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Phenolic-Rich Ethanolic Extracts of African Culinary Spices Exhibit Comparable Antioxidant Efficacy to Rosemary (Salvia Rosmarinus): A Phytochemical and Radical Scavenging Assessment

Nwagbo, C.C.[1]; Okafor, G.I.[2], Chude, C.O[1]. and Ndukwe, O. O[3].

1. *Chukwuemeka Odumegwu Ojukwu University, Igbariam, Department of Food Science and Technology, Faculty of Agriculture, P.M.B 02, Anambra State, Nigeria.*
2. *University Of Nigeria, Department of Food Science and Technology, Faculty of Agriculture, 410001, Nsukka. Enugu State, Nigeria.*
3. *Nnamdi Azikiwe University, Department of Crop Science and Horticulture, Faculty of Agriculture, P.M.B 5025, Ifite Awka, Anambra State, Nigeria.*

Corresponding author: Nwagbo, C.C *(cn.nwagbo@coou.edu.ng)*

Abstract

Background

Culinary spices and herbs are known to possess excellent antioxidant activities that promote health and wellness and are linked to their phytochemical compositions. Ricinodendron heudelotii and Chrysobalanus icaco are tropical spices, while Salvia rosmarinus is a herb of Mediterranean origin.

Materials and Methods

This study evaluated the phytochemical composition (phenolics, terpenoids, flavonoids, oxalates, saponins, alkaloids, cardiac glycosides, tannins, and phytates) and the antioxidant activities (DPPH, FRAP, and TAC) of ethanolic extracts of Ricinodendron heudelotii, Chrysobalanus icaco, and Salvia rosmarinus using butylated hydroxytoluene (BHT) as a positive control. The spices were extracted using 100% ethanol. The phytochemical composition and antioxidant activities of the extracts obtained were determined using standard methods.

Results

The values of phytochemicals varied with ranges in flavonoids; phenolics; terpenoids; oxalates; saponins; alkaloids; cardiac glycosides; tannins and phytates as follows respectively: 7.89-13.12 mg QE /g; 98.08-192.19 mg GAE /g; 1.88-24.24 mg GAE/g; 35.67-68.77 mg/100g; 0.00-18.14 mg/100g; 0.00-6.46 mg/100g; 6.19 -19.65 mg/100g; 0.63 -1.15 mg CE /g and 19.31 – 113.17 mg/100g. The highest percentage Ferric reducing ability (FRAP) was seen in this order: Gallic acid (99.27 %), Salvia rosmarinus (75.46%) > Ricinodendron heudelotii (62.58 %) >BHT (45.35 %) > Chrysobalanus icaco (64.42 %). Ricinodendron heudelotii and Salvia rosmarinus extracts exhibited the highest Total antioxidant capacity (TAC) (11.45 and 12.47 %) compared with cocoplum (6.7 %).

Conclusion

The results indicated that the ethanolic extracts of Ricinodendron heudelotii and Chrysobalanus icaco are potential antioxidants with properties comparable to Salvia rosmarinus and superior to those of butylated hydroxytoluene.

Keywords

Cocoplum, free radical scavengers, oleoresin, plant bio-actives, phytonutrients, Njangsa, Rosemary.

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I. Introduction

The rising global prevalence of metabolic diseases such as type 2 diabetes, cardiovascular diseases, and cancer simultaneously sparks increased research interest in the preventive roles of natural dietary antioxidants [1]. This is because cellular damage from oxidative stress has been implicated as the key driver in the pathogenesis of these metabolic diseases. Oxidative stress from excessive reactive oxygen species can be reduced by consuming natural foods with radical-scavenging properties [2]. To this end, plants'

phytochemicals, such as phenolics, flavonoids, tannins, terpenoids, alkaloids, and saponins, are gaining attention for their potential to provide significant antioxidant protection.

Spices and herbs are important sources of natural antioxidants, which play important roles in delaying the progression of inflammatory, degenerative, and even infectious diseases; protecting against lipid deterioration; and replacing synthetic antioxidants with healthier substitutes [3; 4]. Again, spices stimulate appetite, improve digestion, and reduce symptoms of common cold, nausea, and vomiting [5]. Diets rich in spices have been associated with reduced risk of chronic and infectious diseases [6, 7]. The functional properties of spices, such as preservation, coloring, medicinal, flavoring, and insecticidal effects, are attributed to some of their chemical constituents, which include anthocyanins, alkaloids, flavonoids, isoflavonoids, tannins, coumarins, glycosides, terpenes, phenolic acid, ascorbic acid, and carotenoids [3, 8]. Phenolic compounds, flavonoids, and terpenes are especially responsible for the antioxidant and preservative properties of spices [3]. Most plants' phytochemicals act as antioxidants through their excellent ability to donate hydrogen from the hydroxyl groups extracted from their phenolic rings to stabilize free radicals in the body and in food systems. Natural antioxidants are considered more beneficial than synthetic antioxidants because they are safer, more efficient, more readily absorbed in the gastrointestinal tract, and contain additional nutrients [9]. Moreover, the multiple phytochemicals present in natural antioxidants can act synergistically, conferring greater antioxidative capacity than synthetic antioxidants [10].

Rosemary (*Salvia rosmarinus*), a perennial Mediterranean herb, is among the most rigorously characterized culinary spices, with validated antioxidant efficacy [11]. The extract is the most important natural antioxidant from spices because of its versatility and economic importance [12]. It has been accepted as a natural food antioxidant by both the European Food Safety Authority (EFSA) and the United States Food and Drug Administration (FDA), and it further serves as a global reference standard in functional ingredient research. *Salvia rosmarinus* is one of the important spices in global trade, with various applications ranging from cosmetics, antiseptics, and preservatives to foods and drugs [13]. Its culinary importance stems from its lack of effects on the organoleptic qualities of food, as it is odorless, flavorless, and colorless, with appreciable antioxidant activity that performs better than most synthetic antioxidants [14]. *Salvia rosmarinus* (Rosemary) has been identified as a source of antioxidative bioactive compounds, including carnosol, carnosic acid, rosmarinic acid, rosmanol, and rosemaridiphenol [15]. It has been successfully used to preserve pork products [16] and soybean oil [17].

In Nigeria, the seeds of *Ricinodendron heudelotii* and *Chrysobalanus icaco*, and the leaves of Salvia rosmarinus, are popular culinary spices and herbs used in the preparation of stews, soups, and sauces [18, 19]. Defining spices as natural products derived from the fruit, leaves, seed, root, bark, berry, bud, flower, or leaves of plants, which are used to improve the flavor, aroma, taste, and color of food products, identifies both herbs and spices using the common name "spice". Spices can be further defined as "aromatic vegetable substance in the whole, broken, or ground form, the significant function of which in food is seasoning rather than nutrition and from which no portion of any volatile oil or other flavoring principle has been removed" [20]. While spices are aromatic products derived from various parts of plants other than the leaves, herbs are derived from plant leaves. They are usually used fresh or processed in food preparations due to their rich flavor and, at times, medicinal properties. Herbs have appreciable quantities of polyphenols compared to spices [12].

The seed of the *Ricinodendron heudelotii* is a yellowish, sweet-smelling, lesser-known edible forest product with most of its uses confined to Sub-Saharan Africa. The flavorful seeds are used to flavor savory dishes such as fish and chicken sauces and pepper soups [21]. *Chrysobalanus icaco* Linnaeus (family: Chrysobalanaceae; common names: icaco, cocoplum, and gbafilo) is a shrub that originated from West and Central Africa, northern South America, southern states of México, the West Indies, Central America, and the Caribbean. The seed of the tree is also a lesser-known fruit that contains a nut with an almond-like taste and flavor. The nuts from the seeds of *Chrysobalanus icaco* are roasted or ground and used in Nigeria as spice flavoring in pepper soups [5]. Besides their use in meals, the seeds of *Ricinodendron heudelotii* are used in folk medicine in West Africa for the treatment of gonorrhea and fever in babies [22, 23], and preliminary pharmacognostic and ethnobotanical studies have shown that they possess antimicrobial, antidiarrheal, and hepatoprotective properties [24, 25]. On the other hand, the nuts of *Chrysobalanus icaco* Linnaeus are used in Northern Brazil, as infusions in the treatment of diabetes, high cholesterol, diarrhea, bleeding, and abdominal pain [26]. The leaves of *the Salvia rosmarinus* plant are used in folk medicine as a sedative, laxative, and stimulant, and in the treatment of inflammatory, rheumatic, bacterial, and spasmodic diseases. It is also used to treat headaches, common colds, and sore throats [27]. Nutritionally, the seed of *Ricinodendron heudelotii* is a rich source of protein, lipids, and micronutrients. The protein content of the seeds (30%) is higher than that of several known high-protein seeds, such as soybean and cowpea [28]. Besides, the seed of *Ricinodendron heudelotii* can be considered as a high oil seed as it has up to 46% lipids, which are predominantly made up of polyunsaturated fatty acids (Omega 3 and 6) in a manner comparable to that of fish [14]. In addition, it has a low carbohydrate content [28]. The seed is rich in fat-soluble vitamins (A, D, E, and K) and some trace

elements [14]. Scientific literature establishes a relationship between the phytochemical constituents of plants and their radical-scavenging abilities, which can be measured using standardized in vitro assays such as the 2,2-diphenyl-1-picrylhydrazyl (DPPH), Ferric Reducing Antioxidant Power (FRAP), and Phosphomolybdenum-based Total Antioxidant Capacity (TAC) assays [30].

While *Salvia rosmarinus* has been established globally as one of the most potent natural antioxidants among spices, rigorous quantitative phytochemical profiling and comparative antioxidant potentials of *Ricinodendron heudelotii* and *Chrysobalanus icaco* have not been reported in the peer-reviewed literature, and given that enhanced benefits from the use of spices as antioxidants are related to their phytochemical composition, the importance of the lesser-known and underutilized African spices, *Ricinodendron heudelotii* and *Chrysobalanus icaco*, as antioxidants could be highlighted when compared with those of *Salvia rosmarinus* and the synthetic antioxidant butylated hydroxytoluene. Despite the growing body of literature on phytochemical constituents of African and tropical plant species, critical gaps persist. There is a paucity of comparative studies that systematically benchmark the antioxidant and phytochemical constituents of these underutilized West African culinary spices against internationally standardized references, such as *Salvia rosmarinus*, and synthetic antioxidants, such as BHT. Quantitative characterization is essential for repositioning indigenous plant resources within global functional food taxonomies. Again, a full-spectrum phytochemical profile of phenolics, flavonoids, terpenoids, alkaloids, saponins, cardiac glycosides, and antinutritional factors such as oxalates and phytates for both *Ricinodendron heudelotii* and *Chrysobalanus icaco* within a single, methodologically unified study is grossly lacking in the literature. Lastly, the application of multiple antioxidant assay systems, considered best practices, has not been rigorously applied to these two species in published literature. These gaps limit the functional potentials, applications, and evidence-based assessments of these underutilized spices. This study, therefore, aims to compare the phytochemical constituents of the ethanolic extracts of *Salvia rosmarinus, Ricinodendron heudelotii*, and *Chrysobalanus icaco* under similar conditions and to evaluate their antioxidant capabilities relative to butylated hydroxytoluene.

II. Materials And Methods

Sample Collection

The three plant species investigated in this study were selected based on three convergent criteria: their documented culinary relevance, preliminary ethnobotanical evidence of bioactive potential, and the paucity of rigorous comparative phytochemical data in the peer-reviewed literature. The seeds of *Chrysobalanus icaco*, *Ricinodendron heudelotii*, and *Salvia rosmarinus* leaves were bought from a local market in Awka, Anambra State, Nigeria. The spices were identified at the Department of Botany, University of Nigeria, Nsukka.

Sample Preparation

The spices and herbs shown in Plate 1 were thoroughly washed with distilled water to remove impurities. The seeds of *Chrysobalanus icaco* were cracked open to remove the hulls and extract the nuts. They were gently dried at ambient temperature (25-30°C) for 48 hours until a constant weight was achieved. They were then milled separately using a food mill (Delta Eco Logic, 1000W, Delta, India).

Extraction Protocol

Ethanolic extraction was preferred because of the GRAS status (Generally regarded as safe) and intermediate polarity. The milled spices were macerated in 100% ethanol at a standardized ratio of 1:10 (w/v) of spice powder to solvent. It was left to stand for 72 h at room temperature with occasional shaking. The slurry was filtered through a Whatman No. 1 filter paper. The filtrate was concentrated in a rotary evaporator at 40 °C for 30 minutes, then dried to constant weight in an oven at 40 °C to remove residual ethanol. It was stored in sealed amber bottles in the freezer at -180 °C until use. The yield of the extracts, expressed as a percentage of the starting dry spice powder, was calculated gravimetrically. The reagents used for the chemical analyses were of analytical grade and purchased from Sigma-Aldrich and Merck (Germany).

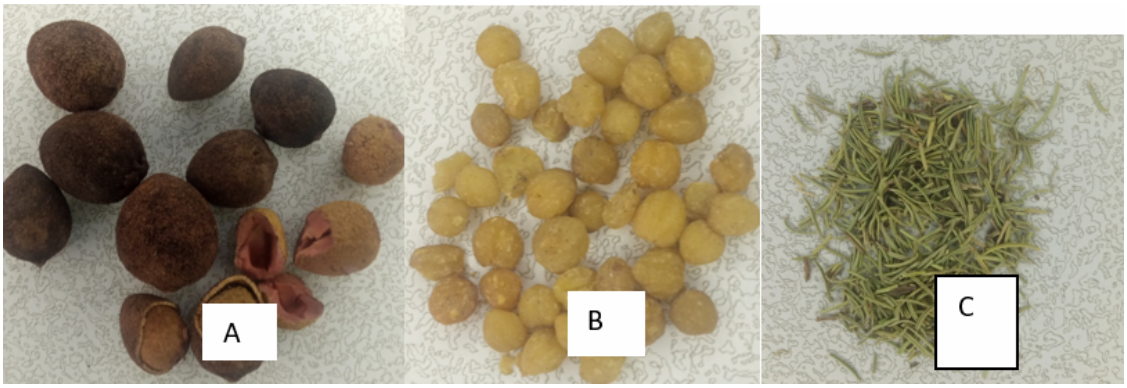

Plate 1: A = Dehulled and undehulled seed kernel of *Chrysobanus icaco;* B = *Ricinodendron heudelotii; C = Salvia rosmarinus.*

Qualitative Phytochemical Determinations

Test for Tannins

Each extract was measured (3 ml) into a pipette containing 2 ml of 1 % hydrochloric acid. The mixture was shaken to observe a red precipitate, confirming the presence of tannins [17].

Test for saponins

Each extract (2 g) was weighed into a test tube and mixed with 20 mL of distilled water. The mixture was boiled for 10 minutes and then filtered. The filtrate (10 ml) was mixed with distilled water (5 ml), and the mixture was vigorously shaken to form a persistent froth. Olive oil (3 drops) was added to the froth, which was then shaken vigorously. Afterward, the observation of a stable foam confirmed the presence of saponins [31].

Test for Phenolics

Each extract was measured into a test tube (1.0 ml) using a pipette. A mixture was prepared by adding 1.0 mL of 10% ferric chloride to the test tube containing the extract. On stirring, a greenish-black precipitate confirmed the presence of phenolics [31].

Test for alkaloids

A mixture was prepared by combining 1.4 g of mercuric chloride with 60 mL of distilled water in a beaker. Another mixture was made by combining 4.5g of potassium iodide with 20 ml of distilled water in another beaker. The two separate mixtures were carefully combined and diluted to 100 mL with distilled water. Each extract (1.0 ml) was measured into a test tube and mixed with 1.0 ml of the potassium iodide and mercuric chloride mixture. After shaking thoroughly, an observed cream-coloured precipitate indicated the presence of alkaloids [31].

Test for Cardiac Glycosides

Each extract was measured (1ml) into a pipette and mixed with 10 ml of 50 % sulphuric acid. The mixture was heated in a water bath for 5 minutes, after which 10 mL of Fehling's solution was added. The mixture was boiled for an additional 5 minutes. An observed brick red precipitate was used to confirm the presence of glycosides [31].

Test for Terpenoids

Each of the extracts (5 ml) was added to a pipette, and 2 ml of chloroform and 3 ml of concentrated sulphuric acid were added. An observed reddish-brown coloration indicated the presence of terpenoids [31].

Test for Steroids

Each extract was measured (0.5 ml) into a test tube, and a mixture was prepared with 1 ml of concentrated sulphuric acid. A color at the interface indicated the presence of steroids [31].

Test for Flavonoids

About 1.0 mL of the spice extract was added to a test tube. Then 1.0 mL of 10% lead acetate solution was added to the same test tube and mixed thoroughly to observe a color change or precipitate, which confirmed the presence of flavonoids [31].

Quantitative Phytochemical Determinations

Determination of total tannin content of spice extracts

The methods of Ezeonu and Ezikeme [31] were used. The Folin-Denis reagent was prepared by mixing 50 g of sodium tungstate (Na2WO4) with 37 cm^3 of distilled water. To this mixture, 10 g of phosphomolybdic acid ($H_3PMo_{12}O_{40}$) and 25 cm^3 of orthophosphoric acid (H_3PO_4) were added. The mixture was refluxed for 2 hours and cooled. Afterward, the mixture was diluted with 500 cm3 of distilled water. Each extract (1 g) was weighed into a conical flask, and 100 cm^3 of distilled water was added. The mixture was boiled for 1 hour and filtered into a 100 cm^3 volumetric flask. Each 10 cm3 of the extract was diluted with 50 cm^3 of distilled water. Folin-Denis reagent (5 cm^3) and saturated Na_2CO_3 solution (10 cm3) were mixed and added to the volumetric flask containing the diluted extract. The mixture was pipetted into a 100 cm3 conical flask for color development. The solution was left to stand for 30 minutes at 25°C in a water bath with constant agitation. Absorption was measured using a SpectraMax 23A spectrophotometer, and optical density was measured at 700 nm. The result was compared against a standard tannic acid curve. The tannic acid curve was prepared by dissolving 0.20 g of tannic acid in distilled water and diluting to the 200 cm^3 mark. Various concentrations were prepared, ranging from 0.2 to 1.0 mg/cm^3. The standard tannic acid solution was pipetted into five individual test tubes containing 5 cm^3 of Folin-Denis reagent, and 10 cm^3 of saturated Na_2CO_3 solution made up to 100 cm^3 with distilled water. The solution was allowed to stand for 30 minutes at 25°C in a water bath. The optical density was measured at 700 nm using a spectrophotometer. The absorbance at 280 nm was plotted against tannic acid concentration.

Tannic acid was calculated as follows:

C = concentration of tannic acid read from the graph

Determination of phenolic acid content of spice extracts

The total phenolic acids of the spice extracts and defatted flours were determined by the methods of N'Dri et al. [32] and the Folin-Ciocalteu assay [33]. A weighed quantity of the ground spice sample (1 g) was extracted with 10 mL of 80% methanol at room temperature, then reacted with a tenfold dilution of the Folin-Ciocalteau reagent. Sodium carbonate (6% (w/v) was added, and the final volume was made up with deionized water. The mixture was incubated at room temperature for 15 min, and the absorbance was measured against a gallic acid standard. The blank was prepared as above under similar conditions, but without the ground spices; the absorbance was measured at 725 nm using a spectrophotometer (PG Instruments, England). Total phenolic content was expressed as mg gallic acid equivalent (GAE)/100 g sample.

Determination of total flavonoid content of spice extracts

Flavonoids were quantified using the methods of Ezeonu and Ejikeme [31]. A weighed quantity of 2.5 g of the respective extracts was mixed with 50 cm^3 of 80% aqueous methanol in a 250 cm^3 beaker. The mixture was covered and left to stand at room temperature for 24 hours. A supernatant and residue were formed. The supernatant was discarded, and the residue was filtered using Whatman filter paper 42. The procedure was repeated three times using the filtered residue and 50 cm^3 of ethanol. The re-extracted filtrate was placed in a crucible, dried over a water bath for 60 minutes at 50°C, cooled in a desiccator, and weighed. The procedure was repeated with the filtrate till a constant weight was obtained. The percentage of flavonoids was calculated as

Determination of terpenoid content of spice extracts

This was done using the methods of [34]. The spice extracts and defatted flour samples were extracted with 1 mL of methanol for 48 hours in the dark, then centrifuged (Model 2010, Kubota, Japan) for 15 minutes at 12000 rpm. The supernatant (200 µL) was added to 1.5 mL of chloroform in a 2 mL flask and thoroughly mixed. The mixture was incubated at room temperature for 3 minutes. After incubation, 100 µL concentrated sulphuric acid (H2SO4) was added and incubated at room temperature in the dark for 2 hours. At the end of incubation, a reddish-brown precipitate formed in each flask. The precipitate was separated from the supernatant, and 1.5 mL of methanol was added to the precipitate. After thorough mixing, absorbance was measured at 538 nm using a UV-Vis spectrophotometer. The values were plotted in a standard graph. Piscidinol was used as the standard for the plotting graph.

Determination of alkaloid content of spice extracts.

The method of Ezeonu and Ejikeme [31] was used. The extract (2.5 g) was weighed into a 250 cm3 beaker, and a mixture of 200 cm3 10% acetic acid and ethanol was added. The mixture was allowed to stand for 4 hours. Afterward, the extract was boiled in a water bath until the volume was reduced to 1/4th of the original volume. Fifteen (15) drops of concentrated ammonium hydroxide were added drop-by-drop to the

extract mixture. The mixture was allowed to stand for 3 hours until precipitation formed. The supernatant was discarded, and the precipitate was washed with 20 cm3 of 0.1 M ammonium hydroxide. The precipitate was filtered using filter paper. The residue was dried in an oven, and the percentage of the weighed alkaloid was expressed as:

Determination of saponin content of spice extracts.

Quantitative saponin was determined using the methods of Ezeonu and Ejikeme [31]. A weighed quantity (100 cm^3 of 20%) of aqueous ethanol was mixed with a measured quantity (5 g) of the respective ethanolic extracts in a 250 cm^3 conical flask. The conical flask containing the mixture was heated at 55°C for 4 hours using a hot water bath. This was constantly stirred while the heating was taking place. After heating and cooling, the supernatant was filtered off. An additional 100 cm^3 of 20% aqueous ethanol was added to the residue, and the mixture was heated for an additional 4 hours at 55°C with constant stirring. The residue was evaporated to 40 cm3 using a water bath set to 90°C. A measured volume of diethyl ether (20 cm3) was added to the concentrate, and the mixture was vigorously shaken until the aqueous layer separated from the ether layer. The ether layer was discarded. This extraction using diethyl ether was repeated twice. Again, 60 cm^3 of n-butanol and 10 cm^3 of 5% sodium chloride were added, and the extract was again extracted twice, shaken vigorously, and filtered. The sodium chloride layer was discarded, and the remaining solution was heated in a water bath for 30 minutes, then transferred to a crucible. The residue was dried in an oven until a constant weight was obtained. The saponin content was calculated thus:

Determination of Cardiac Glycoside content of spice extract.

Cardiac glycoside was determined using the methods of Tofighi *et al.* [35] by dissolving a 10% extract of the extract in 10 mL of freshly prepared Baljet's reagent (95 mL of 1% picric acid + 5 mL of 10% NaOH). After an hour, the mixture was diluted with 20 mL of distilled water, and the absorbance was measured at 495 nm using a spectrophotometer. For the preparation of the standard curve, 10 mL of quercetin at different concentrations (12.5-100 mg/L) was prepared. Total glycoside was expressed as mg of quercetin per g of dried extracts.

Antioxidant Activity Determination

Determination of 1,1-diphenyl-2 picrylhydrazyl free radical scavenging ability (DPPH)

The DPPH value was calculated using the methods of Li *et al*. [36]. A measured quantity (7.89 mg) of DPPH was dissolved in 100 ml of 99.5% ethanol and kept in the dark for 2 hr. A measured volume (1,000 µL) of the solution was added to 800 µL of Tris-HCl buffer (pH 7.4) and 200 µL of the test sample solution in a test tube. The mixture was shaken and kept at room temperature for 30 min. The absorbance of the solution at 517 nm was measured using a spectrophotometer. A measured quantity (1,200 µL) of ethanol and 800 µL of Tris-HCl buffer (pH 7.4) were used as the blank.

The inhibition ratio (%) was calculated below:

Where A1 is the absorbance of the blank, and A2 is the absorbance of the testing sample solution. IC_{50}, which represents the concentration of the sample required to scavenge 50% of DPPH free radicals, was used to plot a linear regression.

Determination of the Ferric Reducing Ability

The FRAP value was calculated using the methods of Li *et al*. [36]. Anhydrous sodium acetate (455.30 mg) was weighed and mixed with 50 ml of distilled water and 3.97 ml of glacial acetic acid. The mixer was filled up to 250 ml with distilled water. A measured quantity of TPTZ (156.20 mg) was dissolved in distilled water, and 0.17 ml of concentrated hydrochloric acid was added. The solution was diluted to 100 mL to prepare a TPTZ solution at 10 mmol/L. A quantity of Iron (III) chloride hexahydrate **(**$FeCl_3 \cdot 6H2O$) (270.03 mg) was weighed, dissolved, and diluted to 50 ml with water. This yielded an Iron chloride solution at 20 mmol/L. The acetic acid buffer, TPTZ solution, and Iron (III) chloride solution were mixed in a 10:1:1 ratio to give the FRAP working solution. The mixture was incubated at 37◦C and used up within 1–2 hr. A volume of 180.0 µL of the FRAP solution was mixed with 5 µL of the sample, shaken well, and incubated in the dark at 37◦C for 15 min. The absorbance was measured at 593 nm. Trolox was used as the standard, and distilled water as the blank control. Trolox concentration was selected under the condition of absorbance value ranging from 0.2 to 0.8 to draw a standard curve. The calibration curve of $FeSO4 \cdot 2H2O$ would be plotted by using different

concentrations (250-1500 µM). FRAP value would be determined for each solution and expressed as µM FeSO4 · 2H2O. The FRAP was calculated below:

FRAP value (mol TE⁄g DW) = c × V × tm

Where c is the Trolox concentration (µmol/ml) of the corresponding standard curve of the diluted sample, V is the sample volume (ml), t is the dilution factor, and m is the weight of the sample dry matter (g).

Determination of the Total Antioxidant Capacity (TAC) of ethanolic extracts

The Total Antioxidant Capacity (TAC) of the respective spice extract at different concentrations was determined by the phosphomolybdate method as described by Prieto *et al.* [37], with minor modifications. A measured quantity (3 ml) of the test extracts at different concentrations was mixed with 3 ml of the reagent solutions (0.6 M sulphuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate) in separate test tubes. The test tubes were covered with aluminum foil and kept in a boiling water bath at 100°C for 90 min. The reaction mixture was allowed to cool to room temperature, and the absorbance of the solution was measured at 695 nm against a blank containing 3 ml of reagent solution and the appropriate volume of the dissolving solvents. The blank was incubated under the same conditions as the test samples. Ascorbic acid was used as a standard reference compound to compare the activities of the extracts.

Statistical Analysis

The data were analyzed statistically using SPSS (version 21). The means were separated using LSD to determine the significant difference $p < 0.05$).

III. Results

Extract Yield

The percentage yield of the spice extracts varied across the three spices, as shown in Table 1. *Ricinodendron heudelotii* had the highest extract recovery, followed by *Chrysobalanus icaco* and *Salvia rosmarinus.* The variations are consistent with differences in species cell wall constituents, moisture content, and the proportion of ethanol-soluble secondary constituents in each spice matrix.

Qualitative Phytochemical Screening

The results of the phytochemical screening of the ethanolic extracts of *Ricinodendron heudelotii, Chrysobalanus icaco,* and *Salvia rosmarinus* are shown in Table 2. A total of eight major phytochemical classes were screened. Tannins, phenolics. Tannins, phenolics, cardiac glycosides, steroids, and terpenoids were detected in all three extracts, though with variable intensities. Tannins were strongly present (+++) in both *R. heudelotii* and *S. rosmarinus* and moderately to strongly present in *C. icaco* (+). Phenolics were strongly detected (+++) in *R. heudelotii* and *S. Rosmarinus* and moderately detected in *C. icaco* (++). Cardiac glycosides were recorded as moderately present (++) in *R. heudelotii,* strongly present (+++) in *C. icaco* and *S. rosmarinus*. Steroids were strongly present (+++) in R. heudelotii, moderately present in C. icaco, and S. rosmarinus. Terpenoids exhibited variable intensities, with strong presence in S. rosmarinus and weak (+) presence in both *R. heudelotii* and *C. icaco.*

Saponins were detected in *R. heudelotti* (++) and *S. Rosmarinus* (+), but were absent (-) in *C. icao*. Alkaloids were observed to be moderately present (++) in both *R. heudelotti* and *S. rosmarinus*, but were absent in *C. icaco.* Flavonoids were detected as moderately (++) and strongly (+++) present in *R. heudelotti* and *S. Rosmarinus,* but absent (-) in *C. icao.*

Table 1: Extraction yield of spice oleoresins

	R. heudelotti ***(Njangsa)***	*C. icao* **(Agbafilo)**	*S.rosmarinus* **(Rosemary)**
Extract yield (%)	58.80 ± 0.03	40.47 ± 0.19	16.40 ± 0.12

Table 2: Qualitative Screening of the ethanolic spice extracts

Phytochemicals	***Ricinodendron heudelotii***	***Chrysobalanus icaco***	***Salvia Rosmarinus***
Saponins	+ +	-	+
Tannin	+ + +	+	+ + +
Phenolics	+ + +	+ +	+ + +
Alkaloids	+ +	-	+ +
Cardiac glycosides	+ +	+ +	+
Terpenoids	+	+	++ +
Flavonoids	++	-	++ +

Key: - = Absent; + = weakly present; ++ = Moderately present; +++ = Strongly present

Quantitative Phytochemical Composition

The quantitative phytochemical composition of the three ethanol spice extracts is shown in Table 3, with statistical differences ($p < 0.05$) demonstrated.

Total phenolic content (TPC) differed significantly ($p < 0.05$) among the three spice extracts. *Salvia rosmarinus* and *R. heudelotii* had the highest TPC at 192.19 and 149.05 mg GAE /g, respectively, while *C. icaco* was 98.08 mg GAE /g. The TPC of *S. rosmarinus* was 1.29-fold and 1.96-fold higher than that of *R. heudelotii* and *C. icaco*, respectively, indicating that *S. Rosmarinus* possessed the richest phenolic fraction among the three extracts evaluated. Total flavonoid content (TFC) also varied significantly ($p < 0.05$) across the three spices. *S. rosmarinus* had the highest TFC at 13.12 mg QE/g, while *R. heudelotii* was next (9.69 mg QE/g) and *C. icaco* was least (7.89 mg QE/g). These findings were broadly consistent with the qualitative screening shown in Table 2 above, which reported the absence of detectable flavonoids in *C. icaco.*

Terpenoid content differed between the three spice extracts. *S. rosmarinus* (7.88 mg GAE/g) recorded the highest terpenoid concentration at 24.94 mg/GAE/g, substantially exceeding both *C. icaco* (2.48 mg GAE/g) and *R. heudelotii* (1.88 mg GAE/g). The terpenoid content of *S. rosmarinus* was about 2.63-fold and 3.17-fold higher than that of *C. icaco* and *R. heudelotii.* The tannin content differed among the three spice extracts. *S. rosmarinus* had the highest tannin concentration at 1.15 mg CE/100g, followed by *R. heudelotii* and *C. icaco at* 0.95 and 0.63 mg CE/100g, respectively. The relative ranking of tannin concentration across the three spices was consistent with the intensity scores recorded in the qualitative screening in Table 1. The saponin content varied across the three spices. *R. heudelotii* had the highest saponin concentration (18.14%), followed by *S. rosmarinus* and *C. icaco* (5.40 and 0.00%). This corroborates the data in Table 2. The saponin content of *R. heudelotii* was approximately 3.36-fold greater than that of *S. rosmarinus.* The alkaloid content differed across the three spices, with S. rosmarinus recording the highest concentration (6.46%), followed by R. heudelotii and C. icaco (3.87% and 0.00%, respectively). This is consistent with the negative qualitative screening result in Table 1.

Cardiac glycosides differed across the three spice extracts. The highest contents (19.65 and 12.25 mg/100g) were recorded for *R. heudelotii* and *C. icaco.* The least value was seen in *S. rosmarinus* (6.19 mg/100g). Oxalate concentrations differed among the three extracts, with C. icaco having the highest oxalate concentration (68.77 mg/100g), followed by S. rosmarinus and R. heudelotii (54.06 and 35.67 mg/100g, respectively). *R. heudelotii* demonstrated the lowest oxalate content across the three spice extracts. Phytate content also varied across the spice extracts, with *C. icaco* recording the highest phytate concentration of 113.17 mg/100g, followed by *S. rosmarinus* and *R. heudelotii* (19.31 and 10.96 mg/100g). The phytate content of C. icaco was approximately 10.33 and 5.87-fold higher than that of R. heudelotii and S. rosmarinus, respectively.

Table 3: Quantitative composition of the ethanolic spice extracts of Salvia rosmarinus, Ricinodendron heudelotii, and Chrysobalanus icaco.

Phytochemicals	*Ricinodendron heudelotii*	*Chrysobalanus icaco*	*Salvia rosmarinus*
Saponins (%)	$18.14^{c} \pm 0.19$	$0.00^{a} \pm 0.00$	$5.40^{b} \pm 0.37$
Tannins (mg / 100 g)	$0.95^{b} \pm 0.02$	$0.63^{a} \pm 0.02$	$1.15^{c} \pm 0.01$
Phenolics (mg GAE /g)	$149.05^{b} \pm 2.29$	$98.08^{a} \pm 1.08$	$192.19^{c} \pm 0.83$
Alkaloids (%)	$3.87^{b} \pm 0.03$	$0.00^{a} \pm 0.00$	$6.46^{c} \pm 0.25$
Cardiac Glycosides (mg/100g)	$19.65^{a} \pm 0.94$	$12.25^{c} \pm 1.54$	$6.19^{b} \pm 0.99$
Terpenoids (mg GAE/g)	$1.88^{a} \pm 0.03$	$2.48^{b} \pm 0.24$	$24.94^{c} \pm 0.48$
Flavonoids (mg QE /g)	$9.69^{b} \pm 0.17$	$13.12^{c} \pm 0.00$	$7.89^{a} \pm 0.08$
Oxalates (mg/100g)	$35.67^{a} \pm 1.53$	$68.77^{b} \pm 1.02$	$54.06^{c} \pm 1.42$
Phytates (mg/100g)	$113.17^{c} \pm 3.98$	$96.30^{a} \pm 1.11$	$19.31^{b} \pm 0.65$

Values are mean ± SD of triplicate determinations (n=3). Means in the same row bearing different superscript letters are significantly different (p< 0.05). GAE = Gallic acid equivalent; QE = Quercetin Equivalent; CE = Catechin Equivalent

In vitro Antioxidant Activity

DPPH Radical Scavenging Activity

The DPPH radical scavenging activities of the three spice extracts and the reference standards (gallic acid and BHT) are shown in Fig 1. All extracts showed concentration-dependent DPPH radical scavenging activity, with percentage inhibition increasing progressively with increasing extract concentration across the evaluated concentration ranges. At the highest concentration tested, *Salvia rosmarinus* had the highest DPPH radical scavenging, followed by *R. heudelotii* and *C. icaco*. Gallic acid, as the reference standard, consistently showed the highest radical scavenging activity across all concentrations, while BHT demonstrated intermediate activity relative to the spice extracts. DPPH radical scavenging ability of *R. heudelotii* was comparable to and at several concentration points, exceeded that of the synthetic antioxidant, BHT, while *C. icaco* consistently recorded lower scavenging values relative to *R. heudelotii* and *Salvia rosmarinus.* IC_{50} values derived from dose-response curves confirmed the relative potency ranking of the extracts, with *S. rosmarinus* recording the lowest IC_{50} value (highest potency) among the plant extracts, followed by *R. heudelotii* and *C. icaco.*

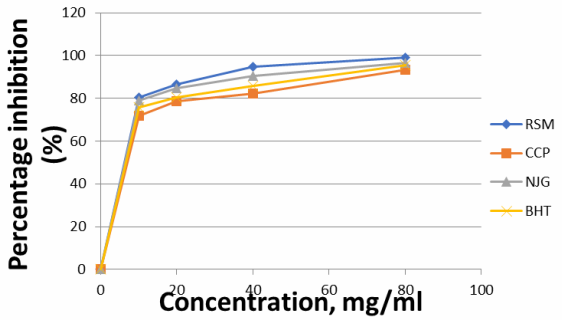

Fig 1: DPPH radical scavenging ability of the ethanolic extracts of *Salvia rosmarinus, Ricinodendron heudelotii,* and Chrysobalanus icaco.

Keys: RSM = Salvia Rosmarinus extract; CCP = Chrysobalanus icaco extract; NJG = Ricinodendron heudelotii extract, and BHT = butylated hydroxytoluene.

Ferric Reducing Power (FRAP)

The ferric-reducing antioxidant power (FRAP) percentages of the three extracts and the reference standards are shown in Fig 2. Percentage FRAP inhibition increased with increasing concentration (mg/ml). The highest FRAP inhibition was observed at 80 mg/ml, with Gallic acid showing the greatest effect (99.27%) among the spices, confirming its role as a potent electron-donating antioxidant. Among the plant extracts, *S. rosmarinus*, BHT, and *R. heudelotii* had comparable FRAP activity at 75.46%. The least FRAP activity was observed in *C. icaco* at 64.42% and 62.58%, respectively.

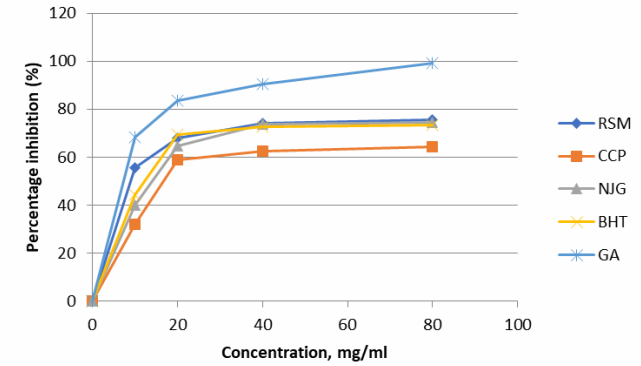

Fig 2: FRAP radical Scavenging ability of the ethanolic extracts of *Salvia rosmarinus, Ricinodendron heudelotii,* and *Chrysobalanus icaco*.

Keys: RSM = Salvia Rosmarinus extract; CCP = Chrysobalanus icaco extract; NJG = Ricinodendron heudelotii extract, and BHT = butylated hydroxytoluene.

Total Antioxidant Capacity (TAC)

The total antioxidant capacities (TAC) of the three extracts are presented in Figure 3. *S. rosmarinus* had the highest TAC at 12.47%, followed by *R.heudelotii* and *C .icaco* at 11.45 and 6.70%, respectively. The TAC values of *S. rosmarinus* and *R. heudelotii* were closely comparable, differing by only 1.02%, while *C. icaco* recorded a lower TAC relative to both *S. rosmarinus* and *R. heudelotii.* Across all three antioxidant assays, *S. rosmarinus* consistently recorded the highest antioxidant activities. At the same time, *R. heudelotii* demonstrated antioxidant performance closely approaching that of *S. rosmarinus,* particularly in the FRAP and TAC assays. *C. icaco* had the lowest antioxidant activity across all three spice assays.

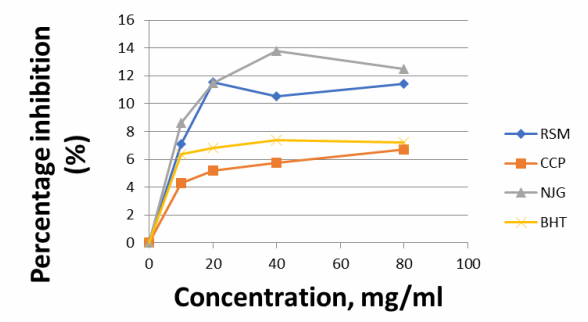

Fig 3: Total Antioxidant Capacity (TAC) ability of the ethanolic extracts of *Salvia rosmarinus, Ricinodendron heudelotii*, and *Chrysobalanus icaco.*
Keys: RSM = Salvia Rosmarinus extract; CCP = Chrysobalanus icaco extract; NJG = Ricinodendron heudelotii extract, and BHT = butylated hydroxytoluene.

IV. Discussion

Phytochemical Contents of the Spices Studied

This study evaluated the qualitative and quantitative phytochemical composition and in vitro antioxidant activities of the ethanolic extracts of two underutilized African culinary spices, *Ricinodendron heudelotii* and *Chrysobalanus icaco*, against the globally recognized Mediterranean herb, *Salvia rosmarinus*, and the synthetic antioxidant, butylated hydroxy anisole (BHT). The collective findings demonstrate that the ethanolic extracts of both African spices contain diverse and substantial levels of secondary metabolites, and that their antioxidant activity, especially that of *Ricinodendron heudelotii*, compares favorably with that of *Salvia rosmarinus.* Across multiple antioxidant assays, it consistently surpasses BHT in ferric reducing antioxidant power. These findings directly address the central research question of whether phytochemically rich extracts of underutilized African culinary spices possess antioxidant activity comparable to internationally recognized botanical standards. These findings provide scientific evidence for the repositioning of these spices within the functional food literature.

The significantly higher total phenolic content (TPC) recorded for *S. Rosmarinus* (192.19 mg GAE/g) relative to both *R. heudelotii* and *C. icaco* (149.05 and 98.08 mg GAE/g) is consistent with the well-established literature characterizing rosemary as one of the phenolic-richest culinary herbs, attributed to its abundant carnosic acid, carnosol, and rosmarinic acid constituents [38, 11]. The TPC recorded for R. heudelotii in the present study is substantial. Phenolics are excellent antioxidants due to their ability to donate hydroxyl groups that scavenge free radicals [39].

Comparable or slightly lower phenolic values for R. heudelotii have been reported in prior phytochemical surveys [24, 25]. However, direct quantitative comparisons across studies are complicated by methodological heterogeneity in extraction solvents, plant parts, and assay calibration standards. The TPC recorded for *C. icaco* in the present study is consistent with reports from the Caribbean and South American populations, where the leaf and fruit extracts contain moderate phenolic concentrations [40, 41]. However, inter-population phytochemical variability attributable to edaphic, climatic, and post-harvest processing factors is acknowledged as a source of comparative uncertainty.

The trends observed for flavonoid content are as follows: *S. Rosmarinus >R. Heudelotii>C. icaco* further reinforces *S. Rosmarinus* as a flavonoid-rich botanical. Flavonoids contain polyphenolic compounds with diverse structures that contain antioxidant abilities through their phenolic hydroxyl groups. Through their polyphenolic hydroxyl groups, they can donate hydrogen atoms or electrons to stabilize free radical species [42]. The moderate flavonoid content of *R. heudelotii* indicates that the spice constitutes a dietary source within the African food system. Flavonoids possess strong free radical scavenging properties and have been shown to delay the onset or progression of inflammatory diseases, such as tumors, ulcers, and coronary heart disease [43]. Flavonoids also possess anti-microbial activities [31]. Foods rich in flavonoids can therefore be used as nutraceuticals. The comparatively low TFC of *C. icaco* in the present study contrasts with the flavonoid glycosides in leaf extracts of *C. icaco* populations [44]. This discrepancy could be attributed to organ-specific phytochemical partitioning, with flavonoid concentration typically higher in leaf tissues than in fruit and seed matrices, and to the exclusive use of 100% ethanol, which may not optimally solubilize all flavonoid glycoside fractions compared with hydroethanolic mixtures [45].

The finding that S. rosmarinus had the highest terpenoid concentration (24.94 mg GAE/g) among the three culinary spices, substantially exceeding both C. icaco and R. heudelotii (2.48 and 1.88 mg GAE/g), represents one of the most scientifically significant outcomes of this study. The terpenoids are the largest and most structurally diverse class of plant metabolites. It encompasses, but is not limited to, monoterpenes,

sesquiterpenes, diterpenes, and triterpenes, many of which have demonstrated antioxidant, anti-inflammatory, anti-microbial, and anti-cancer bioactivities [46]. The high terpenoid content of *R. heudelotii* is consistent with the known chemical ecology of the Euphorbiaceae family, to which *R. heudelotii* belongs. Plants in the Euphorbiaceae family are known to characteristically accumulate terpenoid-rich oleoresinous fractions in their seed tissues [47]. This suggests that the terpenoid fraction may be a primary driver of the antioxidant activity observed in R. heudelotii extract, positioning the spice as a potentially rich source of terpenoids for pharmaceutical and food applications. Terpenoids are responsible for the flavor and aroma of aromatic plants. They are important plant metabolites that possess multiple cyclic groups and five isoprene units. They are also excellent antioxidants [48]. Notably, the terpenoid content of *R. heudelotii* was the lowest across the three spices in the present study. Terpenoids are reported in the literature to be one of the major bioactive constituents in rosemary [11].

The high saponin content of *R. heudelotii* (18.14%) relative to *S. rosmarinus* (5.40%) and the complete absence of detectable saponins in *C. iacao* are consistent with prior reports in ethnobotanical literature. Saponins are amphiphilic glycosides with well-documented bioactivities, including cholesterol-lowering, immunomodulatory, and antimicrobial effects. Saponins are bitter-tasting compounds that exhibit anti-cancer and anti-cholesteromic activities [49]. Most herbal medications contain saponins [50]. Saponins inhibit the formation of foams and are therefore used as surfactants. Industrially, they are used in the production of steroid hormones, food additives, emulsions, and fire extinguishers. Their substantial presence in *R. heudelotii* seeds likely reflects the ecological and biological roles in seed protection against predators [51]. The higher alkaloid content recorded in *S. rosmarinus* (6.46%) compared with *R. heudelotii* (3.87%) and the absence of detectable alkaloids in *C. icaco* are broadly consistent with the established alkaloid chemistry of the Lamiaceae family. To which rosemary belongs, though the alkaloid content of *S. rosmarinus* is generally considered a minor contributor to its overall bioactivity profile relative to its phenolic fraction [38]. Alkaloids are bitter-tasting industrial raw materials used in the production of pharmaceuticals [25] and can be extracted from plant materials. The range of pharmaceutical applications of alkaloids includes antimalarial, anticancer, antibacterial, and antihyperglycaemic properties. Foods rich in alkaloids can therefore serve as nutraceuticals and functional foods [52, 53]. Ogbuagu *et al.* [48] observed that the alkaloid contents of various fractions of aqueous, hexane, and ethyl acetate extracts of R. heudelotii ranged between 0.68 and 0.79 mg/100g. From this study, the highest alkaloid concentration (3.87 %) was observed in *R. heudelotii.*

The complete absence of detectable alkaloids and saponins in *C. icaco* across both qualitative and quantitative analyses represents a potentially important safety and quality characteristic for food applications, as both compound classes can exert adverse physiological effects at elevated concentrations [54]. Tannins were most abundant in *R. heudelotii* and *Salvia rosmarinus*. Tannins could be extracted from these spices and utilized in the industrial production of materials such as pharmaceuticals, dyes, and inks [31]. Tannins are used in the food industry to clarify wine, beer, and fruit juices. Tannins exhibit good antioxidant, antiviral, antibacterial, and antitumor activities [55].

The highest glycoside concentration was recorded in *R. heudelotii* (19.65 mg/100g) and *C. icaco* (12.25 mg/100g), with *S. rosmarinus* having the least value (6.19 mg/100g). From a bioactive perspective, cardiac glycosides are well-established positive inotropic agents with pharmacological importance in the management of cardiac arrhythmias and congestive heart failure, due to their ability to increase the force of myocardial contraction and smooth muscles. They have been shown to affect neural tissues [31, 56]. Their prescience in the spice extracts provides partial corroboration for the traditional cardiovascular applications attributed to these spices in West and Central African ethnomedicine (24; 44). *Chysobalanus icaco* can therefore be used in the production of pharmaceuticals for the treatment of heart diseases.

Antinutritional Factors: Oxalates and Phytates of the spice extracts.

The significantly higher oxalate and phytate content recorded for *C. icaco* (68.77 and 96.30 mg/100g, respectively) relative to R. heudelotii (35.67 and 113.17 mg/100g) and S. rosmarinus (54.06 and 19.31 mg/100g) has important functional and nutritional implications. Oxalates and phytates are classified as antinutritional factors due to their well-documented capacity to chelate divalent minerals such as calcium, iron, and zinc, thereby reducing their bioavailability and potentially contributing to micronutrient deficiencies in populations with high dietary dependence on plant foods [57]. The oxalate and phytate levels recorded for the three spices fall within the ranges reported for edible plant materials. The levels are also below the thresholds for acute toxicological concern [58]. Importantly, conventional food processing techniques such as soaking, boiling, fermentation, and germination are shown to widely reduce oxalate and phytate concentrations in plant foods [59, 60]. Based on this, the anti-nutritional burdens of these spices in typical culinary use may be considerably lower than values reported for the unprocessed ethanolic extracts analyzed in the present study. The relatively low content of antinutritional factors in R. heuelotii is a favorable characteristic that strengthens its candidacy as a functional food.

Antioxidant activities of the spice extracts

The concentration-dependent DPPH radical scavenging activity demonstrated by all three extracts is consistent with the established literature on plant polyphenols, in which increasing extract concentrations progressively saturate DPPH radical reaction sites via hydrogen-atom donation and electron-transfer mechanisms [61]. The superior DPPH activity of *S. rosmarinus* relative to the two African spice extracts is consistent with its higher TPC and TFC, since phenolics and flavonoids are likely the primary molecular substrates mediating DPPH radical scavenging in plant extracts [62]. The finding that *R. heudelotii* demonstrated DPPH scavenging activity comparable to that of BHT at several concentrations is particularly significant. BHT is a lipophilic synthetic phenolic antioxidant widely used as a positive reference standard in antioxidant research. The fact that a plant extract showed higher DPPH activity than its synthetic alternative provides a meaningful criterion for comparative positioning of natural antioxidants against synthetic alternatives [63]. This report is consistent with earlier reports on related species in the Euphorbiaceae family, whose seed extracts have demonstrated robust DPPH scavenging activity. This robust DPPH scavenging ability could be attributed to the combined contributions of phenolics, flavonoids, and terpenoids [46]. The lower DPPH activity of *C. icaco* relative to *R. heudelotii* and *S. rosmarinus* is consistent with its lower TPC and TFC, reinforcing the well-established correlation between phenolic content and radical scavenging capacity in plant systems [64].

FRAP evaluates the ability of an antioxidant to disrupt the chain of free radical formation by the donation of hydrogen atoms to quench free radicals. The antioxidant properties of rosemary are attributed to the isoprenoid units originating from carnosic acid and carnosol. This usually disrupts the continuous chain reaction mechanism of the oxidation reaction. *Salvia rosmarinus* and *Ricinodendron heudelotii* contain phenolic compounds that convert lipid- and hydroxyl-free radicals into stable products. The phytochemicals also chelate metal ions. The overall antioxidant activities of individual compounds can be summed to exceed those of synthetic antioxidants such as BHT, propyl gallate, and butylated hydroxytoluene [48].

The highest percentage inhibition at 80 mg/ml was observed in the following order: Gallic acid (99.27 %) > S. rosmarinus (75.46 %) > *R. heudelotii* (62.58 %) >BHT (45.35 %) >*C icaco* (44.42 %). FRAP assay measures the ability of an antioxidant to break free radical formation by the donation of hydrogen ions when an antioxidant reacts with ferric tripyridyltriazine [Fe^{3+}-TPTZ] complex, producing a colored ferrous tripyridyltriazine (Fe^{2+}-TPTZ)[65]. The antioxidant properties of rosemary have been established [11, 66]. The FRAP assay measures the ability of antioxidant compounds to reduce ferric ion (Fe^{3+}) to ferrous ion (Fe^{2+}) in an acidic environment. This is particularly relevant to the prevention of iron-catalyzed lipid peroxidation in food systems and biological tissue [67].

Total Antioxidant Capacity (TAC) of the Spice Extract

The Total antioxidant capacity (TAC), like the FRAP, uses the single-electron transfer method to measure an antioxidant's ability to transfer a single electron to a free radical, thereby reducing it. It also measures the quantity of free radicals scavenged by a test solution and is used to quantify the antioxidant capacity of biological materials. The TAC assay is based on the reduction of molybdenum 6+ (Mo [VI]) to Mo (V) Molybdenum 5+ (Mo[V]) by an antioxidant sample. This initiates the formation of a green-coloured phosphate-molybdenum (Mo) (V) complex under acidic conditions [37].

The Total antioxidant capacity (TAC) of the spice extracts shows that *S. rosmarinus* and *R. heudelotii* extracts showed the highest TAC inhibition capacity, followed by BHT. *C. icaco* showed the least total antioxidant capacity. The percentage inhibition of all the oleoresins increased with increasing concentration. Nedamani *et al. [17] showed that green tea oleoresin at concentrations of 50 to 250 µg/ml showed significantly ($p < 0.05$) higher antioxidant activity than rosemary, BHT,* and oak oleoresins. Increasing concentrations of green tea and rosemary oleoresins increased their total antioxidant activities; however, at lower concentrations, rosemary oleoresin showed better antioxidant performance than green tea oleoresin.

V. Conclusion

The ethanolic extracts of *Ricinodendron heudelotii and Salvia rosmarinus showed the highest phytochemical composition compared to* that of *Chrysobalanus icaco.* This could explain the high antioxidant properties of the extracts of Ricinodendro heudelotii and Salvia rosmarinus, as measured by the FRAP, DPPH, and TAC assays. The identified phytochemicals in the spices can be isolated and purified for use as industrial materials, pharmaceuticals, or functional foods.

Author Contribution

The research was conceptualized by Nwagbo, C.C., PhD, and supervised by Prof. G.I. Okafor, U.C. Data collection and the experiment were done by Nwagbo, C.C., PhD; Prof. O.O. Ndukwe analyzed the data;

while the writing and formatting of the manuscript were done by Nwagbo, C.C., PhD, and Chude, C.O., PhD. All the authors proofread, edited, and approved the final manuscript.

Competing Interests

The authors declare no competing interests in the publication of this research.

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