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Effect of Boiling and Wet Frying on Nutritional and Antinutrients Content of Traditional Vegetables Commonly Consumed in Malawi

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Abstract

This study was carried out to evaluate the effects of boiling and wet frying on nutritional and antinutrients content of *Amaranth hybridus*, *Moringa oleifera*, *Bidens pilosa* (black jack), *Corchorus olitorius* (Jute mallow) and *Ipomea batatas* (sweet potato) leaves. The edible portions of the vegetables were either boiled or wet fried for ten minutes then dried alongside the raw vegetables under the shade. Crude fats, minerals, vitamins and antinutrients were determined in the dried materials. Wet frying increased the oil content of the vegetables by a range of 15.49% to 28.40 % and was hence associated with lower % ash and mineral contents. Wet frying significantly reduced ($P \leq 0.05$) beta-carotene in all the vegetables except in jute mallow. Boiling had no significant effect on beta-carotene in most of the vegetables. Boiling significantly reduced ($P \leq 0.05$) ascorbic acid in all the vegetables while wet frying preserved ascorbic acid in all the vegetables. Both boiling and wet frying significantly reduced ($P \leq 0.05$) oxalates in all the vegetables except in black jack. Both boiling and wet frying significantly ($P \leq 0.05$) reduced the concentration of phytates in most of the vegetables. However, boiling was more effective in reducing the amount of phytates. Boiling reduced higher concentrations of tannins in all the vegetables as compared to wet frying. Boiling was associated with better retention of minerals and beta-carotene, and greater reduction of antinutrients in most of the vegetables. Wet frying was more advantageous in retaining vitamin C. The different species showed differences in retention of various minerals and vitamins.

Keywords: Vitamins, minerals, anti-nutrients, boiling, wet frying, traditional vegetables, Malawi

1. Introduction

Vegetables are the most affordable source of minerals and vitamins for families in most developing countries (Kenya Demographic Health Survey, 2014). In Malawi, most households especially from the rural and peri-urban areas depend on plant based food and vegetables as source of minerals and vitamins (Cathoric Relief Services [CRS], 2017). Traditional leafy vegetables are widely utilized in Malawi and thus play a big role in contributing to nutrition. Leafy vegetables are rich sources of iron, pro-vitamin A (beta-carotene), vitamin C and zinc among other vitamins and minerals (Maundu, 2014).

According to the assessment survey conducted by CRS, (2017), the following traditional vegetables are widely consumed and preferred within the southern region of Malawi: Amaranth, *Corchorus olitorius* (jute mallow) leaves, *Moringa oleifera* , *Ipomea batatas* (sweet potato) leaves, *Bidens pilosa* (black jack) leaves , pumpkins leaves, *Cleome gynandra* leaves and cowpea leaves. Among these, Amaranth, Jute mallow, Black jack and Cleome gynandra plants grow wildly in the bush or as weeds in the fields.

Farmers harvest these traditional and wild vegetables in the bush and the gardens for consumption and sale. Sweet potato leaves, pumpkins leaves and cowpea leaves are harvested from the cultivated fields and are consumed or sold as vegetables. These commonly consumed vegetables in Malawi play a big role in contributing to health and nutrition through the vitamins and minerals that they possess. According to CRS, (2017), Amaranth leaves are nutritionally rich in calcium, iron, beta carotene and ascorbic acid; sweet potato leaves leaves are rich sources of iron, ascorbic acid and beta carotene; black jack leaves are rich in beta carotene, iron, Zinc and ascorbic acid; *Cleome gynandra* leaves are rich sources of ascorbic acid, beta carotene, folic acid and calcium; *Moringa oleifera* leaves are rich sources of beta carotene, vitamin E, iron, folic acid and calcium; and Jute mallow leaves are rich in beta carotene, iron, folic acid ascorbic acid, calcium and protein.

The nutrients being supplied by these indigenous and traditional vegetables are very important to human health and nutrition. Most of the vitamins and minerals found in vegetables such as beta carotene, ascorbic acid, iron, zinc and magnesium contributes to improvement of the immune function (Ebrahimzadeh, M. A., Pourmorad, F., & Bekhradnia, A. R. (2008). Beta carotene which is a precursor of vitamin A is essential for growth, development, immunity and good vision. Beta carotene and ascorbic acid also play a role of antioxidants and helps to reduce the risk of diseases related to oxidative stress such as diabetes mellitus, cardiovascular diseases and some cancers (Yang & Keding, 2009 ; Uusiku, N. P., Oelofse, A., Duodu, K. G., Bester, M. J., & Faber, M. (2010). Iron is essential for prevention of iron deficiency anemia which is the main causes of anemia in the world. The main risk factors of iron deficiency anemia are low intake of iron, poor bioavailability from iron food containing phytates and polyphenols (Passone, M. A., Resnik, S. L., & Etcheverry, M. G. (2005). Zinc is also a micronutrient which is responsible for normal growth function and immune function; its biological roles are structural, as catalyst and as a regulatory ion (Etcheverry, P., Grusak, M. A., & Fleige, L. E. (2012).

Vegetable containing diets however, may lead to reduced availability of minerals from the diets due to presence of antinutrients (Etcheverry et al., 2012). Traditional leafy vegetables are plenty in Sub-Saharan Africa including Malawi and they are known to contain anti-nutrients such as phytates, tannins, glycosides, oxalates, alkaloids and hydrocyanic acid. Tannins are identified as plant polyphenols that are capable of forming complexes with metal ions and macro-molecules like proteins and polysaccharides (Olawoye & Gbadamosi, 2017). Tannins affect the nutritional value of food products by chelating minerals like iron and zinc and reducing the absorption of these minerals as well as forming complexes with protein thereby inhibiting their digestion and absorption (Olawoye et al., 2017). Tannins are responsible for a decrease in growth rate as well as a non-palatable taste as they contribute to protein inhibition by forming complexes (Etcheverry et al., 2012).

Phytic acid (phytates) is the major phosphorous storage compound in traditional leafy vegetables. Phytic acid has been reported to inhibit the absorption of minerals such as calcium, iron and zinc; and reduce the bioavailability of these minerals in food (Etcheverry et al., 2012). Too much of a phytate rich diet is associated with nutritional diseases such as rickets and osteomalacia or osteoporosis in children and adults (Otunola & Afolayan, 2017) respectively.

Oxalic acid (Oxalates) exists in many leafy vegetables and plant foods. Depending on species, oxalic acid can occur as soluble salts of potassium and sodium or as insoluble salts of calcium, magnesium or iron or it can occur as a combination of soluble and insoluble salts (Essack, Odhav, & Mellem, 2017) . This forms strong chelates with dietary calcium thereby inhibiting its absorption (Akwaowo, Ndon, & Etuk, 2000) . It is well known that oxalic acid and its salts can have a deleterious effect on human nutrition and health, mostly by decreasing calcium absorption and aiding the formation of kidney stones (Olawoye et al., 2017).

Food processing techniques are often utilized in order to reduce antinutrients in food. Cooking is a common form of processing of plants that are consumed as a food source at household level. Some studies have suggested that different cooking methods may have different effects on different nutrients and antinutrients. Thus, the micronutrients and antinutrients are affected differently by processing, depending on the type of processing, as well as the type of vegetable species. Cooking causes changes in the phytochemistry of the leafy vegetable affecting its nutrients bioavailability and health benefit properties. The degree of these changes depends largely on the cooking methods as well as the type of the vegetable (Odhav, B., Beekrum, S., Akula, U., & Baijnath, H., 2007).

This study was therefore conducted to investigate the effect of short time boiling and sautéing (wet frying) on nutrients retention and antinutrients content in five traditional vegetables commonly consumed in Malawi. Boiling and wet frying are the common methods of cooking vegetables in Malawi.

2. Materials and Methods

2.1 Sample Collection and Preparation

Five traditional leafy vegetables that are commonly consumed in Malawi (*Amaranth hybridus*, *Moringa oleifera*, *Bidens pilosa* (black jack), *Corchorus olitorius* (Jute mallow) and *Ipomea batatas* (sweet potato leaves) were used in this study. Vegetable samples were randomly collected from the gardens in the southern region of Malawi. *Moringa oleifera* leaves were sampled from the Moringa trees in the district of Chikwawa, Malawi. Edible portions of the fresh vegetable leaves in this study were harvested and put in the sealed plastic bags. The plastic bags containing the vegetables were placed in portable coolers and transferred to a laboratory at Malawi university of Science and Technology (MUST) for processing. Vegetable leaf samples were washed with tap water followed by distilled water before further processing. The vegetables were then cooked using the methods that are commonly used in Malawi, thus boiling and wet frying (sautéing). A portion of each of the vegetable samples (about 1 kilogram) was boiled in 800ml of distilled water for 10 minutes with frequent turning to allow even cooking in stainless steel pots. Similar portions (1 kilogram) of the samples were wet fried in 200ml of vegetable oil for 10 minutes with frequent turning to allow even cooking in stainless steel pots. Other similar portions (1kilogram) of the raw samples were air dried in a shade until crispy dry without cooking. The boiled and wet fried samples were also dried under shade as was done with the raw samples until crispy dry. The temperature during the drying period ranged from 29-35 degrees Celsius. Dried samples were wrapped in alluminium foils and kept in tightly closed plastic containers. All the samples were then transferred to Jomo Kenyatta University of Agriculture and Technology (JKUAT), Food Biochemistry laboratory for chemical analysis.

2.2 Nutritional Analysis

2.2.1 Determination of Crude Fats

Crude fat content was determined using Soxhlet method according to AOAC. To achieve this, 5g of ground dry sample was placed in the thimble then the thimble was placed in the soxhlet extractor. Then 150mL round bottom flask was cleaned and filled with 90 ml petroleum ether. The whole setting was placed on a heating mantle to allow the petroleum ether to boil. The extraction was done for almost 6 hours. The condensing unit was then removed from extraction unit to allow the sample to cool down as it had finally removed all the lipids. The flasks containing extracted fat were then placed in the oven at $102^{o}C$ to dry to constant weight then were placed in a desiccator before they were weighed. The % Crude fat was calculated using the following method:

$$\% \text{ Crude fat} = (W_2 - W_1) \times 100 / S \tag{1}$$

Where W_1 = weight of empty flask, W_2=weight of flask and extracted fat, and S= weight of sample.

2.2.2 Determination of Ash and Minerals

Minerals (zinc, iron, calcium, magnesium and copper) were determined according to AOAC (1995, Method 970: 12). To achieve this, about 2 grams of each sample was weighed and delivered into the crucibles. The crucibles were placed on a hot plate under a fume hood and the temperature was increased slowly until smoking ceased to char the samples. Samples were then put in muffle furnace and temperature was increased gradually to $250^{0}C$ and heated for 1 hour. The temperature was then increased to 550 ^{0}C and incinerated to complete ashing. Thereafter, the temperature was decreased to 300 ^{0}C, and the crucibles were removed and cooled to room temperature. The ash was measured using an analytical balance to determine percentage of ash in the samples. The ash was then transferred quantitatively to 100 mL beakers containing 20 mL of 1N HCL, then heated at about 80-90 ^{0}C on a hot plate for 5 minutes. These were then transferred to 100 mL volumetric flask and were filled to the mark with 1N HCL. Insoluble matter was filtered and the filtrate was kept in a labeled polyethylene bottles. The absorbances of the solutions were read by Atomic Absorption Spectrophotometer (AAS) Shimadzu Japan. Minerals standards were prepared at varying concentrations to make the calibration curves. Iron was measured at a wavelength of 284.3nm, zinc was measured at 213.9nm, calcium was measured at 422.7nm, magnesium was measured at 285.5nm and copper was measured at 324.8nm.

2.2.3 Determination of Beta Carotene

Beta carotene content in the vegetable samples was analyzed using column chromatography and UV Spectrophotometer. Extraction of the carotenoids was done using acetone and petroleum ether as described by Rodriguez-Amaya, D. & Kimura, M., (2004) . Briefly, approximately 2 grams of each sample was weighed using analytical balance and placed in a mortar with about 10 mL of acetone. This was followed by thorough grinding with a pestle then the acetone extracts were transferred into 100 mL volumetric flasks. The residues were again extracted with 10 mL acetone and the extracts were added to the contents of the volumetric flasks. The extraction with acetone was continued until the residues no longer gave color. The combined extracts were then made to a volume of 100 mL with acetone. About 50mL of each extract was evaporated to dryness using rotary evaporator. The residue was dissolved with 10 mL petroleum ether and the solution was introduced into a chromatographic column to elute beta-carotene. The eluted beta-carotene was collected in 50ml volumetric flasks and made to a volume of 25 mL with petroleum ether. The absorbances of the solutions were read at 440 nm using a UV-Vis spectrophotometer. Beta carotene standards were prepared and read together with the samples at 440nm.

2.2.4 Determination of Ascorbic Acid

Ascorbic acid content of the samples was determined by High Performance Liquid Chromatography (HPLC) method (Vikram, V. B., Ramesh, M. N., & Prapulla, S. G. (2005) with some modifications. To achieve this, about 2 g of each sample was weighed and extracted with 30mL 0.8% metaphosphoric acid. The liquid extract was centrifuged at 10,000 rpm. The supernatant was filtered and diluted with 10 mL of 0.8% metaphosphoric acid using 0.45 µL filter and 20 µL of the filtrate was injected in HPLC for analysis. Various concentrations of ascorbic acid standards were prepared to make a calibration curve. HPLC analysis was done using Shimadzu UV-VIS detector at a wavelength of 266.0nm. The mobile phase was 0.8% metaphosphoric acid with flow rate of 1.2 mL/minute.

2.3 Antinutrients Determination

2.3.1 Determination of Phytates

Phytates content was determined using HPLC as described by (Camire, & Clydesdale. (2006). To achieve this, about 0.5 g of each sample was extracted with 10 mL of 3% H_2SO_4 and shaken at the automatic shaker for 45minutes. The contents were filtered and the filtrate was transferred to a boiling water bath to heat for 5 minutes followed by addition of 3 mL of $FeCl_3$ solution (6 mg ferric iron per mL in 3% H_2SO_4). The contents were then heated for 45 minutes to complete precipitation of the ferric phytate complex. Samples were then centrifuged at 2500 rpm for 10 minutes and the supernatant was discarded. The precipitate was washed with 30 mL of distilled water, centrifuged and the supernatant was discarded. A 3 mL of 1.5 N NaOH was added to the residues and the volumes were brought to 30 mL with distilled water. The contents were then heated for 30 minutes in a boiling water bath to precipitate the ferric hydroxide. Samples were then cooled and centrifuged and the supernatant was transferred into a 50 mL volumetric flask. The precipitate was rinsed with 10 mL distilled water, centrifuged and the supernatant was added to the contents of the volumetric flask. This was filtered using 0.45µL filter before HPLC analysis. The mobile phase was 0.005 N sodium acetate in distilled water, at a flow rate of 0.5 µL/minute.

2.3.2 Determination of Oxalates

Oxalic acid contents of the vegetable samples was determined by HPLC method as described by (Chong, Y., Liu, Y., & Yanping, F. (2002). To achieve this, about 0.3g of each sample was homogenized in 10 mL of 0.5N HCL. The homogenate was heated at 80 ^{0}C for 10 minutes with intermittent shaking on the water bath. To the homogenate, distilled water was added up to a volume of 25 mL. About 3 mL of the solution was withdrawn and centrifuged at 12,000 rpm for 10 minutes. About 1 ml of supernatant was passed through a micro filter (0.45µL) before HPLC analysis. Phytic acid standards were prepared at varying concentrations for quantification. HPLC analysis was done by UV-VIS detector using a solution of 0.01 N H_2SO_4 as mobile phase. The flow rate was 0.6 mL/ minute and was detected at a wavelength length of 221 nm.

2.3.3 Determination of Tannins

Tannins were estimated by Vanillin-HCl method as described by Millet P, (2013). Approximately 0.1g of ground dry leaf vegetable samples were accurately weighed into Erlenmeyer flasks. 10 ml of 4% HCL in methanol was pipetted into each flask, sealed with parafilm and shaken (KS 250 basic, Germany) for 20 minutes, centrifuged (HPLC-CTO-10AVP Shimadzu; detector used- Shimadzu RID6A Refractive Index Detector) for 10 minutes at 4500 rpm and supernatants were transferred to 25 ml volumetric flasks. The residues were extracted for the second time using 5 ml of 1% HCL in methanol for 10 minutes. The aliquots of the first and the second extracts were combined and made up to 25 ml volume using methanol. A set of catechin (Sigma) standards solutions were prepared ranging from 10 to 100 ppm using methanol as a solvent. One (1 ml) of suitably diluted extracts were taken in a test tube and 5ml of freshly prepared vanillin-HCl reagent was added to each test tube. To correct for interference of natural pigments in the dry vegetables, a blank sample was prepared by subjecting the original extract to the reaction conditions without the vanillin reagent. These were prepared by adding 5 ml of 4% HCL in methanol to 1 ml of the aliquots of the extracts that were pipetted into the test tubes. The absorbances of the standard solutions, sample extracts and blanks were read using a UV-VIS Spectrophotometer (Shimadzu, UV mini 1240, Japan) at 500 nm exactly 20 minutes after adding Vanillin-HCL reagent to the samples and standards. A standard curve was prepared from the readings of the catechin standard solutions. Tannin content was expressed in mg of catechin equivalent (CE) per 100g of sample (mg CE/100g).

2.4 Data Analysis

Data was analysed using STATA software (STATA 14.0, 2015, Texas, USA). The mean differences for nutrients and antinutrients within the sample groups as affected by treatments was tested for its significance differences using one way analysis of variance (ANOVA) by Bonferroni test. A p-value of ≤ 0.05 was used for the test of significance. All samples were analyzed in triplicates.

3. Results and Discussion

3.1 Effects of Wet Frying and Boiling on Nutrients Content

3.1.1 Effects of Wet Frying and Boiling on Crude Fats

The results for Crude fats in the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Table 1. The percentages of crude fats in the dry uncooked vegetables ranged from 1.07% to 2.28%. The mean amount of crude fats in the five vegetables were 2.28%, 2.18%, 1.91%, 1.32% and 1.07% in *Moringa oleifera*, black jack, sweet potato leaves, jute mallow and *Amaranth hybridus* respectively.

Table 1. Crude fat content (%) in traditional vegetables as influenced by cooking methods

Vegetable leaves	**Dried (n=3)**	**Wet fried (n=3)**	**Boiled (n=3)**
Sweet potato	1.91 ± 0.06^{b}	30.31 ± 0.46^{a}	2.82 ± 0.13^{b}
Black jack	2.18 ± 0.45^{b}	31.61 ± 1.47^{a}	2.70 ± 0.35^{b}
Moringa oleifera	2.28 ± 0.48^{b}	19.00 ± 0.26^{a}	1.81 ± 0.17^{b}
Jute mallow	1.32 ± 0.62^{b}	$16.81.1.31^{a}$	2.42 ± 0.33^{b}
Amaranth hybridus	1.07 ± 0.40^{b}	28.07 ± 2.53^{a}	1.68 ± 1.06^{b}

Entries are Mean ±SD

Values in the same row followed by the same superscripts are not significantly different at $\alpha=0.05$ using Bonferroni ANOVA test.

There was no significant difference in the percentage of fats between the boiled vegetables and the raw vegetables. Wet frying significantly increased ($P \geq 0.05$) the amount of fats in all the vegetables. The increase of fats in the wet fried samples is due to absorption of fats by the vegetables during the process of wet frying. The percentages of fats in the wet fried vegetables ranged from 16.81% to 30.31%. The differences in the percentage of absorbed fats in the wet fried vegetables might be due to different matrix of the vegetable leaves.

3.1.2 Effect of Boiling and Wet Frying on Ash Content

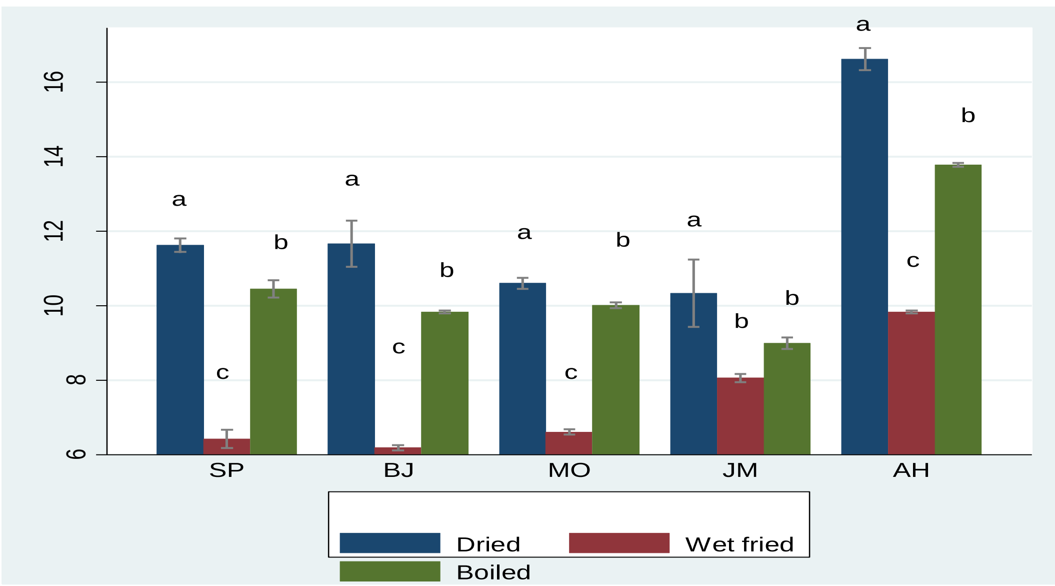

Figure 1. Mean % of ash in traditional vegetables as influenced by cooking methods. SP=Sweet potato; BJ= Black jack; MO= *Moringa oleifera*; JM= Jute mallow and AH=*Amaranthus hybridus*. Mean ±SD values (n=3) in the same group followed by the same superscripts are not significantly different at ($p \leq 0.05$) using Bonferroni ANOVA test

The ash content in the dry uncooked vegetables ranged from 10.33% to 16.61%. The ash content in these dry uncooked vegetables were 16.61%, 11.67%, 11.62%, 10.60%, 10.33% and in the leaves of *Amaranth hybridus*, black jack, sweet potato, *Moringa oleifera* and jute mallow respectively. Figure 1 indicate that there were significant differences in the percentages of ash as a result of wet frying and boiling in all the vegetables. Wet frying resulted to higher losses of ash in all the vegetables compared to boiling except in jute mallow vegetables where the ash reduction was statistically similar ($P \geq 0.05$) for wet fried and boiled jute mallow. The higher reduction of ash percentages in wet fried as compared to boiled vegetables is as a result of high absorption of oils in the wet fried vegetables that led to apparent decrease in percentages of ash. The loss of ash due to boiling could be as a result of leaching of minerals in the boiling water. Thus most minerals were leached into the boiling water and this led to reduced ash content because the ash contains minerals. These results tally with the work done by Traoré, K., Parkouda, C., Savadogo, A., Ba, F., Regine, H., & Yves, K., (2017) where it was found that the amount of ash reduced after blanching and boiling of vegetables that included jute mallow and *Amaranth cruentus L*. The authors found that the amount of ash reduced in jute mallow and Amaranth from 12.40% and 16.33% to 9.37% and 14.27% respectively after boiling for 30 minutes due to leaching of minerals in the boiling water.

In this study, the percentage of ash in jute mallow and *Amaranthus hybridus* reduced from 10.60% and 16.61% to 8.06% and 9.83% after wet frying; and to 8.99% and 13.78% after boiling them respectively. The apparent reduction of percentages of ash in the wet fried vegetables is due to increased oil content. Gunathilake, K. D. P. P., Ranaweera, K. K. D. S., & Rupasinghe, H. P. V., (2018) reported that during deep-fat frying, oils undergo physicochemical changes; the food dehydrates, and oils penetrates the food.

3.1.3 Effect of Boiling and Wet Frying on Iron Content

Figure 2 presents the iron content of the five traditional leafy vegetables; sweet potato, black jack, *Moringa oleifera*, jute mallow and *Amaranthus hybridus*. It also presents the amount of iron in the vegetables as influenced by wet frying and boiling of each of the traditional vegetables. The amount of iron in the dry uncooked vegetables ranged from 37.22mg/100g to 48.21mg/100g on dry wet basis. The iron content in the dry uncooked vegetables were 48.21mg/100g, 40.43mg/100g, 37.22mg/100g, 37.30mg/100g and 44.89mg/100g in the leaves of sweet potato, black jack, *Moringa oleifera*, jute mallow and *Amaranth hybridus* respectively. Boiling and wet frying for 10 minutes did not significantly reduce ($P \geq 0.05$) iron content in black jack leaves although there was some slight losses of iron due to these processes. There were significant losses ($P \leq 0.05$) of iron in sweet potato leaves, *Moringa oleifera* leaves and jute mallow leaves as a result of wet frying and boiling. Wet frying significantly ($P \leq 0.05$) reduced iron content in *Moringa oleifera* and jute mallow vegetables as compared to boiling the same vegetables for 10 minutes. The losses of iron due to boiling is as a result of leaching of the mineral iron into the boiling water. These results are similar to work done by Lewu, M. N., Adebola, P. O., & Afolayan, A. J. (2009) where the authors found that there were losses of iron due to boiling in most of the vegetables. Habwe, F. O., Walingo, M. K., Abukutsa-onyango, M. O., & Oluoch, M. O. (2009) also found a high reduction of iron content as a result of wet frying as compared to boiling for 5 minutes in *Amaranthus hybridus*. However, Ojo, O. O., Taiwo, K. A., Scalon, M., Oyedele, D. J., & Akinremi, O. O. (2016) reported slight increase of iron in *Solanum marcrocarpon* after boiling for 5 minutes in seven cultivars.

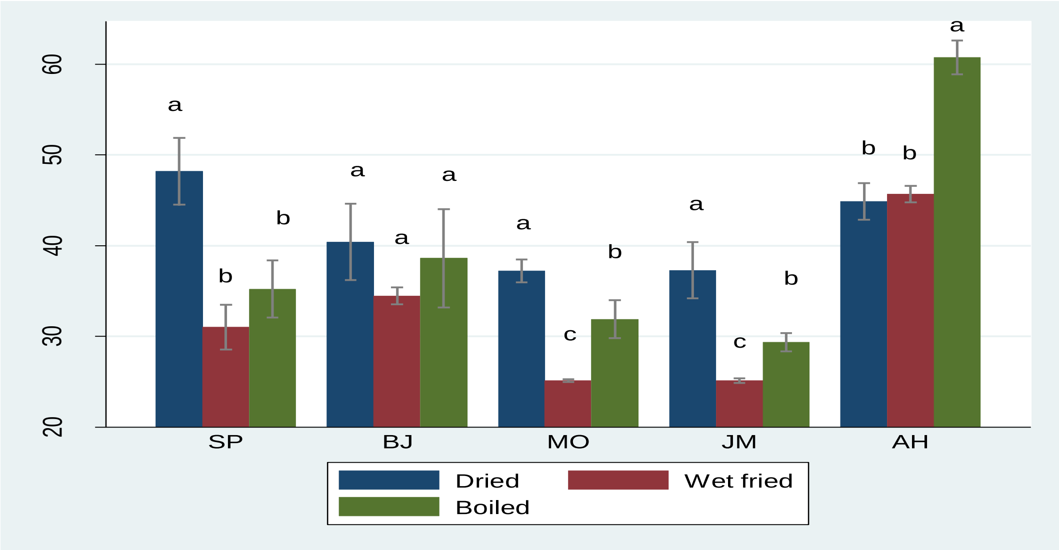

Figure 2. Mean amount of iron in traditional vegetables as influenced by cooking methods. SP=sweet potato, BJ= Black jack, MO=*Moringa oleifera*, JM=Jute mallow and AH=*Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at ($p \leq 0.05$) using Bonferroni ANOVA test

3.1.4 Effect of Boiling and Wet Frying on Zinc Content

The results for Zinc content of the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Table 2. The amount of zinc in the dry uncooked vegetables ranged from 4.42mg/100g to 10.59mg/100g on dry weight basis. The mean amount of zinc in these vegetables were 5.47mg/100g, 7.27mg/100g, 10.59mg/100g, 4.42mg/100g and 5.70mg/100g in the leaves of sweet potato, black jack, *Moringa oleifera*, jute mallow and *Amaranth hybridus* respectively. There was a significant reduction ($P \leq 0.05$) of zinc in sweet potato leaves, *Moringa oleifera* leaves, and Jute mallow due to wet frying and boiling for 10 minutes. Boiling of vegetables was also reported to reduce amount of zinc in different cultivars of Colocasia esculenta vegetables (Lewu et al., 2009). Boiling did not significantly reduce the amount of zinc in black jack leaves, however, wet frying reduced the zinc concentration significantly ($P \leq 0.05$). Wet frying also decreased the amount of zinc in Jute mallow significantly ($P \leq 0.05$) compared to boiling the same vegetables for 10 minutes due to apparent increase in fats. There was also a significant reduction of zinc in Amaranthus hybridus due to wet frying as compared to boiling.

Table 2. Zinc content (mg/100g DM) in traditional vegetables as influenced by cooking methods

Vegetable leaves	**Dried (n=3)**	**Wet fried (n=3)**	**Boiled (n=3)**
Sweet potato	5.47 ± 2.38^{a}	2.43 ± 0.70^{b}	6.15 ± 0.87^{b}
Black jack	7.27 ± 0.98^{a}	4.82 ± 0.64^{b}	6.49 ± 0.16^{a}
Moringa oleifera	10.59 ± 2.32^{a}	1.78 ± 0.04^{b}	2.48 ± 0.03^{b}
Jute mallow	4.42 ± 0.12^{a}	2.37 ± 0.05^{c}	3.01 ± 0.07^{b}
Amaranth hybridus	5.70 ± 0.20^{b}	4.73 ± 0.12^{c}	9.03 ± 0.20^{a}

Entries are mean ± SD

Values in the same row followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test.

3.1.5 Effect of Boiling and Wet Frying on Copper Content

Figure 3 presents the results for amount of Copper in the raw dried vegetables and their respective wet fried and boiled vegetables. The amount of Copper in the raw dried vegetables ranged from 1.29mg/100g to 3.90mg/100g. The mean amount of Copper in the vegetables were 1.29mg/100g, 1.55mg/100g, 1.98mg/100g, 3.20mg/100g and 3.90mg/100g in *Moringa oleifera*, *Amaranth hybridus*, jute mallow, sweet potato leaves and black jack respectively. The results indicate that there was no significant loss ($P \leq 0.05$) of copper due to boiling of sweet potato leaves, black jack leaves and jute mallow leaves. There was however significant decrease (P≤0.05) of copper due to wet frying in sweet potato leaves, black jack leaves, and jute mallow leaves because these vegetables absorbed higher oils. There was no significant loss of copper due to wet frying in *Moringa oleifera* leaves because *Moringa oleifera* absorbed relatively less amount of oils that resulted to apparent less effect on copper content. Lewu et al., 2009 reported good retention of copper after boiling in several cultivars of Colocasia esculenta with little or no losses of the mineral in other cultivars. Ojo et al., (2016) also reported slight reduction of copper in Solanum marcrocarpon after boiling for 5 minutes.

3.1.6 Effect of Boiling and Wet Frying on Calcium Content

The results for amount of Calcium in the five vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Figure 4. The amount of Calcium in the uncooked dried vegetables ranged from 150.86mg/100g to 559.75mg/100g. The mean amount of Calcium in the leafy vegetables were 150.86mg/100g, 176.54mg/100g, 242.95mg/100g, 396.10mg/100g and 559.75mg/100g in black jack , jute mallow, sweet potato leaves, *Amaranth hybridus* and *Moringa oleifera* respectively. There were significant losses (P≤0.05) of calcium due to wet frying in the vegetable leaves of sweet potato, black jack, *Moringa oleifera* and *Amaranthus hybridus* due to apparent increase in crude fats. There was no significant loss of calcium as a result of boiling in black jack, *Moringa oleifera*, jute mallow and *Amaranthus hybridus* leafy vegetables due to possible insolubility of calcium in these vegetables. In a study by Ojo et al., 2016, it was found that boiling retained the amount of Calcium after boiling Solanum marcrocarpon for five minutes. Wet frying did not significantly reduce calcium content in jute mallow leafy vegetables.

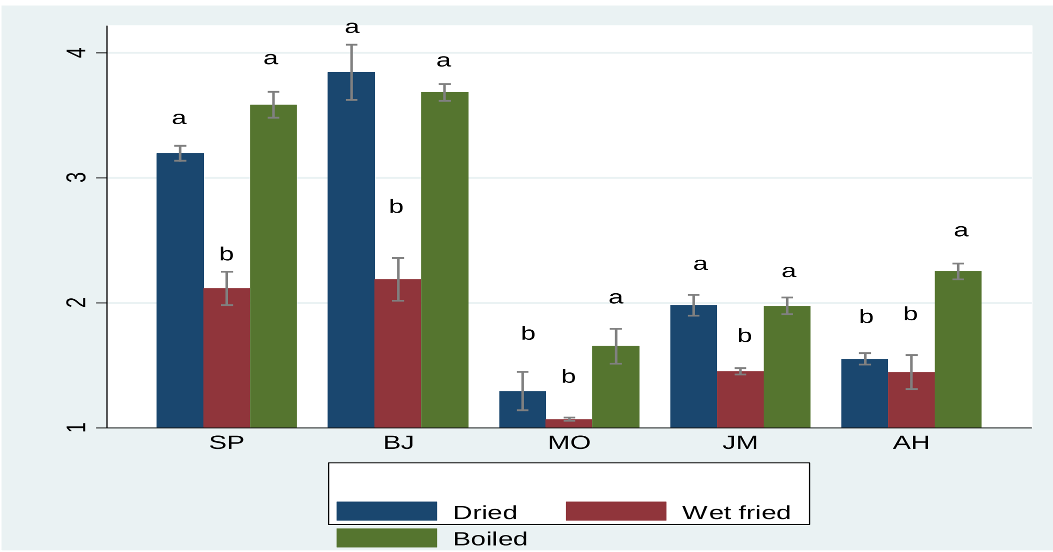

Figure 3. Mean amount of Copper in traditional vegetables as influenced by cooking methods. SP=sweet potato, BJ=Black jack, MO=*Moringa oleifera*, JM=Jute mallow and AH= *Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test

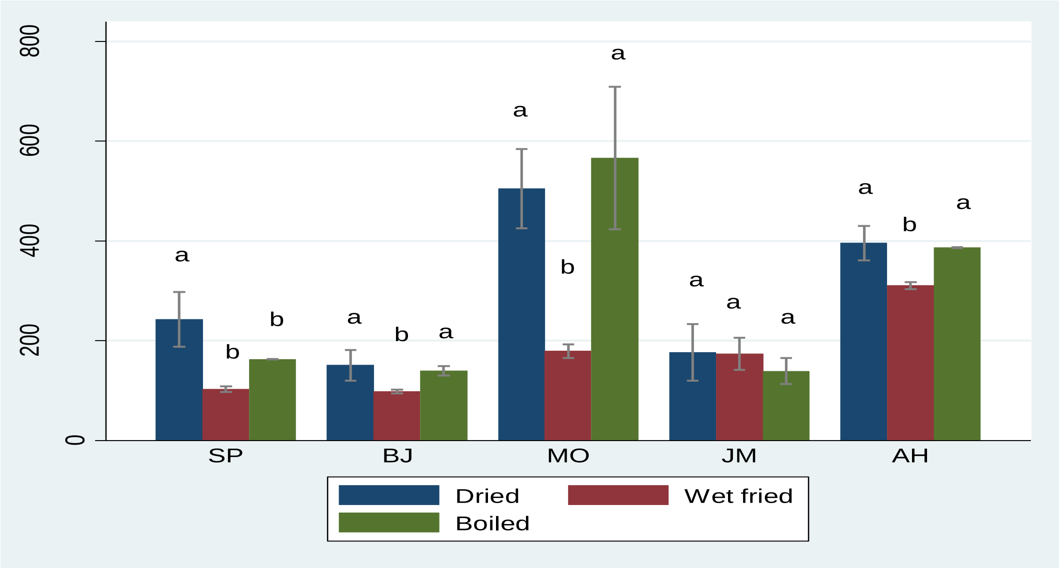

Figure 4. Mean amount of Calcium in traditional vegetables as influenced by cooking methods. SP=sweet potato, BJ=Black jack, MO=*Moringa oleifera*, JM=Jute mallow and AH= *Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test

3.1.7 Effect of Boiling and Wet Frying on Magnesium Content

Magnesium content of the five traditional leafy vegetables and their respective boiled and wet fried counterparts are presented in table 3. The amount of Magnesium in the uncooked dry vegetables ranged from 101.19mg/100g to 196.22mg/100g. The mean amount of Magnesium in the leafy vegetables were 101.19mg/100g, 142.23mg/100g, 154.67mg/100g, 156.07mg/100g and 196.22mg/100g in jute mallow, black jack, *Moringa oleifera*, sweet potato leaves and *Amaranth hybridus* respectively. There were significant losses (P≤0.05) of Magnesium due to wet frying in leafy vegetables of sweet potato, black jack, *Moringa oleifera*, and *Amaranth hybridus*. Boiling significantly (P≤0.05) reduced the amount of Magnesium in sweet potato leaves but not as much as wet frying. There was no significant loss of Magnesium as a result of boiling in the vegetable leaves of black jack, *Moringa oleifera*, jute mallow and *Amaranthus hybridus*. Lewu et al., 2009 however reported slight reduction of Magnesium in some cultivars of Colocasia esculenta after boiling for five minutes. The reduction of Magnesium in the vegetables as a result of boiling is due to leaching of the mineral in the boiling water.

Table 3. Magnesium content (mg/100g) in traditional vegetables as influenced by cooking methods

Vegetable leaves	**Dried (n=3)**	**Wet fried (n=3)**	**Boiled (n=3)**
Sweet potato	156.07±2.49^{a}	93.47±2.34^{c}	134.83±5.45^{b}
Black jack	142.23±2.09^{a}	101.37±5.08^{b}	146.89±5.01^{a}
Moringa oleifera	154.67±4.40^{b}	148.25±4.91^{b}	179.61±5.85^{a}
Jute mallow	101.19±5.77^{a}	93.99±1.33^{a}	106.47±1.17^{a}
Amaranth hybridus	196.22±0.60^{a}	189.45±1.59^{b}	196.96±3.18^{a}

Entries are Mean ±SD

Values in the same row followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test.

3.1.8 Effect of Boiling and Wet Frying on Beta-carotene Content

Figure 5 presents the results for mean amount of beta-carotene in the five traditional vegetables and the influence of 10 minutes wet frying and boiling for each of the vegetables on beta-carotene. The amount of beta-carotene in the uncooked dried vegetables ranged from 829.68 μg/100g to 5791.64 μg/100g on dry weight basis. The mean amount of beta-carotene in the leafy vegetables were 5791.64 μg/100g, 2153.29 μg/100g, 1242.21 μg/100g, 1055 μg/100g and 829.68 μg/100g in *Moringa oleifera*, jute mallow, black jack, sweet potato leaves and *Amaranth hybridus* respectively. Boiling did not significantly reduce (P≤0.05) beta-carotene content in the vegetables leaves of sweet potato, black jack and *Moringa oleifera*. There was however better retention of beta-carotene in sweet potato and black jack leaves as a result of boiling. Wet frying significantly reduced beta-carotene content in black jack leafy vegetables. There was no significant loss (P≤0.05) of beta-carotene in *Amaranthus hybridus* due to wet frying, however, boiling retained the vitamin significantly in the same vegetable. There was also a significant retention of (P≥0.05) beta-carotene due to boiling for 10 minutes in jute mallow vegetables. These results agrees with the work by Ogliano, V. I. F., & Ellegrini, N. I. P. (2008) where they found that in most vegetables frying reduced the amount of beta-carotene and boiling for a short period increased beta-carotene in broccoli and courgettes vegetables. Cooking of green fresh vegetables has been reported to promote release of carotenoids from the matrix because of the disruption of carotenoids-protein complexes, leading to better extractability and higher concentrations in cooked samples (Ogliano et al., 2008). Beta-carotene losses due to frying has been attributed to loss of the initial carotenoids concentration because of leaching into oil at higher processing temperature. Traoré et al., 2017 also reported a reduction of beta-carotene in jute mallow and amaranth due to shade drying alone. The results for shade dried samples of jute mallow and amaranth in this study agrees with those reported by Traoré et al., 2017. Results from the study by Putra, U. (2009) showed that both boiling and stir-frying increased the beta-carotene (2 to 4.2 times) of pumpkin. It was found that boiling for 4 minutes resulted in the highest (4.2 times) increase of beta-carotene to 8.0 mg/100g from 2.0mg/100g. Six minutes boiling, on the other hand, resulted in 270% (3.7 times) increase in beta-carotene content. In this study all the vegetables were either wet fried or boiled for 10 minutes. The 10 minutes cooking in this study may attribute to more losses of beta-carotene as compared to when they would be cooked at a shorter period. Long time cooking is attributed to longer exposure to oxidation and heat thereby leading to more losses of beta-carotene. The higher losses of beta-carotene due to wet frying compared to boiling at 10 minutes in this study might be attributed to the fact that carotenoids are fat-soluble compounds and solubilized readily in oil during stir-frying as explained by Putra, 2009.

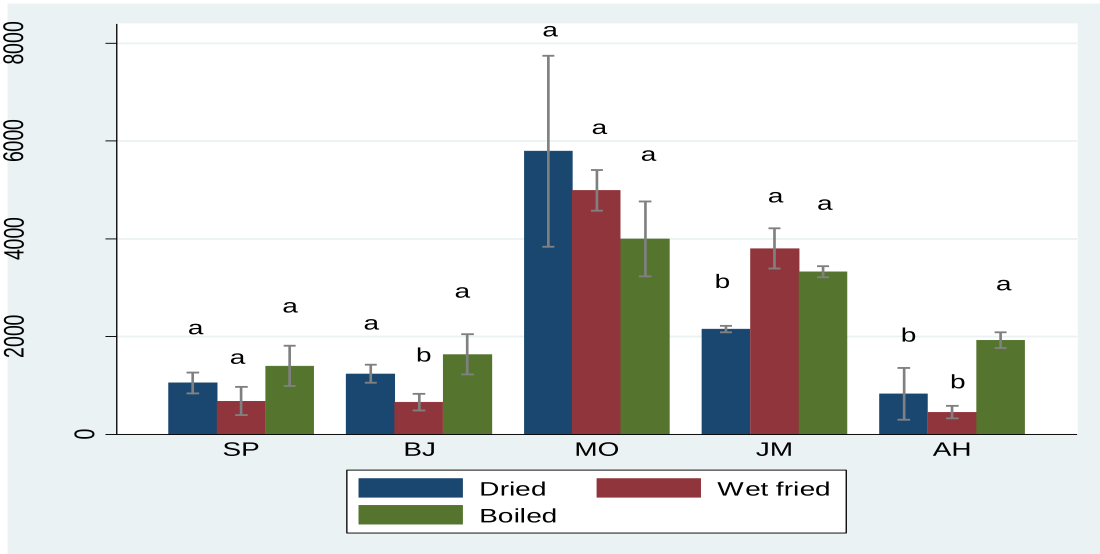

Figure 5. Mean amount of beta-carotene in traditional vegetables as influenced by cooking methods. SP=sweet potato, BJ=Black jack, MO=*Moringa oleifera*, JM= Jute mallow and AH= *Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test

3.1.9 Effect of Boiling and Wet Frying on Vitamin C (Ascorbic acid) Content

The results for Vitamin C content of the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Figure 6. The amount of ascorbic acid in the uncooked dry vegetables ranged from 7.93mg/100g to 35.81mg/100g on dry weight basis. The mean amount of beta-carotene in the leafy vegetables were 35.81mg/100g, 28.78mg/100g, 25.48mg/100g, 22.85mg/100g and 7.93mg/100g in the leaves of sweet potatoes, black jack, *Moringa oleifera*, jute mallow and *Amaranth hybridus* respectively. Boiling significantly reduced (P≤0.05) vitamin C content in all the vegetables except in *Amaranthus hybridus* where the amount of vitamin C was slightly reduced. Wet frying significantly retained (P≥0.05) vitamin C in all the five traditional vegetables. The vitamin C losses in the vegetables due to boiling might be attributed to leaching of the vitamin in the boiling water because Vitamin C is water soluble. Singh & Harshal, 2016 reported losses of Vitamin C content in several vegetables after boiling for 10 minutes and after blanching and microwaving. In their study, microwaving the vegetables significantly reduced the amount of Vitamin C than blanching and boiling. The high retention of vitamin C due to wet frying in the wet fried samples in this study might be due to its preservation in the cooking oil because vitamin C is slightly soluble in oil. There were slight higher vitamin C content in almost all the wet fried vegetables compared to uncooked dried vegetables because the wet fried vegetables were dried alongside the uncooked vegetables and more losses of vitamin C in uncooked vegetables might occur during drying. The results for wet frying in this study, agrees with Masrizal, M., & Giraud, D. (1996) where it was found that stir frying in cooking oil had the highest retention (by 1.31-1.83 fold) of vitamin C in several vegetables than boiling. Armesto, J., Gómez-limia, L., Carballo, J., Martínez, S., Armesto, J., Gómez-limia, L., … Armesto, J. (2019) also reported significant losses of vitamin C in Brassica oleracea after boiling for 20 and 30 minutes.

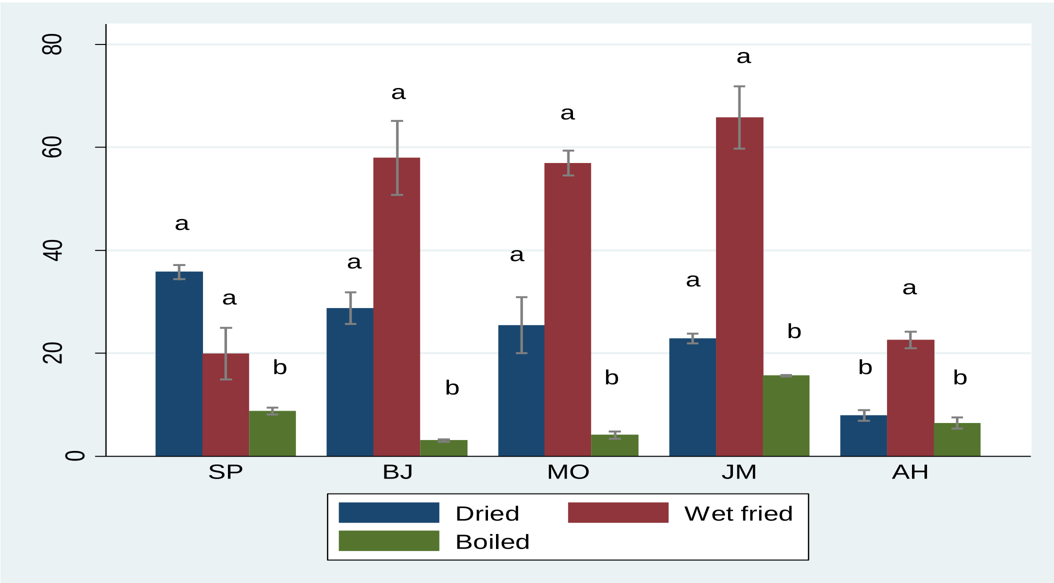

Figure 6. Mean amount of ascorbic acid in traditional vegetables as influenced by cooking methods. SP= sweet potato, BJ=Black jack, MO=*Moringa oleifera*, JM=Jute mallow and AH=*Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test

3.2 Effects of Wet Frying and Boiling on Anti-nutrients

3.2.1 Effects of Wet Frying and Boiling on Oxalates

The results for oxalates in the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in figure 7. The amount of oxalates in the uncooked dry vegetables ranged from 77.06mg/100g to 771.95mg/100g on dry weight basis. The mean amount of oxalates in these uncooked vegetables were 77.06mg/100g, 276.07mg/100g, 286.73mg/100g, 306.95mg/100g and 771.95mg/100g in black jack, jute mallow, sweet potato leaves, *Moringa oleifera* and *Amaranth hybridus* respectively. Both boiling and wet frying significantly reduced (P≤0.05) amount of oxalates in vegetable leaves of sweet potato, *Moringa oleifera*, jute mallow and *Amaranthus hybridus*. Ojo et al., (2016) also reported a reduction of oxalates in Solanum marcrocarpon vegetables after boiling for five minutes. In this study, there was no significant reduction (P≥0.05) of oxalates in black jack leaves. The loss of oxalates in both wet fried and boiled black lack leaves was 17%. Also, Mcewan, R., Shangase, F. N., Djarova, T., & Opoku, A. R.,(2014) reported a significant reduction of Oxalates in Colocasia esculenta after boiling as compared to stir frying.

3.2.2 Effects of Wet Frying and Boiling on Phytates Content

The results for phytates content in the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Table 4. Phytates content in the uncooked dry vegetables ranged from 72.17mg/100g to 129.15mg/100g on dry weight basis. The mean amount of phytates in these uncooked vegetables were 72.17mg/100g, 86.64mg/100g, 99.80mg/100g, 124.95mg/100g and 129.15mg/100g in *Amaranth hybridus*, jute mallow, *Moringa oleifera*, black jack and sweet potato leaves respectively. Boiling significantly reduced (P≤0.05) the amount of phytates in jute mallow and *Amaranthus hybridus* vegetables. There were significant losses (P≤0.05) of phytates due to wet frying in *Moringa oleifera* and jute mallow vegetables. There were slight losses of phytates in both wet fried and boiled sweet potato and black jack leafy vegetables though not significant (P≥0.05). Wet frying reduced the amount of phytates in *Amaranthus hybridus* and black jack vegetables by 47% and 32% respectively. Results by Mcewan et al., (2014) revealed a significant reduction of phytates after boiling and stir frying, where stir frying reduced the phytates more than boiling for the same period in the tubers of Colocasia esculenta. The losses of phytates due to wet frying and boiling might be as a result of thermal degradation and dissolution in water.

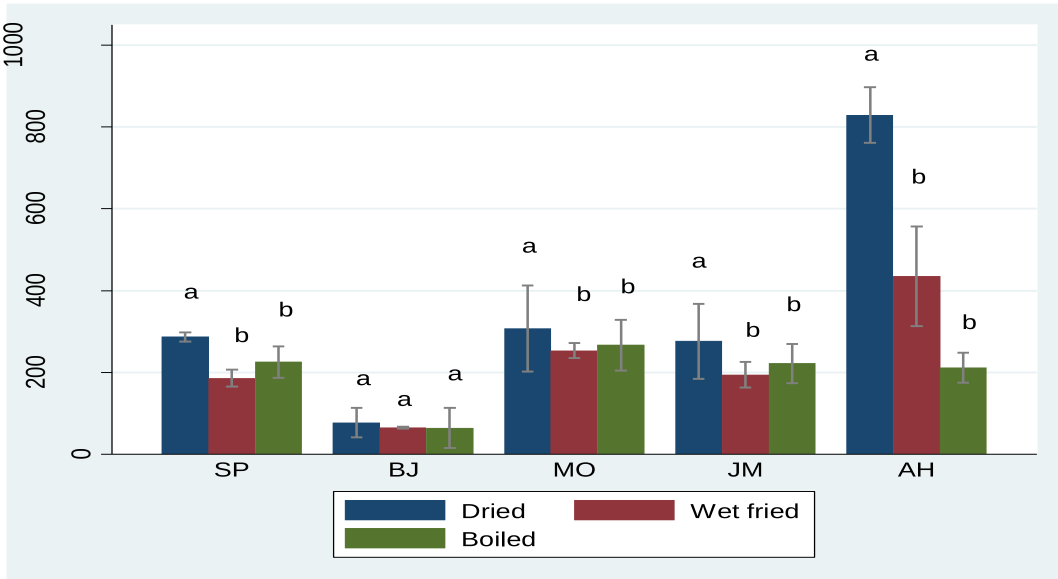

Figure 7. Mean amount of Oxalates in traditional vegetables as influenced by cooking methods. SP=sweet potato, BJ=Black jack, MO=*Moringa oleifera*, JM=Jute mallow and AH=*Amaranthus hybridus*. Mean ±SD values in the same group followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test

Table 4. Phytate content (mg/100g) in traditional vegetables as influenced by cooking methods

Vegetable leaves	**Dried (n=3)**	**Wet fried (n=3)**	**Boiled (n=3)**
Sweet potato	129.15±42.47^{a}	123.91±13.55^{a}	118.48±11.41^{a}
Black jack	124.95±52.25^{a}	84.98±13.57^{a}	99.35±40.76^{a}
Moringa oleifera	99.80±10.29^{a}	69.28±5.46^{b}	87.11±0.36^{a}
Jute mallow	86.64±12.51^{a}	43.95±12.51^{b}	44.75±8.14^{b}
Amaranth hybridus	72.17±18.19^{a}	37.90±14.11^{a}	12.42±9.63^{b}

Entries are Mean ±SD

Values in the same row followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test.

3.2.3 Effects of Wet Frying and Boiling on Tannins Content

The results for tannins content in the five traditional vegetables and its respective wet fried and boiled counterparts for each vegetable are presented in Table 5. The amount of tannins in the uncooked dry vegetables ranged from 42.94mg/100g to 77.16mg/100g on dry weight basis. The mean amount of tannins in these dry uncooked vegetables were 42.94mg/100g, 47.91mg/100g, 49.53mg/100g, 61.18mg/100g and 77.16mg/100g in jute mallow, *Amaranth hybridus*, *Moringa oleifera*, sweet potato leaves and black jack leaves respectively. Boiling significantly reduced (P≤0.05) the amount of tannins in jute mallow and sweet potato leafy vegetables. There was no significant loss of tannins due to wet frying in all the vegetables. Boiling reduced the amount of tannins in sweet potato leaves and *Amaranthus hybridus* by 42.69% and 36% respectively. Wet frying reduced the amount of tannins in black jack leafy vegetables by 31%. Significant losses of tannins were reported by Jugran, A. K., & Chaudhary, W. Y.,2016 in *Peeonia emodi* leaves after boiling the leaves from different stages of growth. The losses of tannins due to boiling and frying are attributed to thermal degradation of tannins during cooking as reported by Gunathilake et al., 2018. In this study, the amount of tannins in wet fried jute mallow increased by 8.09% compared to the dry uncooked jute mallow. The amount of tannins in *Moringa oleifera* leafy vegetables increased by 13.79% and 30.67% as a result of wet frying and boiling the vegetables for ten minutes respectively. These results agrees with Gunathilake et al.,2018 where it was found that in some vegetables, tannins content increase due to breakdown of the complex tannins compounds present in the vegetables during heat processing to simple tannins. Also, increase in total polyphenols such as tannins during thermal processing might be due to the liberation of polyphenols from the intracellular protein complexes, changes in plant cell structure, matrix modifications, or the inactivation of the polyphenol oxidases (Gunathilake et al., 2018).

Table 5. Tannins content (mg/100g DM) in traditional vegetables as influenced by cooking methods

Vegetable leaves	**Dried (n=3)**	**Wet fried (n=3)**	**Boiled (n=3)**
Sweet potato	61.18 ± 15.48^{a}	52.73 ± 25.96^{a}	35.06 ± 8.84^{b}
Black jack	77.16 ± 23.27^{a}	53.42 ± 14.448^{a}	70.56 ± 4.51^{a}
Moringa oleifera	49.53 ± 7.10^{a}	56.36 ± 13.52^{a}	64.72 ± 8.65^{a}
Jute mallow	42.94 ± 17.48^{a}	46.37 ± 12.46^{a}	32.98 ± 19.58^{b}
Amaranth hybridus	47.91 ± 3.53^{a}	33.87 ± 11.19^{a}	30.50 ± 6.01^{a}

Entries are mean ±SD

Values in the same row followed by the same superscripts are not significantly different at α=0.05 using Bonferroni ANOVA test.

4. Conclusions

The findings from the present study indicate that minerals, crude fats, beta-carotene, vitamin C, oxalates, phytates and tannins of selected five traditional vegetables are altered during common cooking practices; boiling and wet frying. Wet frying reduced the amount of nutrients such as iron, zinc, copper, calcium, magnesium and beta-carotene in most of the vegetables as compared to boiling. On the other hand, wet frying retained and preserved the amount of Vitamin C in all the vegetables while boiling reduced vitamin C content in all the vegetables. Wet frying significantly increased the amount of crude fats in all the vegetables while boiling slightly reduced crude fats in the vegetables. Boiling has shown to have varying effects on iron, zinc, calcium, magnesium, and beta-carotene depending on the type of leafy vegetable. Boiling retained significant amounts of beta-carotene in all the vegetables. Both boiling and wet frying reduced the amount of antinutrients (oxalates, phytates and tannins) in most of the vegetables. Boiling had the highest effect to reduce tannins as compared to wet frying. The results of the study can be used for making recommendations on food processing methods to preserve the health benefits of the studied vegetables and reduce the antinutrients of the vegetables.

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