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ORIGINAL RESEARCH ARTICLE

The Nutraceutical and Functional Food Potentials of Dry Doum Palm Fruit (*Hyphaene thebaica*)

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ABSTRACT
Doum palm fruit is one of the underutilized fruits and is mainly used by the local people without knowing the nutritional value and the pharmacological components associated with the fruit parts. Thus, this research was designed to evaluate the proximate composition, antioxidant activity and phytochemical content of doum palm fruit. The fruit sample was obtained from the farm and market and was portioned into six; the epicarp, mesocarp, epicarp and mesocarp blend obtained from the farm and market were all converted into flour. Proximate analysis was done using the standard method, antioxidant activity using 2, 2-diphenyl-1-pierylhyrazyl DPPH method after water and solvent (ethanol) extraction of the samples at different concentrations: 50 %, 60 %, 70 % and 100 % ethanol and 100 % water, which were used for the six different flours for each that makes it up to 30 samples. While phytochemicals were identified using LC-MS. Results showed that samples collected from the farm had higher proximate composition than the ones obtained from the market. Samples from the farm showed higher antioxidant activity at 595.30 and 62.59 mgGAE/g for total phenolic and flavonoid contents, respectively; 0.078 and 2008.9 IC_{50} (µg/ml) for the DPPH and Reducing power showed by the Samples from the farm. The phytochemical constituents showed that samples from the farm have more bioactive compounds than those obtained from the market. Compounds such as Phytoene, Liriodenine Xanthophylls e.t.c were detected. Thus, the findings proved the presence of a considerable amount of nutraceutical and phytochemical constituents in the dry doum palm fruit. Therefore, it can be further studied to look for ways to benefit from its rich potential in managing various ailments.

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KEYWORDS
Doum palm fruit, Doum palm fruit market extract, Doum palm fruit proximate composition, Doum palm fruit antioxidant

INTRODUCTION
Doum palm (*Hyphaene thebaica*) is one of the world's most beneficial plants and is an Egyptian, Sudan and sub-Saharan African palm (Islam *et al.,* 2022; Sabre *et al.,* 2022). The perennial plant is also distributed in the desert and subtropical regions of the world (FAO 2006; Aboshora *et al.,* 2014; Khalil *et al.,* 2020; Mansur, 2021). *Hyphaene thebaica* is a common palm tree with edible fruit that belongs to the family *Arecaceae* (Ghada *et al*., 2020; Khalil *et al.,* 2020; Hussiena *et al.,* 2021; Sabre *et al.,* 2022). It also grows well in northern Nigeria (Aremu and Fadele, 2011). It is named differently, such as doum palm, doom palm, gingerbread palm, zembaba, mkoma, arkobkobai and kambash (Orwa *et al.,* 2009; Auwal *et al.,* 2013). The oval, apple-sized bright orange fruit has a reddish shell, a dense, spongy, delicious, fibres rich fruit flesh with a gingerbread-like flavour, and a big kernel and the fruit's coating is eatable and may be crushed into powder or sliced into pieces (Islam *et al.,* 2022). And the fruit tastes sweet (Abdel-Rahman *et al*., 2014).

Doum fruit is an excellent source of carbohydrates, micronutrients such as vitamins, especially niacin, folic acid, pyridoxine, riboflavin, and thiamin and important minerals like potassium, sodium, calcium, magnesium, as well as phosphorus (Admassu *et al.,* 2013; Aboshora *et al*., 2014; Islam *et al.,* 2022). The Doum contains proteins, coumarin, essential oils, saponins, reducing sugars, alkaloids, flavonoids, hydroxycinnamates, glycosides, phenolic compounds, and fatty acids (Hsu *et al.,* 2006; Shady *et al.,* 2021). Doum contains higher moisture, crude fiber, ash, protein, fat, and vitamins (Islam *et al.,* 2022). It contains a high amount of amino acids valine, leucine, and some non-essential amino acids such as alanine, aspartic acid, glutamic acid, glycine, serine and proline (Abdel-

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Rahman, 2011). Doum fruits are rich in fibres, antioxidants, B-complex vitamins, and essential minerals in the epicarp and the mesocarp and have a considerable content of monosaccharides such as glucose and fructose (Aboshora *et al.,* 2014).

Antioxidants play an important role in food protection from oxidation processes and are used as dietary supplements to remove potentially damaging oxidizing agents in a living organism (Shahidi and Chandrasekara, 2015). Various studies revealed the fact that doum fruit extracts contain high levels of phenols and flavonoids, which possess significant antioxidant and antibacterial activities (Hsu *et al.*, 2006; Aboshora *et al.*, 2015; El-Beltagi *et al.,* 2018 Atito et al., 2019). However, antioxidant compounds and their antioxidant activities vary according to seasonal variations and the type of phenolic content in the fruit (Laya and Koubala, 2020). Researchers reported that doum fruits are rich in volatile compounds and polyphenols and have good anticancer and antimicrobial properties (Aboshora *et al.,* 2014).

Doum has nutritional and pharmacologic properties (Aboshora *et al.,* 2014). It was used in different countries to treat diabetes, obesity, hypertension, and dyslipidemias and to reduce cardiovascular diseases (Hsu *et al.,* 2006; Salib *et al.,* 2013). According to Bayad (2016), the fruits of *H. thebaica* have antimicrobial, antioxidant, antidiabetic, antihypertensive and hypolipidemic effects. Doum fruit has been used as an anti-hyperlipidemia treatment (Sa'adah *et al.,* 2017).

Doum fruits are consumed in dry, fresh form or cut off into slices before drying and powdering for food product formulation (Shady *et al.,* 2021; Kolla *et al.,* 2021; Shamandy and Saad, 2022). The fruits are transformed into traditional beverages, juice, jelly or puree and are usually used to prepare nutritive diets and other food products (Kolla *et al.,* 2021; Sabre *et al.,* 2022). The fruit has been a popular component of tea preparation consumed for refreshment, regulation of body weight and blood glucose (shady *et al.,* 2021). These consequently necessitated the urge to evaluate the quality of dry doum palm fruit (*hyphaene thebaica)* powder and extract to further explore its benefits and potential, especially in combating many health problems.

MATERIALS AND METHODS

Sample collection and preparation

The market sample of doum palm fruit was purchased from Yankaba market, Kano State and a fresh doum palm fruit sample was collected from Kafin Hausa Bulangu Jigawa State. The samples were transported in Polythene bags under good condition to the laboratory for analysis.

The market and farm Doum palm fruits were sorted, cleaned, and separated, and different samples were obtained for the doum palm powder in the form of epicarp, mesocarp, and the epicarp and endocarp blend for both farm and market doum palm, which makes six (6) samples that were stored transferred for the extraction.

Extraction of samples

During the ethanol extraction sample was measured in the thimble (full) and closed with cotton wool. It was in different concentrations: 50 %, 60 %, 70 % and 100 % ethanol and 100 % water, which was used for epicarp, mesocarp and epicarp and mesocarp blend for each of the above various concentrations of ethanol, which makes it up to 30 samples. The extraction process was for 6 h, and the samples were transferred to the water bath for 3 h. Samples were transferred into amber bottles with foil paper and BUK CDA for phytochemical analysis. Samples were transferred into amber bottles and transported to the laboratory for analysis. All samples were kept in a refrigerator at -20 ^{o}C.

Proximate analyses

Moisture content, total ash content, crude protein, crude fibre and fat content were determined according to AOAC (2010) standard method. Carbohydrate was determined by difference. The energy value was determined using a modified method described by Chinma and Gernah (2007). Energy values were calculated using Atwater factors (protein x 3.5 + carbohydrate x 3.5 + fat x 8.5).

Antioxidant activity

The concentration of phenolics in the doum palm samples extracts was determined using the folin ciocalten method (Singleton *et al.,* 1999). The reaction mixture was prepared by mixing 1 ml of methanolic solution of extract with 2.5 ml of 10 % Folin-ciocalten's reagent dissolved in water, and the content was mixed. After 3 minutes, 2.5 ml 7.5 % sodium carbonate ($NaHCO_3$) solution was added. The samples were incubated at 45 ^{0}C for 45 minutes. The absorbance was read using a spectrophotometer at 765 nm against a blank (distilled water). The samples were prepared in triplicate for each analysis, and the mean value of the absorbance was obtained. A calibration curve was constructed using garlic acid standard solutions (20, 40, 60, 80 and 100 mg/l). Then, the content of phenols in extracts was expressed in terms of garlic acid equivalent (mg of GA/g of extract).

$$X(conc.) = Y - 0.1499 / 0.0031$$

The content of flavonoids in the doum palm sample extracts was determined according to a modified colourimetric assay with aluminium chloride (Quettier *et al.,* 2000). Methanol solution (1 ml) of the extract (1 mg/ml) was added to a test tube, followed by the addition of 0.3 ml of solution of $NaNO_2$ (0.05 g/l). After 5 minutes, 2 ml of NaOH (1 mol/l) was added to the mixture, the solution was mixed, and the absorbance was measured at 510 mn against a blank (distilled water). Quecertine was used as the standard for constructing a calibration curve in different concentrations (20, 40, 60, 80 and 100 mg/l). Flavonoid content was expressed in terms of quecertine equivalent. (QE) (mg QE/g of extracts).

$$X(conc.) = Y + 0.0687 / 0.0142$$

Finally, for the reducing power method (RP), the method is based on the principal increase in the reaction mixtures' absorbance. An increase in the absorbance indicates an increase in the antioxidant activity. In this method, the antioxidant compound forms a coloured complex with potassium ferricyanide, trichloroacetic acid and ferric chloride, measured at 700 nm. An increase in absorbance of the reaction mixture indicates the reducing power of the compound (Jayaparakash *et al.,* 2001), as in the method described by Oyaizu (1986).

Determination of the in vitro antioxidant activities of extracts using 2, 2-diphenyl-1-pierylhyrazyl (DPPH) photometric assay

The extract's free radical scavenging activity was analysed using a DPPH assay using a spectrophotometer. Each of the test extracts (2 ml) at different concentrations (25, 50, 100,200 and 400 µg/m l0 was mixed with 0.5 mM DPPH (in 1 ml of methanol) in a cuvette. The absorbance at 517 nm was taken after 30 min of incubation in the dark at room temperature. The concentrations were placed in triplicates, and the percentage of antioxidant activity was calculated as follows:

$$Percentage\ antioxidant = 100 - [(as - ab)x\ 100\ x\ (\text{absorbance of control})^{-1}]$$

Where:

as = absorbance of the sample

ab = absorbance of blank

One millilitre of methanol plus 2.0 ml of the extract was used as the blank, while 1.0 ml of methanol was used as the negative control. Ascorbic acid (vitamin C) was the reference standard (Iwalewa *et al.,* 2008).

LC-MS Screening and identification of doum palm extracts

The sample's ethanol extraction was measured in the thimble (full) and closed with cotton wool. It was in different percentage (%) which was 100 %, 70 %, 60 % and 50 %. In the conical flask, 100 ml of ethanol was measured, and 70 % was added to the extract. It follows a serial way of addition. The addition of the percentage of ethanol is according to the mixture of reagents example, 60 % of ethanol, 40 % of distilled water, 100 % of ethanol is complete ethanol, 70 % of ethanol, 30% of water, 50 % of ethanol with 50 % of distilled water. The extraction process is 6hrs and the sample was transferred to the water bath for 3hrs. Then, the sample was transferred to amber bottles and covered with foil in a refrigerator at -20 °C before being them to BUK for phytochemical profiling using Lc-ms. Some of the fractions obtained from the CC of the doum palm extracts were subjected to the LC–MS analysis, which was performed on Agilent LCMS-6120B (Agilent, Santa Clara, CA, USA) coupled with a diode-array detector (DAD) using a Poroshell 120 EC-C18 (4.6 × 150 mm, 4 µm) column. The temperature of the column oven was kept at 25 °C. Isocratic elution was employed for the analysis, with a mobile phase consisting of 0.1 % formic acid in water (solution A, 80 %) and methanol (solution B, 20 %), with a post-time of 5 min before the next injection. The flow rate of the mobile phase was 1.0 mL/min, and the injection volume was 20 µL of the sample. HMDB (Human Metabolic Database) was used to express the bioactive compound.

Statistical analysis

The mean difference was considered significant at $p \leq 0.05$. A statistical package for social science (SPSS) version for Windows was used. Conversions and calculations were carried out with Microsoft Excel.

RESULTS AND DISCUSSION

Table 1, showed the result of the proximate composition of the doum palm fruit epicarp mesocarp and epicarp & mesocarp blend from market and farm.

Table 1: Proximate composition of the doum palm fruit epicarp from market and farm

	Epicarp	Mesocarp	Epicarp and Mesocarp	Epicarp	Mesocarp	Epicarp and Mesocarp
Parameter (%)		From market			From farm	
Fat	0.29±0.03[a]	0.72±0.03[a]	3.81±3.01[b]	0.41±0.04[b]	0.63±0.05[a]	6.79±5.58[a]
Moisture	1.88±0.04[a]	4.73±2.08[a]	4.74±2.07[b]	4.30±0.08[b]	5.74±0.55[b]	8.33±3.90[a]
Protein	3.80±0.12[a]	4.07±0.16[a]	6.24±2.18[b]	4.23±0.48[b]	3.94±0.12[a]	8.97±3.42[a]
Crude fibre	23.05±0.23[a]	7.74±3.92[a]	4.92±1.95[b]	23.36±0.27[a]	11.08±3.63[b]	8.39±3.25[a]
Ash	5.34±0.06[a]	7.50±0.05[b]	9.36±6.17[b]	6.26±0.14[b]	6.24±0.05[a]	14.18±7.20[a]
Carbohydrates	34.38±0.29[a]	27.61±3.33[a]	25.95±3.85[b]	38.57±0.55[b]	30.06±3.46[b]	26.42±5.02[a]

Values are expressed as mean ± standard of triplicate. Values within the same row bearing different superscripts are significantly different ($p<0.05$).

Significant differences exist in the carbohydrate content, fat content, moisture content, protein content and Ash between the samples collected from the market and farm. Table 1 shows the result of the proximate composition of the doum palm fruit from the market and farm with a significant difference at $p < 0.05$ among the mesocarp samples. Significant differences exist in the moisture content, carbohydrate, crude fibre and ash content between the samples collected from the market and farm. There is no significant difference in the fat and protein content between market and farm samples at $p < 0.05$.

This study revealed that doum palm fruit obtained from the farm contained significantly higher proximate composition (fat, moisture, protein, crude fibre, Ash, and carbohydrates). The crude fibre (23.36 %) varies from the crude fibre (75.81 %) found by FAO (2006) and (18.36 %) found by (Abdel-Rahman *et al.,* 2014). The fibre cleanses the digestive tract by removing carcinogens from the body and preventing the absorption of excess cholesterol. The high Ash content reflects the mineral content of the doum palm fruit. This work revealed that the Ash content of (8.97 %) was higher than the ash content (7.30 %) reported by FAO (2006) and (7.17 %) found by Abdel-Rahman *et al.* (2014). The doum palm fruit obtained from farm moisture content was significantly higher than that obtained from the market and higher than the quantity (5.44 %) that Abdel-Rahman et al. (2014) reported. The carbohydrate content of this research work was found to be as high as (38.57 %), and this result varies (50.00 %) from Abdel-Rahman *et al.* (2014). The protein content (8.39 %) found in this research varies from (3.80 %) found by FAO (2006). The fat content of this research work (6.79 %) was found to be higher than (0.95 %) found by Abdel-rahman *et al.* (2014). Variations in most of the proximate compositions like Moisture, protein, Ash, Fat, Crude fibre and Carbohydrates in this study, with some literature, could be due to the species, time/season and long storage of the doum palm obtained from the market that was kept for one year or more than that, that was what gave the doum palm fruit obtained from farm higher significant value than other literature.

Table 2 revealed the presence of the Antioxidant activity (total phenolics and flavonoid content) of both the doum palm fruit obtained from the farm and the market.

Table 2: Antioxidant activity of the doum palm fruit

Samples	Total phenolics (mgGAE/g)	Total Flavonoids (mgQE/g)	DPPH IC_{50} (µg/ml)	Reducing power IC_{50} (µg/ml)
Mesocarp (farm) 50 % Ethanol	595.30 ± 24.93^{a}	59.93 ± 1.32^{c}	0.078 ± 0.027^{a}	1055.6± 5.75c
Mesocarp (farm) 60 % Ethanol	420.68 ± 17.42^{c}	45.75 ± 1.78^{b}	0.003 ± 0.004^{c}	2008.9 ± 13.88^{a}
Mesocarp (farm) 70 % Ethanol	382.51 ± 1.348^{c}	38.83 ± 2.33^{b}	0.001 ± 0.000^{b}	1107.3 ±3.62^{b}
Mesocarp (farm)100 % H_2O	600.89 ± 84.31^{a}	26.22 ± 1.32^{d}	0.004 ± 0.003^{c}	1023.8 ± 0.90^{d}
Epicarp (market) 100 % Ethanol	401.75 ± 37.27^{b}	45.64 ± 4.58^{b}	0.005 ± 0.003^{c}	1741.1 ± 1.50^{e}
Epicarp (farm) 60 % Ethanol	550.35 ± 6.15^{a}	44.51 ± 1.48^{b}	0.022 ± 0.034^{c}	2006.0 ± 5.18^{a}
Epicarp (farm) 100 % Ethanol	453.47 ± 22.63^{c}	62.59 ± 4.16^{a}	0.001 ± 0.000^{b}	1522.4 ± 1.44^{f}
Epicarp & mesocarp (market) 50 % Ethanol	364.44 ± 5.79^{c}	44.42 ± 3.11^{b}	0.041 ± 0.015^{c}	1125.9 ± 3.45^{g}
Epicarp & mesocarp (market) 60 % Ethanol	424.66 ± 2.33^{c}	50.49 ± 2.06^{b}	0.012 ± 0.009^{c}	1366.1 ± 2.13^{h}
Epicarp & mesocarp (market) 70 % Ethanol	350.36 ± 3.49^{c}	39.16 ± 1.48^{b}	0.050 ± 0.072^{c}	1876.5 ± 1.77^{i}

Values are expressed as mean ± standard deviation of triplicate. Values within the same column bearing different superscripts are significantly different ($p<0.05$).

The total flavonoid content of epicarp farm 100 % ethanol (62.59 mg QE/g) was the highest to the lowest (38.83 mg QE/mg) of mesocarp farm 70 %. These results agreed with those reported by Khider *et al.* (2022), who found (51.436-67.540 mg QE/g). While the total flavonoid content of mesocarp farm 100 % water extract was the lowest (26.22 mg QE/g), which was a result of the water extract, the ethanol extract of doum palm fruits is higher than doum palm water extract in total flavonoids content reported by Aamer (2016). On the other hand, samples obtained from the market are from 45.75 to 39.16 mg QE/g, which varies from the doum palm fruit from the farm. The results showed that the ethanol extracts from the farm are higher than water extracts and doum extracts

Table 3: Phytochemicals identified in the samples from the farm

R/time	Compounds	Formula	Mass(m/z)	Polarity
Doum mesocarp from farm (50 % ethanol)				
7.746	Acetic acid	$C_{25}H_{25}N_3O_8S_2$	540.099	-ve
6.160	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
7.746	Phytoene	$C_{40}H_{64}$	197.290	+ve
12.745	Guanine	$C_{15}H_{28}$	215.236	+ve
12.897	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
Doum mesocarp from farm (60 % ethanol)				
8.657	Phenylalanine betaine	$C_{12}H_{17}NO_2$	286.147	+ve
8.848	3-Dehydrosphinganine (C20)	$C_{20}H_{39}NO_2$	408.357	+ve
12.897	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
6.995	Phytoene	$C_{40}H_{64}$	197.285	+ve
Doum mesocarp from farm (70 % ethanol)				
1.811	Octacosane	$C_{28}H_{58}$	359.444	+ve
12.811	Xanthophylls	$C_{41}H_{58}O_3$	215.246	+ve
12.897	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
7.985	Phytoene	$C_{40}H_{64}$	197.285	+ve
Doum mesocarp from farm (100 % ethanol)				
5.982	Phytoene	$C_{40}H_{64}$	197.282	+ve
10.825	Lirodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
2.251	Octacosane	$C_{28}H_{58}$	359.444	+ve
6.251	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
Doum epicarp from farm (100 % ethanol)				
12.897	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
8.891	Amylamine	$C_5H_{13}N$	260.301	-ve
5.999	Phytoene	$C_{40}H_{64}$	197.285	+ve
1.991	Octacosane	$C_{28}H_{58}$	359.444	+ve
Doum epicarp from farm (60 % ethanol)				
2.511	Octacosane	$C_{28}H_{58}$	359.444	+ve
12.507	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
5.960	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
8.257	Phenylalanine betaine	$C_{12}H_{17}NO_2$	286.147	+ve
Doum epicarp & mesocarp from farm (50 % ethanol)				
12.897	Liriodenine	$C_{26}H_{18}N_2O_2P_2$	489.030	-ve
7.250	Phenylalanine betaine	$C_{12}H_{17}NO_2$	286.147	+ve
2.321	Octacosane	$C_{28}H_{58}$	359.444	+ve
3.160	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve

Table 4: Phytochemicals identified in the samples from the market

R/time	Compounds	Formula	Mass(m/z)	Polarity
Doum mesocarp from market (60 % ethanol)				
5.889	Phytoene	$C_{40}H_{64}$	197.274	+ve
12.880	Guaiane	$C_{15}H_{28}$	215.236	+ve
12.991	Xanthophylls	$C_{41}H_{58}O_3$	215.276	+ve
6.673	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
8.996	Amylamine	$C_5H_{13}N$	260.301	-ve
Doum epicarp and mesocarp from the market (70 % ethanol)				
5.995	Phytoene	$C_{40}H_{64}$	197.285	+ve
1.854	Xanthophylls	$C_{41}H_{58}O_3$	215.246	+ve
7.180	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
7.899	Amylamine	$C_5H_{13}N$	261.301	-ve
Doum epicarp from market (100 % ethanol)				
12.246	Xanthophylls	$C_{41}H_{58}O_3$	215.246	+ve
6.921	Dicyclo hexyl carbodiimide	$C_{13}H_{22}N_2$	229.167	+ve
6.255	Phytoene	$C_{40}H_{64}$	197.285	+ve
9.592	Amylamine	$C_5H_{13}N$	260.301	-ve

obtained from the market. The total phenolic content of doum palm extracts of mesocarp farm 100 % water was higher (600.89 mgGAE/g). The farm extracts of ethanol had various concentrations (595.30-382.51 mg GAE/g), which varied from the total phenolics content (139.48-116 mgGAE/g) found by Abshora *et al.* (2015). The total phenolic content of doum palm extract was obtained from the market (350.36-424.66 mg GAE/g) by Abshora *et al.* (2015). The total flavonoid and phenolics content using various concentrations of 50 %, 60 %,70 % and 100 % ethanol for epicarp and mesocarp blend parts of doum palm fruit obtained from farm in this study are higher, respectively.

The results showed that the higher the concentration, the higher the absorbance. The increased absorbance of the reaction mixture indicates a higher reducing power of the doum palm fruit extract. The reducing power of the doum palm extracts increased with the concentration. The free radical scavenging activities were compared with ascorbic acid, a known antioxidant, which agreed with Kumazawa et al.'s (2002) work. The activity was determined as a function of their percentage inhibition (% I). The result showed that the ethanol extracts showed that doum palm fruit could scavenge the DPPH stable free radical methods, which is an easy, rapid and sensitive way to evaluate the antioxidant activity of a specific compound or plant extracts. The model of scavenging DPPH radicals used in the rapid screening method commonly employed for evaluating antioxidant activities is based on their ability to scavenge to donate hydrogen ions Kumazawa *et al.* (2002). The results revealed that a larger percentage of the sample exhibited the ability to scavenge the free radicals used in a concentration-dependent manner as their % I decreased with decreased as their % I decreased with a decrease in concentration. This agrees with the work of Onocha *et al.* (2010). The reduction in absorbance of DPPH caused by the ethanol extract of doum palm fruit was measured, and the percentage inhibition showed a decreasing trend with the decrease in concentration of extract of doum palm (Usunomena and Egharevba, 2014). The scavenging activity of the extract could be linked to the presence of secondary metabolites such as flavonoids. Table 2 presents the IC_{50} for DPPH radical scavenging of doum palm fruit, indicating a strong antioxidant potential displayed by doum palm extracts. The IC_{50} of antioxidant compounds, in terms of biological radicals' inhibition, is proportional to antioxidant strength in an inverse manner since it is the concentration of a compound required to neutralise or scavenge 50 % of a radical (DPPH in this case) that could pose a danger to other biological molecules. Different researchers have reported antioxidant activity in the doum palm plant's leaves and fruit pulp (Mohammed *et al.* (2010) and Lamis *et al.* (2018). This study revealed that the results of the doum palm fruit extracts of mesocarp farm 70 % ethanol and epicarp farm 100 % ethanol have IC_{50} of 0.001, which agreed with the ascorbic acid standard IC_{50} (0.001). The result for the mesocarp from the farm was 50 %, 60 % and 100 % water (0.078, 0.003, and 0.004), respectively, and for the epicarp from a farm, 60 % was 0.022. Compared to the doum palm fruit obtained from market epicarp market, 100% ethanol presents (0.005), epicarp and mesocarp blend 50 %, 60 % and 70 % ethanol presents (0.041, 0.012 and 0.0050) which varies from (0.0625, 0.125, 0.250 and 0.500) of doum palm fruit pulp found by Datti *el al.* (2018). There was a concentration-dependent increase in the percentage of antioxidant activity for all concentrations tested. Ascorbic acid was used as the standard for the DPPH antioxidant activity testing Datti *et al.* (2018).

Table 3 presents the phytochemicals identified in the samples from the farm. Many compounds from mesocarp farm 50 %, 60 %, 70 % ethanol and 100 % water, epicarp farm 60 % and 100 % ethanol farm.

Table 4 presents the phytochemicals identified in the samples from the market. For the market samples, epicarp market 100 % ethanol and epicarp & mesocarp market 50 %, 60 % and 70 % ethanol extracts were detected.

According to previous works, there was no information on the same compounds discovered in this study on doum palm fruits. This makes the study a novelty by discovering 10 phytochemicals compounds in the doum palm fruits (i.e. Phytoene, Liriodenine, Acetic acid e.t.c). Phytoene was present in both the farm samples, the fresh fruit and the samples collected from the market. They are carotenoids, antioxidants in preventing vitamin A deficiency and reduce the risk of various chronic diseases (Eggersdorfe and Wgss, 2018). Liriodenine is an alkaloid from plants of many genera and exhibits a wide range of pharmacological activities (Chen, 2013). Lirodenine compound was identified as a potentially useful antimicrobial (Zhang *et al.,* 2002) and anticancer (Khamis *et al.*, 2004). Liriodenine was found from samples collected from a farm (i.e. mesocarp farm 50 %, 60 %, 70 % ethanol and 100 % water, epicarp farm 60 % and 100 % ethanol farm). Phenylalanine was also discovered, and this compound is an amino acid which possesses anti-depressant potential in a study conducted by (Akram *et al.*, 2020). Xanthophylls were also present in doum palm fruit samples. They are carotenoids. Xanthophyll may be cancer preventive as a scavenger of free radicals, a quencher of reactive oxygen and nitrogen species and a chain-breaking antioxidant (Sara and Elizabeth, 2018). Acetic acid is a short-chain fatty acid that has demonstrated biomedical potential as a dietary therapeutic agent for managing chronic and metabolic illness comorbidities. In human beings, its consumption may improve glucose regulation and insulin sensitivity in individuals with cardiometabolic conditions and type 2 diabetes mellitus (Daniela *et al.*, 2021).

CONCLUSION

Doum palm fruit *hyphaene theibaica* (epicarp, mesocarp and epicarp & mesocarp) is widely used as food and as medicine for treating several disease conditions. The aim of this research, which focused on determining the proximate composition, antioxidant activity and

identification of the bioactive compounds of ethanol and water extract of doum palm fruit, has been achieved. The fruit parts have been found to contain appreciable amounts of bioactive compounds such as Phytoene, Liriodenine and Xanthophylls as well as vital antioxidants (phenolics and flavonoids), and their presence is an indication of their benefits and potentialities in combating of many illnesses.

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