Journal of Medicinal Plants Studies
www.PlantsJournal.com

ISSN (E): 2320-3862
ISSN (P): 2394-0530
www.plantsjournal.com
JMPS 2022; 10(5): 112-118

Received: 11-06-2022
Accepted: 15-07-2022

Bekibele Grace E
[1] World Bank African Centre of Excellence in Public Health and Toxicological Research (PUTOR), University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria
[2] Department of Biochemistry, University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria

Anacletus Francis C
[1] World Bank African Centre of Excellence in Public Health and Toxicological Research (PUTOR), University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria
[2] Department of Biochemistry, University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria

Patrick-Iwuanyanwu Kingsley C
[1] World Bank African Centre of Excellence in Public Health and Toxicological Research (PUTOR), University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria
[2] Department of Biochemistry, University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria

Corresponding Author:
Bekibele Grace E
[1] World Bank African Centre of Excellence in Public Health and Toxicological Research (PUTOR), University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria
[2] Department of Biochemistry, University of Port Harcourt, PMB, 5323, Port Harcourt, Rivers State, Nigeria

The nutritive and anti-nutritive components in the Nigerian-cultivated red cabbage vegetable and aqueous extracts

Bekibele Grace E, Anacletus Francis C, and Patrick-Iwuanyanwu Kingsley C

DOI: https://doi.org/10.22271/plants.2022.v10.i5b.1473

Abstract
The inclusion of red cabbage vegetables in locally prepared meals is gradually becoming popular and quickly gaining acceptability. The study, therefore, seeks to quantify the nutrients, estimate the phytochemicals, and determine the antioxidant capacity of the Nigerian-cultivated red cabbage vegetable. The analyses were executed in line with accepted standard procedures. On analysis, the vegetable was shown to contain a higher percentage of carbohydrate (45.72±1.96), moisture (23.23 ±0.29), and proteins (15.05±0.35), compared to the ash content (5.01±0.04), lipids (7.23±0.98) and fibre (3.77±0.32). The vitamin content ranged from 60.43±0.05 for vitamin C to 0.02± 0.15 for vitamin B2, occurring in the order: C>E>A>B12>B9>D>B3>B6>B1 and B2. A total of 35 phytochemical compounds were identified with appreciable levels of antioxidant capacity. This proves that the red cabbage vegetable grown in Nigeria is compact with nutrients which can be fully maximized when the anti-nutrients are minimized.

Keywords: Minerals, phytochemicals, red cabbage, vitamins

1. Introduction
The search is on for foods with biological components which when incorporated into diet regimens meet nutritional needs, and also provide a needed affront against disturbing disease conditions plaguing the populace. Such foods have been described as "functional foods" [1]. Research has shown that such components could be of animal or micro-organisms origin, but are more commonly accessed when certain plants are consumed [2]. In this category are cruciferous vegetables, and an important member of this class is *Brassica oleracea var. capitata f. rubra*, known also as the red cabbage vegetable.
Red cabbage is an herbaceous biennial, dicotyledonous flowering plant with red or purple leaves, locally eaten in Cole slaw preparations or juiced to make drinks. Varieties of uses other than the conventional ones mentioned above are quickly springing up as the vegetable gains recognition in Africa, such as the addition of the pureed vegetable in the preparation of baked cassava flakes aimed at fortifying the widely consumed meal with fibre from the vegetable, and the addition of the ground vegetable in corn flour broth, etc. Creative uses for the vegetable are arising on account of the host of beneficial compounds with nutritive and disease-reducing capacities which have been isolated; like carbohydrates, proteins [3], vitamins C, E, K, and B [4], minerals [5], and phytochemicals like polyphenols [6], flavonoids (mainly anthocyanin) [7], and glucosinolates [3]. Experimentation into the biological activity of this important vegetable revealed the presence of significant antioxidant activities [6, 8].
The bio-concentration of nutritive compounds in the red cabbage vegetable has been ascribed to depend on the cultivars, prevailing climatic conditions, the environment where they are grown, and the genetic constitution [19]. In Nigeria, the vegetable is popularly cultivated in Jos, Plateau state, where the climate best supports its growth, since optimum yield is derived when it is cultivated in cold regions [4]. Variations in nutritional composition have been reported when cultivars from different regions, including Asia and Europe were compared, suggesting further that environmental influences could be affecting the quality of the yield [5]. So far, studies fully describing the nutrient content and antioxidant capacity of the red cabbage vegetable grown in Africa, precisely Nigeria is still lacking. This study, therefore, aims to

quantify the nutrient content, screen the phytochemicals and analyse the antioxidant capacity of the Nigerian-grown red cabbage vegetable, in a bid to provide supporting evidence of its composition to aid comparisons with other regions of the world.

2. Materials and Methods

2.1. Materials

Spectrophotometer (UNICO spectrophotometer, UV2150), Weighing balance (ME303E), Electric blender (Panasonic, MX-337N), Potassium hydroxide, sodium hydroxide, petroleum ether, ferric chloride, glacial acetic acid, phosphate buffer, isopropyl alcohol, ammonia, methanol, folin-ciocalteu reagent, sodium phosphate, trichloroacetic acid (Loba Chemie PVT. Ltd. Laboratory reagents and fine Chemicals, Jehangir Villa, 107, Wodehouse Road, Colaba, Mumbai, 400 005. India.), anhydrous sodium sulphate, absolute alcohol, sodium sulphate, ammonium thiocyanate, aluminium chloride, chloroform (Guangdong Guanghua Sci-Tech Co. Ltd., Daxue road, Shantou, Guangdong, 515000, China.), xylene, sulphuric acid, per chloric acid, hydrochloric acid, Potassium permanganate, phenyl hydrazine (Central Drug House Ltd., Vardaan House, Daryaganj, Delhi- 110002, India.), dinitrophenyl hydrazine reagent (Lab Tech Chemicals, Qualikems Fine chemicals, vt. Ltd., 68/69 G.I.D.C. industrial estate, Nandesari, Vado, Pin: 391340, India.), acetic anhydride (Merck KGaA, 64271, Darmstadt, Germany), sodium nitrate solution, thiobarbituric acid, potassium hexacyanoferrate (III) (Molychem, Genu road, Mumbai 400002, India).

2.2. Red cabbage collection and identification

The red cabbage used in this study was harvested at full maturity after 120days of cultivation from a local farm in Rayfield, Jos South Local Government Area of Plateau state, North Central, Nigeria in October, 2020. At 'the Herbarium Unit' of the Department of Plant Science and Biotechnology of The University of Port Harcourt, Nigeria, the plant was presented for identification. After which, documentation of the received samples was done and filed by assigning a reference number: UPH / PSB / 2021 / 012, and a herbarium number: UPH / P / 243 for later referencing purposes.

2.3. Red cabbage aqueous extracts preparation

Freshly harvested red cabbage leaves were washed under running water to remove dirt and other contaminants. When water droplets had been expunged, the vegetable was sliced and ground into slurry to break the cell walls of the plant with the aid of a laboratory blender (Panasonic, MX-337N). Then 350g of the slurry were measured out, to which about 300mls of deionized water was added, after which the mixture was allowed to stand with frequent agitations in an adequately sealed beaker for 24hrs. The extracts were then filtered out with the aid of a Whatman No.1 filter paper and stored at 4 °C in a refrigerator for use.

2.4. Proximate Analysis of red cabbage vegetable

The AOAC [10] methodologies were applied in determining the nutrient composition of the vegetable. For the moisture content, method No. 934-01was utilized, while No. 984-13 was applied in the crude protein determination. The ash content in the cabbage samples were estimated using methods No. 942-05, while the crude fibre assay applied No. 978-10 of the AOAC method. On the other hand, the carbohydrate was estimated by using the equation below:

Carbohydrate (%) = 100 – (% Ash + % Moisture + % Fat + % Protein + % Fibre) (1)

2.5. Vitamin composition estimation

The spectrophotometric estimation of vitamins A, E, C, B_1, B_2, B_3, B_6, B_{12}, and D present in the fresh red cabbage extracts was done following the spectrophotometric procedures below.

2.5.1. Vitamin A, E, C, and D

Vitamin A was estimated by the method of Bayfield and Cole [11], based on the reaction between vitamin A acetate or palmitate with TCA (trichloroacetic acid). While the vitamin E content in the red cabbage extract was analyzed in the sample by using Emmerie-Engel reaction as stated by Rosenberg [12], Vitamin C was analysed as presented by Roe and Keuther [13] using spectrophotometry. Also, Vitamin D was estimated using the Amer *et al*. method [14].

2.5.2. Vitamin B_1 and B_2 Estimation

To appropriately labeled test tubes for sample and standard, 5mls of the sample and standard were added, after which 2mls of hydrochloric acid (1M), 2mls glacial acetic acid, 2mls potassium permanganate (15% w / v) and 2ml phosphate buffer (pH 6.8) were added and mixed adequately. The absorbance was read at 261nm (vitamin B_1) and 242nm (vitamin B_2).

2.5.3. Vitamin B_3 (Nicotinamide) estimation

This was also estimated by spectrophotometry. About 5ml of the sample extract was introduced into 20ml of anhydrous glacial acetic acid and heated slightly. After which 5ml of acetic anhydride was put in and thoroughly mixed. Then 2 -3 drops of a crystal violet solution was used as indicator, and the mixture titrated with 0.1M per chloric acid to produce a greenish-blue colour.

To determine the concentration, the calculation below was used:

$$\text{Vitamin}B_3 = \frac{\text{titre value x } 0.0122}{0.1} \quad (2)$$

2.5.4 Vitamin B_6 Estimation

5ml of sample extract was dissolved in a mixture of 5ml anhydrous glacial acetic acid and 6ml of 0.1M mercury (II) acetate solution. Then 2 drops of crystal violet was added as indicator, which were now titrated with 0.1M per chloric acid to achieve a green colour at the end point.`

To determine the concentration, the relationship is used: each ml of 0.1M per chloric acid is equivalent to 0.02056g of $C_8H_{11}NO_3HCL$

2.5.5 Folic Acid (Vitamin B9)

Two test tubes, A and B, were marked for sample and standard and were set aside. Then, 2 ml of 0.02% potassium permanganate solution, 2% sodium nitrate solution, 4 M hydrochloric acid solution, 1 ml 5% ammonium sulpha mate solution and dye solution (0.1% N, N diethyl aniline dye solution in Iso propyl alcohol) were pipetted in the various tubes, thoroughly mixed, kept to rest at 37 °C for 15 minutes, then its absorbance was read at 535 nm against blank.

2.5.6 Vitamin B_{12} Estimation

Vitamin B_{12} was prepared by coupling reactions with pyridine.

Procedure: About 2ml of the sample and blank solutions were put into different marked test tubes, to which 2 ml of 0.2% phenyl hydrazine (in a 1:5v / v hydrochloric acid and alcohol mixture) was added and thoroughly mixed. The mixture was then heated with the aid of a water bath and cooled at room temperature. Then 2ml of the mixture (ammonia and alcohol in ratio of 1:1) and 1ml pyridine were added in each test tube, and the absorbance read at 635 nm against blank. The cobalamine standard was also analyzed and treated same as sample.

A calibration curve was constructed from which the concentration of the sample was determined by extrapolations.

2.6. Elemental analysis

K, Na, Mg, Zn, Cu, Mo, Se, Mn, Fe, and Ni assay was done with the use of an Agilent FS240AA Atomic Absorption Spectrophotometer according to the method of APHA [15].

The calibration curves for the elements were prepared by plotting the absorbance of standards against their concentrations.

2.7 Quantitative phytochemical analysis

The estimation of the alkaloids was done using the Harborne method [16], while the Makkar *et al*., method [17] was used in the tannins determination. Also, the Maga method [18] was applied in the phytic acid estimation.

$$\% \text{ Phytic acid} = \frac{\text{Titre value} \times 0.00195 \times 1.9 \times 100 \times 3.55}{\text{Wt of Sample}} \quad (3)$$

Furthermore, the quantitative estimation of sterols were carried out using the Mahdu *et al*., method [19], and the method stated by Indumathi *et al.* [20] was utilized in the terpenoids estimation. The amount of total phenolic content in the plant extracts were assessed using Folin-Ciocalteu reagent procedure using the Lister and Wilson method [21]. While the total flavonoids of three replicate extracts expressed as Catechol Equivalent (CE) were determined using the method described by Zhishen *et al*. [22]. Also, the total anthocyanin (TA) determination was done using the method (single and differential pH) described by Fuleki and Francis [23].

2.8 GC-MS Conditioning for qualitative phytochemical screening

GC–MS analysis of the red cabbage extract was carried out using an Agilent 6890 gas chromatograph with a 5975 MS detector equipped 30-m x 0.25 - mm or 0.32 - mm ID fused-silica capillary column chemically bonded with SE-54 (DB-5 or equivalent), 1-µm film thickness (Agilent). The following temperature ramp was used: injector at 250 °C, oven initially at 200 °C, held for 1 min and heated to 230 °C (1.5 °C min-1, then held for 10 min). The characterization and identification of phytochemicals, from the sample was completed in the SCAN mode with the m/z range varied from 35 to 450. The flow rate of the helium as carrier gas was 1 mL min-1; manual injection; the injection volume was 1 µL. Interpretation of mass spectrum of GC-MS was done using the database of National Institute of Standard and Technology (NIST). The mass spectrum of unknown component was compared with the spectrum of the known component stored in the NIST library. Major components were identified with authentic standards and recorded from computerized libraries film thickness.

2.9 Measurement of free radical scavenging activity

The total antioxidant capacity (TAC) of the extracts was assessed by spectrophotometry by the phosphor molybdenum method according to the procedure described by Prieto *et al*.[24], while the DPPH scavenging assay was executed as described by Lim and Quah [25].

$$\text{Radical scavenging activity}(\%) = I - \frac{\text{Asample}}{\text{Ablank}} \times 100 \quad (4)$$

Where,

A is absorbance at 517 nm

The ferric reducing antioxidant capacity (FRAC) assay was analyzed in line with the methods stated by Thaipong *et al.* [26].

3. Results

3.1. Proximate Analysis (%) of Red Cabbage (*Brassica oleracea var. capitata f. rubra*)

The proximate composition of the Nigerian-grown red cabbage vegetable used in the study is captured in Table 1. It presents the vegetable to possess elevated amounts of carbohydrate, followed by the moisture content, crude protein, lipid content, ash content, and crude fibre.

Table 1: Proximate Analysis (%) of Red Cabbage (*Brassica oleracea var. capitata f. rubra*)

Parameter	Percentage (%) Content
Moisture Content	23.23±0.29
Ash Content	5.01±0.04
Crude Lipid	7.23±0.98
Crude Fibre	3.77±0.32
Crude Protein	15.05±0.35
Crude Carbohydrate	45.72±1.96

Values are expressed as Mean ± SD of three replicate samples

3.2 Vitamin Composition (mg/kg) of Red Cabbage Aqueous Extract.

The result of the vitamin composition in the red cabbage aqueous extracts is captured in Table 2, showing appreciable levels of vitamins A, E, C, D, B_9, and B_{12}. However, the concentration of vitamins B_1, B_2, B_3, and B_6, were low.

Table 2: Vitamin Composition (mg/kg) of Red Cabbage Aqueous (*Brassica oleracea var. capitata f. rubra*) Extract

Components	Concentration (mg / kg)
Vitamin A	7.26±0.01
Vitamin E	14.33±0.07
Vitamin C	60.43±0.05
Vitamin D	1.21±0.16
Vitamin B_1	0.02±0.03
Vitamin B_2	0.02±0.15
Vitamin B_3	0.63±0.20
Vitamin B_6	0.16±0.09
Vitamin B_9	1.72±0.05
Vitamin B_{12}	3.77±0.17

Values are expressed as Mean± SD of three replicate samples

3.3 Elemental Content of Aqueous Extracts of Red Cabbage.

The result of the elemental content in the red cabbage aqueous extracts is captured in Table 3, occurring in the order: K> Na>Mg>Zn>Cu>Mo>Se>Mn>Fe> Ni.

Table 3: Elemental content (ppm) in the aqueous extract of red cabbage

Components	Concentration (ppm)	Allowable Limit* (mg / kg)
Zinc (Zn)	0.67±0.07	60
Manganese (Mn)	0.04±0.61	10
Copper (Cu)	0.20±1.12	40
Iron (Fe)	0.04±0.19	42.5
Nickel (Ni)	0.01±0.10	10
Chromium (Cr)	0.01 ±0.92	2.3
Sodium (Na)	4.89±0.56	-
Magnesium (Mg)	2.96±0.11	-
Potassium (K)	6.89±1.24	-
Molybdenum (Mo)	0.10±1.18	-
Selenium (Se)	0.08±0.02	-

Values are expressed as Mean ± SD of three replicate samples. *WHO / FAO 2007 [30]

3.4 Phytochemical composition of red cabbage aqueous extract

Table 4 is a presentation of the phytochemical content of the red cabbage aqueous extracts. From the analysis, a high total phenolic content was recorded in the analysis, which was closely followed by the anthocyanin and the flavonoids content. There were minimal concentrations of alkaloids, phytic acid, tannins, steroids and terpenoids.

Table 4: Phytochemical composition of red cabbage aqueous extract

Phytochemical	Concentration
Alkaloids (mg / 100 g)	18.26±0.01
Tannins (mg / 100 g)	12.95±0.04
Phytic acid (%)	15.23±0.32
Terpenoid (%)	0.20±0.12
Steroids (mg / 100 g)	7.63±0.01
Flavonoids (mg CE / g)	46.31±0.05
Total Phenolic Content (TAE) / g)	133.42±0.01
Anthocyanins (mg GAE / g)	96.01±0.50
Total Antioxidant Capacity (TAE)	87.59±0.01

Values are expressed as Mean ± SD of three replicate samples. CE: Catechol Equivalent; TAE: Tannic Acid Equivalent

3.5 GC / MS Screening of Red Cabbage (*Brassica oleracea* var. *capitata* f. rubra) aqueous extract

The GC/MS screening for bioactive compounds present in the red cabbage aqueous extracts as presented in Table 5, revealed the presence of about 35 bioactive compounds.

Table 5: GC / MS screening of red cabbage (*Brassica oleracea var. capitata f. rubra*) aqueous extract.

S. No	Compound	Retention Time (min)	Molecular Weight (g / mol)	Peak Area (%)
1.	2,2-dimethoxybutane	8.85	118.00	2.68
2.	3-Furaldehyde	9.36	96.00	3.57
3.	Neocurdine	9.77	236.00	8.71
4.	Ethyl-2,2-diethyl propionate	10.31	190.00	4.37
5.	Maltol	10.87	122.00	10.39
6.	1,2,3-propanetriol-1-acetate	12.66	134.00	1.91
7.	Quinoline-3-methyl	13.43	143.00	6.30
8.	Coumaric acid	14.95	164.00	1.90
9.	Copaene	15.57	204.00	3.62
10.	Delphinidin	16.34	303.24	5.78
11.	Caryophyllene	16.90	204.30	13.27
12.	Gamma-sitosterol	18.26	414.00	4.61
13.	Cyanidin	18.76	287.24	10.19
14.	Beta-Amyrin	19.42	410.00	5.43
15.	Pyrrolidine-1-(1,6-dioxooctadecyl)-	19.87	351.00	1.32
16.	Alpha-ergo sterol	19.92	398.00	7.58
17.	2-pyrazoline,1-isopropyl-5-methyl	20.34	126.00	4.73
18.	Resorcinol, bis (*tert*- Butyldimethylsilyl)	20.73	246.00	3.91
19.	Peonidin	21.47	301.27	8.22
20.	Eugenol	21.82	164.20	6.38
21.	Anabasine	22.26	162.30	1.33
22.	Benzyl isoquinoline	22.64	219.28	0.87
23.	Malvidin	22.95	331.30	6.73
24.	Phytol	23.20	128.17	2.21
25.	Phytic acid	23.58	660.04	17.39
26.	Myrcene	23.79	136.23	6.82
27.	Pelargonidin	24.22	271.24	8.58

28.	Beta-caryophyllene	24.77	204.36	0.73
29.	Sparteine	26.36	234.39	3.11
30.	Pelletierine	26.73	141.21	1.49
31.	Campesterol	26.93	400.70	0.86
32.	Lupenone	27.31	424.70	3.25
33.	Squalene	27.62	410.70	2.78
34.	Carpaine	27.81	478.70	1.46
35.	Lobeline	28.67	337.46	0.72

3.6 Measurement of free radical scavenging activity of Various Concentrations (µg / ml) of red cabbage (*Brassica oleracea* var. *capitata* f. rubra) aqueous extract

Table 6 is a representation of the DPPH-scavenging activity (%), ferric reducing antioxidant capacity (nm), and total antioxidants capacity (nm) of various concentrations (µg / ml) of red cabbage aqueous extract of *Brassica oleracea* var. *capitata* f. rubra.

From the result, it was recorded that the red cabbage aqueous extract showed an appreciable comparative DPPH-scavenging activity to the standard (ascorbic acid) at 5, 10, 20, 30, 40 and 50µg / ml. A rising scavenging activity was recorded, ranging from 16.65±0.30 to 43.74±1.10 for the aqueous extract, and 55.09±0.95 to 68.64±1.14 for the ascorbic acid.

A statistical (p<0.05) comparison between the FRAC results of the aqueous red cabbage extract and the ascorbic acid also revealed a near similarity of activities. While the FRAC values of the red cabbage aqueous extracts ranged from 0.09± 0.01 to 0.23±0.03, and that of the ascorbic acid ranged from 0.10± 0.46 to 0.42±0.02.

Furthermore, the TAC analysis of the different concentrations (5, 10, 20, 30, 40 and 50 µg/ml) revealed that the values of the red cabbage aqueous extract were significantly (p<0.05) lower than those of the ascorbic acid, ranging from 0.12±0.01 to 0.34±0.03, and 0.15±0.01 to 0.55±0.02 respectively.

Table 6: Measurement of free radical scavenging activity of various concentrations (µg / ml) of Red Cabbage (*Brassica oleracea* var. *capitata* f. rubra) Aqueous Extract

Concentration (µg / ml)	DPPH (%) Extract	DPPH (%) ascorbic acid	FRAC (nm) Extract	FRAC (nm) ascorbic acid	TAC (nm) Extract	TAC ascorbic acid
5	16.65±0.30	55.09±0.95*	0.09±0.01	0.10±0.46	0.12±0.01	0.15±0.01*
10	19.55±0.21	57.74±0.09*	0.13±0.01	0.17±0.02	0.20±0.01	0.30±0.02*
20	29.59±0.39	59.22±1.06*	0.16± 0.01	0.25±0.02	0.29±0.01	0.44±0.02*
30	39.97±0.04	66.47±0.71*	0.18±0.01	0.33±0.01	0.31±0.01	0.52±0.01*
40	33.94±0.82	62.32±0.32*	0.21±0.01	0.40±0.02	0.31±0.01	0.52±0.01*
50	43.74±1.10	68.64±1.14*	0.23±0.03	0.42±0.02	0.34±0.03	0.55±0.01*

Values are expressed as Mean ± SD of three replicate samples. *p<0.05 shows significant increase in values of ascorbic acid in comparison with the red cabbage aqueous extracts

4. Discussion

When proximate composition analyses are executed, they are done to enable the quantitative evaluation of nutrient content in food crops so as to ascertain their nutritive value and qualification as food crops. In this present study, the vegetable was shown to possess an elevated percentage of carbohydrate, followed by the moisture and protein content. On the other hand, the lipid content, ash content, and crude fibre were low. This finding presents the vegetable to be highly nutritious and a good source of nutritive components, although varying slightly with the reports of Ashfaq *et al*., [5] for the Pakistan-grown red cabbage vegetable, where 89.84% moisture, 0.81% ash content, 2.95% crude fibre, and 0.92% protein were recorded. While the Drozdowska *et al*., study [3], reported an ash content of 8.66%, 17.03% protein, and 0.87% fat in mature red cabbage vegetables grown in Poland.

The consumption of foods loaded with vitamins; as found in vegetables and fruits still remain one of the safest methods for meeting the daily requirements of these vitamins. The red cabbage vegetable has a rich supply of essential / antioxidant vitamins like C, E, and B vitamins [4]. Studies by Singh *et al*. [28] indicated that red cabbage contained 24.38 vitamin C, 0.044 β-carotene, 0.046 Lutein and 0.261 DL-α-tocopherol (all in mg / 100g fw). These studies are in agreement with the findings of this study which recorded an abundance of vitamins occurring in the order:

$C>E>A>B_{12}>B_9>D>B_3>B_6>B_1$ & B_2

Fruits and vegetables are laden with elements needed to maintain the structural functioning of enzymes (Cu, Fe, Mn, Se, and Zn), red blood cells build-up (Fe, I, and Mn), immune response (Zn, Cu and Se), and the maintenance of the antioxidant and pro-oxidant balance (Mn and Mo) [29]. The red cabbage vegetable is rich in minerals like potassium, magnesium, manganese, calcium, sodium, and trace amounts of iron [5], making it a viable source of the needed minerals.

The elemental concentration in the aqueous extracts shows that the extract was rich in the needed minerals for systemic functionality. Comparing the analysed values with those of the WHO / FAO [30] allowable limits showed that all elements were below the limits set. Also the values were lower than the observed values in the cabbage vegetables grown in an industrial area (Mojo area) in Ethiopia [31], and Pakistan [5], but shared some similarities with what was noticed in a Ghana study [32].

Research reveals that the red cabbage vegetable has an appreciable amount of phenolic compounds and flavonoids (predominantly anthocyanin), compared to the green variety [33]. These compounds fall into the non-nutritive biologically active category in plants called phytochemicals. They have been applied in many 'trado-medical' treatment regimens to promote health and avert disease in several cultures around the world. The quantity of phytochemicals captured in Table 4, shows appreciable amounts of polyphenols, anthocyanins, and flavonoids in the aqueous extract, while the alkaloids, tannins and sterols were in small amounts. This study is in agreement with the study by Liang *et al*., [6] were a high polyphenols, flavonoids, and anthocyanin content was recorded. The amount of bioactive compounds in the red

cabbage is said to be dependent on the cultivars, maturity, climatic conditions, growth environment / other environmental factors and the genetic make-up [9].

The GC-MS screening of the aqueous extracts of red cabbage revealed the presence of about 35 bioactive compounds, showing the presence of alkaloids, anthocyanins, mono, di, and sesquiterpene, plant sterols, phytic acid and polyphenolic compounds, with significant biological activities.

From the analysis, the aqueous extracts of the red cabbage showed an appreciable comparative DPPH-scavenging and FRAC activity compared to the standard (ascorbic acid) at 5, 10, 20, 30, 40 and 50µg / ml, which appeared to increase with the increasing extract concentration. Also, the total antioxidant capacity analysis of the different concentrations (5, 10, 20, 30, 40 and 50 µg / ml) showed a rising antioxidant capacity with increasing concentration, though lower than the vitamin C. The polyphenols group of compounds present in red cabbage sets it apart as a potent antioxidant with the ability to scavenge free radicals within cells, prolonging life and health. Consuming a significant amount of red cabbage could reduce the risk of certain non-communicable diseases, owing to their rich concentration of certain compounds like Vitamin C, β-carotenes, folic acid, tocopherol, flavonoids, flavones, anthocyanin, catechin and ISO-catechins [28].

Several studies have quantified the total antioxidant capacity (TAC), 1, 1-Diphenyl-2-picyrylhydrazyl (DPPH) free radical scavenging activity and ferric reducing antioxidant capacity (FRAC) assay of red cabbage, in order to estimate the antioxidant potentials inherent in the vegetable. TAC values for red cabbage from these studies were 10.59µgAAE / mgfw [34], and 87.19% [8]. The DPPH radical scavenging activity is often used to determine the antioxidant activity of most plant extracts. DPPH is a free radical that has a nitrogen ion at the centre [6]. Studies have revealed the DPPH radical scavenging ability in the red cabbage to be: 69.82% [6], and 89.04% when aqueous extracts were used at 40 µg / ml [35]. Studies determining the FRAC activity of the red cabbage extract found values which fell within: 0.53 (absorbance) [6], and 80.87µmol TE / GFW [34].

5. Conclusion

This research has reported the red cabbage vegetable to be rich in carbohydrates, proteins, vitamins, and minerals. It promises to be a good alternative for people looking to manage their weight as the lipid content was low. Some important phytochemicals such as anthocyanin with beneficial health effects were identified, while some level of antioxidant capacity was exhibited, increasing with elevated concentration. The study differed from similar studies on the red cabbage vegetable grown in other parts of the world, in that the Nigerian variety was shown to contain some percentage of phytic acid with the propensity to chelate some essential minerals thereby reducing their bioavailability. Conclusively, the red cabbage vegetable would be a good dietary addition for maintenance of health provided ways of reducing the anti-nutrient content is adopted in the preparation methods.

6. Acknowledgement

This work received part funding from the World Bank Africa Centre of Excellence in Public Health and Toxicological Research, University of Port Harcourt, Rivers State, Nigeria.

7. Conflict of interest statement

The authors declare that there are no conflicting interests.

8. Data Set Reference

https://doi.org/10.6084/m9.figshare.20372529

9. References

1. Tur JA, Bibloni MM. Functional Foods. In: Caballero B, Finglas PM, Toldra F (ed) Encyclopaedia of Food and Health. Kidlington, Oxford; c2016. p. 157-161. https://doi.org/10.1016/3978-0-12-384947-2.00340-8.
2. Hasler CM. Functional Foods: Benefits, concerns, and challenges. A position paper from the American Council on Science and Health. J Nutr. 2002;132(12):3722-3781. https://doi.org/10.1093/jn/132.12.3772.
3. Drozdowska M, Leszczynska T, Koronowicz A, Piasna-Slupecka E, Domagala D, Kusznierewicz B. Young shoots of red cabbage are a better selected nutrients and glucosinolates in comparison to the vegetable at full maturity. Eur. Food Res. Technol. 2020;246:255-2515. https://doi.org/10.1007/s00217-020-03593-x.
4. Draghici GA, Lupu MA, Borozan A, Nica D, Alda S, Alda L, *et al*. Red cabbage, millennium functional food. J Hortic. For. Biotech. 2013;17(4):52- 55.
5. Ashfaq F, Butt MS, Nazir A, Jamil A. Compositional analysis of Pakistani green and red cabbage. Pak. J Agric. Sci. 2018;55(1):191-196. https://doi.org/10.21162/PAKJAS/18.6547.
6. Liang Y, Li Y, Zhang L, Liu X. Phytochemicals and antioxidant activity in four varieties of head cabbages commonly consumed in China. Food Prod. Process. Nutr. 2019;1-3. https://doi.org/10.1186/s43014-019-0003.
7. Mizgier P, Kucharska AZ, Sokol-Letowska A, Kolniak-Ostek J, Kidon M, Fecka I. Characterization of phenolic compounds and antioxidant and anti-inflammatory properties of red cabbage purple carrots extracts. J. Funct. Foods. 2016;21:133-146. https://doi.org/10.1016/j.ff.2015.12.004.
8. Cruz AB, Pitz HD, Veber B, Bini LA, Maraschin M, Zeni ALB. Assessment of bioactive metabolites and hypolipidemic effect of polyphenolic-rich red cabbage extract. Pharm. Biol. 2016;54(12):3033-3039. https://doi.org/10.1080/13880209.2016.1200633.
9. Hart DJ, Scott KJ. Development and evaluation of an HPLC method for the analysis of carotenoids in foods and measurement of the carotenoid in foods and measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. Food Chem. 1995;54:101-111.
10. Horwitz W, Latimer GW. Association of Official Analytical Chemists International. Official methods of analysis of AOAC International. 18th ed, AOAC International, Gaithersburg, Maryland; c2006.
11. Bayfield RF, Cole ER. Colorimetric estimation of Vitamin A with trichloroacetic acid. Methods Enzymol. 1980;67:189-195. https://dpoi.org/10.1016/s0076-6879(80)67026-8.
12. Rosenberg HR. Chemistry and physiology of the vitamins. Interscience Publisher, New York; c1992. p. 452-3.
13. Roe JH, Kuether CA. The determination of ascorbic acid in whole blood and urine through 2, 4-dinitrophenylhydrazine derivative dehydroascorbic acid. J Biol. Chem. 1943;147:399-407.
14. Amer MM, Wahbi AM, Hassan SM. Colorimetric determination of vitamin D in some oily pharmaceutical preparations. Analyst. 1975;100:238-242. https://doi.org/10.1039/AN9750000238.

15. American Public Health Association. 3111B, Direct air-acetylene flame method, standard methods for the examination of metals, 20th Ed., APHA, AWWA, WEF; c1998.
16. Harbone JB. Phytochemical methods: A guide to modern techniques of plant analysis, Chapman and Hall, London, UK; c1973.
17. Makkar HPS, Blummel M, Borowy NK, Becker K. Gravimetric determination of tannins and their correlation with chemical and protein precipitation methods. J Sc. Food Agric. 1993;61(2):161-165. https://doi.org/10.1002/jsfa.2740610205.
18. Maga JA. Phytate: Its chemistry, occurrence, food interaction, nutritional significance and methods of analysis. J Agric. Sci. Food Chem. 1983;30:1-9.
19. Mahdu M, Sailaja V, Satyadev TNVSS, Satyanarayana MV. Quantitative phytochemical analysis of selected medicinal plant species by using various organic solvents. J. Pharmacogn. Phytochem. 2016;5:25-29.
20. Indumathi C, Durgadevi G, Nithyavani S, Gayathri PK. Estimation of terpenoid content and its antimicrobial property in Eincostemma litorrale. Int. J Chem. Tech. Res. 2014;6(9):4264-4267.
21. Lister E, Wilson P. Measurement of total phenolics and ABTS assay for antioxidant activity (personal communication). Crop Research Institute, Lincoln, New Zealand, 2001.
22. Zhishen J, Mengcheng T, Jianming W. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem. 1999;64(4):555-559. https://doi.org/10.1016/S0308-814(98)00102-2
23. Fuleki T, Francis FJ. Quantitative methods for anthocyanins: Extraction and determination of total anthocyanin in cranberries. J Food Sci. 1968;33(1):72-77. https://doi.org/10.1111/j.1365-2621.1968.tb00887.x.
24. Prieto P, Pineda M, Aguilar M. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphor molybdenum complex: specific application to the determination of Vitamin E. Anal. Bio chem. 1999;269(2):337-41. https://doi.org/10.1006/abio.1999.4019.
25. Lim YY, Quah EPL. Antioxidant properties of different cultivars of Portulaca oleracea. Food Chem. 2007;103(3):734-740. https://doi.org/10.1016/j.foodchem.2006.09.025.
26. Thaipong K, Boonprakob U, Crosby K, Cisneros-Zevallos L, Byrne D. Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts. J Food Comp. Anal. 2006;19:669-675. https://doi.org/10.1016/j.jfca.2006.01.003.
27. Kumari S. Environmental Biochemistry. Random Publications, New Delhi; c2012.
28. Singh J, Upadhyay AK, Bahadur A, Singh B, Singh KP, Rai A. Antioxidant phytochemicals in cabbage (*Brassica oleracea* L., var *capitata*). Sci. Hortic. 2006;108:233-237. https://doi.org/10.1016/j.scienta.2006.01.017.
29. Gharibzahedi SMT, Jafari SM. The importance of minerals in human nutrition. Bioavailability, food fortification, processing effects and nano-encapsulation. Trends Food Sci. Technol. 2017;62:119-132. https://doi.org/10.1016/j.tifs.2017.02.017.
30. WHO / FAO. Expert Committee on Food Additives. Cambridge University Press, Cambridge; c2007. p. 329-336.
31. Gebeyehu HR, Bayissa LD. Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia. PLOS ONE. 2020;15(1):e0227883. https://doi.org/10.137/journal.pone.0227883.
32. Ametepey ST, Cobbina SJ, Akpabey FJ, Duwiejuah AB, Abuntori ZO. Health risk assessment and heavy metals contamination levels in vegetables from Tamale Metropolis, Ghana. Int. J Food Contam. 2018;5:5. https://doi.org/ 10.1186/s40550-018-0067-0.
33. Leja M, Kaminska I, Kolton A. Phenolic compounds as the major antioxidants in red cabbage. Folia Hortic. 2010;22(1):19-24. https://doi.org/10.2478/fhort-2013-0146.
34. Rokayya S, Li CJ, Zhao Y, Li Y, Sun CH. Cabbage (*Brassica oleracea* L. var. *capitata*) phytochemicals with antioxidant and anti-inflammatory potential. Asian Pac. J Cancer Prev. 2013;14(11):6657-6662. https://doi.org/10.7314/APJCP.2013.14.11.6657.
35. Gaafar AA, Aly HF, Salama ZA, Khaled MM. Characterizing the antioxidant and anticancer properties of secondary metabolites from red and white cabbages *Brassica oleracea* L. var. *capitata*. World J. Pharm. Res. 2014;3(4):171-186.