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Cooking sweetpotato roots increases the *in vitro* bioaccessibility of phytochemicals and antioxidant activities, but not vitamin C

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ABSTRACT

The percent bioaccessibility of phytochemicals and antioxidant activities (ABTS and FRAP) of cooked sweetpotato storage roots (peeled and unpeeled) of varying flesh colours was assessed *in vitro*. Generally, the phytochemicals' bioaccessibility increased with cooking compared to the raw roots, except in vitamin C. The raw roots had vitamin C bioaccessibility of 92 %, while for cooked, it ranged between 61 % (baking) and 73 % (frying). For phenolics and flavonoids, peeling the roots significantly ($P < 0.001$) increased bioaccessibility by 11 % and 4 %, respectively. For the other phytochemicals, the bioaccessibility of peeled roots did not differ significantly ($P > 0.05$) from unpeeled ones. Cooked roots had higher antioxidant activities than in raw. Vitamin C may have acted as a pro-oxidant as it was the only phytochemical with inverse relation with antioxidant activities. Boiling, steaming, baking, frying, or microwaving sweetpotato roots increases the *in vitro* bioaccessibility of phytochemicals and antioxidant activities, but not vitamin C.

1. Introduction

Given the association between diet and health and the increasing global prevalence of nutrition-related non-communicable diseases, functional foods have become the focus of current research. Many bioactive compounds in food, including phytochemicals, amino acids and peptides, dietary fibre, vitamins, minerals, and fatty acids, are reported to potentially reduce the incidences of chronic diseases when consumed in sufficient doses (Aguiar et al., 2019). As food ingredients pass through the gastrointestinal tract (GIT), many changes can modify their structure and ultimately influence their absorption and metabolism (Karaś et al., 2017). Therefore, for these compounds to achieve their desired effects, they must be able to withstand processing, be accessible and efficiently absorbed from the GIT into circulation and distributed to target tissues and organs (Toydemir et al., 2022). Much scientific research exists on evaluating bioactive compounds content in foods. However, these studies are inadequate in determining their effects on the body, and consequently health.

Bioavailability (biological availability) refers to the proportion of a specific food component that becomes available after consumption to be used in biological functions (Fairweather-Tait & Southon, 2003). For a nutrient to become bioavailable, it must first be made bioaccessible. Bioaccessibility is the proportion of the consumed nutrient that is released from the food matrix during digestion and therefore becomes available for absorption by epithelial tissue in the GIT (Galanakis, 2017). Following bioaccessibility, the food component then undergoes tissue uptake and assimilation by the target tissue, eliciting the appropriate physiological response. This process is known as bioactivity (Galanakis, 2017). Nutrient bioavailability is determined by several factors including the physicochemical form of the specific nutrient and dose ingested, the food matrix structure and interaction with other food components, enhancers or inhibitors of absorption, storage and processing methods of the food, and host-related factors such as gastric acidity, nutrition status, and gut microflora (Fairweather-Tait & Southon, 2003; Toydemir et al., 2022). In the strictest sense of the term, bioavailability can only be measured by *in vivo* analysis of the

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metabolites present in plasma or urine after consuming a specific food (Chitchumroonchokchai & Failla, 2018). This is because the metabolic endpoint is impossible to determine using *in vitro* means. However, bioaccessibility can be determined by *in vitro* methods (Wu & Chen, 2021). Although limitations may arise from *in vitro* assessment of bioaccessibility, researchers have verified that the evaluation of bioaccessibility by *in vitro* models can be well correlated with results from human studies and animal models (Cardoso et al., 2015; Mulet-Cabero et al., 2020; Wu & Chen, 2021).

It is worth noting that different processing methods applied to foods before consumption may have significant effects on their phytochemical bioaccessibility and antioxidant potential. Although thermal processing could have a negative or positive effect on nutrient bioaccessibility, the bioaccessibilities of phytochemicals in cooked food are likely to increase compared to their raw forms. This may be due to the rupture of plant cell walls and subsequent dissociation of nutrient-matrix complexes or conversion into more active molecular components (Cilla et al., 2018).

The bioaccessibility of phenolic compounds could be influenced by their interaction with carbohydrates, proteins, fats, and fibre in the food matrix in two ways (Mihaylova et al., 2021). The bonds formed may protect the phenolic compounds from oxidation during digestion, or protein-phenol complexes could decrease the phenolics' bioaccessibility due to enzyme inactivation or protein precipitation (Mihaylova et al., 2021). The bioaccessibility of phenolic compounds is usually<30 % of the total amount ingested, although in a few cases, polyphenol bioaccessibility could reach 50 % (Lorenzo et al., 2019). The synergy between the starch and endogenous phenolics in starchy foods may inhibit their bioaccessibility through competitive interactions with glucose transporters (Furrer et al., 2018). The proportions of soluble and insoluble dietary fibres of foods reportedly influenced flavonoids' bioaccessibility (de Lima et al., 2017; Hamed et al., 2021). The food matrix thus plays a crucial role in the bioaccessibility of nutrients and bioactive compounds from foods.

Due to their lipophilic nature, carotenoids are poorly dispersed in the aqueous media of the GIT (Rodríguez-Roque et al., 2016). After being released from the food matrix, carotenoids must be solubilised into micelles, which are molecular masses that transport fat-soluble molecules, before they can become bioaccessible by the intestinal epithelium (Shilpa et al., 2020). Other phytochemicals present in a food matrix, containing carotenoids such as phenolics, flavonoids, and alkaloids, may change the physicochemical properties of micelles, thereby affecting carotenoid bioaccessibility. Dietary fibre has been reported to decrease carotenoid bioaccessibility by binding to phospholipids and bile acids, inhibiting lipase activity, and increasing the viscosity of digestive fluids. These processes decrease micellarisation, leading to decreased carotenoid bioaccessibility (Shilpa et al., 2020).

Once released from plant tissues, anthocyanins can be affected by pH changes and exposure to heat, light or oxygen (Li et al., 2021). The acidic pH of the stomach provides a favourable medium for anthocyanin stability. However, anthocyanins are poorly absorbed in the small intestine, and their general bioavailability has been observed to be between 1 and 2 % based on urine or plasma recoveries and about 12 % using Carbon-13 tracer studies (Li et al., 2021).

Sweetpotato has been recommended as a potential functional food in the Sub-Sahara African region due to its significant amounts of phytochemicals (Amagloh et al., 2021; Bechoff et al., 2011; Bengtsson et al., 2010). Its consumption as a food-based approach may positively complement efforts to mitigate the health and economic burdens imposed by increasing prevalences of nutrition-related non-communicable diseases (Amagloh et al., 2021). Although studies have been conducted on sweetpotato endogenous phytochemicals and their retention levels after the application of various heat treatments, these results would not be of much benefit if their bioaccessibilities are unknown. The bioaccessibility of carotenoids (especially beta-carotene) after processing orange-fleshed sweetpotato has been studied in detail (Bechoff et al., 2011; Bengtsson et al., 2010; Bengtsson et al., 2009; Berni et al., 2015; Failla et al., 2009; Tumuhimbise et al., 2009). A few studies have also investigated processing effects on bioaccessibility of phenolic compounds, including anthocyanins in purple-fleshed sweetpotato (Kubow et al., 2016; Meng et al., 2019; Miranda et al., 2013; Yang et al., 2019). However, to the best of our knowledge, there is no single comprehensive study looking at *in vitro* bioaccessibility of a range of bioactive compounds in different sweetpotato genotypes with varying flesh colours. Owing to the fact that the interactions between phytochemicals and other components in the food matrix, such as minerals, fibre, starch or proteins, can alter their bioaccessibilities (Mihaylova et al., 2021), this is worth investigating as varying flesh colours of sweetpotato contain varying amounts of these components (Kourouma et al., 2019). Hence, given this knowledge gap, this study aimed to investigate the bioaccessibilities of phenolic compounds, flavonoids, carotenoids, anthocyanins, vitamin C, and antioxidant activities of varying flesh colours of Ugandan sweetpotato genotypes after subjection to different processing methods.

2. Materials and methods

2.1. Study experimental design

A 2x6x6 factorial experimental design was employed for this study. The first factor, peel condition, had two levels (peeled and unpeeled). Six (6) sweetpotato genotypes were used. Each genotype was independently subjected to six (6) processing methods - five (5) cooking methods and raw (uncooked) roots used as control samples.

2.2. Sweetpotato materials used for the study

All sweetpotato genotypes used for this study were planted in a trial field at the National Agricultural Research Organisation (NARO) - National Crops Resources Research Institute (NaCRRI) in Uganda. The six (6) sweetpotato genotypes were PF-167 (deep purple-fleshed advanced yield trial clone), NASPOT 13 O (deep orange-fleshed variety), NASPOT 8 (pale orange-fleshed variety), NAROSPOT 1 (pale yellow-fleshed variety), NASPOT 11 (cream-fleshed variety), and 'Ssetyabule' (white-fleshed local farmer genotype). Apart from 'Ssetyabule', the others are improved varieties from NaCRRI.

2.3. Sweetpotato storage roots sampling

This procedure has been described in detail in (Amagloh et al., 2022a,b). The sweetpotato roots were all harvested at physiological maturity between 4 and 5 months after planting. Harvesting was done separately on three (3) occasions. This gave rise to three (3) independent biological replicates of each genotype to be used in all experimental procedures. About 20 roots of different sizes were randomly selected for each genotype. The sweetpotato storage roots were washed under running tap water, air-dried and stored at room temperature for three (3) days before processing. During processing, each storage root was cut into two (2) longitudinal halves; one half was peeled and used as the peeled treatment. The other half remained unpeeled and used as the unpeeled treatment.

2.4. Sweetpotato storage roots processing

These methods have been adequately described elsewhere (Amagloh et al., 2022a,b). The raw roots used as the control samples, were cut into slices of 1.5 mm thick and frozen at −18 to −20 °C. The remaining roots were subjected to five household cooking techniques - boiling, steaming, baking, frying, and microwaving. For all methods, except frying, the sweetpotato roots used were diced into 2.5 cm^3 portions. Boiling was done in a covered saucepan at 96–97 °C for 25 min. Steaming was done at 93–95 °C for 30 min. For baking, roots were single-layered in an aluminium baking pan and baked in an electric oven at 180 °C for 1 h.

Microwaving was done at 700 W on a medium–high setting for 15 min. Roots for the frying treatment were cut into 1 cm-thick chip and deep-fried in unfortified sunflower oil at 160 °C for 8 min with an electric fryer.

All cooked samples were allowed to cool to room temperature and frozen at −18 to −20 °C for at least a week. Frozen samples, including the frozen raw roots, were lyophilised at −35 to −40 °C for 72 h; afterwards, the samples were ground with an electric mill and passed through a 420 μm aperture sieve. Samples were packaged in polyethene bags and stored at −18 to −20 °C until required for laboratory analyses.

2.5. Laboratory analyses

The phytochemicals measured were total phenolic compounds, total flavonoids, total carotenoids, total monomeric anthocyanin, and vitamin C. In addition, total antioxidant activity was measured using the 2,2′-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) radical scavenging assay and the Ferricyanide Reducing Antioxidant Potential (FRAP) assay. All phytochemical contents and antioxidant activities were evaluated on samples before and after *in vitro* digestion. The methods and results for samples before *in vitro* digestion have been discussed in detail in a previous publication (Amagloh et al., 2022a,b).

2.6. In vitro digestion

The simulated *in vitro* digestion procedure was based on previous studies (Bechoff et al., 2011; Bengtsson et al., 2009; Meng et al., 2019). This method reproduced three physiological steps of the human digestion process: oral, gastric, and small intestinal phases of digestion. An oral phase was included in this study since sweetpotato is a starchy food and starch digestion begins in the mouth (Bengtsson et al., 2009). All solutions used were freshly prepared.

2.6.1. Oral phase

To mimic oral digestion, 0.5 g of freeze-dried sample was added to 10 ml of 0.1 mg/ml alpha-amylase dissolved in 0.9 % NaCl. The mixture was homogenised for 10 min at 37 °C in a shaking water bath.

2.6.2. Gastric phase

The pH of the homogenate from the oral phase was adjusted to 2.2 ± 0.1 with 1 M HCl to mimic the pH in the stomach. This was followed by adding 2 ml porcine pepsin solution (40 g/L in 0.1 M HCl). The mixture was incubated for 1 h at 37 °C in a shaking water bath.

2.6.3. Intestinal phase

The pH of the digest from the gastric phase was adjusted to 7.0 ± 0.1 with 1 M $NaHCO_3$. Then 3 ml of a mixture containing porcine pancreatin and bile extract (2 g/L pancreatin and 12 g/L bile extract in 0.1 M $NaHCO_3$) was added. This brought the final pH of the mixture to 7.5 ± 0.1. The mixture was incubated for 1.5 h at 37 °C in a shaking water bath to complete the digestion process. Samples were dipped in an ice bath for 1 min to deactivate the enzymatic process.

Samples from the simulated digestion were centrifuged at 4400 × g for 20 min. The supernatant fraction was passed through a 0.45 μm filter paper and the filtrate was collected for analysis. The bioactive compounds and antioxidant activities were analysed according to the methods described elsewhere (Amagloh et al., 2022a,b). The percent bioaccessibility for each parameter was calculated as follows:

$$\%bioaccessibility = \frac{Bioactive\ \ compound\ \ content\ \ of\ \ sample\ \ after\ \ in\ \ vitro\ \ digestion \times 100}{Bioactive\ \ compound\ \ content\ \ of\ \ undigested\ \ sample}$$

2.7. Statistical methods

The data generated were subjected to a multi-factorial analysis of variance to compare the main and interaction effects of the three (3) factors: sweetpotato genotype, cooking method, and peel condition on the percent bioaccessibilities of the bioactive compounds content and antioxidant activities. The statistical software employed was 'Agricolae' Package in R Programming Language (version 4.1.0). The means were compared by Fisher's LSD *post hoc* test at a significance of $P < 0.05$. All values were expressed as the means ± standard deviations of triplicate biological samples and reported on a dry weight basis. Pearson's correlation (r) was carried out to determine linear relationships between each pair of response variables. In addition, principal component analysis (PCA) was conducted using the Paleontological Statistics software (version 4.03) to determine the contribution of the response variables to the variance of the dataset, and to identify the interrelationships among the individual bioactive compounds and antioxidant activities.

3. Results

3.1. Percent bioaccessibilities of phytochemicals and antioxidant activities

Results of the main effects of peel condition and cooking method are presented in Tables 1 and 2 respectively; the interaction effect for genotype vs cooking method is presented in Table 3.

3.1.1. Effect of peeling

The percent bioaccessibilities of unpeeled roots ranged from 7 % in total anthocyanin content to 72 % in vitamin C content; and for peeled, from 7 % in anthocyanins to 73 % in vitamin C (Table 1). Peeling the sweetpotato roots resulted in significant increases in bioaccessibilities ($P < 0.001$) for total phenolic compounds and total flavonoids. For phenolic compounds content, peeled roots were 11 % more bioaccessible than unpeeled, while for flavonoids peeling the roots resulted in a 4 % increase in bioaccessibility. Peeling did not significantly ($P > 0.05$) affect bioaccessibilities of total carotenoids, vitamin C, anthocyanins and antioxidant activity.

3.1.2. Effect of cooking method

The bioaccessibility of total phenolic compounds ranged from 21.81 % in raw roots to 45.89 % in boiled roots, while that of total flavonoids was between 16.14 % in the raw and 61.70 % in boiled roots (Table 2). For phenolics and flavonoids, boiling and steaming gave higher bioaccessibilities than baking, frying, or microwaving. For total carotenoids, cooking the sweetpotato storage roots resulted in bioaccessibilities between 2.8 and 3.4 times that of raw roots. Among all the cooking methods, frying gave the highest bioaccessibility of total carotenoids (76.01 %; $P < 0.001$). Boiling, steaming, baking, and microwaving gave statistically similar bioaccessibilities of total carotenoids. For all bioactive compounds and antioxidant activities, except in vitamin C, cooking resulted in a significantly higher ($P < 0.001$) percent bioaccessibility compared to the raw roots. In vitamin C however, raw roots were the most bioaccessible (92.05 %). Baking resulted in the least vitamin C bioaccessibility of 60.83 %, while the other cooking methods, with an average bioaccessibility of 71.17 %, did not differ significantly ($P >$

Table 1
Percent bioaccessibilities of phytochemicals and antioxidant activities of sweetpotato roots as influenced by peeling.

Peel condition	TPC	TFC	TCC	VC	TMAC	ABTS	FRAP
With peel	31.94 ± 3.61[b]	43.29 ± 16.51[b]	58.51 ± 11.23[a]	72.42 ± 18.47[a]	7.13 ± 4.18[a]	47.73 ± 17.41[a]	49.78 ± 11.63[a]
Without peel	42.95 ± 11.17[a]	47.03 ± 17.77[a]	58.08 ± 14.72[a]	73.43 ± 15.45[a]	7.12 ± 4.20[a]	47.40 ± 14.20[a]	47.96 ± 11.16[a]
P-value	<0.001	<0.001	0.751	0.477	0.653	0.762	0.090

All values are reported on a dry weight basis, which are means ± SD of three independent biological replicates (n = 3). Means in the same column with different superscripts are significantly different (P < 0.05). TPC = total phenolic compounds; TFC = total flavonoid content; TCC = total carotenoid content; VC = vitamin C; TMAC = total monomeric anthocyanin content.

Table 2
Percent bioaccessibilities of phytochemicals and antioxidant activities of sweetpotato roots as influenced by cooking method.

Cooking Method	TPC	TFC	TCC	VC	TMAC	ABTS	FRAP
Raw	21.81 ± 12.90[d]	16.14 ± 6.97[d]	22.08 ± 5.73[c]	92.05 ± 5.11[a]	0.79 ± 0.03[e]	17.08 ± 7.53[d]	9.81 ± 3.02[d]
Boiling	45.89 ± 14.24[a]	61.70 ± 9.96[a]	62.61 ± 10.76[b]	69.67 ± 15.09[b]	12.01 ± 0.02[a]	53.40 ± 10.09[b]	60.06 ± 12.62[a]
Steaming	45.83 ± 16.51[a]	61.09 ± 9.24[a]	64.17 ± 11.46[b]	71.51 ± 13.99[b]	12.00 ± 0.02[a]	53.63 ± 10.54[b]	58.60 ± 10.51[a]
Baking	35.81 ± 14.13[bc]	40.97 ± 6.00[c]	62.54 ± 7.31[b]	60.83 ± 14.68[c]	8.00 ± 0.03[b]	48.69 ± 10.53[c]	54.49 ± 10.34[b]
Frying	41.61 ± 17.53[ab]	48.10 ± 8.06[b]	76.01 ± 10.11[a]	73.26 ± 16.96[b]	3.99 ± 0.02[d]	59.89 ± 12.23[a]	48.81 ± 16.41[c]
Microwaving	33.72 ± 13.57[c]	42.97 ± 6.82[c]	62.34 ± 12.57[b]	70.24 ± 16.54[b]	6.00 ± 0.02[c]	52.71 ± 9.34[b]	61.47 ± 12.55[a]
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

All values are reported on a dry weight basis, which are means ± SD of three independent biological replicates (n = 3). Means in the same column with different superscripts are significantly different (P < 0.05). TPC = total phenolic compounds; TFC = total flavonoid content; TCC = total carotenoid content; VC = vitamin C; TMAC = total monomeric anthocyanin content.

0.05) in their bioaccessibilities.

The highest score for anthocyanin bioaccessibility was 12 % in boiled and steamed roots, which was about 15.2 times that of raw roots. Among the cooking methods, frying gave the least anthocyanin bioaccessibility of 4 %. For all the bioactive compounds and antioxidant activities, boiling and steaming did not differ significantly in their bioaccessibilities.

Cooked roots had higher bioaccessibilities for both ABTS and FRAP antioxidant activities than raw roots. For ABTS, cooking increased bioaccessibility by 2.9 to 3.5 times that of raw roots, while for FRAP, cooked roots had bioaccessibilities between 5 and 6.3 times as much as raw roots. For both ABTS and FRAP, no significant differences existed among boiling, steaming, or microwaving.

3.1.3. Effect of sweetpotato genotype and cooking method

The percent bioaccessibilities differed significantly by genotype and cooking method for all phytochemicals and antioxidant activities, except total phenolic compounds and flavonoids (Table 3). Irrespective of the sweetpotato genotype, all cooking methods resulted in higher bioaccessibilities for phenolic compounds, flavonoids, carotenoids, anthocyanins and antioxidant activities compared to the raw roots. For vitamin C, however, the opposite was true for all genotypes. The bioaccessibility of vitamin C for raw roots was between 84.39 % in NASPOT 8 to 95.51 % in NASPOT 11. However, for cooked roots, vitamin C bioaccessibility ranged from 39.58 % in baked PF-167 to 87.54 % in microwaved NASPOT 11. Baking resulted in the lowest bioaccessibility of vitamin C in all genotypes.

For all the genotypes, frying resulted in the highest bioaccessibility of total carotenoids among the cooking methods. Fried 'Ssetyabule' had the highest bioaccessibility for total carotenoids (92.80 %; P < 0.001), which was 54 % higher than in steamed NASPOT 8, with the least carotenoid bioaccessibility. After *in vitro* digestion, anthocyanins were not detected in any of the sweetpotato genotypes except in the purple-fleshed PF-167.

Cooking increased the bioaccessibilities of both ABTS and FRAP antioxidant activities among all the genotypes. For ABTS antioxidant activity, cooking increased the bioaccessibility between 1.5 times in baked NAROSPOT 1 and 3.9 times in microwaved 'Ssetyabule' compared to their respective raw samples. The highest percent bioaccessibility of ABTS antioxidant activity was observed in fried NAROSPOT 1 (75.17 %) and the lowest in raw 'Ssetyabule' (11.74 %). For FRAP antioxidant activity, the bioaccessibility ranged from 6.39 % in raw NASPOT 13 O to 75.36 % in microwaved NASPOT 8. Cooking increased bioaccessibility of FRAP between 3.2 and 10.2 times that of the control samples.

3.2. Interrelationships among the percent bioaccessibilities of phytochemicals and antioxidant activities

The correlations between phytochemicals and antioxidant activities are presented in the heat map in Fig. 1. The ABTS antioxidant activity had statistically significant positive correlations with total phenolics (r = 0.53; P < 0.001), total flavonoids (r = 0.74; P < 0.001), and total carotenoids (r = 0.60; P < 0.001). Similarly, statistically significant positive correlations were observed between the FRAP antioxidant activity and total phenolics (r = 0.32; P = 0.006), total flavonoids (r = 0.72; P < 0.001), and total carotenoids (r = 0.58; P < 0.001). On the contrary, vitamin C had a statistically significant negative correlation with both ABTS (r = -0.47; P < 0.001) and FRAP (r = -0.58; P < 0.001).

The PCA yielded six (6) principal components (PCs), with the first two accounting for 77.1 % of the total variation in the dataset (Fig. 2a and 2b). All the phytochemicals and antioxidant activities exhibited a positive relationship with PC1, with only vitamin C showing a negative relationship. Similar vector directions were observed for total carotenoids and FRAP antioxidant activity and, total flavonoids and ABTS antioxidant activity. All the raw samples were observed to be clustered in the negative direction of PC1, while a majority of the observations for cooked samples were in the positive plane of PC1, correlating with the individual phytochemicals and antioxidant activities (Fig. 2a).

2a.

3.3. Phytochemical content and antioxidant activities after in vitro digestion

The charts presented in Fig. 3a to 3f show the values obtained for phytochemicals and antioxidant activities after subjecting the processed sweetpotato samples to *in vitro* digestion. All the phytochemicals content differed significantly (P < 0.05) at the third level interaction by sweetpotato genotype, cooking method and peel condition. For antioxidant activities, FRAP was significantly different (P = 0.006), while ABTS was not (P = 0.096).

The total phenolic compounds content (0.43–66.83 mg GAE/g; P <

Table 3
Percent bioaccessibilities of phytochemicals and antioxidant activities as influenced by sweetpotato genotype and cooking method.

Sweetpotato Genotype	Cooking Method	TPC	TFC	TCC	VC	TMAC	ABTS	FRAP
Ssetyabule	Raw	8.46 ± 2.22^{p}	14.16 ± 6.97^{n}	24.02 ± 4.13st	92.75 ± 1.91^{ab}	ND	11.74 ± 0.42^{l}	12.52 ± 0.59^{kl}
Ssetyabule	Boiling	36.6 ± 5.35^{d-m}	59.44 ± 7.74^{b-e}	89.72 ± 30.11^{ab}	73.47 ± 13.42^{f-k}	ND	45.91 ± 0.77^{i}	55.52 ± 8.64^{e-i}
Ssetyabule	Steaming	35.17 ± 4.05^{f-n}	56.35 ± 4.61^{c-f}	85.81 ± 12.12^{a-d}	58.38 ± 12.73^{mno}	ND	45.27 ± 2.01^{i}	49.98 ± 6.51^{ij}
Ssetyabule	Baking	25.02 ± 5.13^{k-o}	41.47 ± 5.69^{i-l}	55.74 ± 6.81^{mno}	49.64 ± 1.67^{op}	ND	45.11 ± 2.37^{i}	53.52 ± 3.11^{f-j}
Ssetyabule	Frying	34.99 ± 3.75^{g-n}	43.93 ± 4.63^{h-k}	92.80 ± 28.67^{a}	74.09 ± 12.62^{e-k}	ND	45.94 ± 1.87^{i}	51.87 ± 4.69^{f-j}
Ssetyabule	Microwaving	20.78 ± 4.47^{nop}	45.31 ± 6.23^{h-k}	72.24 ± 10.32^{e-i}	71.28 ± 13.78^{g-l}	ND	46.04 ± 1.69^{hi}	52.34 ± 5.02^{f-j}
NASPOT 11	Raw	15.13 ± 4.03^{op}	24.81 ± 8.77^{m}	27.97 ± 6.48^{rs}	95.51 ± 2.36^{a}	ND	16.87 ± 3.18^{kl}	9.14 ± 0.99^{l}
NASPOT 11	Boiling	46.55 ± 9.15^{a-h}	62.87 ± 9.12^{a-d}	64.63 ± 3.05^{h-n}	71.08 ± 16.46^{g-l}	ND	46.09 ± 3.44^{hi}	54.08 ± 3.98^{f-j}
NASPOT 11	Steaming	41.12 ± 5.73^{b-j}	64.73 ± 15.38^{abc}	80.87 ± 6.66^{b-f}	81.07 ± 14.69^{b-g}	ND	46.98 ± 2.30^{ghi}	56.20 ± 9.73^{e-i}
NASPOT 11	Baking	36.97 ± 7.21^{d-l}	44.13 ± 3.11^{h-k}	59.19 ± 11.16^{k-o}	70.47 ± 12.21^{g-l}	ND	45.43 ± 3.88^{i}	45.95 ± 4.88^{j}
NASPOT 11	Frying	39.94 ± 5.70^{c-k}	54.73 ± 6.63^{d-g}	82.89 ± 3.81^{a-e}	74.57 ± 11.04^{e-j}	ND	50.12 ± 4.05^{e-i}	59.23 ± 6.07^{d-h}
NASPOT 11	Microwaving	40.47 ± 7.34^{b-k}	45.69 ± 4.5^{h-k}	70.29 ± 10.43^{f-k}	87.54 ± 12.66^{a-d}	ND	46.80 ± 6.57^{ghi}	50.35 ± 2.86^{hij}
NAROSPOT 1	Raw	36.11 ± 6.73^{e-n}	13.38 ± 4.37^{n}	17.35 ± 2.06st	93.97 ± 2.38^{a}	ND	21.90 ± 16.82^{k}	7.91 ± 0.29^{l}
NAROSPOT 1	Boiling	54.29 ± 16.26^{abc}	61.95 ± 10.11^{a-d}	52.68 ± 18.34^{op}	78.26 ± 19.84^{d-h}	ND	52.99 ± 19.45^{d-i}	74.09 ± 13.27^{ab}
NAROSPOT 1	Steaming	55.48 ± 8.23^{ab}	61.57 ± 5.22^{a-d}	54.94 ± 3.71^{no}	74.89 ± 8.44^{e-j}	ND	50.47 ± 17.36^{e-i}	64.18 ± 10.32^{cde}
NAROSPOT 1	Baking	37.70 ± 7.81^{d-l}	34.00 ± 5.8^{l}	60.75 ± 12.59^{j-o}	62.46 ± 4.70^{k-n}	ND	31.71 ± 6.51^{j}	60.58 ± 7.25^{def}
NAROSPOT 1	Frying	48.05 ± 18.67^{a-g}	49.67 ± 9.48^{f-i}	75.47 ± 3.60^{d-h}	77.62 ± 19.15^{d-i}	ND	75.17 ± 15.26^{a}	50.87 ± 18.45^{g-j}
NAROSPOT 1	Microwaving	41.48 ± 13.00^{b-j}	38.72 ± 9.05^{kl}	71.22 ± 11.82^{f-j}	65.87 ± 11.20^{i-m}	ND	47.74 ± 10.76^{f-i}	60.65 ± 10.16^{def}
NASPOT 8	Raw	30.99 ± 16.58^{i-n}	13.15 ± 3.40^{n}	26.79 ± 3.11st	84.39 ± 6.71^{a-f}	ND	17.55 ± 4.13^{kl}	8.12 ± 0.48^{l}
NASPOT 8	Boiling	51.62 ± 19.29^{a-d}	65.87 ± 10.34^{ab}	43.48 ± 6.80^{pq}	81.30 ± 8.25^{b-g}	ND	57.86 ± 3.61^{cde}	55.51 ± 18.46^{e-i}
NASPOT 8	Steaming	60.03 ± 27.83^{a}	62.63 ± 5.41^{a-d}	38.44 ± 2.88^{qr}	80.60 ± 15.7^{c-g}	ND	55.03 ± 5.40^{d-h}	50.58 ± 5.82^{g-j}
NASPOT 8	Baking	43.60 ± 23.19b^{c-i}	43.25 ± 8.35^{h-k}	39.10 ± 2.19^{qr}	50.07 ± 10.15^{op}	ND	57.11 ± 9.37^{cde}	59.39 ± 12.58^{d-g}
NASPOT 8	Frying	50.97 ± 19.64^{a-e}	46.65 ± 11.54^{g-k}	66.54 ± 8.07^{h-m}	87.44 ± 17.53^{a-d}	ND	60.60 ± 6.66^{bcd}	51.21 ± 14.39^{g-j}
NASPOT 8	Microwaving	42.21 ± 16.98^{b-j}	42.92 ± 6.49^{h-l}	43.18 ± 4.50^{pq}	71.44 ± 7.46^{g-l}	ND	55.71 ± 1.72^{d-g}	75.36 ± 8.90^{a}
NASPOT 13 O	Raw	22.79 ± 11.86^{l-p}	14.74 ± 5.68^{n}	20.78 ± 1.35st	90.94 ± 4.36^{abc}	ND	17.92 ± 2.97^{kl}	6.39 ± 0.62^{l}
NASPOT 13 O	Boiling	51.84 ± 14.97^{a-d}	69.13 ± 10.37^{a}	72.54 ± 4.96^{e-i}	63.73 ± 7.53^{j-m}	ND	60.88 ± 8.07^{bcd}	53.14 ± 6.34^{f-j}
NASPOT 13 O	Steaming	51.40 ± 14.30^{a-e}	65.50 ± 13.17^{ab}	67.26 ± 4.57^{g-l}	67.32 ± 11.15^{h-m}	ND	66.12 ± 8.28^{abc}	65.30 ± 12.00^{bcd}
NASPOT 13 O	Baking	44.67 ± 17.35^{a-i}	41.31 ± 3.59^{i-l}	55.80 ± 3.87^{mno}	60.94 ± 6.82^{l-o}	ND	58.94 ± 2.49^{b-e}	53.71 ± 18.03^{f-j}
NASPOT 13 O	Frying	50.64 ± 15.47^{a-f}	45.63 ± 8.46^{h-k}	87.17 ± 8.86^{abc}	74.29 ± 14.29^{e-k}	ND	67.71 ± 6.56^{ab}	20.46 ± 2.25^{k}
NASPOT 13 O	Microwaving	41.54 ± 16.41^{b-j}	39.92 ± 7.66^{jkl}	64.04 ± 4.41^{i-n}	70.80 ± 8.77^{g-l}	ND	61.35 ± 7.29^{bcd}	60.42 ± 16.45^{def}
PF-167	Raw	12.04 ± 2.56^{op}	16.59 ± 5.88^{mn}	15.58 ± 1.74^{t}	94.72 ± 2.10^{a}	0.79 ± 0.02^{e}	16.51 ± 3.84^{kl}	14.77 ± 0.98^{kl}
PF-167	Boiling	34.48 ± 4.43^{g-n}	50.92 ± 0.72^{e-h}	52.58 ± 3.00^{op}	50.79 ± 2.80^{nop}	12.01 ± 0.02^{a}	56.67 ± 2.96^{def}	68.02 ± 2.41^{a-d}
PF-167	Steaming	31.81 ± 4.75^{h-n}	55.78 ± 2.53^{def}	62.19 ± 3.88^{i-o}	66.77 ± 8.47^{h-m}	12.00 ± 0.02^{a}	57.92 ± 2.85^{cde}	65.33 ± 5.73^{bcd}
PF-167	Baking	26.92 ± 3.53^{j-o}	41.68 ± 4.07^{i-l}	56.82 ± 8.26^{l-o}	39.58 ± 2.00^{p}	8.00 ± 0.03^{b}	53.85 ± 1.41^{d-i}	53.79 ± 4.00^{f-j}
PF-167	Frying	25.05 ± 4.49^{k-o}	47.98 ± 2.90^{f-j}	78.11 ± 8.81^{c-g}	51.55 ± 4.57^{no}	3.98 ± 0.02^{d}	59.82 ± 2.15^{bcd}	59.22 ± 5.10^{d-h}
PF-167	Microwaving	21.22 ± 1.73^{m-p}	45.29 ± 5.40^{h-k}	69.54 ± 6.49^{f-k}	85.72 ± 5.17^{a-e}	6.00 ± 0.02^{c}	58.64 ± 11.20^{b-e}	69.71 ± 7.31^{abc}
P-value		0.915	0.087	<0.001	<0.001	<0.001	<0.001	<0.001

All values are reported on a dry weight basis, which are means ± SD of three independent biological replicates (n = 3). Means in the same column with different superscripts are significantly different at $P < 0.05$. Superscript letters a-g implies all letters between 'a' and 'g', both inclusive. TPC = total phenolic compounds; TFC = total flavonoid content; TCC = total carotenoid content; VC = vitamin C; TMAC = total monomeric anthocyanin content; ND = not detected.

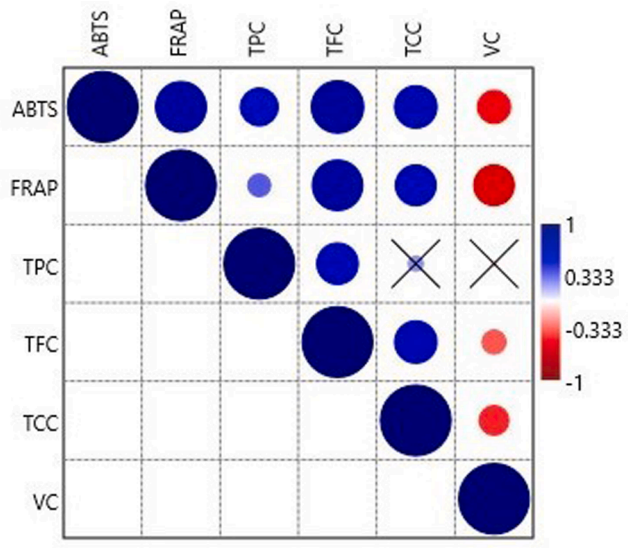


Fig. 1. Correlation matrix showing the correlations between the percent bioaccessibilities of each pair of variables (phytochemicals and antioxidant activities) of processed sweetpotato roots. A darkening shade of blue shows an increasing positive correlation. A darkening shade of red shows an increasing negative correlation. Boxes marked with "an X" are not statistically significant ($P > 0.05$). TPC = total phenolic compounds; TFC = total flavonoids content; TCC = total carotenoids content; VC = Vitamin C. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

0.001) was highest in unpeeled-boiled NASPOT 11 and least in peeled-raw NASPOT 13 O. Among cooked samples, however, peeled-fried NASPOT 8 had the least amount (0.94 mg GAE/g) of total phenolics. For all cooked samples, total phenolics content was significantly higher ($P < 0.001$) in 'Ssetyabule', NASPOT 11, and PF-167 (30.09–66.83 mg GAE/g) than in NAROSPOT 1, NASPOT 8, and NASPOT 13 O (0.94–14.03 mg GAE/g). A similar trend was observed for total flavonoids content.

After *in vitro* digestion, NASPOT 13 O (50.70–220.58 μg/g) had about 17 times the total carotenoids content in 'Ssetyabule' (5.37–10.82 μg/g). The raw-unpeeled roots were highest for vitamin C content, retaining between 37.89 μg AAE/g in 'Ssetyabule' and 156.67 μg AAE/g in NASPOT 11. Among the cooking methods, the unpeeled-microwaved roots had the highest vitamin C content (17.18–61.39 μg AAE/g), about 3.5 times that of peeled-baked roots, which had the least. Whether peeled or unpeeled, no significant differences ($P = 0.68$) existed in anthocyanin content between boiled and steamed roots of PF-167. Comparing the cooking methods, frying with and without the peel resulted in the lowest anthocyanin content in the sweetpotato storage roots (0.61 and 0.50 mg/g, respectively) after *in vitro* digestion.

With antioxidant activity, ABTS did not differ significantly among the sweetpotato genotypes, cooking methods and peel condition after *in vitro* digestion. In contrast, the FRAP antioxidant activity was significantly higher ($P = 0.006$) in unpeeled-microwaved PF-167 (105.21 μg AAE/g), unpeeled-boiled 'Ssetyabule' (103.62 μg AAE/g), and unpeeled-boiled PF-167(97.66 μg AAE/g). These samples had about 41 times the antioxidant activity in peeled raw NASPOT 11, the sample with the least.

After *in vitro* digestion, the values obtained for the phytochemicals reflected their original content before digestion. For instance, total phenolics were still higher in 'Ssetyabule', NASPOT 11 and PF-167 compared with NAROSPOT 1, NASPOT 8 and NASPOT 13 O. Further, vitamin C was highest in unpeeled microwaved roots and least in peeled baked roots (Amagloh et al., 2022a).

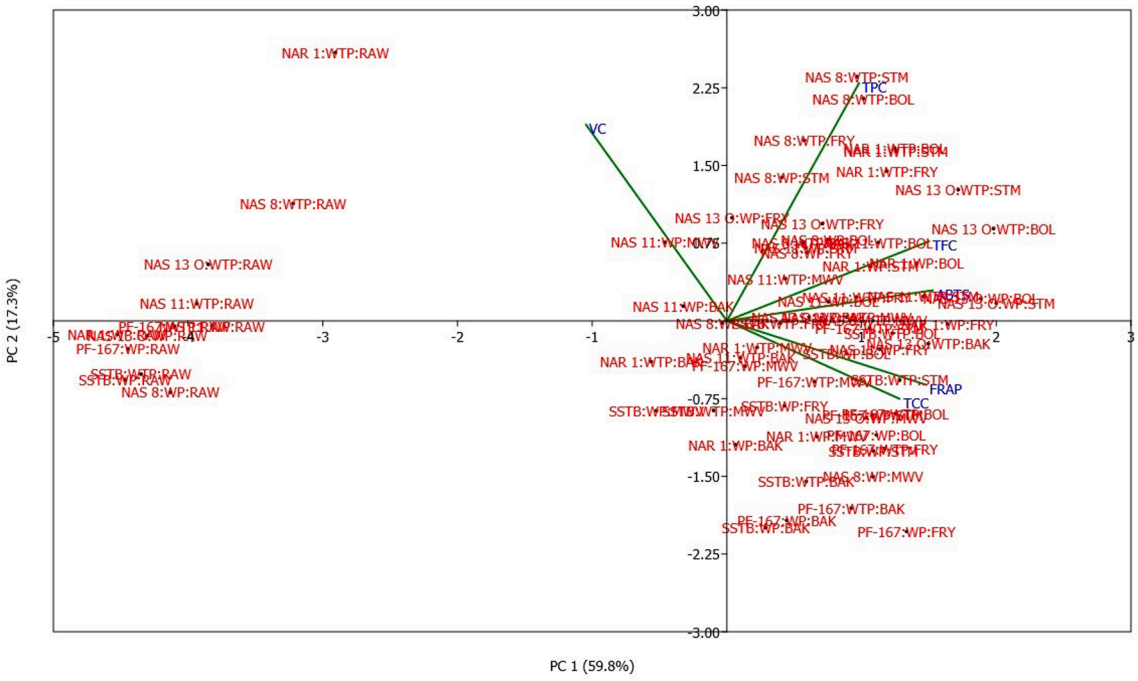
4. Discussion

Literature regarding the influence of food processing on bioactive compounds after *in vitro* gastrointestinal digestion is divergent. Cooking methods such as boiling, steaming, roasting, and frying have enhanced bioaccessibility of phytochemicals (de Lima et al., 2017; Hamed et al., 2021). On the other hand, other researchers have suggested that phytochemicals such as phenolic compounds are easily degradable in the GIT, where they are metabolised into compounds with different physicochemical properties, resulting in decreased bioaccessibility (Stafussa et al., 2021). In the same way, some scientists argued that phytochemicals are highly sensitive to pH changes in the GIT. In addition, their interaction with other components in the food matrix, such as minerals, fibre or proteins, can result in lower bioaccessibilities of the phytochemicals (Mihaylova et al., 2021).

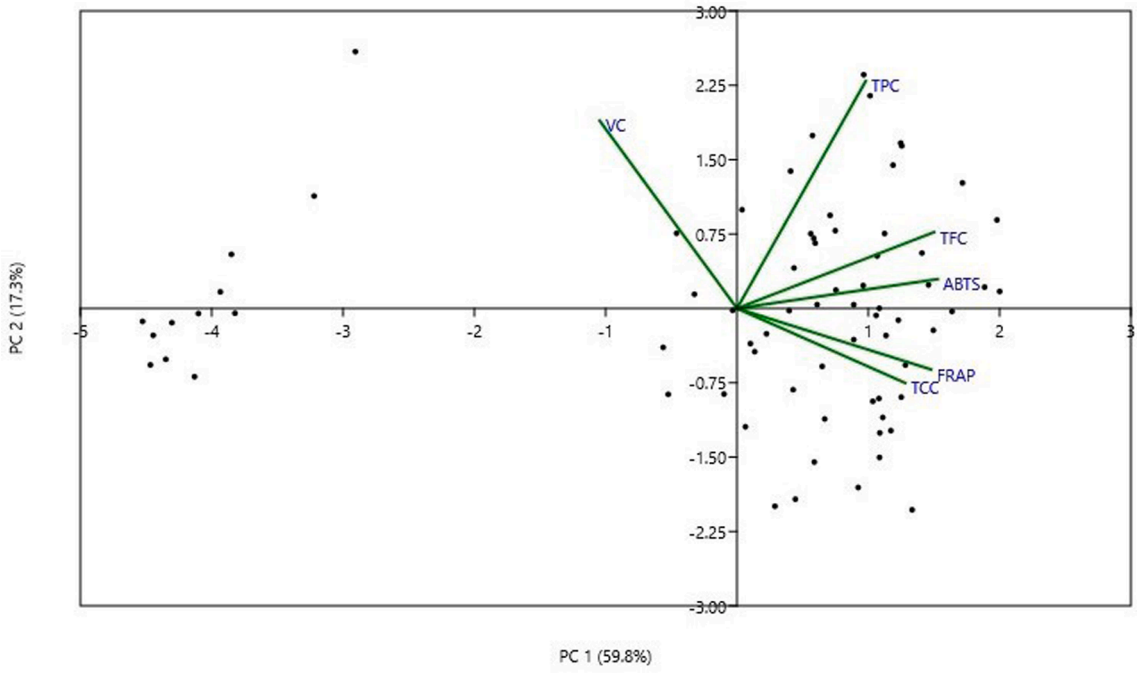
Due to the thermal capacity of water, wet cooking may result in less destruction of food components when compared with dry cooking. Cooking methods that employ relatively low temperatures and/or shorter times have also been shown to enhance the bioaccessibility of phenolic compounds in potatoes. For example, potato tubers that were boiled for 6.5 min and 18 min led to higher recovery of phenolics than the tubers boiled for 30 min (Perla et al., 2012). These hypotheses corroborate with the current study, in which boiling and steaming resulted in higher bioaccessibilities for phenolics, flavonoids, and anthocyanins than baking, frying, or microwaving (Table 2).

The higher phenolics and flavonoids for the cooked samples than the raw could be due to heat treatment enhancing the mobilisation of phenolic bioactive compounds from the food matrix, making them more bioavailable than raw food (Arfaoui, 2021). Another hypothesis may be that heat processing softens and ruptures plant cell walls, enabling the phenolic compounds to be more extractable during analytical procedures (de Lima et al., 2017). Although phenolic compounds' bioaccessibility has been suggested to be usually<30 %, and in a few cases up to 50 % (Lorenzo et al., 2019), we observed up to 60 % bioaccessibility of phenolics and 69 % of flavonoids (Table 3). Similar to our results, a study on cooked potatoes reported bioaccessibilities of 53–80 % in phenolics and 58–83 % in flavonoids (Hamed et al., 2021), while in another study, boiled and microwaved cassava roots also gave 73 % and 75 % bioaccessibility of phenolics, respectively (de Lima et al., 2017). These observations highlight the effects of different food matrices on bioaccessibility of phytochemicals.

Comparing phenolics and flavonoids in unpeeled and peeled sweetpotato roots in the present study, the bioaccessibilities decreased in unpeeled samples with a higher dietary fibre content than the peeled samples (Table 1). Dietary fibre associated with polyphenols in food matrices may retard bioaccessibility of the polyphenols. This results from phenolic compounds-dietary fibre complex formations in which the polyphenols are embedded within the indigestible fibre matrix (Jakobek & Matić, 2019; Pérez-Jiménez et al., 2009). This may have accounted for the lower bioaccessibility of phenolics in unpeeled compared with peeled roots in our research. However, it has been proposed that those phenolic compounds that bind to dietary fibre may pass on to the colon, where they are fermented by bacteria, releasing some beneficial compounds that improve antioxidant status in the colon (Pérez-Jiménez et al., 2009). This action has been related to preventing certain diseases, such as colorectal cancer (Pérez-Jiménez et al., 2009). In humans, host-related factors that influence bioavailability of phenolic compounds may include intestinal or systemic factors (D'Archivio et al., 2010). Following consumption of dietary polyphenols, mastication and the reduced pH in the stomach initiate the release of phenolic compounds by softening and disintegrating the food matrix (Lorenzo et al., 2019). Absorption of some components occur in the small intestine, releasing aglycones that enter the epithelial cells by passive diffusion. The polyphenols not absorbed in the small intestine pass on to the colon where they are hydrolysed by microflora into phenolic acids. The variability within individual gut microbiota is a determinant factor in



(a)



(b)

Fig. 2. PCA biplot showing the interrelationships among the *in vitro* bioaccessibilities of individual phytochemicals and antioxidant activities of processed sweetpotato genotypes on the axes of principal components 1 (x-axis) and 2 (y-axis). The vectors represent the dependent variables of the dataset. The dots in Fig. 2b represent the individual observations for the sample points shown in red lettering in Fig. 2a. VC = Vitamin C; TPC = total phenolic compounds; TCC = total carotenoids content; TFC = total flavonoids content. SSTB, NAS 11, NAR 1, NAS 8, NAS 13O and PF-167 are the sweetpotato genotypes. RAW, BOL, STM, BAK, FRY, and MWV represent the processing methods. WP = with peel and WTP = without peel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

bioaccessibility of phenolic compounds. Thus, any single polyphenol may generate several metabolites, influencing its biological activity (D'Archivio et al., 2010).

Our findings indicate that the bioaccessibility of vitamin C was higher in raw roots than in cooked ones. This may have occurred because, as a thermo-labile compound, vitamin C is prone to enzymatic and chemical oxidation occurring during processing, especially at higher temperatures, causing losses during cooking (Rodríguez-Roque et al., 2015). Comparing temperature and time effects on vitamin C retention in sweetpotato suggest that cooking time may be more important than

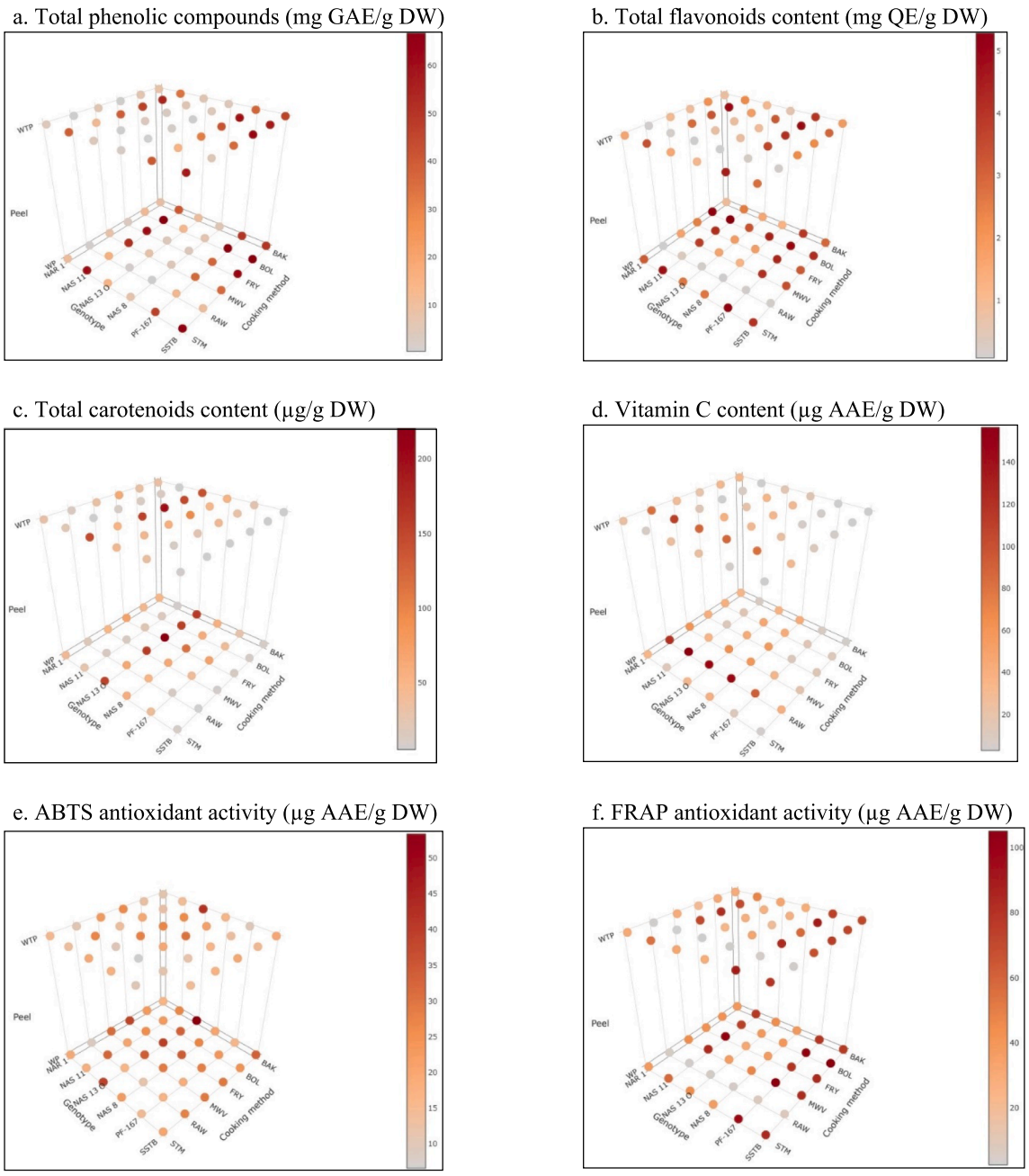


Fig. 3. Interactions among sweetpotato genotype, cooking method and peel condition on the actual content of phytochemicals and antioxidant activities in the samples after simulated *in vitro* gastrointestinal digestion. GAE = gallic acid equivalent; DW = dry weight; QE = quercetin equivalent; AAE = ascorbic acid equivalent.

temperature in determining vitamin C losses (Johnson et al., 2016). A study reported high losses (up to 16.5 % reduction) in vitamin C bioaccessibility of fruit-based beverages that were thermally processed. In contrast, treating those same samples with high-intensity pulsed electric fields or high-pressure processing did not modify the vitamin C bioaccessibility compared to the raw fruit drink (Rodríguez-Roque et al., 2015). It was opined that these non-thermal methods could inactivate the oxidative enzymes that would otherwise degrade vitamin C (Rodríguez-Roque et al., 2015). Thus, if vitamin C preservation is of interest, then these non-thermal processing methods should be considered. Consuming raw sweetpotato roots is not recommended because they contain high levels of an antinutritional factor (trypsin inhibitor), suppressing protease action, thus leading to poor protein digestibility (Senanayake et al., 2014). Heating at 100 °C for 15 min completely inactivates the trypsin inhibition activity (Senanayake et al., 2014). The least vitamin C bioaccessibility observed with baking compared with the other cooking methods in our study could have resulted from changes in the matrix of the sweetpotato roots during baking, limiting the extent of degradation and consequently extraction. When the microstructure of boiled, steamed, baked and deep-fried sweetpotato roots were examined, it was observed that the cell walls of baked roots were thicker with smaller intercellular spaces compared to the other cooking methods (Tumuhimbise et al., 2009). This would imply a lower surface area of the food matrix during digestion.

Although heat processing generally leads to losses in endogenous carotenoids in foods, in some studies, carotenoid bioaccessibility in sweetpotato has been reported to improve with cooking (when compared with the raw food) due to the disintegration of cell walls and

organelle membranes housing the carotenoid structures. This phenomenon may result in a greater surface area for digestive enzymes to act, thereby releasing carotenoids from the food matrix into micelles (Bengtsson et al., 2010; Bengtsson et al., 2009; Tumuhimbise et al., 2009). It has also been suggested that heat denatures protein-carotenoid complexes in which the carotenoids are embedded, thereby causing their release from the food matrix. These reasons may collectively account for the higher percent bioaccessibilities of total carotenoids in cooked samples in the present study compared to the raw (Table 2). Contrary to our findings, thermal processing has been suggested to reduce carotenoid bioaccessibility by causing isomerisation of the carotenoid molecules, thereby decreasing their solubility in micelles (Cilla et al., 2018). Apart from food matrix interactions, this conflicting information on carotenoid bioaccessibility may be due to differences in analytical methods or equipment used.

Regarding the higher carotenoid bioaccessibility in fried sweetpotato roots compared with the other cooking methods in our study, carotenoid bioaccessibility has been established to increase with the addition of oil. Bengtsson and co-workers reported that heat processing and adding 2.5 % cooking oil could enhance beta-carotene bioaccessibility by up to 22 % in orange-fleshed sweetpotato (Bengtsson et al., 2009). Similarly, in another study, deep fried sweetpotato roots had the highest beta-carotene bioaccessibility compared with boiled, steamed and baked roots (Tumuhimbise et al., 2009). In this research, we used unfortified sunflower oil to fry the sweetpotato roots. In a study comparing the influence of different oil types on carotenoid bioaccessibility, sunflower oil had the highest bioaccessibility of all-trans beta-carotene, followed by margarine and beef fat (Chilungo et al., 2019). These results suggest the need to evaluate how cooking methods may affect phytochemical bioaccessibility and investigate the impact of cooking style, such as oil type on the bioaccessibilities of bioactive compounds in commonly consumed foods. The proportion of the different types of carotenoids present in each sweetpotato genotype may account for the differences in bioaccessibility observed with the same cooking method (Table 3). It has been reported that bioaccessibility of lutein > β-cryptoxanthin > β-carotene > lycopene due to their individual hydrophilic or lipophilic nature (Kopec & Failla, 2018).

The low percent bioaccessibility values recorded for anthocyanins in the current study could be attributed to their highly unstable nature at intestinal pH (Li et al., 2021). In a study on purple-fleshed sweetpotato, anthocyanins were observed to be relatively stable after gastric digestion; however, after intestinal digestion was completed, anthocyanin recovery was down to only 10 % (Yang et al., 2019). This corroborates our finding of 12 %, being the highest bioaccessibility of anthocyanins. In another study, anthocyanins were no longer detectable after complete *in vitro* gastrointestinal digestion (Bouayed et al., 2011). However, 91.2 % recovery was detected after the gastric phase that was statistically similar to the original content, suggesting that anthocyanins are more stable to gastric conditions (Bouayed et al., 2011). This is a limitation of the present study as we did not measure anthocyanin content after gastric digestion but only after completion of the intestinal phase.

Even under *in vivo* conditions, it has been acknowledged that anthocyanins are not absorbed in the small intestine but can be directly absorbed from the stomach by binding to proteins in the stomach tissue (Li et al., 2021). Another school of thought suggests that anthocyanins have a relatively large molecular weight and can only be absorbed in the lower part of the small intestine or the colon after being hydrolysed by bacteria and converted to phenolic acids (Chen et al., 2021). Since bacteria involvement could not be simulated in our *in vitro* digestion model, this could account for the low anthocyanin bioaccessibility. Nevertheless, even if anthocyanins are not absorbed in the small intestine, their role in neutralising free radicals in the GIT cannot be downplayed. The GIT is constantly exposed to oxidative stress from diet-derived bacteria and toxins. Thus, presence of antioxidants such as anthocyanins in the GIT may play a role in scavenging these harmful oxidants, thereby preventing diseases linked to their activities (Li et al., 2021). Among the different cooking methods employed in our study, anthocyanin bioaccessibility was least for frying (Table 2). This may suggest that frying, with the shortest heating time of 8 min was not enough to adequately disintegrate the sweetpotato cell matrix and subsequently the release of anthocyanins from the matrix during digestion was impaired.

The percent bioaccessibilities of antioxidant activities we observed may be due to the synergistic effects of the individual bioactive compounds investigated, except for vitamin C. With both ABTS and FRAP antioxidant activities, all forms of cooking resulted in higher bioaccessibilities compared with the raw sweetpotato roots (Table 2). Furthermore, correlations between our response variables showed positive relationships between each phytochemical and antioxidant activities (ABTS and FRAP), except in vitamin C (Fig. 1). This is also evidenced by the PCA (Fig. 2a), in which vitamin C correlated with the raw roots while the remaining phytochemicals were more closely associated with the cooked roots. In this study, vitamin C may have acted as a pro-oxidant, not an antioxidant. This pro-oxidant nature of vitamin C has been reported to occur in the presence of molecular oxygen, some metal ions, or alkaline pH, a condition existing under our simulated intestinal phase of digestion (Kaźmierczak-Barańska et al., 2020). However, while this phenomenon has been observed *in vitro*, it has been suggested that it is irrelevant physiologically as there is no evidence of such occurring under *in vivo* conditions (Kaźmierczak-Barańska et al., 2020). Thus, the *in vitro* method may not be suitable for studying the antioxidant potential of foods containing vitamin C. The limitations of this study, therefore, lie in the *in vitro* digestion model used.

5. Conclusions

The bioaccessibilities of phenolic compounds, flavonoids, carotenoids, anthocyanins, vitamin C, and antioxidant activities after simulated *in vitro* gastrointestinal digestion of cooked sweetpotato storage roots were investigated. Regardless of the sweetpotato genotype, all cooking methods increased bioaccessibilities of all the phytochemicals compared to the raw roots, except for vitamin C, in which the raw roots had a higher bioaccessibility than the cooked ones. Peeled roots had higher bioaccessibilities than unpeeled roots for phenolic compounds and flavonoids. The most significant increase in carotenoid bioaccessibility among the cooking methods occurred with frying. Thus, losses in carotenoids during cooking could be compensated for by their increased bioaccessibility. After simulated *in vitro* digestion, anthocyanin bioaccessibility was generally low, and vitamin C may have exhibited pro-oxidant properties. Nevertheless, these results may be irrelevant as they may react differently under *in vivo* conditions. The significant variations in bioaccessibilities observed provide a critical knowledge base to all stakeholders involved in the sweetpotato value chain. A better understanding of these results and their importance in a health-related context will place researchers in a better position to breed nutrient-rich improved sweetpotato genotypes and guide consumers and processors on optimising processing methods to maximise the retention of specific bioactive compounds. Further, it is noteworthy that aside the type of processing, food matrix interactions have also been reported to influence the bioaccessibilities of bioactive compounds. Thus, future research could evaluate the influence of different food components such as protein, fat, fibre, and micronutrients on sweetpotato phytochemicals and recommend food combinations that enhance their bioaccessibilities.

Ethics statement

This research did not involve any animals or human subjects.

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CRediT authorship contribution statement

Flora Christine Amagloh: Methodology, Conceptualization, Resources, Writing – original draft, Writing – review & editing, Funding acquisition. **Gaston Ampe Tumuhimbise:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Benard Yada:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Arnold Katungisa:** Resources, Writing – review & editing, Funding acquisition. **Francis Kweku Amagloh:** Methodology, Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Archileo N. Kaaya:** Methodology, Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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