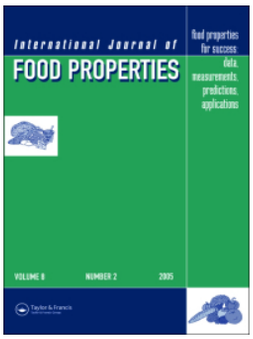

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Polyphenols, antioxidant activity, and functional properties of baobab (*Adansonia digitata* L) seeds soaked in monovalent ion salts

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ABSTRACT

Baobab (*Adansonia digitata* L.) seeds are underutilized and native to Savannah regions of Africa. The problem of the hard-to-cook (HTC) phenomenon with antinutrients exists. The application of monovalent ion salt solutions becomes important. This study analyzed the effect of soaking in deionized water, 0.5% w/v monovalent ion salts (NaCl, $NaHCO_3$), sodium salt of a divalent ion ($Na_2S_2O_5$) on the polyphenyl, antioxidant activity, and functional properties. The salts caused protein, crude fiber, vitamin C, and dry matter contents of 40.2–44.6 g/100 g, 7.78–9.46%, 3.0–3.4 mg/100 g, and 80.4–86.2%, respectively. Seed thickness, weight, and color were influenced by soaking in monovalent salt solutions. The total phenolic content (TPC), total flavonoid content (TFC), and proanthocyanidins range was 251–326 mg GAE/100 g, 236–288 mg TE/100 g, and 59–70.4 mg LE/100 g respectively. The Ferric Reducing Antioxidant Power (FRAP), DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging, and ABTS + (2,2′-azinobis-3-ethyl benzothiazoline-6-sulfonate) ranged between 208.4–291.3 mg EA/g, 86.0–104 mg TE/g, and 98.3–110 µmol AEAC/100 g respectively. Bulk density, phytates, and oxalates were reduced significantly ($p < 0.05$), and gelatinization temperature increased. Monovalent salts reduce antinutrients, promote solubilization of polyphenols, modify the seed properties, and contribute to softening of the seeds.

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Introduction

Understanding the relationship between Hard-to-Cook (HTC) phenomena and different processing techniques as well as their practical applicability can promote the processing of the underutilized African baobab (*Adansonia digitata* L.) seeds and enhance their utilization, marketing, and production of sustainable food material. The baobab tree is a high-yielding, drought-resistant, all-season plant belonging to the *Malvaceae* family and is distributed in drier regions of tropical Africa.[1] The African baobab tree is the oldest and largest surviving angiosperm with multi-purpose uses, as it produces significant non-timber forest products (NTFPs).[2] The tree produces fruits that are globose in shape (Figure 1a) have a hard shell with velvety yellowish-brown hairs that contain seeds (Figure 1b) covered with a whitish pulp (Figure 1c).

The baobab tree plays an important role in humans as a source of nutrition.[2] Global food and nutrition security, agricultural supply chain, and sustainable livelihoods have been negatively affected by COVID-19, especially in Africa.[3] The use of underutilized edible fruits such as the African baobab seeds as sources of food becomes very important. Baobab seeds are not only beneficial to nutrition but also an ideal food material in the functional food market because of their good polyphenol, amino acid profile, and antioxidant activity.[4]

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The African baobab seeds may be eaten raw, roasted, boiled or fermented, dried and then ground into flour for use as soups or thickeners in preparations of stew and as a flavoring agent.[5,6] The baobab seeds are important as traditional medicine and the oils have been used in the treatment of diseased teeth and inflamed gums and diarrhea.[5] The authorizing of African baobab by the European Commission and its approval by the Food and Drug Administration (FDA) as a novel food and an ingredient,[7] creates possibilities for global commercialization. The utilization of baobab seeds is often limited due to the HTC phenomenon and the presence of antinutrients that occurs at high temperatures (30–40°C) and high relative humidity (RH) (>75%) in drier areas of the tropical and subtropical regions. Different processing techniques, such as chemical, biological, and physical treatments have been suggested by Mubaiwa et al.[8]

Information on the processing of African baobab seeds in monovalent ion salts and effects on the phytochemicals and antioxidant activity is not fully documented. Taking into account the strong potential of baobab seeds as functional food, a rich source of essential nutrients, and bioactive compounds, in this work we evaluated the effect of soaking in more monovalent salts on polyphenols, antioxidant activity, and functional properties of baobab seeds.

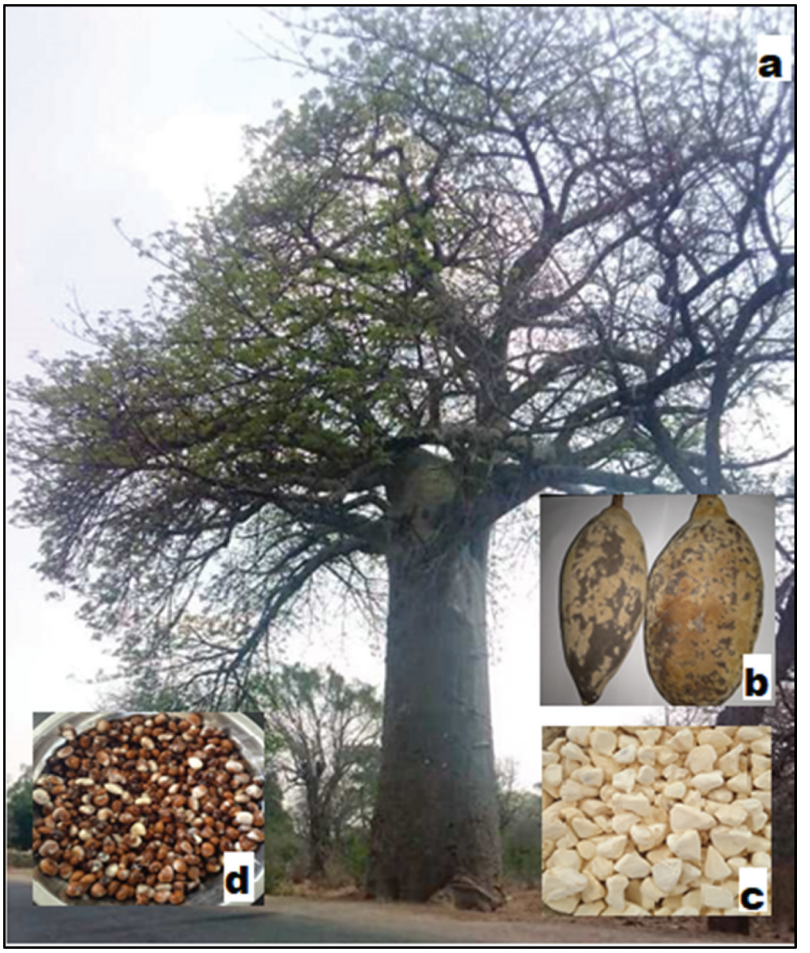

Figure 1. Baobab tree (a), baobab fruit (b), baobab pulp (c), baobab seeds (d)

Materials and methods

Materials

Baobab seeds were purchased from local vendors in Chipinge (19° S 32° E), Zimbabwe. Sodium chloride, sodium bicarbonate, sodium bisulfate, and methanol were obtained from Merck, South Africa. Gallic acid, catechin, leucocyanidin, DPPH, and vitamin C were all from Sigma-Aldrich, USA. Folin-Ciocalteu reagent was obtained from Radchem, South Africa. Trolox was purchased from Acros Organics, China.

Sample preparation and treatments

The baobab seeds were washed with rinsing water to remove any pulp material. The broken and cracked baobab seeds were removed and discarded. The seeds were selected and weighed so that there was equal weight in each soaking treatment. Sub-samples of the 100 baobab seeds were then soaked in deionized water, 0.5% NaCl solution, 0.5% $NaHCO_3$ solution, and 0.5% $Na_2S_2O_5$ solution for 24 h at room temperature. These ions like Cl^-, Na^+ were selected because have a higher affinity for the free water surface. The weights of baobab seeds and pH of monovalent ion salt solutions were recorded before and after soaking. After soaking, the seeds were dried using modified temperature by the AOAC,[9] at 100°C for 2 h, 100°C for 2 h, 102°C for 2 h, and 105°C for 2 h for the baobab seeds soaked in distilled water, 0.5% NaCl, 0.5% $NaHCO_3$ and 0.5% $Na_2S_2O_5$ respectively. These modified conditions were used to obtain uniform weight and moisture content in all the treated seed samples. The dried baobab seed samples were then ground using a laboratory mill (FZ102, Retsch, Pudong, Shanghai) and sieved through a 400 μm sieve for analysis.

Proximate content assays

The moisture content was determined using the Association of Official Analytical Chemists (AOAC) method 925.45, crude fiber using the enzymatic gravimetric method (AOAC method 985.29), Dry matter using oven drying, and crude protein using the Nitrogen Carbon Sulfur (NCS) method, vitamin C content using the Dichlorophenolindophenol (DCPIP) titration test, mineral content using the modified AOAC method adopted from the Standards Association of Zimbabwe Test Method CF-TM -054 using an Inductively Coupled Plasma–Optical Emission Spectrometer (ICP-OES) (ICAP 6500 Radial, ICP – 20104501, England, United Kingdom).[9]

Extraction of polyphenols

The modified extraction process as described by Chipurura[10] was used. The baobab seeds were crushed in a lab mill (FZ102, Retsch, Pudong, Shanghai) and 50 g of sample was first, defatted with 60 mL hexane by overnight stirring, filtered, and then successively extracted twice with hexane for 1 h. The defatted sample (1 g) was homogenized and extracted using 70% aqueous methanol three times by shaking vigorously for 10 min. The samples were then centrifuged at 1610 x g for 10 min in a bench centrifuge (MLC-3000, Thermo Fisher Scientific, Waltham, MA, USA) and the supernatants were filtered through a Whatman no. 1 filter. The filtrate was then evaporated to dryness at 40°C and dissolved in methanol-water (4:1, 10 mL).

Total polyphenols

TPC was determined using a method described by Chawafambira et al.[11] with slight modifications. A 100 mg of dry extract was mixed with 10 ml of 80% methanol and then diluted to 100 ml with the solvent. A 1 mL of sample (methanolic extract solution) was added to a 25 mL volumetric flask with 9 mL of distilled water. A 10 mL of 7% sodium carbonate solution and 1 N Folin-Ciocalteu reagent

(1 mL) were then added and the mixture was incubated at 25°C for 5 minutes. The mixture was then made up to 25 mL by adding distilled water. The absorbance of the mixture was then measured at 765 nm using a UV-vis spectrophotometer (1900i, Shimadzu, Japan) after a 90-min incubation period at room temperature. A calibration equation ($y = 0.0033x + 0.3419$; $R^2 = 0.8521$) was produced using standard gallic acid (Merck) and results were expressed on a dry weight basis (DW) as milligrams of gallic acid equivalents per 100 g sample (mg GAE/100 g DW).

Total content of flavonoids

The extracted sample (100 µL) was mixed with 4 mL of distilled water. To the mixture, 0.3 mL of 5% sodium nitrite and 0.3 mL of 10% aluminum chloride solution were added. Then 2 mL of 1 M sodium hydroxide and 3.3 mL distilled water was added the mixture was incubated for 15 min in a dark room. The absorbance of the test sample was done at 510 nm using a Uv-vis spectrophotometer (1900i, Shimadzu, Japan) and compared to the blank. Catechin standard solutions (12.5, 25, 50, 100 µg/mL) with a calibration equation ($y = 0.003x + 0.0022$) was used to determine the TFC and results were expressed as milligrams of catechin equivalents per 100 g DW sample (mg CE/100 g DW).

Total condensed tannins

Tannins were determined according to the method described by Chipurura.[10] A 0.1 mL of sample extract was mixed with butanol–HCl reagent (butanol: HCl 95:5 v/v). After that, 0.1 mL ferric reagent, prepared by dissolving 2% ferric ammonium sulfate in 100 ml 2 N HCl was then added to the mixture. The mixture was then vortexed for 2 min, heated at 90°C in a water bath for 1 h, and cooled. The absorbance of the mixture was measured at 500 nm against a 50% methanol blank and the results were expressed in milligrams equivalents of leucocyanidin (2-(3,4-Dihydroxyphenyl)-3,4-dihydro-2 H-1-benzopyran-3,4,5,7-tetrol) per 100 g sample (mg LE /100 g DW).

DPPH free radical scavenging and total antioxidant activity assay

The modified 2,2-diphenyl-1-picrylhydrazyl free radical scavenging activity method described by AOAC,[9] was used. A 1 mL of each methanol extract of the sample was mixed with 3 mL of 0.2 mmol/L DPPH methanolic solution and absorbance was measured using a Uv-vis spectrophotometer (1900i, Shimadzu, Japan) at 517 nm. Calibrations with methanol were conducted at 27°C for 20 min in darkness and the DPPH free radical scavenging rate of each sample was expressed as the percentage decrease in absorbance with time. The antioxidants were expressed as mg of Trolox equivalent per 100 g DW of the sample.

The modified ABTS (2,2'-azinobis-3-ethyl-benzothiazoline-6-sulfonate) method described by Chawafambira et al.,[12] was used to determine the total antioxidant activity. ABTS+ (100 mmol/L) and 1.76 mL potassium persulfate ($K_2S_2O_8$) were mixed in a dark place and left to react. The prepared liquid was then diluted with 95% ethanol and analyzed for its absorbance. A 1 mL of each test sample extract was then mixed with 3 mL of ABTS radical solution, and the decolorization of the ABTS+ radical cation was determined in a UV-vis spectrophotometer (1900i, Shimadzu, Japan) at 734 nm. Ascorbic acid was used as a standard and the capacity of free radical scavenging was expressed as µmol ascorbic acid equivalents (AE) /100 g DW of the sample.

Ferric reducing antioxidant power (FRAP) iron reduction test

The method used to determine the FRAP of the baobab extracts was adopted from Bourkhiss et al.[13] A 0.5 mL of each baobab extract sample was mixed with 1.5 mL of tapon phosphate solution (0.2 M; pH = 6.6), and 1.5 mL of 1% potassium hexacyanoferrate ($KFe(CN)_6$). The mixture was heated at 50°C for 25 min in a water bath (Lab Companion 37 L, Jeio Tech, Korea) and cooled to room temperature.

To the cooled mixture, 1.25 mL of 10% trichloroacetic acid ($C_2HCl_3O_2$) was then added and centrifuged at 3000 rpm for 10 min. A volume of 1.25 mL of the supernatant was then mixed with 0.25 mL of 0.1% ferric chloride ($FeCl_3$) and then 1.25 mL of distilled water. The mixture was incubated for 30 min in the dark place and its absorbance was then determined at 700 nm against a blank using the UV-vis spectrophotometer (1900i, Shimadzu, Japan). Results were expressed as mg Trolox/100 g DW.

Phytate and oxalate content

The modified spectrophotometry method described by Wheeler and Ferrel's,[14] was used. The absorbance of the mixture was determined at 510 nm using a UV-vis spectrophotometer (1900i, Shimadzu, Japan). Oxalates were analyzed using a method Rout and Basak[15] and calculated by converting 1 ml of 0.05 M $KMnO_4$ to 2.2 mg oxalate.

Functional properties

The bulk density, gelatinization temperature, and swelling index of soaked baobab seed samples were analyzed using methods described by Chawafambira.[16]

Statistical analysis

All results were expressed as mean ± standard deviation (SD). Data analysis was carried out using Sigma plot Ver.12 at a 5% level of significance. The least significant differences (LSD) test was used to compare the means. The Kruskal Wallis non-parametric test and Analysis of Variances (ANOVA) at $p < .05$ was conducted on the observed data.

Results and discussion

Changes in baobab seed properties

Table 1 shows the pH and weight changes in baobab seeds soaked in monovalent ion salts solutions. Potter[17] indicated that monovalent ion salts solutions with high pH can act as tenderizers and affect the breakdown of macronutrients and pectin substances. The effect of salts on the influence of pH on softening and reducing the HTC in seeds was reported by del-Valle et al.[18] The soaking pH of the monovalent ion salts was able to cause higher hydration rates due to the increased cell membrane permeability.[19] Monovalent salts, especially $NaHCO_3$ and Na_2CO_3, had a great effect on the increasing softening of HTC beans,[20] as well as NaCl.[21]

The change in pH, as well as the color changes in the soaking solution, could be attributed to the presence of polyphenols, and melanin compounds that could have leaked into solution when compared to deionized water. The monovalent salt solutions become reddish-brown whereas deionized water was light brown. The color might have been caused by melanin, which is formed by the oxidation and polymerization of phenols and the presence of flavonoids (anthocyanins, flavonol glycosides), proanthocyanidins, and carotenoids in the seed coat.[22] Similar observations were

Table 1. Weight and pH changes of baobab seeds soaked in monovalent ion salt solutions.

	pH				
	Before	After	Seed length (mm)	Seed thickness (mm)	Weight change (%)
Deionized water	5.5 ± 0.1	6.0 ± 0.1	11.3 ± 0.1	6.38 ± 0.01	8 ± 0.1
0.5% NaCl	7.1 ± 0.1	7.6 ± 0.0	11.0 ± 0.1	6.35 ± 0.01	5 ± 0.1
0.5% $NaHCO_3$	8.3 ± 0.0	8.8 ± 0.1	11.5 ± 0.2	6.43 ± 0.01	13 ± 0.1
0.5% $Na_2S_2O_5$	4.7 ± 0.1	5.0 ± 0.0	11.1 ± 0.0	6.40 ± 0.02	10 ± 0.1

reported in studies by Mubaiwa et al.[23] in Bambara nuts. The observed baobab seed weight is correlated to the seed hardness. The low weight of the raw seeds was influenced by their hardness which was caused by the autolysis of cytoplasmic organelles, weakling plasmalemma integrity, lignification of middle lamella as well as the formation of insoluble pectate and interaction of proteins and phenolic compounds.[8,24] Water imbibition and the presence of more hydroxycinnamic acids (ferulic, p-coumaric, and sinapic acid) bound to the soluble pectin and forming cross-linkages which reduced cell separation to allow more water molecules to enter the seed could have affected the seed thickness during soaking.

Proximate composition of baobab seed soaked in monovalent ion salts

The observed protein content in Table 2 could be attributed to the effect of pH of solutions, the release of 7S and 11S proteins, and the removal of non-proteinaceous (phenols, lipids, and starch) compounds present in the seeds.[25,26] NaCl is a strong electrolyte that can allows water molecules to disrupt molecular linkages on the proteins.[27] Raw baobab seeds are well-known to be hard with a more compact cell arrangement, but during soaking, water molecules would enter into the intracellular spaces and cause the disruption of cell-to-cell adhesion.[28] This is important in breaking the HTC phenomenon and softening the baobab seeds.

Monovalent ion salts solutions were able to cause the degradation of crude fiber by activating the endogenous enzymes. This could be attributed to the hypertonic effect and the presence of monovalent ions that can break the cell tissues, and the release of solid matter.[29] Vitamin C content was low because it leached out into the solution during soaking. Nkafamiya et al.[30] observed a vitamin C content of 6.71 ± 0.04 mg/100 g in the raw baobab seed. The baobab seed is rich mineral composition (Table 1). According to a study by Asogwa et al.,[6] the African baobab seed can provide the human body with the Dietary Reference Intake (DRI) of vital minerals such as K (4700), Na (1500), Ca (1200), Ph (700), Fe (18), and Zn (11 mg/ 100 g), when consumed at adequate quantities.

Variations in bioactive compounds content during

The effects of soaking in monovalent ion salts and deionized water on the bioactive compounds in baobab seeds are shown in Figure 2. The observed changes in the phenolic content could be attributed to the release of these bound phenolics into the solution. Seeds soaked in 0.5% $NaHCO_3$ resulted in high leaching of bioactive compounds as indicated by the reduction in total phenols. This is because of the effect of the ion salt in disruption of the cell system on the seeds and allowing the bioactive compounds to leach out into solution. Condensed tannins or proanthocyanidins that exist as

Table 2. Proximate composition baobab seeds soaked in monovalent ion salts.

Nutrients	Raw seed	Deionized water	0.5% NaCl	0.5% $NaHCO_3$	0.5% $Na_2S_2O_5$
Crude protein (g/100 g DW)	21.4 ± 0.05^{a}	40.20 ± 0.06^{b}	40.29 ± 0.05^{b}	44.60 ± 0.04^{c}	43.16 ± 0.05^{c}
Crude fiber (g/100 g DW)	14.9 ± 0.02^{c}	7.78 ± 0.09^{a}	7.55 ± 0.09^{a}	9.02 ± 0.16^{b}	9.46 ± 0.40^{b}
Moisture (%)	6.4 ± 0.01^{c}	2.52 ± 0.13^{a}	3.74 ± 0.14^{a}	4.73 ± 0.25^{b}	5.22 ± 0.33^{b}
DM (%)	90.7 ± 0.3^{c}	86.2 ± 0.01^{b}	84.4 ± 0.05^{b}	82.3 ± 0.07^{a}	80.4 ± 0.08^{a}
Ascorbic acid (mg/100 g DW)	8.8 ± 0.3^{c}	3.4 ± 0.7^{b}	3.2 ± 0.7^{ab}	3.0 ± 0.5^{a}	3.3 ± 0.7^{b}
Mineral (mg/100 g DW)					
Fe	6.2 ± 0.2^{b}	4.2 ± 0.1^{a}	4.0 ± 0.2^{a}	4.7 ± 0.1^{a}	$4.2 \pm 0.^{a}1$
Ca	1680 ± 10.1^{c}	1230 ± 8.2^{b}	1122 ± 7.5^{a}	985 ± 6.5^{a}	1102 ± 10.2^{a}
K	675.4 ± 9.7^{c}	$325.2 \pm 2.^{b}$	374.2 ± 3.1^{b}	289.4 ± 1.2^{a}	260.6 ± 4.2^{a}
Ph	294.2 ± 8.6^{c}	186.2 ± 6.5^{b}	164.2 ± 2.3^{b}	121.0 ± 1.4^{a}	102.3 ± 3.1^{a}
Zn	5.2 ± 0.1^{c}	2.3 ± 0.2^{b}	1.8 ± 0.1^{b}	1.4 ± 0.2^{a}	1.0 ± 0.1^{a}
Mg	390.6 ± 7.6^{c}	170.2 ± 3.1^{b}	145.1 ± 2.3^{a}	$121.3 \pm 4.^{a}$	114.1 ± 5.2^{a}
Cu	2.4 ± 0.1^{c}	1.6 ± 0.3^{b}	1.2 ± 0.1^{a}	$1.1 \pm 0.2a$	1.0 ± 0.2^{a}

Mean ± standard deviations are reported; DM: Dry matter; Means values within the same row with different superscript letters ($^{a, b, c}$) are significantly different ($p < 0.05$).

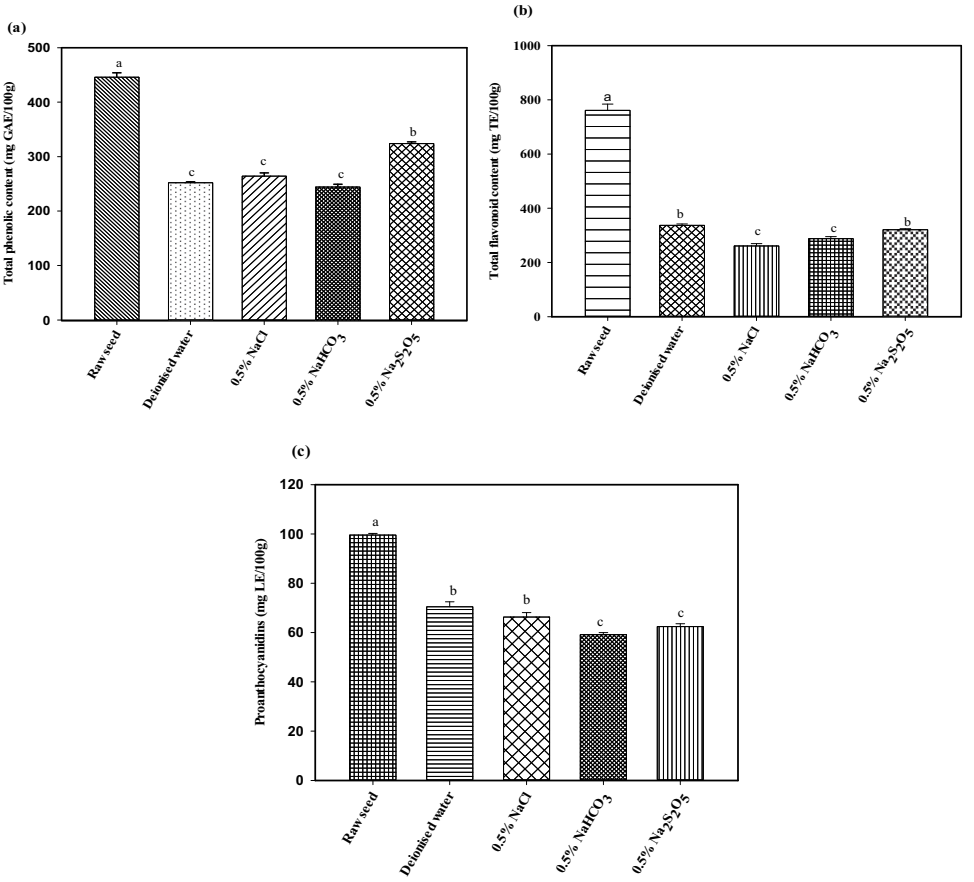

Figure 2. Bioactive compounds of baobab seeds soaked in monovalent ion salt solutions, (a) TPC; (b) TFC; (c) Total tannin content.

oligomers and polymers are released.[31] Ismail et al.[32] identified the presence of phenolic acids that include four hydroxycinnamic acid derivatives (*p*-hydroxycinnamic, caffeic, ferulic, and chlorogenic acids) and three hydroxybenzoic acid derivatives (gallic, protocatechuic, and *p*-hydroxybenzoic acids) in baobab seed extracts. Ndiaye et al.[33] reported a TFC and TPC of 12.82 ± 0.04 µg EQ/mg and 18.36 ± 0.07 µg EAG/mg, respectively, in baobab seed. The reported TFC can be attributed to the presence of flavanols (D- (+)-catechin, (−)-epicatechin) and a flavone (rutin) in baobab seed.[32] The soaking process was able to cause a decrease in tannin content (Figure 3c). Ndiaye et al.[33] reported a tannin content of 1.09 ± 0.04 µg EC/mg of baobab seed extract. The main possible tannins present in the baobab seeds are proanthocyanidins. Monovalent ion salt solutions could break the linkages formed by tannic acid with macromolecules and the intra-molecular force that exist within the tannin structure.[34] Further, the hydrolysis of the polyphenols by the polyphenol oxidase enzyme as well as the breakdown of the tannin complexes such as tannic acid-starch, tannin-protein, and tannin-iron complexes to release free nutrients could have occurred resulting in leaching of the tannins into solution.[35]

Antioxidant activity of soaked baobab seeds

The antioxidant activity of baobab seeds as influenced by soaking in deionized water and monovalent ion salts is shown in Figure 3. The observed antioxidant activity of the soaked baobab seeds extracts could be attributed to the presence of phenolic acids although it was low

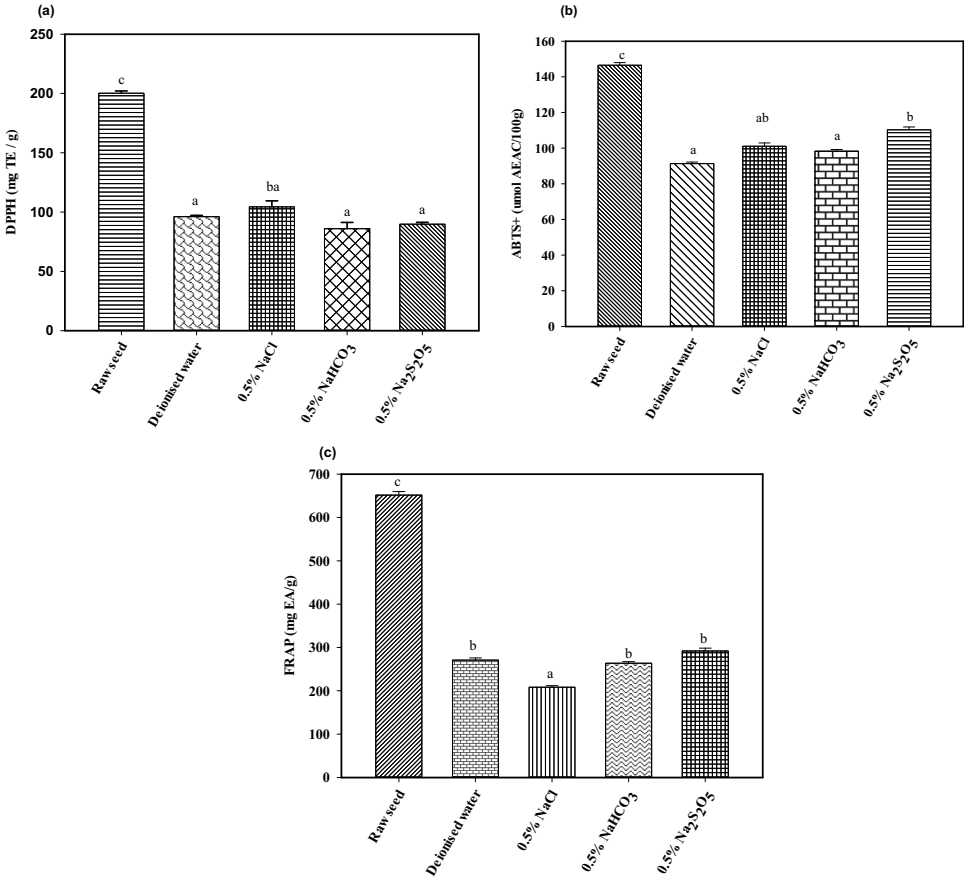

Figure 3. Antioxidant activity of baobab seeds soaked in deionized water and monovalent ion salts, (a) DPPH free radical scavenging, (b) ABST+ activity, (c) FRAP iron reduction.

in seeds treated with 0.5% $NaHCO_3$ and $Na_2S_2O_5$ solutions. $Na_2S_2O_5$ contains 67% of SO_2 and is hydrolyzed by water to bisulfite (HSO_3^-), which reacts with protein SS groups by interchange, freeing a SH group and causing release of complexed phenols with proteins. Ismail et al.[32] identified the presence of D-(+)-Catechin (87.18 ± 14.56 µg/g DW), protocatechuic acid (10.63 ± 3.92 µg/g DW), and (−)-epicatechin (9.78 ± 5.12 µg/g DW) in baobab seeds. The crude fiber and vitamin C (Table 2), might have also contributed to the antioxidant activity. The occurrence of D-(+) catechin as a major phenolic compound in baobab seeds[32] increases the total antioxidant activity.

Table 3. Effect of soaking in alkaline salts and deionized water on phytates and oxalates.

	Phytates (mg/100 g DW)	Oxalates (mg/100 g DW)
Raw seed	6.7 ± 0.2^{c}	1.3 ± 0.3^{b}
Deionized water	2.4 ± 0.1^{b}	0.7 ± 0.1^{a}
0.5% NaCl	2.1 ± 0.1^{b}	0.6 ± 0.1^{a}
0.5% $NaHCO_3$	1.7 ± 0.1^{a}	0.4 ± 0.1^{a}
0.5% $Na_2S_2O_5$	1.4 ± 0.1^{a}	0.3 ± 0.1^{a}
p-value	<0.05	<0.05

Mean ± standard deviations are reported; Means values within the same column with different superscript letters ($^{a, b, c}$) are significantly different ($p < 0.05$).

Table 4. Bulk density, swelling index and gelatinization temperature of baobab seeds soaked in monovalent ion salts and deionized water.

	Bulk density (g/cm)	Swelling index (mL)	Gelatinization temperature (°C)
Raw seed	0.72 ± 0.02^{b}	3.30 ± 0.2^{c}	81.0 ± 1.32^{b}
Distilled water	0.56 ± 0.01^{a}	2.50 ± 0.10^{a}	78.3 ± 2.52^{a}
0.5% NaCl	0.69 ± 0.02^{a}	2.47 ± 0.15^{a}	79.0 ± 3.61^{b}
0.5% $NaHCO_3$	0.57 ± 0.01^{a}	2.70 ± 0.20^{b}	81.3 ± 1.76^{b}
0.5% $Na_2S_2O_5$	0.57 ± 0.02^{a}	2.37 ± 0.21^{a}	83.3 ± 1.53^{c}
p-value	<0.05	<0.05	<0.05

Mean ± standard deviations are reported; Means values within the same column with different superscript letters ($^{a, b, c}$) are significantly different ($p < 0.05$).

Ndiaye et al.[33] recorded an inhibition of the DPPH radical of 20.19 IC_{50} µg/mL from baobab seed extracts. Given the TFC, TPC, and total tannin content present in the soaked baobab seed extract (Figure 3), we can report the proanthocyanidins and flavonoids, could be responsible for the antioxidant activity. Our results of the FRAP were higher than those of DPPH activity. This meant that soaking in monovalent ion salts increases the ability of the antioxidants in the baobab seeds to reduce Fe (3+) to Fe (2+). However, seeds soaked in NaCl had a low FRAP because the Cl^{-} ions were able to attract water molecules and cause the leaching of bioactive compounds into solution.

Phytate and oxalate content

The result as indicated in Table 3 showed a significant decrease in the phytates and oxalate content. The reduction in the phytate content could be attributed to the increased activities of the enzyme, dephosphorylates phytate which terminates the formation of inositol and phosphoric acid thereby releasing the bound minerals during soaking.[36] Osman[37] reported the presence of phytic acid (73 mg/100 g) in raw baobab seeds. The importance of alkaline soaking reducing oxalates and phytates has been recommended.[4]

Functional properties

Baobab seed soaked in monovalent ion salts showed an increase in the gelatinization temperature (Table 4). According to Varriano-Marston and De Omana,[38] ion salts can increase the gelatinization temperature of starch bound in cells of the seed. Further, the barrier to water penetration formed by the seed coat can reduce the rate of starch gelatinization.[39] The observed decrease in the bulk density could be attributed to the breakdown of macronutrients (carbohydrates and proteins) as the water enters the starch granules.[16,17] The low bulk density in soaked baobab seeds makes them a good ingredient in the preparation of weaning foods. The changes in swelling capacity could be attributed to the lower fat content and ability of fat to complex with starch which inhibits swelling. The relatively high protein content in the baobab seed (Table 2) could have caused the decrease in the surface tension of water in the food matrix and influenced the swelling capacity.

Conclusion

Monovalent ion salt solutions with low pH tends to reduce water absorption and reduce softening. Polyphenols such as tannins are reduced but TFC and TFC become relatively high during soaking. The monovalent salts at a concentration (0.5% w/v) can modify seed properties by increasing their thickness and weight. The mechanism of monovalent salts action caused a reduction in FRAP and DPPH radical scavenging activity in soaked baobab seeds. $Na_2S_2O_5$, a sodium salt of a divalent ion produced the optimal effect when compared to other salts.

Phytates, oxalates, bulk density were reduced and gelatinization temperature increased. There is need for the characterization of the phenolic profiles of treated baobab seeds. Further studies on the effects of monovalent salts on starch molecules, in relation to the reduction of the hardness of baobab seed, rate of water uptake and cooking rates of the soaked baobab seeds are recommended.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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