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ASSESSMENT OF NUTRITIONAL QUALITY OF COOKED SWAZI LEAFY VEGETABLES

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ABSTRACT

Swazi leafy vegetables are cheap, seasonal, locally grown and easily available, easy to propagate and store, highly nutritious food substances that are often used to supplement diets and whose nutrient content is affected by processing treatments. The effects of cooking on the nutrient composition of some Swazi vegetables were investigated. Common Swazi vegetables and some exotic cultivars were collected from the Manzini region, then cooked strictly according to Swazi traditional practice, digested and analysed for calcium, copper, iron, magnesium, manganese, potassium and zinc content using flame atomic absorption spectrophotometer and inductively coupled plasma spectrometer. The vegetables investigated were: *Hibiscus escolentus* [upright and exotic cultivars], *Corchorius olitorus, Amaranthus spinosus*, *Amaranthus caudatus*, *Bidens pilosa*, *Solanum nigrum* and *Momordica involucrata*. *Brassica oleracea* and *Spinacia oleracea* were also analysed and compared with other vegetables. Sampled vegetables were divided into two categories. All vegetables in category one were cooked without any additives. In category two *Hibiscus escolentus* and *Corchorius olitorus* were cooked with bicarbonate of soda and common salt; *Amaranthus spinosus*, *Amaranthus caudatus*, *Bidens pilosa*, *Solanum nigrum*, *Brassica oleracea* and *Spinacia oleracea* were prepared with sunflower cooking oil and salt. Only salt was added to *Momordica involucrata*. Results of the study show that cooking significantly ($p \leq 0.05$) reduces zinc, calcium, iron, magnesium, manganese, potassium and copper content of all the vegetables analysed. The percent reductions were: 4.2 – 100% for zinc, 2.0 – 75.6% for calcium, 2.4 – 79.2% of iron, 1.2 – 73.2% for magnesium, 6.6 – 100% for manganese, 1.9 – 67.5% for potassium and 46.4 – 100% for copper. It was also found that addition of salt and bicarbonate of soda enhances loss of minerals. The cooked Swazi vegetables had significantly higher minerals content when compared to exotic varieties such as *Brassica oleracea* which lost most of the minerals when cooked. The loss of minerals in the vegetables may be due to leaching effect during the cooking process. It appears that this leaching effect is exacerbated by addition of sodium bicarbonate, sodium chloride and sunflower cooking oil. Cooking the common vegetables without additives or with small quantities of additives is, therefore, recommended.

Key words: Additives, Minerals, Nutritional quality, Cooked, Swazi, Malvaceae, Amaranthaceae, Asteraceae, Solanaceae, Cucurbitaceae

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INTRODUCTION

Wild vegetables have been the mainstay of human diets for centuries and are receiving renewed attention from nutritionists, healthcare professionals, scientists, educationists, governments and the general public with the recognition that they could significantly contribute to alleviating hunger and malnutrition [1]. Indigenous vegetables represent inexpensive yet high-nutrient sources for the poor segment of the population, especially where micronutrient malnutrition is widespread. Indigenous vegetables grow wild and are readily available in the field as they are easy to propagate. Studies dealing with food security depend on the availability of various information such as consumption data (per capita), dietary surveys, food consumption tables, nutritional tables and nutritional status of different micronutrients such as iron, calcium, zinc, manganese, copper, selenium, iodine and vitamins such as vitamin A, E, B and D. Composition tables report the total available levels of these nutrients in foodstuffs without taking into account the effect of cooking. Total nutritional values reported from most studies are thus misleading in evaluating food security [2, 3].

Previous studies on some common vegetables consumed in Swaziland determined and reported the levels of vitamin A, iron, calcium, zinc and manganese in raw *Corchorius olitorus [Malvaceae]* (ligusha), *Momordica involucrata [Cucurbitaceae]* (inkhakha), *Amaranthus spinosus [Amaranthaceae]* (imbuya), *Bidens pilosa [Asteraceae]* (chuchuza) and *Solanum nigrum [Solanaceae]* (umsobo) [2, 4]. Their findings indicate that these cheap and easily available leafy vegetables are excellent sources of these micronutrients. The mean values for bush okra (*Corchorius olitorus*), bitter gourd (*Momordica involucrata*), tassel flower (*Amaranthus spinosus*), blackjack (*Bidens pilosa*) and black nightshade (*Solanum nigrum*) were 959, 1194, 216, 1114 and 27 micrograms vitamin A per 100 g (All-trans retinal), respectively. These values translated to percentage Recommended Daily Intake (RDI) values of 96%, 119%, 22%, 111%, and 3%, respectively. All the samples analysed were found to be good sources of iron, with *Amaranthus spinosus* having the highest concentration (41 mg/100 g) followed by *Corchorius olitorus* with 29 mg/100g while *Momordica involucrata*, *Bidens pilosa* and *Solanum nigrum* had the lowest content of iron (19 mg/100g). The highest concentration of calcium (2683 mg/100 g) was found in *Amaranthus spinosus* while *Corchorius olitorus* and *Bidens pilosa* generally gave low calcium content (50 - 70 mg/100 g). The highest zinc content (11.6 mg/100 g) was obtained from *Amaranthus spinosus* and the lowest (6.2 mg/100 g) from *Momordica involucrata*. The levels of the important trace element manganese were as follows: *Corchorius olitorus* (14.6 mg/100 g), *Bidens pilosa* (12.4 mg/100 g), *Amaranthus spinosus* (11.7 mg/100 g) and *Momordica involucrata* (3.4 mg/100 g) in descending order of concentration [2].

In spite of the popularity of the vegetables in the Swazi diet, information on their nutritional profile is scarce. Knowledge of the nutritional value of these vegetables in the cooked state is important since consumption of vegetables with good mineral content is vital in ensuring health, especially for people living with HIV and AIDS. This study intended to establish the nutrient composition of common Swazi vegetables when cooked in order to gauge the effect of cooking on micronutrients and determine their level at the point of consumption.

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MATERIALS AND METHODS

Research Design

The investigation was a comparative study. The research examined the content of the micronutrients: iron, calcium, zinc, manganese, copper, magnesium and potassium in eight cooked vegetables as shown in Table 2. The data obtained were compared with the corresponding amounts found in the common exotic foods indicated in Table 3.

Sampling

One kilogram each of leafy vegetables was collected from around Manzini, Matsapha, Luyengo or Mafutseni depending on the availability. A random sampling technique was adopted for all the vegetables where they were either procured from the market or harvested from the farms. Table 2 shows the vegetable samples that were analysed and Table 3 lists the common vegetables that were analysed for comparison purposes. All samples are identified using their SiSwati, English and botanical names.

Pre-treatment and storage

To prevent sample deterioration and retain quality, samples were kept in vacuum bags after being evacuated of air by a vacuum sealer and stored in the freezer at −20 ^{o}C after collection until analysis.

Cooking Methods

The vegetables were cooked in stainless steel pots strictly according to Swazi traditional practice as follows while ensuring that no contamination occurred during the cooking process:

Hibiscus escolentus and Corchorius olitorus

To 250 mL of boiling water was added 50 g of the vegetable sample, 5 g of bicarbonate of soda and 5 g of salt. The mixture was then allowed to boil for a further 10 minutes;

Amaranthus spinosus, Amaranthus caudatus, Bidens pilosa and Solanum nigrum

To 50 mL of water in a pot was added 100 g of the vegetable sample and allowed to boil for 10 minutes. Excess water was then drained. Five mL of cooking oil was used to fry the sample after which 2 g of salt was added;

Brassica oleracea and Spinacia oleracea

Fifty (50) grams of the vegetable sample was chopped into pieces and added together with 50 mL of water in a pot. The sample was allowed to boil for 10 minutes after which excess water was drained. Five (5) mL of cooking oil and 2 g of salt were then added and the sample allowed to simmer for 5 minutes;

Momordica involucrata

Fifty (50) grams of *Momordica involucrata* and 2 g of salt were placed into a pot together with 20 mL of water. The mixture was then allowed to boil for 10 minutes.

Control samples
In all the above cooked vegetables, control samples were prepared. Each control sample contained all the additives but was without the vegetable being investigated.

Micronutrient analysis
The samples were digested using acids and analysed by AOAC [5] method. Copper, manganese and zinc were determined by inductively coupled plasma spectrometer at Laboratory Services of the Swaziland Water Services Corporation (Perkin Elmer, Optima 4300DV, USA) while calcium, iron, magnesium and potassium were determined by flame atomic absorption spectrophotometer (Varian, AA240FS, Mulgrave Victoria, Australia) at the Chemistry Department of the University of Swaziland.

Digestion
Five (5) grams of each dry sample was weighed and placed in microwave bombs. Then 10 mL hydrochloric acid (6M HCl) was added, the bombs sealed, placed in a microwave and digested until dissolution was complete. The samples were then suction-filtered using a membrane filter or ash free Whatman filter paper to avoid adsorption of the ions to be analysed. The residue was then washed down with two successive 10 mL portions of boiling 2M HCl and further heated on a hot plate with 6M HNO_3 until all the HNO_3 was evaporated. Then the resulting solution was filtered on the same filter paper with two successive 10 mL portions of boiling 2M HCl. The filtrate was then put in a 50 mL volumetric flask and diluted to the mark using distilled water.

Measurement
All chemicals and reagents were of analytical reagent grade and were procured from Merck Chemicals (South Africa). Standards of iron, calcium, zinc, manganese, copper, magnesium and potassium were prepared making sure that the samples were bracketed on the calibration curve. The samples were then analysed using flame atomic absorption spectrophotometer (AAS) or inductively coupled plasma (ICP) spectrometer, depending on the detection limits. Each sample was analysed three (3) times in order to generate the relative errors for each sample.

Data Analysis
Data analysis was performed using Microsoft Excel [6] and the results were presented using bar charts. The data were subjected to analysis of variance (ANOVA). Level of significance was accepted at $p \leq 0.05$. All data was expressed as mean ± standard deviation (SD).

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RESULTS

The effects of cooking on mineral contents of selected common Swazi vegetables are given in Table 4. It can be noted that cooking caused significant ($p \leq 0.05$) reductions in some assessed minerals content including zinc, calcium, iron, magnesium, manganese, potassium and copper of all the experimental vegetables. Figure 1 shows the % RDI values of zinc for the treated vegetables. The Recommended Dietary Allowance (RDA) for zinc is 15 mg [7].

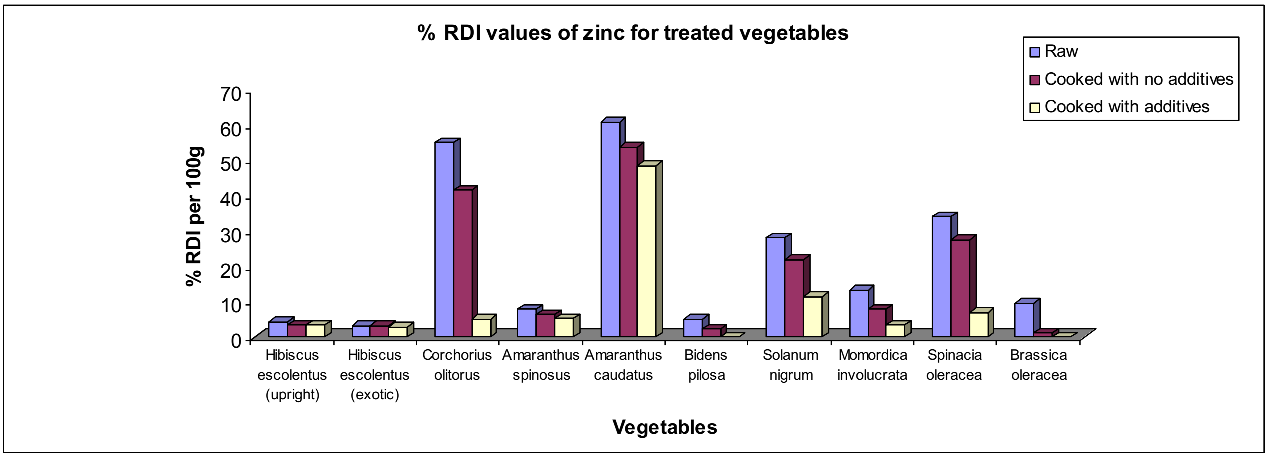

Figure 1: Percentage RDI values of zinc for treated vegetables

Figure 2 shows the % RDI values per 100g of calcium for the treated vegetables. The average RDA for calcium is 1,000 mg [7].

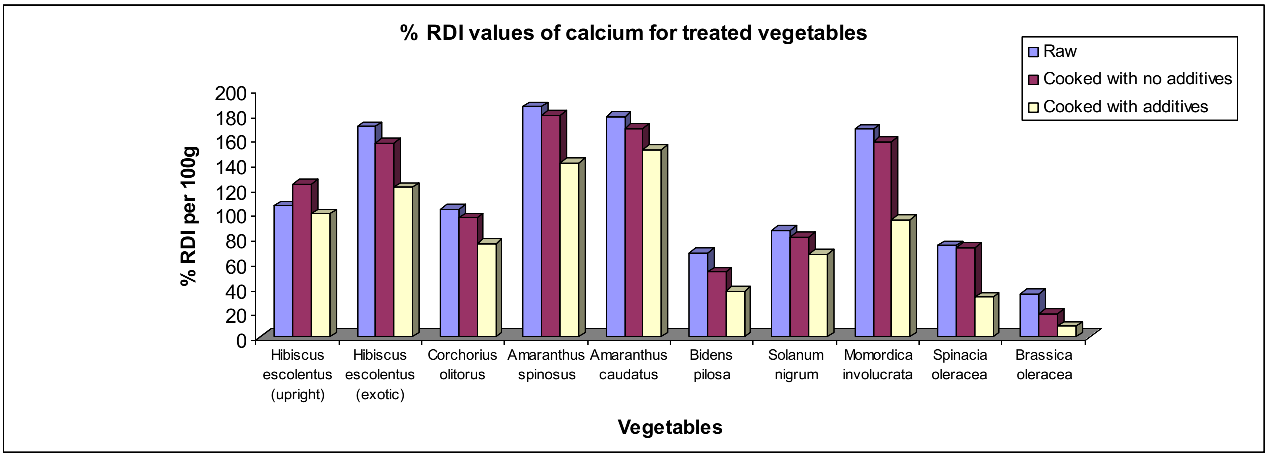

Figure 2: Percentage RDI values of calcium for treated vegetables

The calcium content of all the common vegetables studied was higher than those of exotic vegetables. This may be attributed to the cooking method for exotic vegetables that involved draining excess water through which calcium could have been lost.

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Figure 3 below shows the % RDI values of iron for the treated vegetables. The RDA for iron is 20 mg [8].

With the exception of *Amaranthus caudatus*, the results (Table 4) indicated that cooking caused significant ($p \leq 0.05$) difference in iron content in all the vegetables analysed. Analysis of variance data (Table 5) showed that the iron content in the ten vegetables for the three treatments were significantly ($p \leq 0.05$) different.

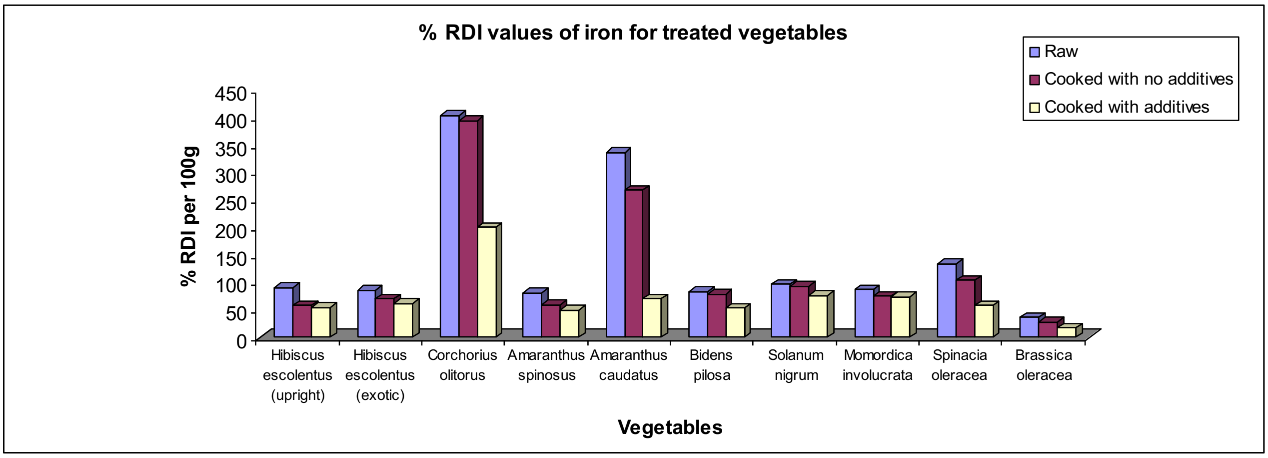

Figure 3: Percentage RDI values of iron for treated vegetables

Figure 4 shows the % RDI values per 100g of magnesium for the treated vegetables. The RDA for magnesium is 400 mg [7].

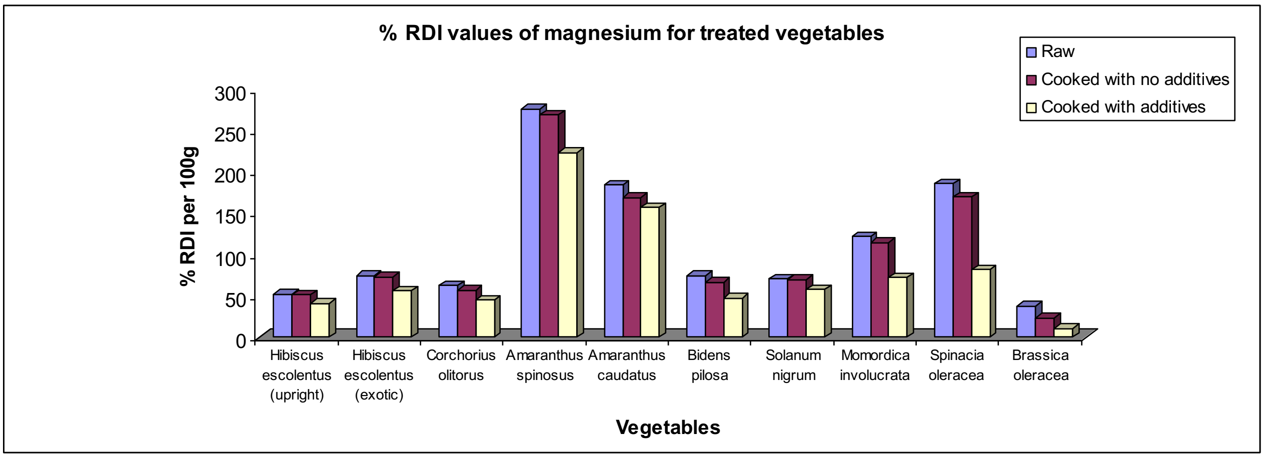

Figure 4: Percentage RDI values of magnesium for treated vegetables

With the exception of *Brassica oleracea*, the results (Table 4) showed that cooking caused significant ($p \leq 0.05$) difference in magnesium content in all the vegetables studied. The decrease in magnesium content may be due to leaching effect during the cooking process. Analysis of variance data (Table 5) indicated that the magnesium content in the ten vegetables for the three treatments were significantly ($p \leq 0.05$) different.

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Figure 5 below gives the % RDI values per 100g of manganese for the treated vegetables. The RDA for manganese is 3 mg [7].

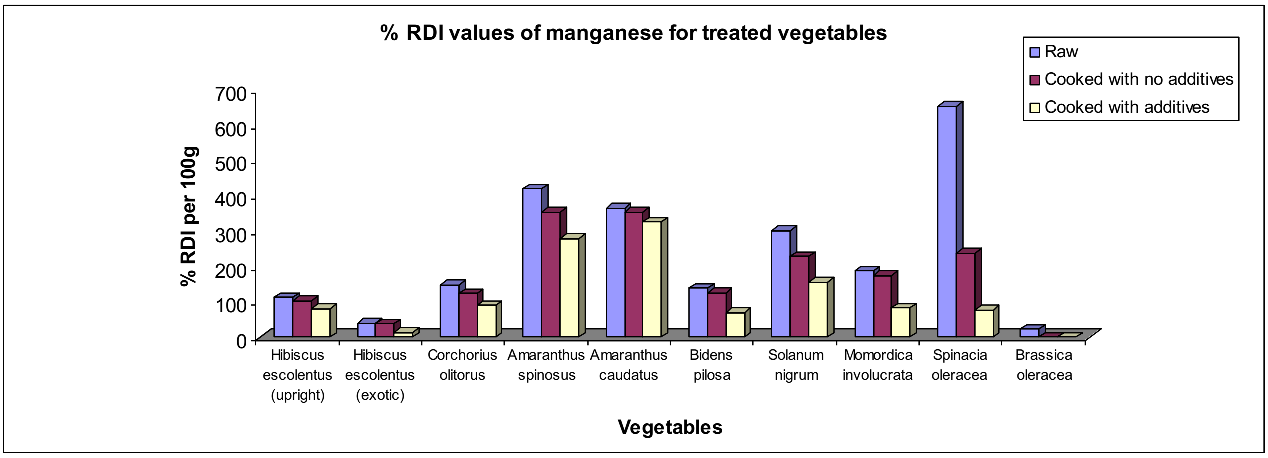

Figure 5: Percentage RDI values of manganese for treated vegetables

Data indicated that sample treatment caused significant ($p \leq 0.05$) difference in manganese content in *Hibiscus escolentus* (upright), *Corchorius olitorus*, *Amaranthus spinosus*, *Amaranthus caudatus*, *Bidens pilosa*, *Solanum nigrum* and *Momordica involucrata* while *Hibiscus escolentus* (exotic), *Spinacia oleracea* and *Brassica oleracea* did not vary significantly ($p \leq 0.05$). Analysis of variance data for the manganese content in the ten vegetables indicated that manganese content was significantly ($p \leq 0.05$) different in all the three treatments.

Figure 6 below indicates the % RDI values per 100g of potassium for the treated vegetables. The maximum RDA for magnesium is 5000 mg [7].

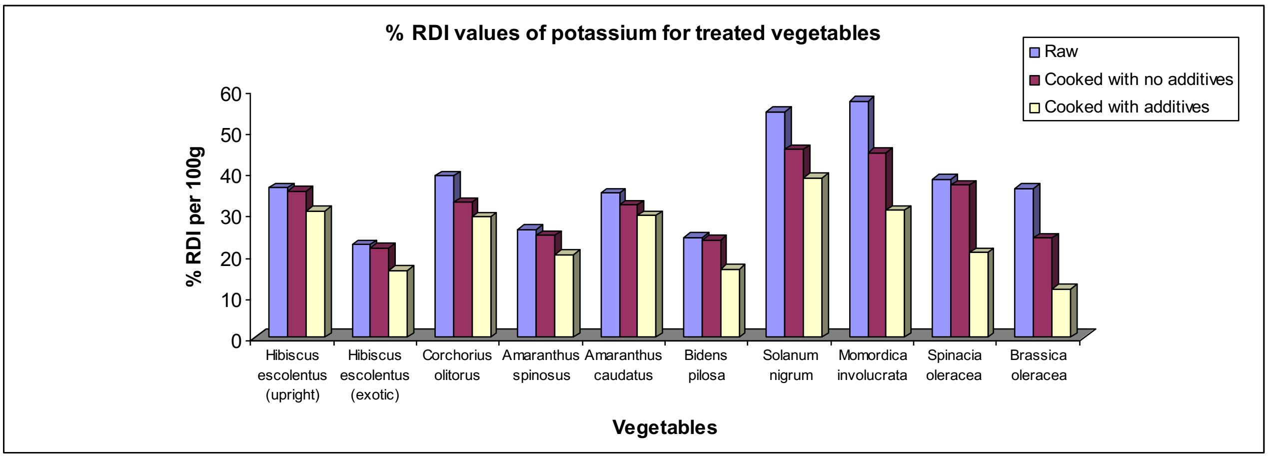

Figure 6: Percentage RDI values of potassium for treated vegetables

The results indicated that cooking caused significant ($p \leq 0.05$) difference in potassium content in all the vegetables analysed except *Brassica oleracea*. Analysis of variance for

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the potassium content showed that there was significant difference ($p \leq 0.05$) in potassium concentrations in the ten vegetables when analysed raw, cooked with no additives and cooked with additives.

Figure 7 shows the % RDI values per 100g of copper for the treated vegetables. The minimum RDA for copper is 1 mg [7].

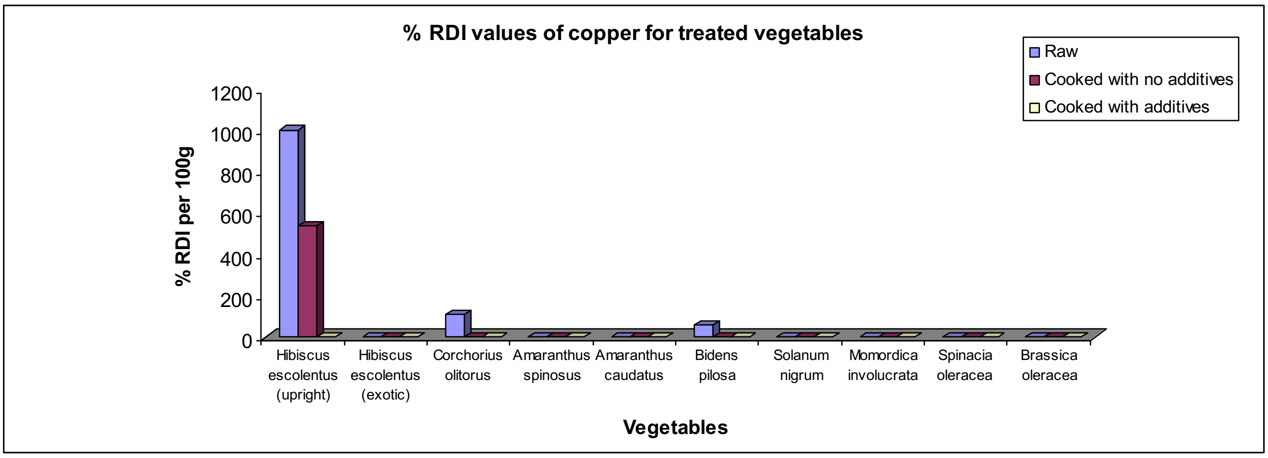

Figure 7: Percentage RDI values of copper for treated vegetables

The results showed that the majority of the vegetables gave unquantifiable amounts of copper that were below the detection limits of the instruments. The results also showed that cooking resulted in a 100% loss of copper in these vegetables.

DISCUSSION

It can be noted from Table 4 that the concentrations of the mineral elements vary significantly ($p \leq 0.05$) with treatments (raw, cooked with no additives and cooked with additives), with higher concentrations in the raw samples. Cooking involves interaction of vegetables with hot water which may rupture the cell wall and soluble minerals may leach out in the cooking medium. This leaching of the minerals may account for the loss in the cooked vegetables. In all cases the loss in mineral contents was amplified when vegetables were cooked with additives. This may be due to increased leaching and complexation occurring between the minerals and the additives thus further reducing the mineral content available.

It is clear from these data (Table 4 and Figure 1) that good sources of zinc in the raw form are *Amaranthus caudatus*, *Corchorius olitorus*, *Solanum nigrum* and *Momordica involucrata* with % RDI values of 60.8%, 55.1%, 28.1% and 13.4%, respectively. These % RDI values are comparable and better than those obtained from conventional vegetables *Spinacia oleracea* (34.1%) and *Brassica oleracea* (9.5%). Upon cooking without additives zinc losses ranged from 4.2 – 88.8% in *Hibiscus escolentus* (upright) and *Brassica oleracea*, respectively. Cooking with additives had the most adverse effect accounting for 12.5 – 100% losses of zinc in *Hibiscus escolentus* (upright) and *Brassica oleracea* or *Bidens pilosa*, respectively. Among the good sources of zinc the vegetable with minimal loss of this mineral when cooked with additives was *Amaranthus caudatus* (20.3%). Similarly, reductions in zinc content of *Amaranthus hybridus* and *Corchorius olitorus* when cooked has been reported earlier by Mepba *et al.* [9].

Data (Table 4) indicated that sample treatment caused significant ($p \leq 0.05$) difference in zinc content in *Hibiscus escolentus* (upright and exotic), *Amaranthus spinosus* and *Amaranthus caudatus* while *Corchorius olitorus*, *Bidens pilosa*, *Solanum nigrum*, *Momordica involucrata*, *Spinacia oleracea* and *Brassica oleracea* did not vary significantly ($p \leq 0.05$). Zinc content was one of the lowest in the vegetables when considered against an average requirement of 12 mg/day for women 15 mg/day for men [7]. Zinc deficiency in developing countries is becoming a growing concern because it has been shown that zinc deficiency is related not only to decreased growth but also increased morbidity. Studies [10] have shown zinc supplementation to be effective in reduction of morbidity associated with infants and children, possibly due to improved immune function.

Analysis of variance (Table 5) for the zinc content in the ten vegetables for the three treatments indicated that zinc was significantly ($p \leq 0.05$) different in raw and cooked with no additives treatments. However, it was not significant ($p \leq 0.05$) in the cooked with additives treatment implying higher concentration of this mineral in former two treatments than latter.

It is evident from the data (Table 4 and Figure 2) that the majority of the vegetables considered are excellent sources of calcium with *Amaranthus spinosus* having the highest concentration of 1859 mg/100g sample (% RDI of 185.9%), closely followed by *Amaranthus caudatus* with calcium content of 1782 mg/100g sample (% RDI of 178.2%) in their raw state. Bwembya *et al.* [2] also made similar observations that indigenous vegetables are good sources of calcium with *Amaranthus spinosus* having the highest content of 2683 mg/100g sample (% RDI of 268.3%). The % RDI values of common vegetables ranged from 68.1% in *Bidens pilosa* to 185.9% in *Amaranthus spinosus* while that of exotic vegetables ranged from 34.6 % in *Brassica oleracea* to 73.7% in *Spinacia oleracea*.

Cooking resulted in decreased amounts of calcium content which was magnified when additives were added. The losses in calcium ranged from 5.7% in *Hibiscus escolentus* (upright) to 75.6% in *Brassica oleracea*. However, despite the observed losses noted after cooking, the cooked common vegetables are still good sources of calcium with % RDI values ranging from 36.9% in *Bidens pilosa* to 151.6% in *Amaranthus caudatus* while values for exotic vegetables were 8.4% and 32.3% for *Brassica oleracea* and *Spinacia oleracia,* respectively. Among the good sources of calcium, the vegetables with minimal loss of this mineral when cooked with additives were upright *Hibiscus escolentus* (5.7%) and *Amaranthus caudatus* (15.0%). *Spinacia oleracea* and *Brassica oleracea* lost significant amounts of calcium ranging from 56.1% to 75.6% respectively. Similarly, reduction in calcium contents of *Chenopodium album* and *Trigonella foenum graecum* leaves cooked in an open pan and pressure cooker have been reported earlier by Sehgal and Yadav [11].

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Data (Table 4) indicated that cooking caused significant ($p \leq 0.05$) difference in calcium content in all the vegetables studied except *Brassica oleracea*. The results for calcium analysis of the common vegetables studied suggest consumption of 100g is sufficient to meet the Recommended Daily Allowance as reflected by high % RDI values.

Analysis of variance (Table 5) for the calcium content in the ten vegetables for the three treatments (raw, cooked with no additives and cooked with additives) showed that there was significant difference ($p \leq 0.05$) in calcium concentrations.

According to West's [3] classification, most of the vegetables studied in this research project are good sources of iron. *Corchorius olitorus* (80.7 mg/100g; % RDI = 403.4%) had the highest amount of iron followed by *Amaranthus caudatus* (67.1 mg/100g; % RDI = 335.4%) while *Brassica oleracea* had the lowest content (7.18 mg/100g; % RDI = 35.9%) in the raw form with only (3.35 mg/100g; % RDI = 16.8%) being available after cooking with additives. This observation is analogous to that made by Bwembya *et al.* [2] whose values in the raw state were (42.0 mg/100g; % RDI = 210%) and (76.0 mg/100g; % RDI = 380%) for *Corchorius olitorus* and *Amaranthus caudatus* respectively. Cooking resulted in a 20.5 to 79.2% decrease in iron content for *Amaranthus caudatus* while that for *Corchorius olitorus* was 2.4 to 50.5%. These iron content values after cooking can be considered adequate when viewed against the average RDA of 20 mg per day. Mepba *et al.* [9] also observed similar reductions in iron content of *Amaranthus hybridus* and *Corchorius olitorus* when cooked. However, despite the generally high iron content of these vegetables, one should acknowledge factors affecting absorption. Rather the bioavailability of iron present in a meal, which depends on its form and the presence or absence of factors that influence absorption and the body's need for iron ultimately determine how much iron that is actually delivered to the body. Latham [12] and Mannar [13] observed that oxalates, phytates and nitrates are compounds that are contained in some of these indigenous plants and affect the absorption of the micronutrients. Iron absorption is enhanced when the vegetable is a good source of vitamin C or when it is consumed with a vitamin C rich food or both.

Amaranthus spinosus (1107.5 mg/100g; % RDI = 276.9%) had the highest magnesium content when cooked. Other good sources of magnesium included *Amaranthus caudatus*, *Spinacia oleracea* and *Momordica involucrata* with values of 737.9, 744.4 and 488.6 mg/100g corresponding to % RDI values of 184.5%, 186.1% and 122.2%, respectively. Moderate concentrations (% RDI of 52.0%–74.4%) were recorded in other leafy vegetables while *Brassica oleracea* had the lowest content of 152 mg/100g (% RDI = 38%). Results from this study are in agreement with those obtained by Ndlovu and Afolayan [14] who found that *Corchorius olitorus* had significantly high concentration of magnesium than that of *Brassica oleracea*. Magnesium occurs abundantly in chloroplasts as a constituent of chlorophyll molecule. Cooking reduced the magnesium content in all the vegetables and only *Amaranthus spinosus* (895.1 mg/100g; % RDI = 223.8%) and *Amaranthus caudatus* (629.9 mg/100g; % RDI = 157.5%) retained sufficient levels to meet the Recommended Daily Allowance of 400 mg/day.

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The majority of vegetables in this study are good sources of manganese with values ranging from 3.39 mg/100g (% RDI = 113%) in *Hibiscus esolentus* (upright) to19.59 mg/100g (% RDI = 653%) in *Spinacia oleracea*. Low manganese contents of 1.21 mg/100g (% RDI = 40.3%) and 0.68 mg/100g (% RDI = 22.7%) were observed in *Hibiscus escolentus* (exotic) and *Brassica oleracea* respectively. Cooking resulted in significantly high level losses (18.2−88.2%). After cooking the vegetable with a high manganese concentration was *Amaranthus caudatus* (9.75 mg/100g; % RDI = 325.0%) while *Spinacia oleracea* despite being ranked top in the raw state had moderate manganese content of 2.31 mg/100g (% RDI = 77.0%) when cooked. *Brassica oleracea* lost all the available manganese during cooking.

The results indicated that the vegetables investigated are moderate sources of potassium with values ranging from 1124.7 mg/100g (% RDI = 22.5%) to 2861.0 mg/100g (% RDI = 57.2%) in the raw form for *Hibiscus escolentus* (exotic) and *Momordica involucrate,* respectively. Cooking reduced the potassium content with highest value being observed in *Solanum nigrum* (1930.0 mg/100g; % RDI = 38.6%) and the lowest in B*rassica oleracea* (587.0 mg/100g; % RDI = 11.7%). These results are in accord to those in literature [9] who observed low potassium content in A*maranthus hybridus* and *Corchorius olitorus* which were further reduced upon cooking. The results for potassium analysis of the vegetables suggest consumption of small quantities to meet the minimum Recommended Daily Allowance (RDA). For instance, the minimum potassium requirement for adults is 2,000 mg daily. It would require up to 1.0 mg/100g of cooked *Solanum nigrum* to meet the RDA. Potassium is a primary electrolyte and a major cation inside the cell and low blood potassium is a life threatening problem [15].

Results for determination of copper levels showed that only *Hibiscus escolentus* (upright), *Corchorius olitorus* and *Bidens pilosa* gave 10.05 mg/100g (% RDI = 1005.0%), 1.10 mg/100g (% RDI = 110.0%) and 0.57 mg/100g (% RDI = 57.0%) when analysed raw. Cooking resulted in a 100% loss of copper in these vegetables. The low content of copper in leafy vegetables suggests a low intake by vegetarians that must seek alternative sources to meet their needs for this mineral.

CONCLUSION

It is evident from the data collected from this study that common Swazi vegetables are good sources of zinc, calcium, iron, magnesium, manganese and potassium and can be used as a cheaper and better alternative to the exotic vegetables such as *Brassica oleracea* obtainable in town outlets. The mineral contents of the vegetables vary with processing treatments (raw, cooking with no additives and cooking with additives) with significantly ($p \leq 0.05$) higher concentrations in raw vegetables. Cooking caused significant ($p \leq 0.05$) reductions in the calcium, iron, magnesium, manganese and potassium contents of *Hibiscus escolentus* (upright), *Corchorius olitorus*, *Amaranthus spinosus, Bidens pilosa*, *Solanum nigrum* and *Momordica involucrata*. Addition of additives when cooking leads to further loss of minerals. In view of the popularity of the Swazi vegetables among the Swazis irrespective of class, gender or age, it is recommended that future research focuses on educating the Swazi population on good cooking practices that avoid draining

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excess water and be encouraged to use fewer additives in order to minimise micronutrients losses. In addition, bioavailability studies should be carried out in order to determine the total nutrient content contained in the commonly consumed Swazi vegetables that is available at the cellular level.

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Table 1: Recommended Daily Intake of Minerals

Mineral	Zn	Ca	Fe	Mg	Mn	K	Cu
(unit)	(mg)	(g)	(mg)	(mg)	(mg)	(g)	(mg)
Female	12	0.8–1.2	15	280	2–5	2–6	1–3.0
Male	15	0.8–1.2	10	350	2–5	2–6	1–3.0

Source: [7]

Table 2: Vegetable samples analysed

siSwati Name	English Name	Botanical Name	Sampling Area
1. Ligusha (Upright)	Okra leaves	*Hibiscus escolentus*	UNISWA Farm, Luyengo Campus
2. Ligusha (Exotic)	Okra leaves	*Hibiscus escolentus*	UNISWA Farm, Mafutseni
3. Ligusha (Indigenous)	Bush okra	*Corchorius olitorus*	Manzini Market
4. Imbuya	Tassel flower	*Amaranthus spinosus*	UNISWA Farm, Mafutseni
5. Imbuya bathwa	Tassel flower	*Amaranthus caudatus*	Luyengo
6. Chuchuza	Blackjack	*Bidens pilosa*	UNISWA Farm, Luyengo Campus
7. Umsobo	Black nightshade	*Solanum nigrum*	Chinese Farm, Matsapha
8. Inkhakha	Bitter gourd	*Momordica involucrata*	Manzini Market

Table 3: Common vegetables analysed for comparison purposes

siSwati Name	English Name	Botanical Name	Sampling Area
1. Liklabishi	Cabbage	*Brassica oleracea*	Mahlanya Market
2. Sipinatji	Spinach	*Spinacia oleracea*	Mahlanya Market

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Table 4: Effect of cooking on minerals* contents of selected common Swazi vegetables

	Composition in mg/100 g						
Treatments	**Zn**	**Ca**	**Fe**	**Mg**	**Mn**	**K**	**Cu**
				Ligusha Upright (*Hibiscus escolentus*)			
Raw	0.66±0.02	1057.00±12.10	18.11±0.18	208.10±4.39	3.39±0.04	1808.00±18.40	10.05±0.28
Cooked with no additives	0.49±0.01 (25.7)	1234.00±17.70 (−16.7)	11.47±0.10 (36.7)	205.60±5.04 (1.2)	3.10±0.03 (8.6)	1773.00±23.90 (1.9)	5.39±0.16 (46.4)
Cooked with additives	0.50±0.05 (24.2)	996.80±24.80 (5.7)	10.87±0.65 (40.0)	162.65±5.48 (21.8)	2.41±0.07 (28.9)	1531.50±36.00 (15.3)	<0.0005 (100.0)
Significant ($p \leq 0.05$)	Yes	Yes	Yes	Yes	Yes	Yes	No
				Ligusha Exotic (*Hibiscus escolentus*)			
Raw	0.48±0.01	1699.00±4.90	16.98±0.23	297.60±3.82	1.21±0.03	1124.70±2.45	<0.0005
Cooked with no additives	0.46±0.04 (4.2)	1564.00±15.30 (7.9)	13.98±0.21 (17.7)	292.40±5.07 (1.7)	1.13±0.04 (6.6)	1086.00±11.50 (3.4)	<0.0005 N/A
Cooked with additives	0.42±0.03 (12.5)	1208.00±32.45 (28.9)	12.24±0.26 (27.9)	223.45±4.29 (24.9)	0.37±0.05 (69.4)	814.95±14.92 (27.5)	<0.0005 N/A
Significant ($p \leq 0.05$)	Yes	Yes	Yes	Yes	No	Yes	N/A

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Table 4 Continued

Treatments	Composition in mg/100 g						
	Zn	**Ca**	**Fe**	**Mg**	**Mn**	**K**	**Cu**
	Ligusha Indigenous (*Corchorius olitorus*)						
Raw	8.27±0.11	1030.60±1.12	80.67±0.64	249.80±0.42	4.43±0.05	1957.20±1.68	1.10±0.04
Cooked with no additives	6.23±0.19 (24.7)	962.00±9.86 (6.7)	78.75±1.04 (2.4)	227.40±0.62 (9.0)	3.69±0.07 (16.7)	1635.00±15.00 (16.5)	<0.0005 (100.0)
Cooked with additives	0.75±0.03 (90.9)	752.20±14.50 (27.0)	39.95±0.52 (50.5)	180.80±3.79 (27.6)	2.71±0.06 (38.8)	1460.50±26.70 (25.4)	<0.0005 (100.0)
Significant ($p \leq 0.05$)	No	Yes	Yes	Yes	Yes	Yes	No
	Imbuya (*Amaranthus spinosus*)						
Raw	1.17±0.12	1858.57±11.56	16.23±0.14	1107.47±0.06	12.57±1.56	1306.63±7.72	<0.0005
Cooked with no additives	0.94±0.42 (19.7)	1794.33±230.29 (3.5)	11.87±2.75 (26.9)	1077.87±147.93 (2.9)	10.63±1.54 (15.4)	1234.33±157.67 (5.5)	<0.0005 N/A
Cooked with additives	0.79±0.34 (32.5)	1406.00±49.54 (24.4)	9.94±1.33 (38.8)	895.10±52.03 (19.2)	8.34±0.50 (33.7)	1002.52±48.37 (23.3)	<0.0005 N/A
Significant ($p \leq 0.05$)	Yes	Yes	Yes	Yes	Yes	Yes	N/A

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Table 4 Continued

Treatments	Composition in mg/100 g						
	Zn	Ca	Fe	Mg	Mn	K	Cu
			Imbuya bathwa (*Amaranthus caudatus*)				
Raw	9.12±0.04	1782.00±19.30	67.07±0.43	737.90±9.96	10.92±0.20	1752.00±19.00	<0.0005
Cooked with no additives	8.06±0.32 (11.6)	1686.00±29.90 (5.4)	53.35±0.29 (20.5)	676.50±5.94 (8.3)	10.60±0.42 (11.1)	1607.00±25.60 (8.3)	<0.0005 N/A
Cooked with additives	7.27±0.06 (20.3)	1515.50±17.10 (15.0)	13.93±0.38 (79.2)	629.90±6.17 (14.6)	9.75±0.10 (18.2)	1474.50±16.20 (15.8)	<0.0005 N/A
Significant ($p \leq 0.05$)	Yes	Yes	No	Yes	Yes	Yes	N/A
			Chuchuza (*Bidens pilosa*)				
Raw	0.76±0.01	680.77±3.34	16.62±0.07	297.47±2.64	4.18±0.01	1210.20±6.65	0.57±0.02
Cooked with no additives	0.34±0.08 (55.3)	525.67±4.03 (22.8)	15.78±0.54 (5.1)	265.23±10.83 (10.8)	3.79±0.02 (9.3)	1178.33±55.72 (2.6)	<0.0005 (100.0)
Cooked with additives	<0.0005 (100.0)	369.00±16.55 (45.8)	10.62±0.82 (36.1)	190.15±7.35 (36.1)	2.05±0.26 (51.0)	824.38±34.21 (13.9)	<0.0005 N/A
Significant ($p \leq 0.05$)	No	Yes	Yes	Yes	Yes	Yes	No

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Table 4 Continued

	Composition in mg/100 g						
Treatments	**Zn**	**Ca**	**Fe**	**Mg**	**Mn**	**K**	**Cu**
			Umsobo (*Solanum nigrum*)				
Raw	4.22±0.02	863.00±8.69	19.31±0.15	282.10±4.87	9.02±0.04	2684.00±24.90	<0.0005
Cooked with	3.29±0.05	809.30±4.48	18.49±0.09	277.90±5.58	6.86±0.05	2282.00±9.20	<0.0005
no additives	(22.0)	(6.2)	(4.2)	(1.5)	(23.9)	(15.0)	N/A
Cooked with	1.71±0.10	668.80±11.89	15.25±0.46	231.65±1.08	4.69±0.18	1930.00±31.80	<0.0005
additives	(59.5)	(22.5)	(21.0)	(17.9)	(48.0)	(28.1)	N/A
Significant ($p \leq 0.05$)	No	Yes	Yes	Yes	Yes	Yes	N/A
			Inkhakha (*Momordica involucrata*)				
Raw	2.01±0.06	1679.00±13.00	17.41±0.35	488.63±4.36	5.61±0.10	2861.00±12.90	<0.0005
Cooked with	1.17±0.56	1575.00±221.72	14.99±01.20	457.10±66.58	5.23±1.07	2237.33±324.90	<0.0005
no additives	(41.8)	(6.2)	(13.9)	(6.5)	(6.8)	(21.8)	N/A
Cooked with	0.51±0.15	944.28±59.67	14.78±5.08	289.37±23.49	2.49±0.62	1539.83±97.20	<0.0005
additives	(74.6)	(43.8)	(15.1)	(40.8)	(55.6)	(46.2)	N/A
Significant ($p \leq 0.05$)	No	Yes	Yes	Yes	Yes	Yes	N/A

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Table 4 Continued

Treatments	Composition in mg/100 g						
	Zn	**Ca**	**Fe**	**Mg**	**Mn**	**K**	**Cu**
			Sipinatji (*Spinacia oleracea*)*				
Raw	5.12±0.02	736.90±1.84	26.57±0.02	744.40±11.72	19.59±0.01	1916.00±20.27	<0.0005
Cooked with	4.14±0.06	722.30±4.24	20.75±0.13	679.20±4.83	7.14±0.06	1844.00±7.70	<0.0005
no additives	(19.1)	(2.0)	(21.9)	(8.8)	(63.6)	(3.8)	N/A
Cooked with	1.04±0.04	323.30±6.86	11.60±0.21	327.50±2.41	2.31±0.07	1030.50±15.80	<0.0005
additives	(79.7)	(56.1)	(56.0)	(56.0)	(88.2)	(46.2)	N/A
Significant ($p \leq 0.05$)	No	Yes	Yes	Yes	No	Yes	N/A
			Liklabishi (*Brassica oleracea*)*				
Raw	1.43±0.01	346.20±0.78	7.18±0.11	152.00±2.10	0.68±0.03	1804.00±8.20	<0.0005
Cooked with	0.16±0.01	188.30±1.85	5.52±0.04	91.58±1.38	<0.0005	1205.00±10.60	<0.0005
no additives	(88.8)	(45.6)	(23.1)	(39.8)	(100.0)	(33.2)	N/A
Cooked with	<0.0005	84.42±0.95	3.35±0.05	40.81±1.11	<0.0005	586.95±6.54	<0.0005
additives	(100.0)	(75.6)	(53.3)	(73.2)	(100.0)	(67.5)	N/A
Significant ($p \leq 0.05$)	No	No	Yes	No	No	No	N/A

Values are means of triplicate determinations ± standard deviations (SD). * Refers to common vegetables for comparison purposes. Data in parentheses are percentage losses of minerals for the respective treatments. N/A – Not applicable

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Table 5: Analysis of variance for minerals contents in the ten different treated vegetables

Description	Zn			Ca			Fe			Mg			Mn			K			Cu		
	Raw	CNA	CA	Raw	CNA	CA	Raw	CNA	CA	Raw	CNA	CA	Raw	CNA	CA	Raw	CNA	CA	Raw	CNA	CA
No. of values	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Minimum	0.48	0.16	0.00	346.2	188.3	84.42	7.18	5.52	3.35	152.0	91.58	40.81	0.68	0.00	0.00	1125	1086	587	0.001	0.001	0.001
25% Percentile	0.73	0.43	0.31	722.9	673.1	357.6	16.52	11.77	10.45	239.4	222.0	176.3	2.85	2.61	1.63	1283	1198	822	0.001	0.001	0.001
Median	1.72	1.06	0.63	1044	1098	848.2	17.76	15.38	11.92	297.5	285.2	227.6	5.02	4.51	2.45	1806	1621	1246	0.001	0.001	0.001
75% Percentile	5.91	4.66	1.20	1720	1603	1258	36.7	28.9	14.9	739.5	677.2	403.1	12.08	8.01	5.60	2139	1942	1534	0.703	0.001	0.001
Maximum	9.12	8.06	7.27	1859	1794	1516	80.67	78.75	39.95	1107	1078	895.1	19.59	10.63	9.75	2861	2282	1930	10.05	5.39	0.001
Mean	3.32	2.53	1.30	1173	1106	826.8	28.62	24.49	14.25	456.5	425.1	317.1	7.26	5.22	3.51	1842	1608	1220	1.172	0.540	0.001
Std Deviation	3.23	2.80	2.16	539.5	546.8	476.4	24.51	23.08	9.63	310.0	301.5	254.7	5.96	3.61	3.20	575.1	433.7	425.6	3.141	1.704	0.000
Std Error	1.02	0.89	0.68	170.6	172.9	150.6	7.75	7.30	3.05	98.03	95.35	80.54	1.89	1.14	1.01	181.9	137.2	134.6	0.993	0.539	0.000
Lower 95% Cl of mean	1.01	0.52	–0.24	787.4	714.9	486	11.08	7.99	7.36	234.8	209.4	134.9	2.99	2.63	1.22	1431	1298	915.1	–1.08	–0.68	0.001
Upper 95% Cl of mean	5.63	4.53	2.84	1559	1497	1168	46.15	41.00	21.14	678.3	640.8	499.3	11.53	7.80	5.80	2254	1918	1524	3.419	1.759	0.001
t value	3.26	2.85	1.90	6.88	6.40	5.49	3.69	3.36	4.68	4.66	4.46	3.94	3.85	4.57	3.47	10.13	11.73	9.06	1.180	1.001	N/A
P value	0.01	0.02	0.09	0.000	0.000	0.000	0.005	0.008	0.001	0.001	0.002	0.003	0.004	0.001	0.007	0.000	0.000	0.000	0.268	0.343	N/A
Significant ($p \leq 0.05$)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	N/A

CAN – Cooked with no additives

CA – Cooked with additives

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