic and ginger oil, respectively. It is the most common long-chain saturated fatty acid in vegetable oil. The absence of caprylic, capric, and lauric acids in garlic oil may be related to the environmental factors. Lauric acid (7.94%), capric acid (4.99%), stearic acid (4.85%), myristic acid (4.80%), linolenic acid (4.79%), and caprylic acid (2.47%) were of other fatty acids particularly presented in ginger oil.

Table 2- Fatty acid profile of ginger and garlic oil

Fatty acid	Garlic	Ginger	Mean	SD	CV (%)
Caprylic acid (C8:0)	0.00	2.47	1.24	1.75	141.30
Capric acid (C10:0)	0.00	4.99	2.50	3.53	141.20
Lauric acid (C12:0)	0.00	7.94	3.97	5.61	141.31
Myristic acid (C14:0)	0.33	4.80	4.97	3.16	63.58
Palmitic acid (C16:0)	19.75	20.52	20.14	0.54	2.68
Palmitoleic acid (C16:1)	0.19	0.55	0.37	0.25	67.57
Margaric acid (C17:0)	0.03	0.03	0.03	0.00	0.00
Stearic acid (C18:0)	1.02	4.85	2.94	2.71	92.18
Oleic acid (C18:1)	24.06	20.77	22.42	2.33	10.39
Linoleic acid (C18:2)	52.20	25.81	39.01	18.66	47.83
Linolenic acid (C18:3)	1.31	4.79	3.06	2.45	80.07
Arachidic acid (C20:0)	0.06	0.24	0.15	0.13	86.67
Arachidonic acid (C20:4)	0.04	0.05	0.05	0.01	20.00
Behenic acid (C22:0)	0.23	0.39	0.31	0.11	35.48
Erucic acid (C22:1)	0.17	0.22	0.20	0.04	20.00
Lignoceric acid (C24:0)	0.62	1.64	1.13	0.72	63.72
Total	100	100			

3.3. Functional property of ginger and garlic oil

According to Table 3, ginger oil had higher SFA (47.87%) than garlic oil (22.04%). Amount of SFA in ginger oil was higher than SFA concentration reported for *Adenanthera pavonina* (31.98%) [35], Bambara groundnut (34.68%) [36], African locust (40.20%), and mesquite bean (40.00%) [37]. Concentration of unsaturated fatty acids was higher than SFAs in both garlic (77.96%) and ginger (52.13%) oil. Concentration of MUFA (24.42%) and PUFA (53.55%) in garlic oil was similar to their concentrations in native pumpkin seed oil (25.10% MUFA and 51.20% PUFA) [38].

Table 3- Functionality parameters of ginger and garlic oil

Parameter	Garlic	Ginger	Mean	SD	CV (%)
SFA	22.04	47.87	34.96	18.29	52.32
MUFA	24.42	21.54	22.98	2.04	8.88
PUFA	53.55	30.65	42.10	16.19	38.46
UFA	77.96	52.13	65.05	18.26	28.07
EFA	53.51	30.60	42.06	16.20	38.52
O/L	0.46	0.80	0.63	0.24	38.10
PUFA/SFA	2.43	0.64	1.54	1.27	82.47
ω6/ω3	39.85	5.39	22.65	24.37	107.59
h/H index	3.87	2.03	2.95	1.30	44.07
AI	0.27	0.91	0.59	0.45	76.27
TI	0.50	0.80	0.65	0.21	32.31

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; UFA; unsaturated fatty acid; EFA: essential fatty acid; O/L: oleic acid/linoleic acid; ω: omega; h/H index: hypocholesterolemic/hyper-cholesterolemic fatty acids; AI: atherogenicity index; TI: thrombogenicity index

A wide range of biological processes including normal growth, and operation of the brain and the nervous system are regulated by PUFA. Long-chain PUFAs (such as arachidonic acid) play crucial role in immune regulation and inflammation [39]. Gene expression, eicosanoids' metabolism, and inter-cellular communication are all impacted by ratio of ω6 to ω3. Therefore, their intake by a balanced diet is crucial to achieve homeostasis and ensure that the organism develops normally. A diet containing the recommended amounts of ω6 and ω3 fatty acids is necessary for optimal metabolism, and helps to prevent chronic degenerative diseases such as cardiovascular disease [20].

According to Cunha et al. [17], there is a risk of increased blood cholesterol level if oil with PUFA/ SFA ratio less than 0.45 is used for human consumption. In our study, PUFA/SFA ratios (0.64-2.43) was above the recommended value by Cunha et al. and also recommendation of the Great Britain Department of Health (0.45), indicating that both oil samples are healthy for human consumption [40].

A high h/H index in edible oil is desirable [20]. It is directly correlated with enhancement of cholesterol metabolism and production of high-density lipoproteins [18]. According to Table 3, h/H index was 3.87 for garlic oil, and 2.03 for ginger oil. With regard to AI and TI, the scientists reported that the oil with AI and TI less than 1 is a good candidate for healthy diet [17,20], that is in accordance with the results achieved in our study. Considering all the characteristics evaluated in our study revealed that both ginger oil and garlic oil are of potential sources with drastic roles in prevention of various chronic diseases and development of human health.

4. Conclusion

In this study, fatty acid profile, functional properties, and physicochemical characteristics of garlic and ginger oil were evaluated. Unsaturated fatty acids, particularly linoleic and oleic acids, were predominant in both oil samples. Garlic and ginger oil had PV and AV lower than the maximum permitted level, and IV, SP, and USM were within the acceptable range for edible oil. The qualification study revealed that both garlic and ginger oil contain desirable level of PUFA especially ω3 and ω6. It makes them appropriate in folk medicine and also common culinary purposes. Although, garlic oil had better functionality than ginger oil. Inclusion of high linoleic and oleic acids in both samples is of great importance and introduces them as health-promoting oil. However, a cost-benefit study is required to evaluate whether they are appropriate for industrial use or not.

5. Conflict of interest

The authors declare that they have no conflict of interest.

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