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Effect Of Drying Method On Theantioxidant, Phytochemical, Antinutrient And Selected Chemical Properties Of Turmeric Powder

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Abstract
Background: *Turmeric (Curcumin longa) is one of the known spices that have culinary uses as well as medical and medicinal uses. It is a golden spice derived from the rhizome of curcuma longa plant which belongs to the family of Zingiberaceae. Turmeric is a therapeutic plant that is consumed as a flavouring, preservative and colouring agent. Turmeric has anti-inflammatory, antioxidant and phytochemical properties. The main active ingredient in turmeric is curcumin. Curcumin has free radical scavenging properties. Despite the health benefits of turmeric, few people use it partly because of the cumbersomeness of the preparation, staining and drying out of the tubers during storage. This study produced turmeric powder and evaluated the effect of drying method on the antioxidant, phytochemical, antinutritional and chemical properties of the products in view of ascertaining the best processing method in terms of nutrient retention.*
Materials and Methods: *In this randomized controlled study, three kilograms (3 kg) of turmeric rhizome were cleaned, peeled, sliced thinly and shared into three equal parts. One part was shade dried for 5 days, the second, sun dried for 48 h and the third oven dried at 55±1^{0}C for 6 h. The dried samples were milled separately and analyzed for antioxidants (curcumin, beta carotene, vitamins C and E), phytochemicals (flavonoids, total phenol, saponin and alkaloids), antinutrients (phytate, tannin and oxalate) and some chemical properties (moisture, fat, calcium, iron, zinc and iodine). Data obtained were analyzed statistically using one way analysis of variance and means separated using Duncan new multiple range test. Significance was accepted at 5 % probability ($p<0.05$).*
Results: *The beta carotene, vitamin C, E and curcumin contents were high ranging from 24.54 to 27.78, 662.24 to 1397.55, 12.54 to 17.88 and 16.39 to 17.89 mg/100g, respectively, suggesting antioxidant potential of turmeric. The high flavonoid content (7.23 to 9.28 %) indicated that turmeric may have inhibitory activity against disease causing organisms and may act as biological response modifier. The low values of alkaloid and saponin obtained maybe an indication of potency of the product. The low values of phytate (0.88 to 1.1 2 %), tannin (2.02 to 3.96 %) and oxalate (0.15 to 0.20 %) are suggestive of high nutrient bioavailability. The samples exhibited low calcium, iron, zinc, and high iodine values (1.01 to 1.63 %, 0.20 to 0.31, 1.27 to 3.11 and 7.27 to 25.86 percent respectively. Significant ($p<0.05$) variations existed among the values indicating drying techniques influence.*
Conclusion: *The results obtained from the study showed that method of drying has significant effect on the parameters analyzed. Sun drying or shade drying are preferred for turmeric powder processing.*
Keyword: *Turmeric; Antioxidant; Phytochemical; Antinutrient; Curcumin; Curcumin longa*

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I. Introduction

Turmeric is one of the known spices that have culinary uses as well s medical or medicinal uses. It is a golden spice derived from the rhizome of curcuma longa plant which belong to the zingiberaceae family (Gupta et al, 2013). Spices are aromatic or pungent vegetable substances used to flavour foods. Cambridge dictionary defined spice as a substance made from plants that is used to give special flavour to food, while Wikipedia defined spice as a seed, fruit, root, back or other plant substances primarily used for flavouring or colouring food. Spices are made from parts of plant such as fruit, seeds, or roots usually dried and often made into powder. Examples of spices include cinnamon, ginger, cloves, cumin, pepper etc. Spices are different from herbs. Herbs are the leaves, flowers or stem of a plant used for flavouring or as a garnish. Examples are Angelica (Angelica archangelica), Basil, Bay leaf, Corrianda leaf, Curry leaf etc.

Dried curcuma longa is a component of curry powder that gives it yellow colour. Turmeric is used in traditional Indian medicine, Hindu religious ceremony and also widely in foods for its flavour and colour. Yandav (2017) and Akram (2010) described turmeric as being aromatic, stimulant and carminative respectively. Turmeric *(Curcuma longa)* is a therapeutic plant that is widely consumed as a flavouring, preservative and colouring agent

in South Africa, India and China. It is notorious for its unique medicinal properties. Turmeric is cultivated in the tropical regions such as Pakistan, China, Peru, India (Singh and Jain, 2012) including Nigeria. According to Nisar et al. (2015), turmeric is a native of India, grown commercially in many countries of south Asia, China and India, well known for culinary use as a main constituent of curry powder, approved food addictive in the United States, called haldi or haridra in India, Manjal and its powder Manjal thool in Tamil language and also known as Indian saffron because it was broadly used as a substitute to the more expensive saffron spice.

Since ancient times, turmeric has been used as principal ingredient of dishes originating from Bangladesh and India for its colour, flavour and taste. It is also used in social and religious ceremonies, in Ayurvedic and folk medicines against various ailments (Gupta et al 2013, Hassan and Mahmud, 2014). Tanvir et al (2017) recorded that dry turmeric contains 69.48% carbohydrate, 6.3% protein, 5.1% oil, 3.5% minerals and other elements.

Ahmad et al (2010) reported that turmeric is used in the past for treatment of diabetic wounds, cough anorexia biliary disorders and hepatic disorders. Curcuma longa has healing influence on digestive system and embraces mucus secretion in the digestive tract. According to literature, turmeric has specified antibacterial, anti-helmintic, anticancer, antiparasitic, antiseptic, anti-oxidative, anti-inflammatory, anti-rheumatic, anti-tumor, anti-phlegmatic, antiviral, astringent, aromatic, blood purifier, clear skin colour, remove wound maggots, hepta protective, stop liver obstruction, heal wounds, stimulants and sedatives and in the food industries as colouring agent as well as additive to impact flavours in curries. Chainani-wu (2003) reported that turmeric is a source of bioactive compounds such as antioxidants, polyphenols, and flavonoids which can substitute for antibiotics used in food and nonfood products. The volatile constituents of turmeric include tumerone, zingiberene, artumerone and curlone, while the curcuminoids are the non-volatile constituents. The main active ingredient in turmeric is curcumin (a yellow-orange dye) which is also a bioactive element. Curcuminoid mainly comprise of curcumin, dimethoxy curcumin and bisdemethoxycurcumin. According to Naz et al. (2010), curcumin is the main curcuminoid element that is responsible for the turmeric biological functions. It is an orange-crystalline substance that is insoluble in water and a powerful bioactive portion of turmeric.

Allahabad University (AU) biochemists research led by Prof. S.I Rizu said that turmeric is a key to longer life. Some of the health benefits reported that it has anti-inflammatory properties, help prevent arthritis, controls diabetes, detoxifies the liver, improves skin health, prevents cancer, improves digestion, boosts immune system, promotes weight loss, and helps in wood healing. Fresh turmeric has the following benefits-- fight inflammation, lower cholesterol, boosts brain function, aids fat metabolism, and prevents progression of Alzheimer (Arutselvi et al., 2012).

Cooking turmeric rhizome for less than 15 minutes does not destroy turmeric but increase the bioavailability of curcumin. So, heating turmeric is a golden latte or adding it to cooking such as in curry or scrambled egg will maximize its absorption by the body. Another way to increase bioavailability of turmeric is to consume the spice with a source of fat such as avocado pear, peanut butter and nuts, fish, pepper etc. and curcumin will be directly absorbed into the blood stream and by pass the liver (http://www.ncbii nim.n.hgovzpnc)

Phytochemicals are important compounds found in medicinal plants that are not essential for the normal functioning of the human body but are active and exert beneficial effect on health or in amelioration of disease. Turmeric according to Jain (2012) is oleoresin which consist of light volatile oil fraction and a heavy yellow-brown fraction. It comprises of large number of curcuminoids, sesquiterpenoids and monoterpenoids. The active components of turmeric include the flavonoid curcumin and different volatile oil like turmeron, gingibaron and atlanton.

According to Thakur (2013), free radicals with unpaired electrons (hydroxyl, peroxide and superoxide) are formed in the normal and pathological metabolism and compounds which can scavenge free radical compounds contrast many diseases and pathological cells, antioxidants plays significant role in protecting the human body cells from damage by many reactive oxygen species, antioxidants at low molecular concentration contrast the free radicals or converts the radical in an inert compound through oxy-reduction reaction. Free radicals are key offenders in lipid oxidation. Plant which contains biologically active compounds have powerful antioxidant properties, In inflammatory disease, there is excessive production of oxygen, activation of phagocytes hydroxide (OH) radicals and none free radical species which are harmful to the tissues due to direct powerful oxidizing action or indirect formation of OH and hydrogen peroxide radicals from oxygen. Thus, initiates lipid oxidation that results in cell membrane destruction. Inflammatory reaction is aggravated by tissue damage by the production of various medications and chemotactic factors (Thakur, 2013). Turmeric and its components curcumin noted Nisar et al, (2015) showed great antioxidants activity in relation to vitamin C and E and that a study indicated that curcumin was eight times more powerful than vitamin E in inhibiting lipid oxidation. The aqueous extract of fresh rhizomes exhibited greater antioxidant potential relative to dry rhizomes and considerable loss of antioxidant potential of turmeric rhizomes occurred when turned into dry powder.

In spite of all these benefits, few people know and use turmeric partly due to cumbersomeness of the preparation. Turmeric is mostly used fresh which leads to the peeling of the rhizome and pounding. The most irritating and disgusting aspect of the preparation is the staining (colouring) of hands, knives and utensils used in

the preparation. Secondly, the rhizome dries out quickly especially during the dry season making it difficult and impossible to peel which invariably reduces the shelf life. This also leads to the neglect of use not minding the benefits. In Nigerian market, there is no documentation of a successful dry product from turmeric that offers perceptible benefit and valued by consumers. More so, there is no documentation on the chemical composition, anti-nutritional, antioxidant (except curcumin) and phytochemical contents of turmeric powder produced using various drying methods. Thus, the need for the study to produce and evaluate turmeric powder using various drying methods.

Therefore, the aim of this study is to produce turmeric powder and evaluate the antioxidant, phytochemical, antinutrient and some chemical properties of the products in view of ascertaining the effect of these drying methods on the parameters assessed in terms of nutrient retention and also determine the best method to adopt for turmeric powder processing.

II. Materials And Methods

Sources of Materials:

The turmeric and the commercial control used in this study were purchased from new Orie Emene market, Enugu, Enugu state, Nigeria. The chemicals used were bought from standard chemical dealers.

Sample Preparation

Three kilograms (3 kg) of turmeric rhizome was cleaned, washed thoroughly, rinsed and peeled. The peeled turmeric rhizome was sliced thinly (1mm thick) and shared into three equal parts. One part was kept in the kitchen for 5 days to dry (shade drying). The second part was dried under the sun (sun drying) for 48 h and the third part was dried in the oven (oven drying) at 55ºC for 6 h.

At the end of the drying periods, the samples were ground into powder, separately, packaged in airtight polyethylene bag and labeled for analysis.

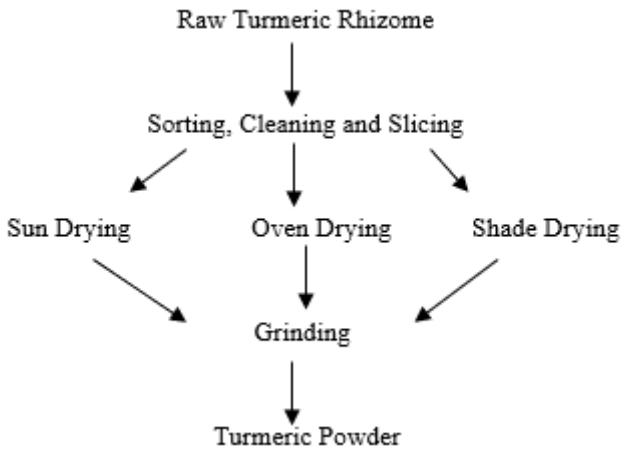

Fig 1. Turmeric powder production process

Chemical Composition
Moisture and Fat Content: AOAC (2010)
Iron, Zinc and Calcium: Atomic Absorption Spectrophotometer (AAS) Okoronkwo et al. (2023)
Calcium: AOAC (2010)
Iodine: Thiosulphate titrimetric method as described by Ekechukwu (2022)
Antioxidants
Curcumin and Beta Carotene: AOAC (2010)
Vitamin C: Titrimetric method as described by Ijeomah, et al. (2024)
Vitamin E: Colorimetric method of Association of vitamin chemists as described by Ijeomah, et al. (2024)
Phytochemicals
Flavonoids, Total phenol, Saponin and Alkaloids: AOAC (2010)
Antinutrients
Phytate, tannin and oxalate Content: AOAC (2010)

Statistical Analysis

Data collected were subjected to one way analysis of variance (ANOVA) using IBM SPSS statistics version 26 software package for Social Science (SPSS Inc., USA), means were separated using Duncan's new multiple range test and significance was accepted at 5 % probability level *(p<0.05)*. Results were expressed as mean ± standard deviation (SD) of triplicate determinations.

III. Result

Antioxidant content of the samples

After analysis, antioxidants found in the samples ranged from Beta carotene: 24.54 – 27.78 µg/g, Vitamin C 562.27 – 1397.55 mg/100g, Vitamin E: 11.64 – 17.88 mg/100g and Curcumin: 11.31 – 17.89 mg/g.

Table I shows the antioxidant contents of the samples [shade (room) dried turmeric powder (ShDTP), sun dried turmeric powder (SuDTP), oven dried turmeric powder (OvDTP) and commercially dried turmeric powder (CoDTP)]. The beta carotene level in the samples was highest (27.78±0.07 µg/g) in the sundried sample and least (24.54±0.09 µg/g) in the oven dried sample while the amount found in sample ShDTP and CoDTP were 25.88±0.05 µg/g and 24.87±0.08 µg/g respectively. There were significant *(p<0.05)* differences among the beta carotene level of the samples. Of all the antioxidants analyzed, vitamin C was the most predominant. Vitamin C was highest (1397.55 mg/100g) in the shade dried (ShDTP) sample and lowest (662.24 mg/100g) in the oven dried (OvDTP) sample. Sundried sample showed vitamin C content of 1067.67 mg/100g. The vitamin C content of the samples was higher *(p<0.05)* than (562.27 mg/100g) of the commercial sample. There were great variations among the vitamin C content of the samples.

Higher vitamin E content was observed in sample SuDTP (17.88±0.00 mg/100g) in relation to other samples. Vitamin E was found to be 14.89±0.01 mg/100g in sample OvDTP and 12.54±0.00 mg/100g in sample ShDTP. Sample CoDTP showed the least value (11.64±0.06 mg/100g). Significant *(p<0.05)* differences existed in the vitamin E contents of the samples. There were variations in the levels of curcumin found in the samples. The highest level (17.89±0.01 mg/g) was observed in sample OvDTP while sample ShDTP recorded the lowest (16.39 mg/g) level of curcumin. Sample SuDTP had 17.39±0.01 mg/g and sample CoDTP (11.31±0.06 mg/g) of curcumin. The values obtained for the antioxidant properties analyzed were higher than those of the commercial (CoDTP) sample except for beta carotene and varied significantly *(p<0.05)* among the samples indicating influence of drying technique.

Table 1. Antioxidant content of the samples.

Parameter mg/100g	ShDTP	SuDTP	OvDTP	CoDTP
Beta Carotene µg/g	25.88^{b}± 0.05	27.78^{a}±0.07	24.54^{d}±0.09	24.87^{c}±0.08
Vitamin C	1397.55^{a}±1.17	1067.67^{b}±2.65	662.24^{c}±1.54	562.27^{d}±2.00
Vitamin E	12.54^{c}±0.00	17.88^{a}±0.00	14.89^{b}±0.01	11.64^{d}± 0.06
Curcumin mg/g	16.39^{c}+ 0.01	17.39^{b} + 0.01	17.89^{a}± 0.01	11.31^{d}± 0.06

values are means of triplicate determination ± standard deviation (SD). Means with different superscripts on the same row are significantly different *(p<0.05)*. ShDTP=Shade dried turmeric powder, SuDTP = Sundried turmeric powder, OvDTP =Oven dried turmeric powder and CoDTP=Commercially dried turmeric powder.

Phytochemical Content of the samples

Phytochemical levels in the samples occurred in the range of: flavonoid (7.23 – 13.60 %), phenol (1.39 – 1.91 mg/g), saponin (4.81 – 6.96 %) and alkaloid (3.35 – 7.11 %).

The phytochemical content of the samples is shown in Table 2. The amount of flavonoid recorded for the samples were SuDTP (7.23±0.005 %), (ShDTP) 9.28±0.005 %, OvDTP (7.49±0.004 %) and CoDTP (13.60±0.005%). Significant *(p<0.05)* differences were observed in the flavonoid contents of the samples. The phenol content (1.91±0.002 mg/g) of the sun-dried sample (SuDTP) differed *(p<0.05)* from that of the other samples. Oven dried (OvDTP) sample had the least value (1.39±0.002 mg/g) of phenol followed by the shade dried sample (ShDTP) (1.76±0.002 mg/g). Sample ShDTP had the highest saponin content (6.96±0.010 %) followed by samples OvDTP (5.95±0.001 %) and CoDTP (5.21±0.001 %). The least was sample SuDTP (4.81±0.001 %). The saponin content of the samples differed significantly *(p<0.05).* Significant *(p<0.05)* difference existed in the alkaloid content of the samples which ranged from 3.35±0.001 % in the shade dried sample to 5.81±0.001 % in the oven dried sample. Sundried sample had alkaloid content of 3.41±0.001 %. The values were lower than the value 7.11±0.001 % observed for the commercial sample.

Table 2. Phytochemical Content of the Samples

Parameter %	ShDTP	SuDTP	OvDTP	CoDTP
Flavonoid	9.28^{b}± 0.005	7.23^{d}± 0.005	7.49^{c}± 0.004	13.60^{a}±0.005
Phenol (mg/g)	1.76^{c}±0.002	1.91^{a}±0.002	1.39^{d}±0.002	1.88^{b}±0.002

Saponin	6.96^{a}±0.010	4.81^{d}±0.001	5.95^{c}±0.001	5.21^{c}±0.001
Alkaloid	3.35^{d}± 0.001	3.41^{c}±0.001	5.81^{b}±0.001	7.11^{a}±0.001

values are means of triplicate determination ± standard deviation (SD). Means with different superscripts on the same row are significantly different *(p<0.05).* ShDTP=Shade dried turmeric powder, SuDTP = Sundried turmeric powder, OvDTP =Oven dried turmeric powder and CoDTP=Commercially dried turmeric powder.

Antinutrient contents of the samples

The antinutrient content of the samples ranged from 0.88 – 1.12 % for phytate, 2.02 – 3.96 % for tannin and 0.15 – 0.21 % for oxalate.

Table 3 shows the antinutrient contents of the samples [shade dried turmeric powder (ShDTP), sun dried turmeric powder (SuDTP), oven dried turmeric powder (OvDTP) and commercial dried turmeric powder (CoDTP)]. The lowest level (0.88±0.001 %) of phytate was observed in sample OvDTP. The level of phytate in the sample, ShDTP (1.12±0.001 %) and SuDTP (1.02±0.001 %) were significantly *(p<0.05)* higher than that of the oven dried sample (0.88±0.001 %). The phytate level (1.02±0.001 %) of sundried sample compared favourably *(p>0.05)* with the phytate level (1.04±0.001 %) of the commercial sample. The value of tannin recorded for shade dried sample was 2.28±0.002 %. This value was significantly *(p<0.05)* higher than the values (2.02±0.002 % and 2.13±0.002 %) recorded for the shade dried sample and commercial sample respectively and lower than the value (3.96±0.001 %) exhibited by the oven dried sample. Oxalate occurred highest (0.20±0.002 %) in sample OvDTP followed by sample SuDTP (0.18±0.003 %) and the least, sample ShDTP (0.15±0.003 %). The oven dried sample (OvDTP) and the commercial sample (CoDTP) (0.21±0.001 %) had comparable *(p>0.05)* oxalate contents. However, significant *(p<0.05)* differences existed among the values of antinutrients obtained for the samples shown in Table

Table 3. Antinutrient Content of the Samples

Parameter %	ShDTP	SuDTP	OvDTP	CoDTP
Phytate	1.12^{a} ±0.001	1.02^{b} ±0.001	0.88^{c} ±0.001	1.04^{b} ±0.001
Tannin	2.28^{b} ±0.002	2.02^{d} ±0.002	3.96^{a} ±0.001	2.13^{c} ±0.002
Oxalate	0.15^{c} ±0.003	0.18^{b} ±0.003	0.20^{a} ±0.002	0.21^{a} ±0.001

values are means of triplicate determination ± standard deviation (SD). Means with different superscripts on the same row are significantly different *(p<0.05)*. ShDTP= Shade dried turmeric powder, SuDTP = Sundried turmeric powder, OvDTP =Oven dried turmeric powder and CoDTP=Commercially dried turmeric powder.

Selected chemical composition of the samples

Selected chemical composition of the samples had values that ranged from moisture (1.43 – 3.13 %), fat (4.52 – 8.27 %), calcium (1.01 – 1.63 mg/100g), iron (0.20 – 0.31 mg/100g), zinc (0.89 – 3.11 mg/g) and iodine (17.27 – 25.86 mg/g).

The chemical composition of the samples [shade dried turmeric powder (ShDTP), sundried turmeric powder (SuDTP), Oven dried turmeric powder (OvDTP) and commercial dried turmeric powder (CoDTP)] is presented in Table 4. The oven dried sample had the least moisture content (1.43±0.002 %) which differed *(p<0.05)* appreciably from the moisture content of other samples (3.13±0.001 % for shade dried sample, 1.98±0.002 % for sun dried samples and 1.84±0.002 % for commercial sample). The fat contents of the samples were low (4.52±0.003 % for sample OvDTP, 6.05±0.001 % for sample SuDTP, 7.23±0.003 % sample ShDTP and 8.27±0.003 % for sample CoDTP). There were significant *(p<0.05)* differences among the fat contents of the samples. The calcium contents of the samples were very low ranging from 1.01±0.002 % in the shade dried samples, 1.28±0.003 % in the commercial sample, 1.33±0.002 % in the oven dried sample to 1.63±0.001 % in the sun-dried sample.

The iron content of the samples was low. Samples ShDTP and CoDTP showed similar *(p>0.05)* iron values (0.20±0.002 %) so also samples SuDTP and OvDTP (0.31±0.001 %). The shade dried sample contained higher level of zinc (3.11±0.001 %) than other heat processed samples (2.62±0.001 % for sun dried and 1.27±0.001 % for oven dried samples). The level of iodine obtained for the samples were high ranging from 17.27±0.002 % in the oven dried sample 20.07±0.002 % in the commercial control, 24.61±0.002 % in the shade dried sample to 25.86±0.001 % in the sun-dried sample. Significant *(p<0.05)* differences existed among the levels of iodine in the samples. Significant *(p<0.05)* variations were observed in the values obtained for the selected chemical components analyzed.

Table 4. Selected Chemical composition of the samples±

Parameter %	ShDTP	SuDTP	OvDTP	CoDTP
Moisture	3.13^{a} ±0.001	1.98^{b} ±0.002	1.43^{d} ±0.002	1.84^{c} ±0.002

Fat	7.23^{b} ±0.003	6.05^{c} ±0.001	4.52^{d} ±0.003	8.27^{a} ±0.003
Calcium	1.01^{d} ±0.002	1.63^{a} ±0.001	1.33^{b} ±0.002	1.28^{c} ±0.003
Iron	0.31^{a} ±0.001	0.20^{b} ±0.002	0.20^{b} ±0.002	0.31^{a} ±0.002
Zinc	3.11^{a} ±0.001	2.62^{b} ±0.001	1.27^{c} ±0.001	0.89^{d} ±0.002
Iodine	24.61^{b} ±0.002	25.86^{a} ±0.001	17.27^{d} ±0.002	20.07^{c} ±0.002

values are means of triplicate determination ± standard deviation (SD). Means with different superscripts on the same row are significantly different *(p<0.05)*. ShDTP=Shade dried turmeric powder, SuDTP = Sundried turmeric powder, OvDTP =Oven dried turmeric powder and CoDTP=Commercially dried turmeric powder.

IV. Discussion

Antioxidant Content of the samples

The variation in the beta carotene contents of the samples shows that drying method influenced the beta carotene content of turmeric powder. The obtained values were lower than 40.45 mg/100g for turmeric and 92.96 mg/100g for total carotenoids recorded by Shirin Adel and Jamuna (2010) for ginger root powder. The low values of beta carotene observed in the samples may be attributed to the effects of heat, light and possible oxidation which may have occurred during drying because these conditions are known to destroy carotene in foods. Of all the antioxidants analyzed, vitamin C was the most predominant. There were great variations among the vitamin C content of the samples. This is an indication that drying method has effect on the vitamin C content of the samples. The very high amount of vitamin C recorded in sample ShDTP was probably due to the fact that heat was not employed during drying. Heat and light are known to destroy vitamin C because it is sensitive to heat and light. The high levels of vitamin C observed in the sample may be as a result of the temperature used in the drying and the intensity of the sun. The low value (10.97 mg/100g) obtained for ginger root powder by Tanvir et al. (2017) was very much lower than those of the samples showing that turmeric is a better source of vitamin C than ginger root or can be as a result of the higher temperature used for drying ginger root.

The highest amount (17.88 mg/100g) of vitamin E showed by sample SuDTP may be attributed to the melting of the fat by the sun. Oven temperature may have dried some of the fat in sample OvDTP while some of the fats might not have melted therefore were not available hence the lowest value (12. 54 mg/) of vitamin E showed by sample ShDTP. The level of vitamin E in the samples were higher *(p<0.05)* than the level (0.21 mg/100g) obtained by Tanvir et al. (2017). Vitamin E is an antioxidant that helps to fight damage caused by free radical micro-organisms to the body (Tanvir et al, 2017). The values of curcumin recorded for the samples were higher than the range of 0.3-8.8% obtained by Gupta et al. (2013). According to Gupta et al. (2013), curcumin (a yellow-orange dye) is the main active ingredient in turmeric whose varied biological properties and lack of toxicity even when administered at higher doses makes its uses attractive to explore.

Phytochemical Content of the samples

The phytochemical content of the samples is shown in Table 2. The residual flavonoids ranged from 7.23 % in the sun dried (SuDTP) sample to 9.28 % in the shade dried (ShDTP) sample. Significant *(p<0.05)* differences were observed in the flavonoid contents of the samples. Non employment of heat during drying of shade dried sample may have accounted for the high value observed for the shade dried turmeric powder. The observed values of flavonoid were higher than 3.51 % obtained by Kela et al. (2023) for dried ginger root. The variation observed in the values of residual flavonoid obtained by Ikpeama et al. (2014) and for the samples may be as a result of the composition of the soil where the tumeric were cultivated. Flavonoids (quercetin) according to Kela et al. (2023) have inhibitory activity against disease causing organisms in animals, may be a biological response modifier i.e. may modify allergens, viruses and carcinogens as well as have anti allergens, anti-inflammatory, anti-microbial, anti-cancer and anti-diarrheal activities. The phenol content (1.91 mg/g) of the sun-dried sample (SuDTP) differed *(p<0.05)* from that of the other samples. Oven dried (OvDTP) sample had the least value (1.39 mg/g) of phenol followed by the shade dried sample (ShDTP) (1.76 mg/g). The low value obtained for sample OvDTP may be due to high temperature used during drying. The observed phenol values were higher than 0.08 % observed by Ikpeama et al. (2014) and lower than 1.81 mg/g recorded by Kela et al. (2023) for ginger root powder except the value 1.91 mg/g obtained for sun dried sample that was higher. Sample ShDTP had the highest saponin content (6.96 %) followed by sample OvDTP (5.95 %) and the least was sample SuDTP (4.81 %).

The saponin content of the samples differed significantly *(p<0.05)* and were higher than the saponin content (0.45 %) of dried turmeric recorded by Ikpeama et al. (2014). Significant *(p<0.05)* difference existed in the alkaloid content of the samples which ranged from 3.35 % in the shade dried sample to 5.81 % in the oven dried sample. The values were lower and higher than the values 7.11 % and 0.70 % observed for the commercial sample and by Ikpeama et al. (2014) respectively for turmeric powder. Alkaloids and saponins appear to have antagonistic interaction at least with regards to antioxidant activity. This potentially lowers their activity as antioxidants and possibly the potency of extracts containing them. Generally, phytochemicals limit the digestibility of proteins and carbohydrates and reduce the bioavailability of these nutrients. Some phytochemicals

are antinutrients that interfere with the absorption of nutrients. Others such as some polyphenols and flavonoids may be pro-oxidants in high digested amounts. Pro-oxidants are chemicals that induce oxidative stress either by generating reacting oxygen species, or by inhibiting antioxidant systems.

Antinutrient content of the samples

The low value of phytate observed in sample OvDTP. may be attributed to high drying temperature. The percentage of phytate recorded for the samples were higher than (0.77 %) recorded by Kela et al. (2023) for ginger root powder. The tannin content of the samples was highest (3.96 %) in the oven dried sample and lowest (2.02 %) in the sun-dried samples. The value of phytate for shade dried sample was 2.28 %. The high tannin content of the oven dried sample may be as a result of heat. The phytate and tannin values obtained from the samples showed that oven drying increases the tannin content and reduces phytate contents of turmeric. The samples showed higher tannin contents relative to 1.08 % and 1.05 % recorded by Ikpeama et al. (2014) for dried turmeric and Kela et al. (2023) for ginger root powder respectively.

Tannins are plant polyphenols which have ability to form complexes with metal ions and with macro molecules such as proteins and polysaccharides. Dietary tannins are said to reduce feed efficiency and weight gain in animals. Environmental factors and the method of preparation of samples may influence the concentration of tannins present in a sample. Tannin presence influences protein utilization and build defense mechanism against microorganisms (Kela et al., 2023). Non application of heat may have accounted for the low level of oxalate observed in the shade dried sample (ShDTP). However, little variations were noticed in the phytate and oxalate contents of the samples. The low level of antinutrients (phytate, tannin and oxalate) of suggestive high bioavailability of the nutrients in turmeric especially calcium, lysine, iron and protein. Antinutrients are chemical substances contained in food which interfere with the bioavailability and utilization of profitable nutrients in the body. Tannins have negative effect on the bioavailability of amino acid including lysine while phytate binds calcium and other minerals in pigmented seeds and coloured foods (Ijeomah et al., 2023).

Selected chemical composition of the samples

The high moisture content reported for sample ShDTP may be due to the fact that heat was not involved in the drying. The study recorded lower moisture values than the values 15.02 % and 13.75 % reported by Shirin Adel and Jamuna (2010) and Sarkar et al. (2023) for dried ginger root and air-dried ginger root respectively. The fat contents of the samples were (4.52-7.23 %) higher than the value 4.37 % reported by Shirin Adel and Jamuna (2010) for dried ginger root. There were significant *($p<0.05$)* differences among the fat contents of the samples. The trend of the levels of fat observed in the samples showed that the higher the temperature of drying, the lower the fat content. The higher calcium values observed in the sundried and oven dried samples relative to the shade dried sample is an indication that temperature influences the calcium content of turmeric. These values were higher than the value 0.21 % and lower than 104.02 mg observed by Ikpeama et al. (2014) and Shirin Adel and Jamuna (2010) for dried turmeric and ginger root powder respectively. The very high calcium value reported for ginger root powder showed that ginger is a good source of calcium while turmeric, because of the recorded low calcium values is not a source of calcium.

The levels of iron in the samples were higher and lower than the levels 0.045 % reported by Ikpeama et al. (2014) for dried turmeric and 9.41 % reported by Shirin Adel and Jamuna (2010) for ginger root powder. The value (3.11 %) of zinc recorded for the shade dried sample was higher than those (2.62 % for sun dried and 1.27 % for oven dried samples respectively) of other heat processed samples due probably to the none involvement of heat during drying suggesting that heat decreases the zinc content of turmeric. The values of zinc obtained for the samples were higher than the value 1.08 % obtained by Shirin Adel and Jamuna (2010) for dried ginger root except for the value 0.89 % observed for the commercial sample. Significant *($p<0.05$)* differences existed among the levels of iodine in the samples. The high iodine values recorded for the samples may be attributed to the composition of the soil where the turmeric was cultivated. The low levels of minerals (iron and zinc) observed in the samples were expected. Ijeomah et al. (2023) noted that plant foods are poor sources of micro minerals especially iron and zinc.

V. Conclusion

The study successfully proved that the method of drying (shade, sun, and oven) had great influence on the antioxidant, phytochemical, antinutrients and selected chemical composition of turmeric powder. It also found out that sun drying produced better and more quality product. This may be attributed to the combined action of temperature and time i.e., low temperature and short drying time unlike shade drying that used low temperature but longer drying time and oven drying that used high temperature and shorter time. Sun drying or shade drying method is recommended for the processing of powdered turmeric.

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