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EFFECTS OF SPROUTING ON THE ANTIOXIDANT POTENTIALS OF GARLIC (*Allium sativum* L.) AND ONIONS (*Allium cepa* L.)

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ABSTRACT

Allium plants (especially garlic and onions) are useful condiments in most kitchens for the preparation of delicacies and in the preparation of decoctions in traditional medicine for the treatment of some emanating ailments, have its shoots sprouted for vegetables while the bulbs are usually discarded. The commonly discarded bulbs may have improved the antioxidant potentials. These improved properties could be utilized to treat or manage some degenerative and non-communicable diseases. The aim of this study was to determine the effects of sprouting on the antioxidant potentials of garlic (*Allium sativum*) and onions (*Allium cepa*). The samples of garlic and bulbs were sprouted for 0 to 10 days. The phytochemicals, phenols, flavonoids, and ascorbic acid; and the antioxidant activities such as 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical-scavenging activity were investigated on the garlic and bulbs using standard methods. A significantly ($P<0.05$) higher total flavonoid content was observed in methanol extract of onions sprouted for eight days (7.84 mg/g RE) and in methanol extract of garlic sprouted for 10 days (20.16 mg/g RE). The onions extracts expressed higher phenolic content on day eight of sprouting, while that of garlic revealed a significant ($P<0.05$) increase till day 10. The DPPH scavenging activity of sprouted garlic and onions recorded the minimum activity on day eight. Garlic highest ascorbic acid content of 8.820 mg/g was recorded on the 10th day, while that of onions was 6.29 mg/g on the 6th day. The results from this study revealed that sprouting of onions and garlic vegetables may be an effective means of improving the antioxidant potential of some *Allium* plants. The results from this study revealed that sprouting of onions and garlic vegetables might be an excellent means of improving the antioxidant potential of *Allium* plants. This study conclude that sprouting should be between four to six days for onions and up to 10 days for garlic before processing for consumption.

Keywords: *Allium cepa* L.; *Allium sativum* L.; Sprout; Bulbs; Shoots; Antioxidant.

INTRODUCTION

Several vegetables have been categorized as medicinal plants; among which are onions and garlic (Saxena *et al*., 2013; Awuchi, 2019). *Allium cepa* L., commonly called onions, has been widely used since time immemorial as spice, food, and herbal remedy. It is a perennial plant that is cultivated in almost every country with favorable climate regions such as Nigeria. Onions have several varieties including yellow, purple, white, green, and red, coupled with the sweet and non-sweet onions. *It* has been considered a well-known herbal medicine in Ayurveda for several symptoms such as catarrh, fever, dropsy, and chronic bronchitis (Kumar and Kumar, 2023). The usable forms are infusion, decoction, fresh juice, and raw, cooked, or roasted bulb. Researchers have reported its efficacious potential for its anti-diabetic, anti-atherogenic, antibiotic, and anticancer therapeutic purposes (Beigoli *et al*., 2021; Subroto *et al*., 2021; Zhao *et al*., 2021; Kumar and Kumar, 2023).

Allium sativum L., commonly known as garlic, is a perennial vegetable crop from the family of arcs (*Aliaceae*). It is a bulb of strong odour and pungent taste, and herbaceous in plantation with height of 20-40 cm (Strika *et al*., 2017). It has antimicrobial activity against many general strains of bacteria, fungi and viruses (Strika *et al*., 2017). It also contains a higher concentration of sulfur compounds which are responsible for its strong smell and medicinal effects. The chemical constituents of garlic have also been reported for its therapeutic efficacy for the management of cardiovascular diseases, diabetes, blood pressure,

cancer, atherosclerosis and hyperlipidaemia (Papu *et al*., 2014; Strika *et al*., 2017). However, aside from its medicinal purposes, onions and garlic are known to be renowned spice and ornamental plants. These vegetables are also eaten raw, made as soup, made into tonic, and applied directly on the skin after being homogenized for several purposes (Salguero, 2010; Devi *et al*., 2014; Wiczkowski, 2018; Kumar and Kumar, 2023).

According to reports, *Allium cepa* L. contains a variety of secondary metabolites such as saponins, polysaccharides, and phenolic and organosulfur compounds. The main bioconstituents of onions are the phenolic and sulfur-containing compounds, onionin A, cysteine sulfoxides, quercetin, and quercetin glucosides. For instance, it has been reported that white onions had the lowest concentrations of anthocyanins and flavonols, whereas the red onions had the highest levels followed by the yellow onions. Additionally, the major compounds differ among the onion's layers. For instance, the primary compounds in the skin and bulb of red onion, respectively, were quercetin and quercetin-4-glucoside. However, some potential health issues, such as the enrichment of heavy metals, pesticide residue, nitrate buildup, and microbial contamination, should not be ignored (Zhao *et al*., 2021).

Garlic is the most common *Allium* plant grown worldwide after shallots. It contains various bioactive compounds, especially in the form of organosulfur compounds and phenolic compounds. These compounds, as antioxidants, in garlic play an important role in preventing tissue damage from the oxidation. Similar to onions, bioactive compounds in garlic are commonly derived from sulfur-containing compounds. They include allicin, diallyl sulfide (DAS), diallyl trisulphide (DATS), diallyl disulfide (DADS), ajoene, and 2-vinyldithiins, which are the main antioxidant compounds and are also important to its biological activity (Galmarini, 2018; Subroto *et al*., 2021). Garlic also contains flavonoids and polyphenols, which are potential antioxidant agents (Ramirez *et al*., 2017). The cysteine-containing garlic metabolite-alliin (S-allyl-L-cysteine sulfoxide), is a soluble, crystal, odourless compound with antimicrobial properties found in undamaged garlic plants. It was first isolated in 1940 and has been shown to have antimicrobial activity against viruses, bacteria, fungi and parasites. This metabolite produces diallyl sulfide, the most important volatile compound of garlic and gives it its characteristic smell (Campos-Vega and Oomah, 2013; Strika *et al*., 2017).

Allium products have been useful in food and pharmaceutical industries partly due to the presence of organosulfur compounds, which have been reported to possess antioxidant and free radical scavenging activities (Strika *et al*., 2017; Ebhomienlen and Azeke, 2020; Subroto *et al*., 2021). However, the antioxidant activity of bioconstituents in vegetables and fruits, including *Allium* plants, can be altered by processing and storage, inclusion of food additives, and interactions with other nutrients. For instance, depending on the cooking techniques, the contents of the cysteine sulfoxides, such as cycloalliin, isoalliin, methiin, and propiin, were altered in different ways in onion by heat processing. Boiling reduced their contents, whereas frying, microwaving, and steaming enhanced it (Zhao *et al*., 2021). Therefore, depending on whether the polyphenol antioxidant compounds are degraded or whether antioxidant products are formed as a result of the release of aglycones and the Maillard reaction formed during the process and storage, thermal processes can decrease or even increase the antioxidant activity of garlic (Subroto *et al*., 2021). According to reports, a number of variables, including this plant's genetic make-up, horticulture practices, storage conditions, distinctive components, extraction procedures, and processing technologies, all affect its antioxidant activity (Zhao *et al*., 2021).

It is worth noting that people subject onions and garlic to sprouting for the purpose of using the shoots as vegetables. After sprouting, their bulbs are usually discarded while the shoots are processed further. However, these usually discarded onion bulbs may have improved antioxidant potentials resulting from sprouting. These improved properties could be harnessed to combat or manage some degenerative and non-communicable diseases (Ebhomienlen and Azeke, 2020; Galieni *et al*., 2020). However, there is dearth information on the effect of different processing

methods on the antioxidant status of onions and garlic which are useful condiments in most kitchens for the preparation of delicacies as well as in the preparation of decoctions in traditional medicine for the treatment of some emanating ailments.

Herein, this study focused on providing information on the effects of sprouting on the bioactive compounds of onions and garlic; and the necessary implementation that can be applied or avoided to retain or increase its quality.

MATERIALS AND METHODS

Sample collection, preparation and extraction

Fresh matured sample of bulbs *(Allium cepa* L.) and garlic (*Allium sativum* L.) were obtained from a local market in Esan North-East Local Government Area (Uromi) in Edo State. The samples were properly authenticated by a plant taxonomist in LAUTECH where voucher number (LHO 642) and (LHO 643) for the garlic and bulbs were deposited.

The dry skin of bulbs and garlic were removed and placed on stainless tray already over laid with wet tissue paper. They were allowed to sprout for up to 10 days in the dark at 25-30 °C. The un-sprouted onion and garlic served as control. Afterwards, 25 g of the raw and the processed samples were minced, grounded and extracted with water, methanol and chloroform.

The method described by Ebhomienlen and Azeke (2020) was adopted for the extraction of the garlic and bulbs. Briefly, 25 g of the sprouted onions (0 day, 2 days, 4 days, 6 days, 8 days and 10 days), and sprouted garlic (0 day, 2 days, 4 days, 6 days, 8 days and 10 days) were separately weighed using an analytical chemical balance into different beakers. They were homogenized separately using a laboratory mortar and pestle. The homogenized samples were extracted with 100 mL of methanol, chloroform and water, respectively. Each sample was centrifuged at 4000 rpm for 30 min. The supernatant of each sample was filtered using Whatman No. 1 filter paper into their respective beakers. It was concentrated and dissolved in dimethyl sulfoxide (DMSO) for use.

Determination of Total Flavonoid Content

The method described by Meda *et al.* (2005) was adopted. 2 mL of 2% aluminium trichloride ($AlCl_3$) in methanol were mixed with the same volume of the onions and garlic extracts separately. The mixtures were incubated at room temperature for 10 min, and their respective absorbance measured at 415 nm with spectrophotometer (JENWAY 6715, Bibby Scientific Ltd., UK). Negative control (without extract) for the garlic and bulbs sample each was used as the blank. The total flavonoid content was determined as milligram of rutin equivalent by using an equation that was obtained from standard rutin graph as:

Absorbance = 0.0144 × total flavonoid (mg/g rutin) + 0.0556

Determination of Total Phenolic Content

The method by Slinkard and Singleton (1997) was adopted with slight modification for the concentration of phenolic compounds in the *Allium cepa* L. (sprouted and boiled) and in the *Allium sativum* L. (sprouted and boiled) extracts, expressed as pyrocatechol equivalents (PEs). Briefly, 1 mL of the onion and garlic extracts each, were measured into separate volumetric flask and was filled with 46 mL of distilled aqueous. Then 1 mL of Folin-Ciocalteu reagent was added and mixed thoroughly in both flasks. After 3 min, 3 mL of 2% anhydrous sodium carbonate (Na_2CO_3) was added and then allowed to stand for 2 h with intermittent shaking. The absorbance was measured at 760 nm in a spectrophotometer (JENWAY 6715, Bibby Scientific Ltd., UK) against a blank consisting of all the reaction agents except the extracts.

The total concentration of phenolic compounds in the extracts was determined as microgram of pyrocatechol equivalent using an equation that was obtained from standard pyrocatechol graph as:

Absorbance = 0.0021 total phenols (µg pyrocatechol) – 0.0092 ($R^2 = 0.9934$)

Determination of 1,1-Diphenyl 2-picrylhydrazyl (DPPH) Radical Scavenging Activity

The free radical scavenging activity of sprouted, boiled onions and garlic extract was determined using the method described by Gadow *et al.* (1997)

with slight modification. 2 mL methanol solution of DPPH radical in concentration of 0.05 mg/mL and 1 mL of plant-extract were placed in cuvettes. The mixture was shaken vigorously and allowed to stand at room temperature for 30 min. Then the absorbance was measured at 517 mm against methanol as blank in spectrophotometer (JENWAY 6715, Bibby Scientific Ltd., UK).

The DPPH radical concentration was calculated using the following equation:

DPPH Scavenging Activity (%) = $[(A_0 - A_1)/A_0] \times 100$

Where A_0 is the absorbance of the negative control (2 mL methanol solution of DPPH radical + 1 mL of 5% DMSO) and A_1 is the absorbance of reaction mixture or standards. Ascorbic acid was used as the standard.

Determination of Ascorbic Acid Concentration

The titrimetric method by Plummer (1978) was adopted for the determination of ascorbic acid concentration in the sprouted, boiled onions and garlic extract. 5 mL of diluted extract was measured into a boiling tube of 1 mL glacial acetic. Then the mixture was titrated with 0.1 mg/mL 2,6-dichlorophenolindophenol solution. A 5 mL solution of 0.022 mg/mL ascorbic acid solution was used as standard. Titre values of samples were compared with this value to obtain their ascorbic acid equivalent.

Statistical Analysis

Data obtained were expressed as mean of triplicates ± standard errors of mean (SEM). Significant differences were tested using Analysis of Variance (ANOVA) and Tukey's Multiple Range Tests using GraphPad Prism version 6.0 (GraphPad Software, San Diego, CA, USA). The differences were considered significant at $P<0.05$.

RESULTS

Table 1 shows the results of the total flavonoid contents of the differently-sprouted garlic which revealed significant ($P<0.05$) increase for the aqueous, methanol and chloroform extracts from day 0 (control) till day 10, when compared to their respective control. Similar trend was observed in Table 3 for the total phenolic contents of garlic for the three extracts (aqueous, methanol and chloroform) compared to the control. The results of the total flavonoid contents of onions is shown on Table 2 below. Here, the total flavonoid contents of the differently-sprouted onions revealed significant ($P<0.05$) increase for the aqueous, methanol and chloroform extracts from day 0 (control) till day 8. However, a significant ($P<0.05$) decrease was observed for the three extracts on day 10 when compared to their respective control. The same trend was observed in Table 4 for the total phenolic contents of onions and the three extracts (aqueous, methanol and chloroform) compared to their respective control.

Table 1: Total flavonoid content (mg/g RE) of differently-sprouted garlic

Extracts	Days of Sprouting					
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	5.39 ± 0.02^{a}	6.69 ± 0.05^{b}	8.50 ± 0.00^{c}	9.09 ± 0.02^{d}	11.00 ± 0.02^{e}	11.96 ± 0.01^{f}
Methanol	5.88 ± 0.10^{a}	9.48 ± 0.03^{b}	13.41 ± 0.06^{c}	15.83 ± 0.03^{d}	18.29 ± 0.04^{e}	20.16 ± 0.08^{f}
Chloroform	4.22 ± 0.06^{a}	6.61 ± 0.02^{b}	7.26 ± 0.00^{c}	8.37 ± 0.06^{d}	9.76 ± 0.00^{e}	10.39 ± 0.06^{f}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant ($P<0.05$) difference. Day 0 = control; RE = rutin equivalent.

Table 2: Total flavonoid content (mg/g RE) of differently-sprouted onions

Extracts	Days of Sprouting					
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	4.06 ± 0.01^{a}	4.87 ± 0.03^{b}	5.19 ± 0.01^{c}	6.12 ± 0.00^{d}	6.71 ± 0.02^{e}	4.95 ± 0.02^{b}
Methanol	4.96 ± 0.02^{a}	5.64 ± 0.03^{b}	6.87 ± 0.01^{c}	7.79 ± 0.02^{d}	7.84 ± 0.02^{d}	5.15 ± 0.07^{e}
Chloroform	3.71 ± 0.02^{a}	3.44 ± 0.02^{b}	4.54 ± 0.01^{c}	5.73 ± 0.01^{d}	5.73 ± 0.01^{d}	3.12 ± 0.01^{e}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant ($P<0.05$) difference. Day 0 = control; RE = rutin equivalent.

Table 3: Total phenolic content (mg/g PE) of differently-sprouted garlic

Extracts	Days of Sprouting					
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	5.89 ± 0.03^{a}	8.85 ± 0.05^{b}	11.73 ± 0.07^{c}	13.57 ± 0.03^{d}	15.11 ± 0.05^{e}	16.95 ± 0.00^{f}
Methanol	6.26 ± 0.00^{a}	9.43 ± 0.02^{b}	14.06 ± 0.050^{c}	17.83 ± 0.06^{d}	21.360 ± 0.00^{e}	24.07 ± 0.00^{f}
Chloroform	4.587 ± 0.02^{a}	5.97 ± 0.00^{b}	7.030 ± 0.02^{c}	9.733 ± 0.06^{d}	11.02 ± 0.00^{e}	12.29 ± 0.04^{f}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant (P<0.05) difference. Day 0 = control; PE = pyrocatechol equivalent

Table 4: Total phenolic content (mg/g PE) of differently-sprouted onions

Extracts	Days of Sprouting					
	0 Day	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	4.84 ± 0.08^{a}	6.60 ± 0.06^{b}	10.42 ± 0.25^{c}	13.33 ± 0.07^{d}	14.03 ± 0.02^{e}	9.53 ± 0.02^{f}
Methanol	5.20 ± 0.05^{a}	6.84 ± 0.08^{b}	10.85 ± 0.06^{c}	14.02 ± 0.29^{d}	15.58 ± 0.03^{e}	10.42 ± 0.19^{c}
Chloroform	3.13 ± 0.02^{a}	4.84 ± 0.10^{b}	8.08 ± 0.05^{c}	11.51 ± 0.04^{d}	12.40 ± 0.06^{e}	8.83 ± 0.03^{f}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant (P<0.05) difference. Day 0 = control; PE = pyrocatechol equivalent.

The results of the DPPH radical-scavenging activity of the differently-sprouted garlic are shown on Table 5 below. These results revealed significant (P<0.05) increase for the aqueous, methanol and chloroform extracts of the DPPH radical-scavenging activity of the differently-sprouted garlic from day 0 (control) to day 10, when compared to their respective control. However, the results of the DPPH radical-scavenging activity of the differently-sprouted onions revealed significant (P<0.05) increase for the aqueous, methanol and chloroform extracts from day 0 (control) till day 8 only, after which a significant (P<0.05) decline was observed on day 10 when compared to the control groups.

Table 5: DPPH radical scavenging activity (%) of differently-sprouted garlic

Extracts	Days of Sprouting					
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	42.07 ± 0.04^{a}	45.36 ± 0.09^{b}	49.16 ± 0.08^{c}	56.84 ± 0.07^{d}	68.30 ± 0.04^{e}	71.23 ± 0.08^{f}
Methanol	46.20 ± 0.08^{a}	58.71 ± 0.10^{b}	63.20 ± 0.09^{c}	72.43 ± 0.05^{d}	83.56 ± 0.07^{e}	96.30 ± 0.10^{f}
Chloroform	37.63 ± 0.05^{a}	39.26 ± 0.05^{b}	44.35 ± 0.07^{c}	46.53 ± 0.10^{d}	59.16 ± 0.06^{e}	64.36 ± 0.08^{f}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant (P<0.05) difference. Day 0 = control.

Table 6: DPPH radical scavenging activity (%) of differently-sprouted onions

Extracts	Days of Sprouting					
	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
Aqueous	26.19 ± 2.38^{a}	37.05 ± 6.17^{b}	56.61 ± 3.55^{c}	66.19 ± 2.38^{d}	89.05 ± 4.76^{e}	67.95 ± 2.38^{d}
Methanol	27.16 ± 2.41^{a}	39.52 ± 8.60^{b}	60.18 ± 8.26^{c}	68.57 ± 4.12^{d}	94.52 ± 2.38^{e}	69.43 ± 4.12^{d}
Chloroform	24.38 ± 2.38^{a}	33.98 ± 3.43^{b}	45.77 ± 10.94^{c}	57.64 ± 4.73^{d}	65.96 ± 2.37^{e}	56.67 ± 2.38^{d}

Data are presented as mean ± SEM of triplicate determinations. Values with different alphabetical superscript within the same row suggests significant (P<0.05) difference. Day 0 = control.

Figure 1 below reveals the results of the ascorbic acid concentration (mg/g) of the differently-sprouted garlic and onions from day 0 (control) till day 10. It was observed that sprouting resulted in a significant (P<0.05) increase in the concentrations of the differently-sprouted garlic from day 0 to day 10; with the maximum increase observed on day 10 when compared to the control. However, sprouting also caused a significant (P<0.05) rise for the differently-sprouted onions from day 0 up until day 6, after which a significant (P<0.05) decline was observed from day 8 to day 10, when compared to the control.

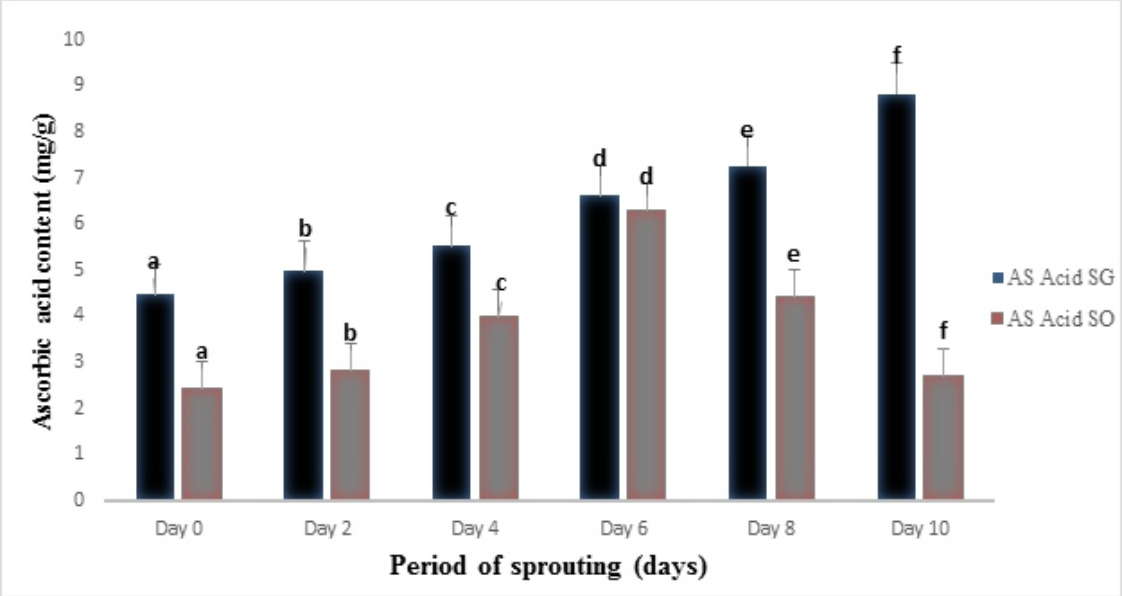

Figure 1: Ascorbic acid content (mg/g) of Differently-Sprouted Garlic and Onions
Data are presented as mean ± SEM of triplicate determinations. Bars with different alphabets indicate significant ($P<0.05$) difference. Day 0 = control; SG = sprouted garlic; SO = sprouted onions; AS = ascorbic.

DISCUSSION

The medicinal purpose of *Allium* vegetables such as garlic and onions is an attributes possessed due to its antioxidants potential. The antioxidant potential is responsible for its immune enhancing functions, anti-microbial and anti-cancer activities, etc. (Samtiya *et al*., 2021; Kumar and Kumar, 2023). Several processes have been observed to increase or decrease the antioxidant properties of medicinal plants, one of which is sprouting. Sprouting is simply a technological method that is used for the germination of seeds; and has been reported to improve the nutritive value of the seeds (Tiwari *et al*., 2013; Ebhomienlen and Azeke, 2020). A study by Zilic *et al*. (2014) reported that sprouting increases the antioxidant potential of some vegetables (such as *Allium* plants), which corroborates the results from this work that sprouting of both garlic and onions may increase the antioxidant potential of this plant. Furthermore, the results obtained from this study revealed that sprouting increases the phenolic and flavonoid contents of garlic up to day 10. This observation is similar to the reports by Yang *et al*. (2020) who reported increase in phenolics and flavonoid contents of garlic and onion. In addition, Atashi *et al*. (2011) reported that storage of garlic at low temperature (4 ^{0}C) for 30 days increase garlic sprouting.

For the onions, methanol extract recorded the highest phenolic (15.58 mg/g PE) and flavonoid (7.84 mg/g RE) contents on eighth day compared to aqueous and chloroform extracts, chloroform extract recorded the lowest phenolic (12.40 mg/g PE) and flavonoid (5.73 mg/g RE) contents on the eighth day. However, the three extracts revealed a decline in the flavonoid and phenolic contents after the eighth day, unlike the results for garlic which increased significantly ($P<0.05$) from day 0 till day 10. This result for the onions corroborates the report of Ebhomienlen and Azeke (2020) who reported an increase in the amount of antioxidants in onions. This could be as a result of the differences in their phytoconstituents. Herbs and spices contain various compounds with antioxidant properties which requires a careful selection of multiple and complementary methods to explore the antioxidant potential of extracts since they involve different mechanisms and sensitivities (Boudiba *et al*., 2023). Flavonoids have been reported to interfere with the activities of the enzymes involved in reactive oxygen species (ROS) generation, quenching of free radicals, chelating transition metals, and rendering them redox inactive in the Fenton reaction (Murti *et al*., 2013). Flavonoids have been reported to decrease risk of coronary heart diseases (Gross, 2004). Extracts rich in phenolic compounds have demonstrated

remarkable bioactivities such as antioxidant, antimicrobial, anticancer, anti-inflammatory, and anti-diabetic activities and also being capable of reducing neurodegenerative and cardiovascular diseases (Boudiba *et al*., 2023). One of the richest sources of flavonoids and phenolic acids used as herbs and spices in human diet is common among the *Allium* plants such as garlic, onions, ginger, etc. (Yang *et al*., 2020). Sellappan and Akoh (2002) reported that onion is one of the rich sources of the main flavonols – quercetin - in human diet. Their flavonol content considerably reduces atherosclerotic processes, inhibits cholesterol accumulation in the blood serum and enhances resistance of vascular walls (Ebhomienlen and Azeke, 2020).

Generally, during sprouting of onions and garlic in this study, phenolic and flavonoid contents peaked at day 10 and day eight for garlic and onions, respectively. This is similar to the study by Majid *et al*. (2016), which revealed the effect of sprouting on the physicochemical, antioxidant and flavonoid profile of selected onions and observed a significant increase in total flavonoid content of sprouted onions compared to the un-sprouted. Also, a study by Vazquez-Barrios *et al*. (2006) suggested that the shelf-life of garlic could be estimated using the internal sprouting index. Hence, sprouting of onions and garlic between eight to 10 days may be a method to increase the total flavonoid and phenolic contents of some *Allium* plants to harness and improve the antioxidant potential of these vegetable plants.

The DPPH radical is a stable free radical that shows a maximum absorption at 517 nm and is widely used to evaluate the free radical-scavenging ability of natural compounds. When free radicals of natural compounds are evaluated, the electron becomes paired off in the presence and absorption is greatly reduced, resulting in decolourization, this decolourization is proportional to the number of electrons taken up (Yamaguchi *et al*., 1998; Smith and Adanlawo, 2014). In this study, sprouted garlic and onion showed increase in DPPH radical-scavenging activities with days of germination. While garlic and onion sprouting spanned from 0 to 10 days, the highest DPPH radical-scavenging activity for onions was recorded on the eighth day and day 10 for garlic. The strongest antioxidant activity was observed with the garlic extracts sprouted for 10 days compared to eighth day for onions. This aligns with the study of Cowie *et al*. (2008) who recorded a significant ($P<0.05$) increase in the free radical-scavenging activity of onions and ginger as concentration of the extract and days of sprouting increased, as well as that of Ebhomienlen and Azeke (2020) who also reported an increase in the DPPH radical-scavenging activity of onions only.

Ascorbic acid is one of the most powerful antioxidants that scavenge harmful free radicals and other ROS. It also regenerates sub-antioxidants, for example, tocopherol, to its functionality (Denre, 2014; Pehlivan, 2017). The results from this study corroborate the report of Denre (2014) who reported a significant ($P<0.05$) increase in the ascorbic acid content of onions with increasing sprouting days. The comparative measure of ascorbic acid content in garlic and onions that was sprouted for different days as well as the un-sprouted (Day 0), as shown in Figure 1, revealed that as sprouting days increased, the ascorbic acid content (8.820 mg/g) of garlic significantly ($P<0.05$) increased proportionately for the 10 days. The control group however recorded the lowest ascorbic acid content (4.47 mg/g) in garlic extracts. Conversely, a significantly ($P<0.05$) higher ascorbic acid content was recorded in onions sprouted for six days (6.29 mg/g), followed by a decrease to 2.70 mg/g on day 10 compared to 2.43 mg/g of day 0. This imply that further sprouting in ascorbic acid concentrations beyond day 6 for onions and day 10 for garlic could result in the reducing power of these vegetable plants. Tahir *et al*. (2015) stated that onions and garlic are rich in phenolic compounds with the former possessing better antioxidant activity than the latter. This may be attributed to the reducing potential of the onions which prevents sprouting from exceeding day 6 of sprouting as observed in garlic which increased as sprouting days increased proportionately. Also, a study by Lean *et al*. (1999) stated that plant polyphenols can act as reducing agents; thus, higher phenolic compound possessed higher reducing potential.

CONCLUSION

The results from this study revealed that sprouting of onions and garlic vegetables might be an excellent means of improving the antioxidant potential of *Allium* plants. It is therefore recommended that sprouting should be between four to six days for onions and up to 10 days for garlic before processing for consumption. The losses emanating from cooking onions and garlic could further be studied to ascertain if the the improved antioxidant potential of bulbs arising from sprouting could help to overcome it.

CONFLICT OF INTEREST

The authors of this work declare that there is no conflict of interest related to this study.

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