Journal of Basics and Applied Sciences Research (JOBASR)
ISSN (print): 3026-9091, ISSN (online): 1597-9962
Volume 3(3) May 2025
DOI: https://dx.doi.org/10.4314/jobasr.v3i3.12

Assessments of Phytochemical and Nutritional Compositions of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds

Karima M. Rabiu[1], Lawal Nura[2]*and Aderounmu Ibrahim Ganiyu[2]
[1]Department of Biological Sciences, Faculty of Science, Yobe State University, Damaturu, Nigeria.
[2]Department of Biochemistry and Molecular Biology, Federal University Dutsin-Ma, Katsina State, Nigeria.
*Corresponding Author Email: nlawalbatagarawa@fudutsinma.edu.ng

ABSTRACT
Plant-derived bioactive compounds have recently attracted considerable interest due to their nutritional and possible medicinal benefits. This study investigated the phytochemical and nutritional composition of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds. Qualitative and quantitative phytochemical analyses revealed distinct profiles: papaya seeds exhibited exceptionally high phenolic content (62.33±2.33) and alkaloids (45.80±0.00); watermelon seeds contained remarkable flavonoid concentrations (32.91±0.01); and clove buds were rich in tannins (14.37±3.37) and eugenol (35.05±0.00). Proximate analysis showed watermelon seeds possessed the highest protein (17.70±0.80%) and lipid content (46.65±0.25%), while papaya seeds contained the highest fibre (21.15±0.25%) and ash content (8.83±0.08%). Mineral analysis demonstrated clove buds were superior sources of calcium (116.25±3.25), magnesium (185.85±0.05), manganese (22.32±0.00), iron (9.45±0.00), potassium (120.11±1.21), and sodium (61.48±0.08). Watermelon seeds excelled in zinc content (5.18±0.98), while papaya seeds contained the highest phosphorus (218.35±2.35) and copper (0.97±0.02) levels. These findings suggest these plant materials possess complementary nutritional profiles with potential applications in functional foods and nutraceuticals targeting specific health conditions or nutrient deficiencies.

Keywords:
Papaya seeds,
Watermelon seeds,
Clove buds.

INTRODUCTION

Natural products have been widely examined for their potential to improve human health, prevent chronic diseases, and serve as functional food additives. Papaya seeds, once considered a waste product of fruit processing, have been shown to be a source of bioactive compounds with diverse bioactivities. Recent studies have elucidated their abundant composition of proteins, essential fatty acids, phenolic compounds, and distinctive bioactive molecules including benzyl isothiocyanate and carpaine (Ferreira and Sarraguça, 2024; Sun and Shahrajabian, 2023). The seeds demonstrate significant antioxidant, antimicrobial, antiparasitic, and anti-inflammatory properties, thereby reinforcing their traditional medicinal uses in diverse indigenous healthcare systems (Rani *et al*., 2024). Similarly, recent comprehensive analyses have revealed the impressive phytochemical composition of watermelon seeds, including phenolics, flavonoids, saponins, and alkaloids, which contribute to their antioxidant, anti-inflammatory, antidiabetic, and hepatoprotective therapeutic effects (Kumar *et al*., 2023; Dhyani *et al*., 2022; Elboughdiri *et al*., 2024; Jomová *et al*., 2024; Karageçili *et al*., 2023; Lam *et al*., 2024; Timilsena *et al*., 2023).

Clove buds have a well-documented history in traditional medicine and culinary uses, in contrast to the previously mentioned seeds. Recent studies have enhanced our comprehension of their intricate phytochemical makeup, especially the abundant essential oil content primarily consisting of eugenol (Pandey *et al*., 2025). Clove buds possess remarkable antioxidant properties, antibacterial effectiveness against multidrug-resistant organisms, and prospective uses in the management of diabetes, neurological disorders, and cancer (Ullah *et al*., 2023). The increasing prevalence of lifestyle-related diseases and microbial resistance to conventional antibiotics has intensified the search for natural alternatives with multifaceted therapeutic properties (Dashti and Khan, 2022). Concurrently, the growing consumer preference for natural ingredients in food and pharmaceuticals has created new opportunities for sustainable utilization of

these plant materials (Pin and Daniel, 2023). Moreover, the integration of these underutilized plant parts into food systems could contribute significantly to addressing nutritional security challenges in various regions worldwide (Nkwonta *et al*., 2023). This study aims to analysethe phytochemical and nutritional composition of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds. By examining and comparing their bioactive constituents, nutritional profiles, and potential applications, this study seeks to provide valuable insights into the untapped potential of these plant materials for improved health outcomes.

MATERIALS AND METHODS

Chemicals/Reagents

All chemical reagents employed in this study were of analytical grade. These chemicals were sourced from reputable and established suppliers.

Collection of Plant Material and Authentication

Carica papaya (papaya), *Citrullus lanatus* (watermelon) fruits, and Syzygiumaromaticum (clove) buds were procured from a local market in Dutsin-Ma, Katsina State, Nigeria. The botanical identity of the specimens was subsequently confirmed by a qualified botanist at the Plant Biology Department's Herbarium, Federal University, Dutsin-Ma, Katsina State. Voucher specimens were deposited with the corresponding accession numbers: *Carica papaya* (FUDMA/PSB/00004), *Citrullus lanatus* (FUDMA/PSB/00118), and *Syzygiumaromaticum* (FUDMA/PSB/00087). Following procurement, the *Carica papaya* and *Citrullus lanatus* fruits underwent initial processing, which involved washing, dissection, and careful extraction of seeds. The seeds from *Carica papaya*, *Citrullus lanatus*, and *Syzygiumaromaticum* buds were then subjected to separate cleaning and drying protocols to ensure optimal quality. To facilitate uniform drying, the seeds were dried at ambient temperature for 72 hours, with periodic stirring. Subsequently, the dried seeds were pulverized into fine powders using a laboratory-grade blender. The resulting powders were sieved to achieve uniform particle size and stored at room temperature for further analysis.

Phytochemical Screening

A qualitative phytochemical screening of *Carica papaya* seed, *Citrilluslanatus* seed and *Syzygiumaromaticum* bud was conducted in accordance with the standardized protocols outlined by Santhi and Sengottuvel (2016).

Test for Alkaloids

About 200mg aliquot of the sample was dissolved in 10ml of methanol and subsequently filtered to obtain a clear filtrate. A 2ml portion of the filtrate was then mixed with a 1% dilute hydrochloric acid (HCl) solution. The resulting mixture was treated with Wagner's reagent, and the formation of a brown or reddish-brown precipitate was observed, indicating the presence of alkaloids in the sample.

Test for Saponins

A quantity of approximately 0.5mg of the sample was added to 5ml of distilled water and vigorously shaken. The persistence of frothing upon shaking indicated the presence of saponins in the sample.

Test for Tannins and Phenols

Exactly 200mg portion of the sample was dissolved in 10ml of distilled water and filtered to obtain a clear filtrate. Subsequently, 2ml of the filtrate was mixed with 2ml $FeCl_3$ solution. The formation of a blue precipitate that eventually turned black indicated the presence of tannins and phenolic compounds in the sample.

Test for Flavonoids

From the sample 200mg was dissolved in 10ml of ethanol and filtered to obtain a clear filtrate. Subsequently, 2ml of the filtrate was mixed with concentrated hydrochloric acid (HCl) and a magnesium ribbon was added. The appearance of a reddish coloration indicated the presence of flavonoids in the sample.

Test for Ascorbic Acid

A 1mg portion of the sample was dissolved in 5ml of distilled water, and then a drop of 5% sodium nitroprusside solution was added, followed by the addition of 2ml of sodium hydroxide (NaOH) solution. Subsequently, a few drops of hydrochloric acid (HCl) were added dropwise, resulting in a colour change from yellow to blue. This colorimetric reaction confirmed the presence of ascorbic acid in the sample.

Quantitative Phytochemical Screening

Estimation of Alkaloids

Alkaloid quantification was performed using the method described by Agoreyo *et al*. (2012). A 5g sample of finely ground powder was mixed with 50ml of 10% acetic acid in ethanol and allowed to stand for 4 hours at 28°C. The mixture was then filtered, and the filtrate was evaporated to one-quarter of its original volume. The concentrated solution was treated with 5ml of ammonium hydroxide solution to precipitate the alkaloids. The precipitate was filtered, washed with 1% ammonia solution, and dried in an oven at 30°C. The weight of the alkaloid precipitate was determined by weighing the filter paper before and after filtering the precipitate, and the alkaloid content was dried and weighed.

Estimation of Saponins

The method described by Gupta (2013) was employed to extract and quantify the desired compound. A 5g sample of finely ground powder was initially weighed,

and 1.0g of this sample was set aside for further processing. The sample was then defatted with 30ml of n-hexane, followed by the addition of 30ml of methanol. The mixture was filtered, and this process was repeated two more times with fresh 30ml portions of methanol. The combined filtrate was then concentrated to one-quarter of its original volume through heating. Next, 100ml of cold acetone was added, and the mixture was refrigerated for 50 minutes. The resulting precipitate was filtered through a pre-weighed filter paper, dried in an oven at 30-40°C, and then re-weighed to determine the weight of the extracted compound.

Estimation of Tannins

The method described by Vetter and Barbosa (1995) was employed to determine the phenolic content. A 0.2g sample of finely ground material was weighed and mixed with 20ml of 50% methanol. The mixture was heated in a water bath at 80°C for 1 hour, cooled, and filtered using Whatman filter paper. The filtrate was collected in a 100ml volumetric flask and diluted to 100ml with distilled water. A 1ml aliquot of the extract was then pipetted into a 50ml volumetric flask, followed by the addition of 20ml of distilled water. Subsequently, 2.5ml of Folin-Dennis reagent and 10ml of 17% sodium carbonate solution were added to the sample and standard. The mixture was properly mixed, made up to the mark with distilled water, and allowed to stand for 20 minutes, resulting in a bluish-green color. Finally, the absorbance of the resulting solution was measured at 760nm to determine the phenolic content.

Estimation of Total Phenolics

The method outlined by Singleton and Rossi (1965) was employed to determine the total phenolic content. A 0.5ml sample was pipetted into a 50ml volumetric flask, followed by the addition of 35ml of water. Then, 2.5ml of Folin-Ciocalteau (FC) reagent was added, and the mixture was swirled, incubated for 1-8 minutes at room temperature, and subsequently treated with 7.5ml of sodium carbonate solution. The mixture was then diluted to 50ml, mixed, and incubated for 2 hours at room temperature. The absorbance was measured at 765nm using a spectrophotometer. If the absorbance reading exceeded that of the 500mg/L standard, the sample was diluted accordingly and re-measured to ensure accurate quantification.

Estimation of Flavonoids

The method described by Harborne (1998) was utilized to extract and quantify the desired compound. Initially, 2g sample was weighed into a conical flask, followed by the addition of 50ml of 2M hydrochloric acid (HCl). The mixture was then boiled for 30 minutes, cooled, and filtered. A 5ml aliquot of the resulting extract was pipetted into another flask, and 5ml of ethyl acetate was added. The precipitate was filtered through a pre-weighed filter paper, dried in an oven at 30°C, and then re-weighed to determine the weight of the precipitate, thus allowing for the calculation of the desired compound's content.

Estimation of Ascorbic Acid

A 1g of sample was weighed into a 25ml conical flask, followed by the addition of 10ml of an oxalic acid (0.05M)-EDTA (0.02M) solution. The sample was then allowed to react for 24 hours, after which it was filtered through 0.45µm filter paper. A 2.5ml aliquot of each sample was transferred to a separate 25ml volumetric brown flask, and 2.5ml of the oxalic acid (0.05M)-EDTA (0.02M) solution was added. Subsequently, meta phosphoric acid, acetic acid (0.5ml), sulphuric acid (5% v/v) solution (1ml), and ammonium molybdate solution (2ml) were added to each volumetric brown flask, and the volume was made up to 25ml with distilled water. Finally, the absorbance was measured at 760nm using a UV/visible spectrophotometer (Hussain *et al*., 2011).

Estimation of Eugenol

Accurately weighed 10mg samples of ethanolic and aqueous clove extracts were dissolved in 99.9% methanol, sonicated for 5-10 minutes, and made up to 10ml with the same solvent. The solutions were filtered using a 2µm syringe filter, and 1µl of the stock solution was injected into a Gas Chromatography (GC) system. The GC analysis was performed using an Agilent Technologies 6850 GC equipped with a split/splitless injector and a Flame Ionization Detector (FID). The injection was done in split mode with a split ratio of 30:1, and the injector temperature was maintained at 260°C. Hydrogen was used as the carrier gas, with an initial flow rate of 2.50ml/min. The separation was achieved using a DB225-MS capillary column (30m x 0.25mm i.d. x 0.25µm film thickness). The oven temperature program consisted of an initial temperature of 40°C held for 3 minutes, followed by a 25°C/min ramp to 240°C, and a final hold time of 1 minute. The total run time was approximately 12 minutes. The FID temperature was set at 250°C, with hydrogen and air flows of 40ml/min and 400ml/min, respectively (Myint *et al*., 1996).

Proximate Analysis of the Diets

Estimation of Crude Protein

The crude protein content was determined using the Kjeldahl method (AOAC 1995; Method 984.13). A 1.0g sample of finely ground feed was digested with 12-15ml of concentrated H_2SO_4 and a Kjeldahl catalyst tablet for 1 hour 15 minutes, resulting in a clear solution. After cooling and dilution with distilled water, the digest was treated with 60ml of 10N NaOH and distilled, releasing ammonia into a boric acid solution. The resulting green-colored solution was then

titrated with 0.1N H2SO4 until the endpoint, indicated by a color change to wine, was reached. This process allowed for the determination of the crude protein content in the sample.

Estimation of Fat

Fat content was determined according to AOAC (2003; Method 920.39). A 1g sample was weighed, placed in a thimble, covered with defatted cotton wool, and oven-dried for 1 hour. The sample was then subjected to fat extraction using 50ml of petroleum ether or ethanol for 1.5 hours. After extraction, the cups were oven-dried for 15 minutes, cooled in a desiccator, and weighed to determine the fat content. The weight difference before and after extraction represented the fat content of the sample.

Estimation of Moisture

The moisture content was determined following the AOAC (1999; Method 934.01) method. A 5g sample was accurately weighed into a pre-zeroed, clean, and dry crucible. The crucible with the sample was then oven-dried at 104°C for 4 hours. After drying, the crucible was cooled in a desiccator and weighed while still warm. The weight loss during drying represented the moisture content of the sample.

Estimation of Crude Fibre

The crude fibre content was determined according to AOAC (1995; Method 962.09). A 1g sample was digested in 1.25% H_2SO_4 for 35 minutes, followed by washing with hot water and digestion in 1.25% KOH for another 35 minutes. The sample was then dried in an oven for 3-4 hours. The dry sample was weighed, then incinerated in a furnace for 1 hour, and the residual ash was weighed. The weight loss during incineration represented the crude fibre content of the sample.

Estimation of Ash Content

The ash content was determined according to AOAC (1995). A 2g sample was accurately weighed into a pre-weighed, clean, and dry crucible. The crucible was then placed in a furnace for 7 hours, incinerating the organic matter. After cooling in a desiccator, the weight of the residual ash was recorded. The weight difference before and after incineration represented the ash content of the sample.

Estimation of Carbohydrate

The carbohydrate content was determined using the Phenol-Sulfuric Acid method. A known weight (0.1-1g) of the sample was mixed with a known volume (10-50mL) of water. Phenol solution (0.5-2mL) and sulfuric acid (0.5-2mL) were added, and the mixture was allowed to react for 10-30 minutes, resulting in a colored compound. The absorbance was measured at 490nm using a spectrophotometer, and the carbohydrate content was calculated using a standard curve or equation (Dubois *et al*., 1956).

Estimation of Metabolizable Carbohydrate (ME)

The Metabolizable Energy (ME) was calculated using the following equation, as described by AOAC (2000): ME (kcal/kg) = (4.0 × %Crude Protein) + (9.4 × %Crude Fat) + (4.2 × %NFE).

Mineral Analysis of the Diets

The mineral contents of the diets were determined by atomic absorption spectrophotometric and colorimetric methods according to AOAC (2000).

Estimation of Calcium (Ca)

Standards: Known volumes (0, 125.0, 250.0, 375.0, and 500.0 µl) of calcium standard (Sigma) were added to 100-ml volumetric flasks, followed by 5 ml of $LaCl_3$ solution. The solutions were diluted to volume with deionized water and mixed well.

Samples: A predetermined aliquot of the sample stock was added to a mixture of 1 ml $LaCl_3$ and 20.5 ml deionized water in a 50-ml culture tube. The tubes were vortexed, taking care to avoid contact between the sample and the Para film.

Instrument Analysis: Standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer. The zero standard served as the blank, and results were expressed in concentration (µg/ml).

Estimation of Phosphorus (P)

Standard Preparation: Standards were prepared by diluting working solutions (0, 2, 5, 8, 10, and 15 ml) to 100 ml with deionized water, adding 20 ml of molybdovanadate reagent, and mixing well. After a 10-minute standing time, 3 ml of each standard were transferred to culture tubes and read at 400 nm on a Genesys 20 spectrophotometer, using the 0 standard as the blank.

Sample Preparation: Unknown samples were prepared by mixing 15 ml of deionized water, 3.084 ml of molybdovanadate reagent, and a predetermined aliquot of the sample in 50-ml culture tubes. After vortexing and a 10-minute standing time, 3 ml of the sample solution were transferred to culture tubes and read at 400 nm on the Genesys 20 spectrophotometer.

Analysis: The concentration of phosphorus (mg P/ml) in the unknown samples was determined from the standard curve generated by the standards.

Estimation of Magnesium (Mg)

Standards were prepared by adding 0, 12.5, 25.0, 37.5, and 50 µl of Mg standard (Sigma) to 100-ml volumetric flasks, followed by 5 ml of LaCl3 solution and dilution to volume with deionized water. Samples were prepared by mixing 1 ml of LaCl3, 20.5 ml of deionized water, and a predetermined aliquot of sample

stock in 50-ml culture tubes. Standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with the zero standard as the blank. Results were expressed in concentration (µg/ml).

Estimation of Manganese (Mn)
Standards were prepared by diluting 75.0, 150.0, 225.0, and 300 µl of Mn standard (Sigma) to 100 ml with deionized water. Samples were diluted as necessary with deionized water. Standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with deionized water as the blank. Results were expressed in concentration (µg/ml).

Estimation of Iron (Fe)
Standards were prepared by diluting 125.0, 250.0, 375.0, and 500.0 µl of Fe standard (Sigma) to 100 ml with deionized water. The standards and sample stock were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with deionized water as the blank. Results were expressed in concentration (µg/ml).

Estimation of Potassium (K)
Standards, 50.0, 100.0, 150.0, and 200.0 µl of K standard (Sigma) were diluted to 100 ml with deionized water. A predetermined aliquot of sample stock was added to 20 ml of deionized water in pre-labeled culture tubes. Standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer with flame emission. Results were expressed in concentration (µg/ml).

Estimation of Sodium (Na)
Standards, 10.0, 20.0, 40.0, and 60.0 µl of Na standard (Sigma) were diluted to 100 ml with deionized water. A predetermined aliquot of sample stock was added to 20 ml of deionized water. Standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer with flame emission, with deionized water as the blank. Results were expressed in concentration (µg/ml).

Estimation of Copper (Cu)
Standards were prepared by diluting 125.0, 250.0, 375.0, and 500.0 µl of Cu standard (Sigma) to 100 ml with deionized water. The sample stock was aspirated directly and diluted as necessary with deionized water. Both standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with deionized water as the blank, and results were expressed in concentration (µg/ml).

Estimation of Zinc (Zn)
Standards were prepared by diluting 25.0, 50.0, 75.0, and 100 µl of Zn standard (Sigma) to 100 ml with deionized water. Samples were prepared by adding a predetermined aliquot of sample stock to 20 ml of deionized water in pre-labeled culture tubes. Both standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with deionized water as the blank, and results were expressed in concentration (µg/ml).

Estimation of Lead (Pb)
Standards were prepared by diluting 125.0, 250.0, 375.0, and 500.0 µl of Pb standard (Sigma) to 100 ml with deionized water. The sample stock was aspirated directly and diluted as necessary with deionized water. Both standards and samples were analyzed using a Shimadzu Atomic Absorption Spectrophotometer, with deionized water as the blank, and results were expressed in concentration (µg/ml).

Statistical Analysis
Data obtained from the study was analyzed using the statistical package for social science (SPSS) software for windows version 21 (SPSS Inc., Chicago Illinois, USA). The results were reported as Mean±SEM of the values and Duncan's comparison was used to compare the mean values. A significance level of $P<0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Results

Table 1: Qualitative Phytochemical Analysis of Papaya Seeds, Watermelon Seeds and Clove Buds.

Phytochemicals	Papaya	Watermelon	Clove
Phenolics	+++	+	+
Tannins	+	+	++
Flavonoids	+	+++	+
Alkaloids	++	++	+
Saponins	+	+	+
Ascorbic Acid	+	+	+
Eugenol	-	+	+++

(+) = Constituent present
(-) = Constituent absent

Table 2: Quantitative Phytochemical Analysis of Papaya Seeds, Watermelon Seeds and Clove Buds

Group	Total Phenolic Content	Tannins	Flavonoid	Alkaloid	Saponins	Ascorbic Acid	Eugenol
Clove buds	4.85±0.01^{b}	14.37±3.37^{a}	3.71±0.39^{c}	1.36±0.38^{c}	7.85±0.00^{c}	4.09±0.01^{b}	35.05±0.00
Watermelon seeds	0.98±0.00^{b}	1.67±0.03^{b}	32.91±0.01^{a}	18.99±0.00^{b}	16.07±0.02^{a}	1.89±0.01^{c}	0.06±0.00
Papaya seeds	62.33±2.33^{a}	5.36±0.03^{b}	6.48±0.08^{b}	45.80±0.00^{a}	16.00±0.00^{b}	6.91±0.01^{a}	0.00±0.00

The result represents the average of three determinations, with the standard error of the mean indicated by Mean±SEM.

Table 3: Proximate Analysis

	CP (%)	EE (%)	MC (%)	CFC (%)	ASH (%)	CC (%)	ME (Cal/100g)
Clove buds	8.62±0.14^{c}	13.09±0.01^{c}	9.04±0.00^{a}	18.76±0.01^{b}	5.22±0.01^{b}	45.31±0.15^{a}	298.45±0.84^{c}
Watermelon seeds	17.70±0.80^{a}	46.65±0.25^{a}	7.59±0.02^{b}	15.45±0.55^{c}	3.60±0.00^{c}	9.02±1.12^{c}	522.19±0.84^{a}
Papaya seeds	13.90±0.00^{b}	28.88±0.88^{b}	7.32±0.11^{b}	21.15±0.25^{a}	8.83±0.08^{a}	19.93±1.31^{b}	360.44±7.28^{b}

The result represents the average of three determinations, with the standard error of the mean indicated by Mean ± SEM. Values with identical superscripts do not exhibit significant differences (P<0.05), while values with different superscript exhibit significant differences. Key: CP: Crude Protein, EE: Ether Extract, MC: Moisture Content, CFC: Crude Fiber Content, ASH: Ash, CC: Carbohydrate Content, ME: Metabolizable Energy

Table 4: Mineral Analysis

	Ca	P	Mg	Mn	Iron	K	Na	Cu	Zinc	Lead
Clove buds	116.25± 3.25^{a}	2.03± 0.01^{c}	185.85± 0.05^{a}	22.32± 0.00	9.45±0 .00^{a}	120.11± 1.21^{a}	61.48± 0.08^{a}	0.55±0 .01^{b}	2.12±0 .00^{b}	0.002± 0.00
Watermelon seeds	48.29± 0.01^{b}	33.60± 2.10^{b}	41.69± 0.29^{b}	2.22± 0.00	8.64± 0.01^{b}	26.00± 0.00^{c}	2.10± 0.00^{c}	0.55± 0.00^{b}	5.18± 0.98^{a}	0.00± 0.00
Papaya seeds	21.25± 0.25^{c}	218.35± 2.35^{a}	16.80± 0.00^{c}	0.93± 4.38	1.05± 0.01^{c}	47.75± 0.00^{b}	9.79± 0.09^{b}	0.97± 0.02^{a}	3.73± 0.07^{ab}	0.00± 0.00

The result represents the average of three determinations, with the standard error of the mean indicated by Mean±SEM

Discussion

The qualitative and quantitative phytochemical analysis of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds shown in Table 1 and Table 2 respectively, reveal distinct phytochemical profiles across these plant materials, with notable variations in the concentration of bioactive compounds, highlighting their unique biochemical profiles and potential therapeutic applications.*Carica papaya* seeds exhibited exceptionally high total phenolic content (62.33 ± 2.33), significantly surpassing both clove buds (4.85 ± 0.01) and watermelon seeds (0.98 ± 0.00), which corroborates findings by Zhou *et al*. (2011), who reported significant phenolic content in papaya seeds contributing to their potent antioxidant properties. The high phenolic content in papaya seeds has been associated with their ability to scavenge free radicals and prevent oxidative stress (Kong *et al*., 2021). In contrast, both watermelon seeds and clove buds showed lower phenolic content, though clove buds exhibited higher tannin content(14.37 ± 3.37), significantly exceeding levels found in papaya seeds (5.36 ± 0.03) and watermelon seeds (1.67 ± 0.03).This is consistent with research by Haro-González *et al*. (2021), who identified substantial quantities of hydrolyzable tannins in clove buds, contributing to their astringent properties and antimicrobial activities.The analysis revealed *Citrullus lanatus* seeds contained remarkably high flavonoid concentrations (32.91 ± 0.01), substantially exceeding levels in papaya seeds (6.48 ± 0.08) and clove buds (3.71 ± 0.39), which aligns with studies by Nadeem *et al*. (2022), who highlighted the presence of quercetin and kaempferol derivatives in watermelon seed extracts. Quercetin and kaempferol are known for their anti-inflammatory and antioxidant properties (Aghababaei and Hadidi, 2023; Alrumaihi *et al*., 2024). Therefore, the presence of these compounds in watermelon seeds likely contributes to the overall anti-inflammatory and antioxidant effects observed when watermelon seeds are studied.The lower flavonoid content in papaya seeds and clove buds is consistent with previous phytochemical screenings that emphasized other compound classes as their primary bioactive constituents (Achukwu, 2022; Lone and Jain, 2022).

Papaya seeds demonstrated exceptionally high alkaloid content (45.80 ± 0.00), followed by watermelon seeds (18.99 ± 0.00), with significantly lower levels in clove buds (1.36 ± 0.38). The presence of alkaloids in papaya seeds supports findings by Ugbogu *et al.* (2023), who identified carpaine and related alkaloids contributing to their antiparasitic and antihelminthic properties. Similarly, Manivannan *et al.* (2020) detected various alkaloids in watermelon seeds, correlating with their traditional use in folk medicine for managing hypertension and inflammatory conditions. Watermelon seeds and papaya seeds showed comparable saponin content (16.07 ± 0.02 and 16.00 ± 0.00, respectively), both significantly higher than clove buds (7.85 ± 0.00). This observation is consistent with research by Tabiri et al. (2016), who reported substantial saponin content in watermelon seeds contributing to their hypocholesterolemic properties. The presence of saponins in papaya seeds has been linked to their membrane-permeabilizing effects and potential applications as natural surfactants (Okeniyi *et al*., 2007). Papaya seeds contained the highest ascorbic acid concentration (6.91 ± 0.01), followed by clove buds (4.09 ± 0.01) and watermelon seeds (1.89 ± 0.01). This finding supports research by Maisarah *et al.* (2014), who identified significant vitamin C content in papaya seeds contributing to their antioxidant capacity. Vuong *et al.* (2013) further noted that ascorbic acid in papaya seeds enhances the bioavailability and stability of other phytochemicals, particularly phenolic compounds. *Syzygiumaromaticum* buds were notably rich in eugenol.Clove buds exhibited exceptionally high eugenol content (35.05 ± 0.00), with minimal levels in watermelon seeds (0.06 ± 0.00) and none detected in papaya seeds, which is consistent with extensive literature identifying eugenol as the primary active constituent of cloves, comprising 45-90% of the essential oil (Ajiboye *et al*., 2016; El-Saber Batiha *et al*., 2020; Khalil *et al*., 2017). The absence of eugenol in papaya seeds and low concentration in watermelon seeds distinguishes the aromatic profile of cloves from the other plant materials. Eugenol's presence explains many of the therapeutic properties attributed to cloves, including analgesic, anesthetic, and antimicrobial activities (Marchese *et al*., 2017). The varied phytochemical profiles observed across these plant materials suggest complementary biological activities and potential synergistic effects when used in combination. As noted by Tungmunnithum *et al.* (2018), plant materials containing diverse phytochemical classes often demonstrate broader therapeutic ranges than those dominated by single compound types.

The proximate analysis of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds in Table 3 reveals distinct nutritional profiles with significant implications for their potential applications.

Watermelon seeds exhibited the highest crude protein content (17.70 ± 0.80%), followed by papaya seeds (13.90 ± 0.00%), with clove buds showing significantly lower levels (8.62 ± 0.14%). This finding aligns with research by Oyeleke *et al.* (2012), who reported protein content between 16-19% in watermelon seeds from different varieties. The high protein content in watermelon seeds supports their emerging role as alternative protein sources, particularly in regions facing protein-energy malnutrition. Hahn *et al.* (2025) and Joshi *et al*. (2021) demonstrated that watermelon seed protein has a favourable amino acid profile with high levels of arginine, glutamic acid, and aspartic acid, making it valuable for nutritional applications.

Watermelon seeds showed remarkably high lipid content (46.65 ± 0.25%), followed by papaya seeds (28.88 ± 0.88%), with clove buds containing significantly lower levels (13.09 ± 0.01%). This substantial lipid content in watermelon seeds is consistent with research by Mahla *et al.* (2018), who characterized watermelon seed oil as rich in unsaturated fatty acids, particularly linoleic acid. This fatty acid profile contributes to watermelon seed oil's potential cardioprotective effects, as demonstrated by Eke *et al.* (2021), who observed significant reductions in LDL cholesterol and triglycerides in hyperlipidemic models treated with watermelon seed oil.The considerable lipid content in papaya seeds aligns with findings by Yanty *et al*. (2014) who demonstrated that papaya seed oil is rich in oleic acid (73.5%), a monounsaturated fatty acid known for its role in maintaining cellular membrane fluidity and integrity.The moderate lipid content in clove buds primarily comprises essential oils rather than fixed oils, as noted by Hemalatha *et al*. (2016), with eugenol and eugenyl acetate as principal components responsible for cloves' distinctive aroma and antimicrobial properties.Clove buds exhibited significantly higher moisture content (9.04 ± 0.00%) compared to watermelon seeds (7.59 ± 0.02%) and papaya seeds (7.32 ± 0.11%). Findings by Corbineau (2024) highlighted that low moisture content in seeds contributes to their extended shelf life and suitability for long-term storage.

Papaya seeds contained the highest crude fiber content (21.15 ± 0.25%), followed by clove buds (18.76 ± 0.01%), with watermelon seeds showing the lowest levels (15.45 ± 0.55%). This substantial fiber content in papaya seeds corroborates research by Vinha *et al.* (2024), who characterized the dietary fiber in papaya seeds as predominantly insoluble, with significant proportions of cellulose and lignin. Chen *et al*. (2023) demonstrated that high-fiber extracts from papaya seeds exhibit prebiotic effects, promoting the growth of beneficial gut microbiota and enhancing intestinal health. The considerable fiber content in clove buds

contributes to their digestive benefits, as noted by Agbaje (2008), who observed improved gastrointestinal transit and reduced constipation in experimental models supplemented with clove powder. Similarly, the moderate fiber content in watermelon seeds supports their potential role in digestive health applications. Papaya seeds demonstrated the highest ash content (8.83 ± 0.08%), significantly exceeding levels in clove buds (5.22 ± 0.01%) and watermelon seeds (3.60 ± 0.00%). This high mineral content in papaya seeds aligns with research by Kolu *et al*. (2021), who identified substantial concentrations of potassium, calcium, magnesium, and iron in papaya seed meal. The moderate ash content in clove buds primarily comprises essential trace elements, as demonstrated by Xue *et al*. (2022), with notable concentrations of manganese, iron, and zinc contributing to cloves' antioxidant mechanisms. Similarly, the mineral composition of watermelon seeds, though lower in total ash, contains nutritionally significant levels of zinc and selenium, as reported by Enemor*et al*. (2019). Clove buds exhibited significantly higher carbohydrate content (45.31 ± 0.15%), followed by papaya seeds (19.93 ± 1.31%), with watermelon seeds showing the lowest levels (9.02 ± 1.12%). Carbohydrates included in spices are crucial for reducing the harmful effects of cholesterol and saturated fats in diets as highlighted by Lartey *et al*. (2023). Complex carbohydrates contribute to papaya seeds' reported antidiabetic effects, as demonstrated by Nnaemeka (2023), who observed improved glycemic control in hyperglycemic models supplemented with papaya seed extracts. The calculated metabolizable energy values reflected the macronutrient composition, with watermelon seeds showing the highest energy density (522.19 ± 0.84 Cal/100g), followed by papaya seeds (360.44 ± 7.28 Cal/100g) and clove buds (298.45 ± 0.84 Cal/100g). This substantial energy content in watermelon seeds primarily derives from their high lipid concentration, making them valuable energy-dense ingredients for specialized dietary applications. The lower energy density of clove buds aligns with their primary application as a spice and bioactive ingredient rather than an energy source, though Otunola (2022) noted that even this moderate energy contribution complements their phytochemical properties in functional food applications.

The data in Table 4 reveals that clove buds possess remarkably high levels of several essential minerals, particularly calcium (116.25 mg), magnesium (185.85 mg), and manganese (22.32 mg). This mineral richness aligns with research by Sahu (2021), who documented cloves as a significant source of minerals that contribute to their medicinal properties. The elevated potassium (120.11 mg) and sodium (61.48 mg) content observed here supports findings by Usta *et al*. (2003), who highlighted cloves' potential role in electrolyte balance.The notable iron content (9.45 mg) in clove buds is particularly significant. Similar findings were reported by Suliman *et al*. (2023), who demonstrated that the substantial iron content in cloves contributes to their antioxidant properties and potential hematopoietic benefits. The presence of zinc (2.12 mg), while moderate compared to the other samples, still represents a nutritionally relevant quantity. Watermelon seeds show a distinctive mineral profile with moderate calcium (48.29 mg) and magnesium (41.69 mg) levels. Their iron content (8.64 mg) is substantial and only slightly lower than clove buds, which is consistent with findings by Vinhas *et al*. (2021), who identified watermelon seeds as potential plant-based iron sources.The standout feature of watermelon seeds is their zinc content (5.18 mg), which is significantly higher than the other samples. This observation supports research by Ihemeje (2024), who identified watermelon seeds as excellent sources of zinc, an essential mineral for immune function and protein synthesis. The phosphorus content (33.60 mg), while not the highest among the samples, remains nutritionally significant and aligns with findings by Diop *et al*. (2020) regarding the mineral composition of cucurbit seeds.Papaya seeds exhibit a unique mineral signature with the highest phosphorus content (218.35 mg), substantially exceeding the other samples. This extraordinary phosphorus concentration supports research by Adeoye *et al*. (2024), who identified papaya seeds as an exceptional source of this mineral essential for growth, repair, and maintenance of cells. The copper content (0.97 mg) in papaya seeds is also the highest among the three samples. While papaya seeds contain the lowest levels of calcium (21.25 mg), magnesium (16.80 mg), and iron (1.05 mg), their zinc content (3.73 mg) is intermediate between clove buds and watermelon seeds, indicating they remain a valuable source of this essential trace element. The unique mineral compositions of clove buds, watermelon seeds, and papaya seeds illustrate their synergistic nutritional characteristics. Clove buds are rich in calcium, magnesium, iron, potassium, and sodium; watermelon seeds offer significant zinc; and papaya seeds supply remarkable phosphorus and copper. These findings indicate possible applications in functional meals and nutraceuticals aimed at addressing specific mineral shortages or health concerns.

CONCLUSION

The study reveals the nutritional and therapeutic potential of *Carica papaya* seeds, *Citrullus lanatus* seeds, and *Syzygiumaromaticum* buds. These underutilized plant materials have significant nutritional and therapeutic value, making them valuable for food, pharmaceutical, and nutraceutical applications. Papaya seeds are rich in phenolic compounds, alkaloids, and phosphorus, with potential

applications in digestive health and antioxidants. Watermelon seeds have high protein and lipid profiles, with potential for protein supplementation and immune function. Clove buds have some mineral profile rich in calcium, magnesium, and manganese, with potential for addressing micronutrient deficiencies. Future research should focus on bioavailability studies and clinical investigations.

REFERENCE

Achukwu, N. (2022). Anitfungal and Phytochemical Screening of Carica Papaya Seed Extract. *Sokoto Journal of Medical Laboratory Science*, *7*(4).

Adeoye, R. I., Olopade, E. T., Olayemi, I. O., Okaiyeto, K., & Akiibinu, M. O. (2024). Nutritional and therapeutic potentials of Carica papaya Linn. seed: A comprehensive review. *Plant Science Today*, *11*(2), 671–680.

Agbaje, E. O. (2008). Gastrointestinal effects of Syzigiumaromaticum (L) Merr. & Perry (Myrtaceae) in animal models. *NIgerian quarterly journal of hospital medicine*, *18*(3), 137-141.

Aghababaei, F., & Hadidi, M. (2023). Recent advances in potential health benefits of quercetin. *Pharmaceuticals*, *16*(7), 1020.

Agoreyo, B. O., Obansa, E. S., & Obanor, E. O. (2012). Comparative nutritional and phytochemical analyses of two varieties of Solanum melongena. *Science World Journal*, *7*(1), 5-8.

Ajiboye, T. O., Mohammed, A. O., Bello, S. A., Yusuf, I. I., Ibitoye, O. B., Muritala, H. F., & Onajobi, I. B. (2016). Antibacterial activity of Syzygiumaromaticum seed: Studies on oxidative stress biomarkers and membrane permeability. *Microbial Pathogenesis*, *95*, 208-215.

Alrumaihi, F., Almatroodi, S. A., Alharbi, H. O. A., Alwanian, W. M., Alharbi, F. A., Almatroudi, A., & Rahmani, A. H. (2024). Pharmacological potential of kaempferol, a flavonoid in the management of pathogenesis via modulation of inflammation and other biological activities. *Molecules*, *29*(9), 2007.

AOAC. (1995). *Official methods of analysis of the association of official's analytical chemists, 17th edn*. *Association of Official Analytical Chemists, Arlington, VA*.

AOAC. (1999). *Official methods of analysis of the association of official's analytical chemists, 17th edn*. *Association of Official Analytical Chemists, Arlington, VA*.

AOAC. (2000). *Official methods of analysis of the association of official's analytical chemists, 17th edn*. *Association of Official Analytical Chemists, Arlington, VA*.

AOAC. (2003). *Official methods of analysis of the association of official's analytical chemists, 17th edn*. *Association of Official Analytical Chemists, Arlington, VA*.

Chen, K., Wu, S., Guan, Y., Ma, Y., Huang, Y., Liu, X., ... & Zhang, G. (2023). Changes in gut microbiota linked to a prevention of cardiac remodeling induced by hypertension in spontaneously hypertensive rats fed a pawpaw fruit diet. *Heliyon*, *9*(5).

Corbineau, F. (2024). The effects of storage conditions on seed deterioration and ageing: How to improve seed longevity. *Seeds*, *3*(1), 56-75.

Dashti, M. G., & Khan, M. S. S. (2022). Herbal Remedies for Lifestyle Diseases: Managing and Preventing Diabetes, Obesity, and Cardiovascular Conditions. *Australian Herbal Insight*, *5*(1), 1-9.

Dhyani, P., Quispe, C., Sharma, E., Bahukhandi, A., Sati, P., Attri, D. C., ... & Cho, W. C. (2022). Anticancer potential of alkaloids: a key emphasis to colchicine, vinblastine, vincristine, vindesine, vinorelbine and vincamine. *Cancer cell international*, *22*(1), 206.

Diop, A., Sarr, S. O., Sall, A. B., Niass, O., Ndiaye, B., & Diop, Y. M. (2020). Nutritional and antioxidant potential of seeds from two Cucurbitaceae species from Senegal. *European Journal of Chemistry*, *11*(4), 364-369.

DuBois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. T., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical chemistry*, *28*(3), 350-356.

Eke, R., Ejiofor, E., Oyedemi, S., Onoja, S., &Omeh, N. (2021). Evaluation of nutritional composition of Citrullus lanatusLinn.(watermelon) seed and biochemical assessment of the seed oil in rats. *Journal of Food Biochemistry*, *45*(6), e13763.

Elboughdiri, N., Lakikza, I., Boublia, A., Aouni, S. I., Hammoudi, N. E. H., Georgin, J., ... & Benguerba, Y. (2024). Application of statistical physical, DFT computation and molecular dynamics simulation for enhanced removal of crystal violet and basic fuchsin dyes utilizing biosorbent derived from residual

watermelon seeds (Citrullus lanatus). *Process Safety and Environmental Protection*, *186*, 995-1010.

El-Saber Batiha, G., Alkazmi, L. M., Wasef, L. G., Beshbishy, A. M., Nadwa, E. H., & Rashwan, E. K. (2020). SyzygiumaromaticumL.(Myrtaceae): traditional uses, bioactive chemical constituents, pharmacological and toxicological activities. *Biomolecules*, *10*(2), 202.

Enemor, V., Oguazu, C., Odiakosa, A., & Okafor, S. (2019). Research article evaluation of the medicinal properties and possible nutrient composition of Citrullus lanatus (Watermelon) seeds. *Res J Med Plant*, *13*(4), 129-35.

Ferreira, C., & Sarraguça, M. (2024). A comprehensive review on deep eutectic solvents and its use to extract bioactive compounds of pharmaceutical interest. *Pharmaceuticals*, *17*(1), 124.

Gupta, M., Thakur, S., Sharma, A., & Gupta, S. (2013). Qualitative and quantitative analysis of phytochemicals and pharmacological value of some dye yielding medicinal plants. *Orient J Chem*, *29*(2), 475-81.

Hahn, A., Liszka, J., Maksym, J., Nemś, A., & Miedzianka, J. (2025). Preliminary Data of the Nutritive, Antioxidative, and Functional Properties of Watermelon (Citrullus lanatus L.) Flour and Seed Protein Concentrate. *Molecules*, *30*(1), 181.

Harborne, J. B. (1998). *Phytochemical methods: a guide to modern techniques of plant analysis*. Chapman and Hall.

Haro-González, J. N., Castillo-Herrera, G. A., Martínez-Velázquez, M., & Espinosa-Andrews, H. (2021). Clove essential oil (Syzygiumaromaticum L. Myrtaceae): Extraction, chemical composition, food applications, and essential bioactivity for human health. *Molecules*, *26*(21), 6387.

Hemalatha, R., Nivetha, P., Mohanapriya, C., Sharmila, G., Muthukumaran, C., & Gopinath, M. (2016). Phytochemical composition, GC-MS analysis, in vitro antioxidant and antibacterial potential of clove flower bud (Eugenia caryophyllus) methanolic extract. *Journal of food science and technology*, *53*, 1189-1198.

Hussain, I., Ullah, R., Khurram, M., Ullah, N., Baseer, A., Khan, F. A., ... & Khan, N. (2011). Phytochemical analysis of selected medicinal plants. *African Journal of Biotechnology*, *10*(38), 7487-7492.

Ihemeje, A. (2024), Comparative Assessment of Nutrient and Phytochemical Properties of Melon, Water Melon and Cucumber Seeds. *Journal of Food and Nutrition*, 3(2).

Jomova, K., Alomar, S. Y., Alwasel, S. H., Nepovimova, E., Kuca, K., & Valko, M. (2024). Several lines of antioxidant defense against oxidative stress: Antioxidant enzymes, nanomaterials with multiple enzyme-mimicking activities, and low-molecular-weight antioxidants. *Archives of Toxicology*, *98*(5), 1323-1367.

Joshi, V., Nimmakayala, P., Song, Q., Abburi, V., Natarajan, P., Levi, A., ... & Reddy, U. K. (2021). Genome-wide association study and population structure analysis of seed-bound amino acids and total protein in watermelon. *PeerJ*, *9*, e12343.

Karagecili, H., Yılmaz, M. A., Ertürk, A., Kiziltas, H., Güven, L., Alwasel, S. H., & Gulcin, İ. (2023). Comprehensive metabolite profiling of Berdav propolis using LC-MS/MS: Determination of antioxidant, anticholinergic, antiglaucoma, and antidiabetic effects. *Molecules*, *28*(4), 1739.

Khalil, A. A., ur Rahman, U., Khan, M. R., Sahar, A., Mehmood, T., & Khan, M. (2017). Essential oil eugenol: Sources, extraction techniques and nutraceutical perspectives. *RSC advances*, *7*(52), 32669-32681.

Kolu, P., Olumide, M. D., & Akintunde, A. O. (2021). Potentials of ripe Carica papaya seed meal using different processing methods as alternative feed ingredients in monogastric animal nutrition. *Nigerian Journal of Animal Science*, *23*(3), 177-184.

Kong, Y. R., Jong, Y. X., Balakrishnan, M., Bok, Z. K., Weng, J. K. K., Tay, K. C., ... & Khaw, K. Y. (2021). Beneficial role of Carica papaya extracts and phytochemicals on oxidative stress and related diseases: a mini review. *Biology*, *10*(4), 287.

Kumar, K., Debnath, P., Singh, S., & Kumar, N. (2023). An overview of plant phenolics and their involvement in abiotic stress tolerance. *Stresses*, *3*(3), 570-585.

Lam, T. P., Tran, N. V. N., Pham, L. H. D., Lai, N. V. T., Dang, B. T. N., Truong, N. L. N., ... & Tran, T. D. (2024). Flavonoids as dual-target inhibitors against α-glucosidase and α-amylase: a systematic review of in vitro studies. *Natural Products and Bioprospecting*, *14*(1), 4.

Lartey, G. S. T. J., Tachie-Menson, J. W., & Adu, S. (2023). Nutritional composition of cinnamon and clove powder and the evaluation of the antimicrobial properties of their extracts: A comparison between Ghana and other countries. *African Journal of Plant Science*, *17*(2), 11-17.

Lone, Z. A., & Jain, N. K. (2022). Phytochemical analysis of clove (Syzygiumaromaticum) dried flower buds extract and its therapeutic importance. *J. Drug Deliv. Ther*, *12*, 87-92.

Mahla, H. R., Rathore, S. S., Venkatesan, K., & Sharma, R. (2018). Analysis of fatty acid methyl esters and oxidative stability of seed purpose watermelon (Citrullus lanatus) genotypes for edible oil. *Journal of Food Science and Technology*, *55*, 1552-1561.

Maisarah, A. M., Asmah, R., & Fauziah, O. (2014). Proximate analysis, antioxidant and anti-proliferative activities of different parts of Carica papaya. *Journal of tissue science & engineering*, *5*(1), 1.

Manivannan, A., Lee, E. S., Han, K., Lee, H. E., & Kim, D. S. (2020). Versatile nutraceutical potentials of watermelon—A modest fruit loaded with pharmaceutically valuable phytochemicals. *Molecules*, *25*(22), 5258.

Marchese, A., Barbieri, R., Coppo, E., Orhan, I. E., Daglia, M., Nabavi, S. F., ... & Ajami, M. (2017). Antimicrobial activity of eugenol and essential oils containing eugenol: A mechanistic viewpoint. *Critical reviews in microbiology*, *43*(6), 668-689.

Myint, S., Daud, W. R. W., Mohamad, A. B., & Kadhum, A. A. H. (1996). Gas chromatographic determination of eugenol in ethanol extract of cloves. *Journal of Chromatography B: Biomedical Sciences and Applications*, *679*(1-2), 193-195.

Nadeem, M., Navida, M., Ameer, K., Iqbal, A., Malik, F., Nadeem, M. A., ... & Din, A. (2022). A comprehensive review on the watermelon phytochemical profile and their bioactive and therapeutic effects. *Food Science and Preservation*, *29*(4), 546-576.

Nkwonta, C. G., Auma, C. I., & Gong, Y. (2023). Underutilised food crops for improving food security and nutrition health in Nigeria and Uganda—a review. *Frontiers in Sustainable Food Systems*, *7*, 1126020.

Nnaemeka, U. M. (2023). Hypoglycaemic and hypolipidemic effect of different solvents extract of unripe Carica papaya seed in streptozotocin-induced diabetic rats. *International Journal of Science and Research Archive*, *8*(1), 075-082.

Okeniyi, J. A., Ogunlesi, T. A., Oyelami, O. A., & Adeyemi, L. A. (2007). Effectiveness of dried *Carica papaya* seeds against human intestinal parasitosis: a pilot study. *Journal of medicinal food*, *10*(1), 194-196.

Otunola, G. A. (2022). Culinary spices in food and medicine: an overview of Syzygiumaromaticum (L.) Merr. and LM Perry [Myrtaceae]. *Frontiers in Pharmacology*, *12*, 793200.

Oyeleke, G. O., Olagunju, E. O., & Ojo, A. (2012). Functional and physicochemical properties of watermelon (Citrullus lanatus) seed and seed-oil. *Journal of Applied Chemistry*, *2*(2), 29-31.

Pandey, A. K., Nath, T. K., & Dhara, S. (2025). Effect of reaction temperatures on optical properties of clove buds derived carbon dots for targeting nucleolus. *Journal of Industrial and Engineering Chemistry*, *141*, 441-455.

Pin, C. H., & Daniel, N. (2023). Processing of herbal-based natural products and functional foods: a review. *Sains Malaysiana*, *52*(9), 2587-2598.

Rani, S. S., Vedavijaya, T., Podila, K. S., Md, Z. A., Chinnanolla, S., Sayana, S. B., & Soujanya, S. C. (2024). In Vivo Antioxidant and Nephroprotective Effects of Ethanolic Extract of Carica papaya Seeds and Its Isolated Flavonoid on Gentamicin-Induced Nephrotoxicity in Wistar Albino Rats. *Cureus*, *16*(4).

Sahu, S. S. (2021). Clove as Nutraceuticals. *NEW DELHI PUBLISHERS*, 165.

Santhi, K., & Sengottuvel, R. (2016). Qualitative and quantitative phytochemical analysis of Moringa concanensis Nimmo. *International Journal of Current Microbiology and Applied Sciences*, *5*(1), 633-640.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture*, *16*(3), 144-158.

Suliman, M. A. E., Ahmed, F. G., El-Kholy, K. F., Mohamed, R. A. E., & Abdel-Mawla, L. F. (2023). Effects of clove (syzygiumaromaticum) on productive performance, nutrients value and digestibility, blood lipid profile, antioxidant status and immune response of growing rabbits. *Online J. Anim. Feed Res*, *13*(1), 1-9.

Sun, W., & Shahrajabian, M. H. (2023). Therapeutic potential of phenolic compounds in medicinal plants—Natural health products for human health. *Molecules*, *28*(4), 1845.

Tabiri, B., Agbenorhevi, J. K., Wireko-Manu, F. D., & Ompouma, E. I. (2016). Watermelon seeds as food: Nutrient composition, phytochemicals and antioxidant activity.*International Journal of Nutrition and Food Sciences*, *5*(2), 139-142.

Timilsena, Y. P., Phosanam, A., & Stockmann, R. (2023). Perspectives on saponins: food functionality and applications. *International Journal of Molecular Sciences*, *24*(17), 13538.

Tungmunnithum, D., Thongboonyou, A., Pholboon, A., & Yangsabai, A. (2018). Flavonoids and other phenolic compounds from medicinal plants for pharmaceutical and medical aspects: An overview. *Medicines*, *5*(3), 93.

Ugbogu, E. A., Dike, E. D., Uche, M. E., Etumnu, L. R., Okoro, B. C., Ugbogu, O. C., ... & Iweala, E. J. (2023). Ethnomedicinal uses, nutritional composition, phytochemistry and potential health benefits of Carica papaya. *Pharmacological Research-Modern Chinese Medicine*, *7*, 100266.

Ullah, M. A., Hassan, A., & Hamza, A. (2023). Role of clove in human medical history. *SAR J Anat Physiol*, *4*(2), 10-19.

Usta, J., Kreydiyyeh, S., Barnabe, P., Bou-Moughlabay, Y., &Nakkash-Chmaisse, H. (2003). Comparative study on the effect of cinnamon and clove extracts and their main components on different types of ATPases. *Human & experimental toxicology*, *22*(7), 355-362.

Vetter, R. E., & Barbosa, A. P. R. (1995). Mangrove Bark: A renewable resin source for wood adhesives. *Acta Amazonica*, *25*(1-2), 69-72.

Vinha, A. F., Costa, A. S., Espírito Santo, L., Ferreira, D. M., Sousa, C., Pinto, E., ... & Oliveira, M. B. P. (2024). High-value compounds in papaya by-products (Carica papaya L. var. Formosa and Aliança): Potential sustainable use and exploitation. *Plants*, *13*(7), 1009.

Vinhas, A. S., Silva, C. S., Matos, C., Moutinho, C., & Ferreira da Vinha, A. (2021). Valorization of watermelon fruit (Citrullus lanatus) byproducts: phytochemical and biofunctional properties with emphasis on recent trends and advances. *World Journal of Advance Healthcare Research*, *5*(1), 302-309.

Vuong, Q. V., Hirun, S., Roach, P. D., Bowyer, M. C., Phillips, P. A., & Scarlett, C. J. (2013). Effect of extraction conditions on total phenolic compounds and antioxidant activities of Carica papaya leaf aqueous extracts. *Journal of herbal medicine*, *3*(3), 104-111.

Xue, Q., Xiang, Z., Wang, S., Cong, Z., Gao, P., & Liu, X. (2022). Recent advances in nutritional composition, phytochemistry, bioactive, and potential applications of Syzygiumaromaticum L. (Myrtaceae). *Frontiers in Nutrition*, *9*, 1002147.

Yanty, N. A. M., Marikkar, J. M. N., Nusantoro, B. P., Long, K., & Ghazali, H. M. (2014). Physico-chemical characteristics of papaya (Carica papaya L.) seed oil of the Hong Kong/Sekaki variety. *Journal of Oleo Science*, *63*(9), 885-892.

Zhou, K., Wang, H., Mei, W., Li, X., Luo, Y., & Dai, H. (2011). Antioxidant activity of papaya seed extracts. *Molecules*, *16*(8), 6179-6192.