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Effect of Different Processing Methods (Roasting and Shade-Drying) on Fatty Acid Profile of Tumeric (*Curcumin longa*)

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Abstract

Temperature has been identified as an important factor affecting the fatty acid composition in food products. The study assessed the effect of roasting and shade-drying on the fatty acid profile of turmeric (*Curcumin longa).* Two kilograms of freshly harvested turmeric were purchased from a local market in Nsukka LGA, Enugu State, Nigeria. Three samples coded A, B and C were used for the study. Samples A and B were subjected to roasting and shade-drying, respectively, while C was untreated and served as a control. Turmeric oil from these samples was extracted and taken to the laboratory for analysis. Standard methods were used for the oil extraction and analysis. Data obtained were analysed statistically using Statistical Product and Service Solution (SPSS) version 22. Analysis of variance (ANOVA) was used to compare means while Turkey HSD-test was used to separate means. Statistical significance was set at $p < 0.05$. The results showed that shade-dried and roasted turmeric had higher ($p < 0.05$) unsaturated fatty acid (2.51 and 2.03 mg), respectively than fresh turmeric (0.53 mg). The total omega-3 fatty acid (1029.93 mg) in the shade-dried and 720.72mg in the roasted samples was higher than that in the fresh sample. The fatty acid profile result revealed that the roasted sample contained the highest amount of oleic acid (43.65 g) while the shade-dried samples had the highest amount (44.14g) of palmitic acid. Therefore, shade-drying and roasting increased the unsaturated fatty acids, polyunsaturated fatty acids (omega-3 and omega-6) and some of the fatty acid profiles of turmeric oil.

Keywords: Roasting, Shade-Drying, Turmeric, Fatty Acid Profile.

Introduction

Globally, there is a rise in the demand for quality oils and fats, and to cope with this increasing demand, it is necessary to utilize some non-conventional sources of fats and oils. Turmeric rhizome is one such source. Turmeric oil is better than other vegetable oils regarding health benefits. However, an increase in temperature during turmeric processing may adversely affect the fatty acid composition as is the case in other food materials. Cortez et al. (2020) showed that heat-related chemical reactions involved in domestic cooking including drying and roasting may alter or compromise the bioactive compounds such as fatty acids in spices by changing their physical, chemical and nutritional characteristics. Similarly, Sheikh et al. (2010) reported that temperature increase decreased the linoleic acid content of the polar lipid fraction.

Turmeric is a spice of a tropical perennial plant, botanically called *Curcuma longa* and belongs to the same family (Zingiberaceae) as ginger (Amadi et al., 2018). It originated from India and Indonesia but it is cultivated throughout the tropics around the world. Yearly, the production of turmeric ranged between 1.1-1.15 million tons worldwide in which India was the leading contributor with 82% productivity share followed by China (8%), Myanmar (4%), Bangladesh (3%), Nigeria (3%) and 2% by others (Kanungo, 2016; Moghe et al., 2012). According to Nasri et al. (2014), it can be used as a food spice, medicine and for income generation. Turmeric powder is the major constituent of curry powder used in confectionery industries for food seasoning and in the international market as a functional food due to its health-promoting properties. As a spice, it adds flavour and colour to dishes. Turmeric is usually transformed into flour before use. Nwaekpe et al. (2015) reported that it is known as the golden spice of life and is regarded as one of the most essential spices used in culinary all over the world because it gives the desirable yellow-orange colour to curry powder.

Many researchers have shown that turmeric has the potential to protect against non-communicable diseases, such as cardiovascular dysfunction, cancer, and diabetes (Lai & Roy, 2004; Moshiri et al., 2015). Research by Amadi et al. (2018) revealed that turmeric is efficiently used in the treatment of circulatory problems, liver diseases, dermatological disorders and blood purification. It has been shown to reduce inflammation. According to Chandrasekaran et al. (2013), the anti-inflammatory action of turmeric may be correlated with its ability to reduce the number of fibroblasts and the synthesis of collagen and mucopolysaccharides that are involved in the formation of granuloma tissue. In addition, McQuillan (2022) found that turmeric's anti-inflammatory action appears to help improve pains associated with rheumatoid arthritis, post-operative inflammation, Crohn's disease, ulcerative colitis, irritable bowel syndrome, and stomach ulcers. Recent research has identified turmeric as an antioxidant. Mansour-Ghanaei et al. (2019) found that curcumin in turmeric in higher dosages could be efficacious in the treatment of non-alcoholic fatty liver disease.

The medicinal benefits of turmeric may be due to the presence of high light-sensitive curcumin of which about 27-53% is lost during heat processing and in the commonly practised open sun drying method (Geethanjali et al., 2016; Suresh et al., 2017). Curcumin is a small molecular weight polyphenolic compound and lipophilic in nature. It is insoluble in water and ether but soluble in ethanol, dimethylsulfoxide, and other organic solvents. Nutritionally, turmeric contains 9.42% crude protein, 4.60%

crude fibre and 6.85% fat, 0.59% of riboflavin, 0.16% of thiamine, and 2.30% of niacin (Ikpeama et al., 2014). According to Imoru et al. (2018) stated that turmeric rhizome contained 3.44mg/g of vitamin A, 0.32 mg/g of B3, 0.84 mg/g of C and 0.39 mg/g of E. According to Uchechukwu (2020), turmeric contains no cholesterol but, it is rich in antioxidants and dietary fibre. These nutrients perform important specific functions in the body.

Fats are used for energy after they are broken into fatty acids. Nkwocha et al. (2019) defined fatty acids as carboxylic acids with a long aliphatic chain that is either saturated or unsaturated in chemistry, particularly biochemistry. Fatty acids are an integral component of cell membrane phospholipids, with specific functional, metabolic, and signalling roles (Calder, 2015). Omega-3- 3 (ω-3) and omega-6 (ω-6) are two main families of polyunsaturated fatty acids (PUFAs) that are relevant to human health. They are known as essential fatty acids because the human body cannot synthesize them and as such must be supplied from the diet (Luo et al., 2021; Wu et al., 2016; Yin et al., 2016). There are three types of omega-3 fatty acids which include alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) (Judge, 2018; Kang, 2004).

Several studies around the globe have shown that omega-3 fatty acids have anti-inflammatory, antithrombin, anti-heart rhythms, can reduce blood lipid levels, and have vasodilating properties (Adili et al., 2018; Calder, 2012; Holub & Holub, 2004; Massaro et al., 2008). The ω-3 fatty acids are polyunsaturated fatty acids characterized by the presence of a double bond on the third atoms away from the terminal methyl group in their chemical structure. They are long-chain polyunsaturated fatty acids (PUFA) that are found in plants and marine organisms. Alpha-linolenic acid (ALA) is a plant-based essential omega-3 polyunsaturated fatty acid with three double bonds (Blondeau et al., 2015). Su et al. (2018) reported that it constitutes 67% of perilla oil, 55% of linseed oil, 42% of peony oil, 32% of sea buckthorn oil, 20% of Bama hemp oil, 10% of rapeseed oil, 8% in soybean oil, and 50% in grape oil. Currently, the edible oil with the most α-linolenic acid is perilla seed oil (Mukhametov et al., 2022).

The World Health Organization/Food and Agriculture Organization (WHO/FAO) (1994) reported that the total n-3 fatty acid intake may be within the 0.5–2%E range. While the minimum dietary requirement of ALA (>0.5%E) for adults can help to prevent deficiency symptoms, the higher value 2%E (ALA) plus n-3 long-chain polyunsaturated fatty acids (LCPUFA) eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) represents the Upper value of Acceptable Macronutrient Distribution Range (AMDR) can range between 0.250 g–2.0 g and may be part of a healthy diet. Whilst ALA may have individual properties in its own right, there is evidence that the n-3 LCPUFA may contribute to the prevention of CHD and possibly other degenerative diseases of ageing. Omega-6 FAs, on the other hand, are PUFAs that are characterized by the presence of a double bond six atoms away from the terminal methyl group in their chemical structure. WHO/FAO (1994) also estimated an average intake of (EAR) for LA of 2%E and an adequate intake (AI) for LA of 2–3% E. The resulting acceptable range (AMDR) for n-6 fatty acids (LA) intake is 2.5–9%E. Whereas the lower value or AI (2.5–3.5%E) corresponds to the prevention of deficiency symptoms, the higher value as part of a healthy diet contributes to long-term health by lowering LDL and total cholesterol levels and therefore the risk for CHD.

The Food and Agriculture Organization (FAO) (1994) recommendation for essential fatty acid consumption showed that there is no rational for a specific recommendation for the n-6 to n-3 ratio, or LA to ALA ratio if intakes of n-6 and n-3 fatty acids lie within the recommendation. However, some authors reported that there is a need for a specific ration of these fatty acids. According to Taha et al. (2014) one of the reasons for the specific ratio of n-6 to n-3, is that a reduction in dietary omega-6 fatty increases the bioavailability of omega-3 polyunsaturated fatty acids in human plasma lipid pools. Simopoulos (2008) showed that decreasing dietary omega-6 fatty acid (i.e. linoleic acid) intake increases the bioavailability of omega-3 fatty acids, which may in turn lower tissue concentrations of the omega-6/omega-3 fatty acid ratio, mitigate the intensity and duration of inflammatory responses and subsequently reduce disease risk.

Recent studies have shown that essential fatty acids are extremely necessary for the growth and development of fetuses and infants, especially for the development of the brain and vision. Thus, women who eat well during pregnancy deposit approximately 2.2 grams of essential fatty acids daily in mother and baby tissues (ChavanGautam et al., 2018; Duttaroy & Basak, 2020; Tressou et al., 2019; Wadhwani et al., 2018). Turmeric contains health-benefiting essential oils such as turmerone, curlone, curumene, cineole, and p-cymene (Nwaekpe et al., 2015) in addition to ω-3 and the omega-6 ω-6 fatty acids. For this reason, it should be consumed adequately to avoid low intakes that would induce essential fatty acid deficiency. However, Simopoulos (1999) reported that essential fatty acid deficiency is rare in humans, but low intakes are said to contribute to dermatitis, renal hypertension, mitochondrial activity disorders, CVDs, type 2 diabetes, impaired brain development, arthritis, depression, and decreased body resistance to infection.

Turmeric is usually boiled and dried before being utilized. Other conventional processing of turmeric consists of slicing the rhizome, sun drying, roasting as well as grinding. Drying is a critically important step during the processing of turmeric with the main aim being to reduce its moisture content from 70-80% at the time of harvest, to a safe limit of 10% for grinding or 6% for safe storage (Singh et al., 2010). The various conditions to which turmeric rhizomes are exposed during processing may have a detrimental effect on the nutritional constituents (Emelike, 2020). Thus, this study determined the effect of different processing methods (roasting and shade-drying) on the fatty acid profile of turmeric (*Curcumin longa*).

Objectives of the study: The specific objectives were to:

1. determine the unsaturated fatty acid contents of the fresh, roasted and shade-dried turmeric oil;
2. estimate the quantity of omega-3 and omega-6 fatty acids in the oil extracted from roasted and shade-dried turmeric samples; and
3. determine the effect of roasting and shade-drying on the fatty acid profile of turmeric oil

Materials and Methods

Study design**:** The study employed a quasi-experimental research design. This design is suitable for the current study because it examined the effect of manipulated independent variables on the dependent variables.

Materials procurement and preparation**:** Two Kilograms (2 kg) of freshly harvested turmeric were purchased from Ogige market, Nsukka Local Government Area, Enugu State. The sample was taken to the Department of Plant Science and Biotechnology Department, Faculty of Biological Sciences, University of Nigeria Nsukka for identification.

The fresh turmeric was sorted and washed with clean running water and put in the colander to drain the water. The drained turmeric was peeled and cut into smaller sizes to make grinding easy. The sample was divided into three equal portions of 600 g each. Sample A and B were subjected to roasting and shade-drying, respectively while sample C was left untreated and served as the control. Sample A was dried in a hot air conventional oven at 55oC for 60 minutes and B was shad-dried for 5 days. All the samples (A, B and C) were ground differently into a fine powder using a Thomas-Wiley laboratory hammer mill, sieved and packaged in an air-tight transparent plastic container.

Fresh turmeric (2 kg)

Sorting

Washing

Draining

Peeling

Cutting

Untreated turmeric shade-dried (5 days) Roasting (muffle furnace at 260°C 30mins) Untreated turmeric

Drying at 55 °C for 60 minutes

Milling using a hammer mill

Sieving

Packaging

Storage at 28 ± 2°C

Figure 1: Processing flow chart of turmeric flour

Extraction of turmeric oil

Method

Two kilograms of fresh turmeric were sorted and washed with clean running water and put in a colander to drain the water. The drained turmeric was peeled and cut in top smaller sizes for easy grinding. The clean dried turmeric was milled using a Thomas- Wiley laboratory hammer mill into a paste. The paste was dissolved in ethanol using a soxhlet extractor. The oil extracted from the turmeric was packaged inside an airtight container and stored at 28. 2°C as shown in the flow chart below.

Fresh turmeric (2kg)
↓
Sorting
↓
Washing
↓
Draining
↓
Peeling
↓
Cutting
↓
Grinding (hammer mill)
↓
Paste
↓
Dissolved in ethanol (soxhlet extractor)
↓
Pick a drop into the analyser
↓
Turmeric oil
↓
Packaging
↓
Storage (28±2oC

Figure 2: Processing flow chart of turmeric oil

Chemical analysis

Determination of total fat

The total fat content of the turmeric was determined using the Kjeldahl method (AOAC, 2010). A 500 ml capacity round bottom flask was filled with 300 ml petroleum ether and fixed to the soxhlet extractor. Two grams of the sample were placed in a label thimble. The extractor thimble was sealed with cotton wool. The heat was applied to the reflux apparatus for 6 hours. The thimble is then removed with care. The petroleum ether was removed and dried at 105°C for 1 hour in an oven. The flask is then cooled in a desiccator and weighed.

$\%\text{fat} = weight\ of\ fat / weight\ of\ sample\ \text{X}100/1$

Determination of fatty acid profile

The fatty acid profile of turmeric was determined using gas chromatography (roasting method). The fresh turmeric is washed with clean water and roasted in a muffle furnace at 260^{o}C for 30 minutes. Turmeric is dried thoroughly and grounded. The sample was passed to a 0.1mm sieve and stored in a cool dry container, 5g of the roasted turmeric sample was measured into the conical flask, and 50 ml of ether was added into a conical flask. The content was thoroughly mixed and allowed to stand for 30 minutes, filtered and kept.

Determination of the fatty acid profile of turmeric using gas chromatography (shade-drying). The turmeric sample was washed with clean water, spread evenly on a clean sheet and subjected to natural airflow for 4-5 days. When the sample was completely dry, it was ground and passed to a 0.1mm sieve and stored in a cool dry container. Five grams of the grounded sample was measured in a conical flask. Fifty millilitres (50ml) of ether was added, and the content was well shaken and allowed to stand for 30 minutes. It was then filtered and kept.

Determination of omega 3 fatty acid and omega 6 fatty acid

Omega 3 fatty acid and omega 6 fatty acids were determined using different spectrophotometer methods. Methylated turmeric samples were measured at different wavelengths with methanol standard. Omega 3 fatty acid = 520nm. Omega 6 fatty acid = 320nm.

$$weight\ of\ fat/weight\ of\ sample \text{ X } 100/1$$

Statistical analysis

Data obtained were analysed using Statistical Product and Service Solution (SPSS) version 22. Results were presented as mean ± standard deviation. One-way Analysis of Variance (ANOVA) was used to compare the means of variables while the Turkey HSD-test was used to separate means at a 5% probability level ($p<0.05$).

RESULTS

Table 1 presents the unsaturated fatty acid contents of fresh, shade-dried and roasted turmeric per 100 g. Fresh turmeric had significantly ($p < 0.05$) lower unsaturated fatty acid (0.53 g) than the shade-dried and roasted samples. Shade-drying and roasting had comparable amounts of unsaturated fatty acids which were 2.51 ±0.02 and 2.03 ±0.03, respectively.

Table 1: Unsaturated fatty acid contents of fresh, shade-dried and roasted turmeric samples (per 100 g)

Sample	Unsaturated fatty acid (Mean ±SD)
FT	0.53 ± 0.03^a
ST	2.51 ± 0.02^b
RT	2.03 ± 0.03^b

Values are Mean ± Standard deviation (SD) of triplicate determination. Mean values on the same column with different superscripts are significant at $p < 0.05$, FT = fresh turmeric, ST= Shaed-dried turmeric, RT = roasted turmeric

Table 2 shows the omega-3 and omega-6 fatty acids in fresh, shade-dried and roasted turmeric (per 100 g). Shade drying and roasting led to significant ($p < 0.05$) increases in the omega-3 and omega-6 fatty acids compared to the fresh sample.

Table 2: Omega-3 and omega-6 fatty acids on fresh, shade-dried and roasted turmeric (per 100 g)

Name of polyunsaturated fatty acids (mg)	FT	ST	RT
Total omega-3 fatty acid	293.89 ± 4.61^b	1029.93 ± 0.08^a	720.72 ± 0.33^a
Total omega-6 fatty acid	0.31 ± 0.01^b	0.53 ± 0.01^a	0.42 ± 0.01^a

Values are Mean ± Standard deviation (SD) of triplicate determination. Mean values on the same column with different superscripts are significant at $p <0.05$, FT = fresh turmeric, ST= Shaed-dried turmeric, RT = roasted turmeric

The effect of temperature (shade-drying and roasting) on the fatty acid profile of turmeric oil is shown in Table 3. The myristic acid content of the fresh and roasted samples was statistically ($p < 0.05$) higher (20.17 ±0.01and 28.48 ± 0.07) compared to the shade-dried sample. The fresh turmeric sample had higher (16.13 ± 0.03) unolenic fatty acid than the shade-dried and roasted samples. However, the unoleic fatty acid content of shade-dried (8.17 ± 0.01) and roasted (10.76 ± 0.01) samples was significantly ($p < 0.05$) higher than that of the fresh sample. The shade-dried sample contained more palmitic (44.14 ± 0.03 mg), linoleic (12.18± 0.06) and Eicosadienoic (10.42 ± 0.02) fatty acids than the other samples.

Table 3: Effect of shade-drying and roasting on the fatty acid profile of turmeric oil per (100g)

Fatty acid (mg)	FT	ST	RT
Myristic acid	20.17 ±0.01^b	3.73 ± 0.04^c	28.48 ± 0.07^a
Palmitic acid	6.32±0.01^b	44.14 ± 0.03^a	0.00 ± 0.00^c
Oleic acid	42.15 ± 0.03^a	31.73 ± 0.06^b	43.65 ± 0.01^a
Unoleic acid	2.14 ± 0.03^b	8.17 ± 0.01^a	10.76 ± 0.01^a
Linoleic acid	3.37 ± 0.05^b	12.18± 0.06^a	3.96 ± 0.56^b
Unolenic acid	16.13 ± 0.03^a	1.85 ± 0.02^b	10.42 ± o.33^b
Eicosadienoic acid	3.84 ± 0.03^b	10.42 ± 0.02^a	0.55 ± 0.01^c

Values are Mean ± Standard deviation (SD) of triplicate determination. Mean values on the same column with different superscripts are significant at p <0.05, FT = fresh turmeric, ST= Shaed-dried turmeric, RT = roasted turmeric

Discussion

The fast increase in the demand for quality fats and oils in the world has aroused the interest of researchers to find other non-conventional sources. Hence, the importance of exploring the effect of temperature on the fatty acid content of turmeric oil in the present study as an alternative to other nutritive quality ones already known. In the present study, the amount of unsaturated fatty acids in all the samples was not negligible implying that it may not serve as an alternative to other conventional oil. However, the fresh turmeric oil had significantly lower unsaturated fatty acid than the oil from both the shade-dried and roasted samples. In the same vein, shade-dried and roasted turmeric oil had significantly higher ω-3 and ω-6 fatty acids compared to the fresh sample suggesting that heat treatment favoured these fatty acids in turmeric oil.

This implies that temperature or application of different processing methods like shade-drying and roasting in this case, provided better oil than oil from the raw turmeric. Unsaturated fats are composed of double bonds which make them liquids at room temperature. They have been found to improve heart health more than saturated fatty acids. Thus, consumption of turmeric oil may help to protect the heart against certain disease conditions. According to Paula et al. (2011), turmeric oil is better than other vegetable oils concerning health benefits.

These observations may be attributable to the effect of heat and the method of extraction on the chemical composition of the spice. Heat-related chemical reactions involved in domestic cooking including drying and roasting have been shown to alter the bioactive compounds such as fatty acids in spices by changing their physical, chemical and nutritional characteristics (Cortez et al., 2020; Sheikh et al., 2010). Additionally, Choi et al. (2014**) reported that** curcuminoids found in turmeric are susceptible to long drying times, high temperatures, extraction, processing, and storage. Omega-6 and ω-3 fatty are essential fatty acids that must be obtained from the diet. However, Weill et al. (2020) reported that it is necessary to strike a balance in the consumption of essential fatty acids to maintain a healthy heart while improving the general physical and mental health of humans.

These fatty acids perform several important functions in the body including but not limited to normal functioning of the brain. It has been found that the brain contains more than 100 billion cells, and ω-3 fatty acids are the main materials that make up these cells (Mukhametov et al., 2022). Calder (2010) reported that they bind to the cell membrane and increase cell membrane fluidity, which is very important for the maintenance of normal brain cells. According to Tanaka et al. (2012), adequate membrane fluidity helps the brain transform and adapt to new information. The anti-inflammatory effect of omega-3 fatty acids can further be used in the treatment of inflammatory diseases. Wyss-Coray and Rogers (2012) found that omega-3 is a precursor to anti-inflammatory hormones and helps relieve inflammation in the brain and other body organs.

The roasted turmeric oil sample had significantly higher myristic fatty acid than the fresh and shade-dried samples. This implies that consumption of roasted turmeric oil may predispose humans to the risk of cardiovascular diseases since it is a saturated fat. Studies by *Mensink (2016) and Schwingshackl et al. (2018) demonstrated that* myristic acid consumption increases the level of low-density lipoprotein (LDL) cholesterol.

The palmitic acid (6.32mg) of the fresh turmeric oils in this study was similar to the study of Paula et al. (2011) who found that three fresh turmeric oils collected in three different regions contained 6.00mg, 5.59mg and 5.73mg of palmitic acid. Significant differences existed in the palmitic and eicosadienoic acids among the three turmeric samples studied. According to Gustone (2011) palmitic acid is the most important and widespread saturated fatty acid present in animal fats and palm oil and the acid has been for a long time been negatively depicted for its putative detrimental health effects, shadowing its multiple crucial physiological activities

The Oleic acid content of the fresh and the roasted oil was statistically comparable to each other while that of the shade-dried sample was significantly lower than the other samples. According to a study by Nollet (2004), oleic acid was lower in all the turmeric oil samples than those in olive oil (55-83Mg) and safflower oil (79.7mg) while the palmitic acid content was comparable to that of safflower oil (5.5-6.5mg). The quantity of oleic acid content of the fresh turmeric oil sample in the present study was similar to those recorded by Paula et al. (2011) which showed that fresh turmeric obtained from three different regions in Bangladesh contained 42.15mg, 43.66mg and 31.73mg of oleic acid. Higher oleic acid contained in the study roasted turmeric oil may help to reduce the raised level of total plasma cholesterol without reducing the high-density lipoprotein (HDL) cholesterol level.

Conclusion

Shade-drying and roasting had comparable and higher amounts of unsaturated, ω-3 and ω-6 fatty acid contents. In terms of the fatty acid profile of turmeric samples, roasting had higher myristic acid, oleic acid and unoleic acid and can be considered the best method because it provides healthier fatty acids (unsaturated fatty acids) than the fresh and shade-dried samples. However, there is a need to strike a balance in the consumption of saturated and unsaturated fatty acids for better overall health.

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