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Changes in some nutritional components of *Vigna racemosa* as influenced by hydrothermal processing techniques

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Abstract

Vigna racemosa is an underutilised hard-to-cook legume in Southwest Nigeria. The seed of *V. racemosa* was subjected to varying degrees of hydration levels (0%, 10%, 25%, 50% 75% and 100%) before treatment with four hydrothermal techniques, atmospheric boiling, atmospheric steaming, pressure boiling and pressure steaming. The highest percentage reduction of 65.56% in cooking time was achieved at a 100% hydration level when the seeds were processed by boiling at elevated pressure. All the hydrothermal techniques had a significant effect ($p<0.05$) on the protein content of the seeds. Hydration of the seeds to 100% followed by boiling at elevated pressure caused the least reduction in the protein and mineral element contents. The seed is a good source of important nutrients that are not degraded beyond the levels necessary to meet physiological needs after processing. Widening the scope of utilisation of this legume seed will make critically important nutrients such as protein more available for the teeming populations in developing countries at affordable prices, and thus, alleviating the problem of protein-energy malnutrition (PEM).

1. Introduction

Human consumption of legumes has been on the increase in many countries of the world particularly in developing countries since the seeds are a good source of nutritional important nutrients. One of the most valuable and practical ways of tackling the problems of protein deficiency is the continued search for and utilisation of protein-rich plants such as legume seeds since the seeds are recognised to be good sources of plant protein (Ojo and Ade-Omowaye, 2015). In the tropics, some legumes are commercially utilised as food crops while some others are lesser-known, underutilised or neglected (Fasoyiro *et al.*, 2012). There are many species of underutilised legumes grown in the tropics. Some of these legumes include *Mallotus subulatus, Canavalia ensiformis, Sphenostylis sterocarpa, Cassia hirsutta, Vigna subterranean* and *Vigna racemosa.* They are cultivated by pleasant farmers for subsistent purposes and are thus brought out for use mostly during the dry season when other crops are out of stock (Ojo *et al.*, 2017a).

The problem of hunger and malnutrition are major challenges facing the world population today. Overdependence on the use of common legumes results in hyke in price. Underutilised legumes that can be used to overcome the problem of protein-energy malnutrition have limitations in their utilisability. Legumes contain antinutritional factors such as tannin, saponin, heamaglutinin, cyanogenic glycoside, phytic acid etc. These antinutritional components must be inactivated and/ or reduced if their value is to be realised because they interfere with normal digestive processes and prevent efficient utilisation of nutrients (Reddy and Sathe, 2002; Sathya and Siddhuraju, 2015; Ojo *et al.*, 2018). Moreover, some of these underutilised legumes are hard-to-cook (Ojo *et al.,* 2017a). In addition to protein, legume seeds contain other nutrients such as fat, fibre, mineral elements and carbohydrates in varying proportions. With the exception of *Glycine max* and *Arachea hypogea*, legumes are not good sources of oil. Regular consumption of legume seeds reduces the incidences of cancer and cardiovascular diseases (Gordon, 1999; Lewis *et al.*, 2005; Ojo, 2018).

Vigna racemosa is an underutilised hard-to-cook legume grown in South-West Nigeria. In an earlier study, the effects of soaking and hydrothermal techniques on the antinutritional components and *in vitro* multi enzymes protein digestibility of *V. racemosa* have been reported. The nutrients and the antinutrient components of *V. racemosa* have also been reported (Ojo *et al.,* 2017b). However, there is a dearth of information on the

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effect of hydrothermal processing techniques on the mineral and proximate components of *V. racemosa*. Therefore, the study is aimed at determining the effects of soaking followed by hydrothermal processing on the proximate and mineral element status of *V. racemosa*. Provision of resultant information, it is hoped, will widen the scope of utilisation and thus alleviate the problems of PEM and food insecurity in developing nations. The future thrust of this work is on the use of *V. racemosa* for the preparation of local dishes such as *moinmoin* (steamed cake), *gbegiri* (bean soup) and *akara* (fried cake): it is believed that widening the scope of its utilisation will create dietary diversity and healthy eating habits.

2. Material and methods

2.1 Sample and preparation

The seeds of *V. racemosa* (Figure 1) were purchased from a local market in Ago-Are (8.67˚N, 3.40˚E), Atisbo Local Government Area of Oyo State, Nigeria. The seeds were winnowed to remove foreign and unwanted materials such as stones, stalks, immature and broken seeds. They were then packaged in a labelled plastic container. Some seeds were ground in a plate mill (Model No. 1A, Nulux Grinding Mill, India). The milled flour sample was packaged in an airtight polyethylene bag, labelled and kept at ambient temperature (25±3˚C) prior to subsequent analysis.

Figure 1. *Vigna racemosa* (*Gbomagungi*)

2.2 Soaking of the legume seed

The legume seeds were soaked in distilled water and the hydration level was determined (Ojo, 2018). About 500 g of the legume seeds were dry cleaned and soaked in 2,500 cm^3 of distilled water in a glass beaker at ambient temperature (25±3˚C) for up to 24 hrs. Change in the moisture content (water absorption) of the seeds during soaking was measured every hour for the first 0-6 hrs and thereafter every 2 hrs. At the time appointed, the seeds were removed from the water and blotted with a women napkin to remove excess water before weighing and returning into the soaking water. The moisture content of the soaked seeds was calculated. Moreover, the water absorption curve was plotted. The curve showed the kinetic increase of the moisture content of the seeds with time. The plateau phase of the water absorption curve was defined as a 100% hydration level. Hydration levels were calculated through a polynomial equation of the water absorption curve. Subsequently, the method described below was used for the boiling and steaming experiments.

2.3 Boiling at atmospheric pressure (BAP)

The legume seeds (500 g) were boiled in water in a domestic cooking vessel (Tower Aluminium, Lagos, Nigeria) at atmospheric pressure. Determination of cooking time for the atmospheric boiling of the seeds was conducted by the tactile method in which the cooked seed was squeezed between the forefinger and thumb with moderate pressure (Ojo *et al*., 2018). A seed was considered cooked when it could be squeezed by finger easily. Cooking time was defined as the time duration, in minutes, of at least 90% of the seeds subjected to cooking. After boiling treatments, the seeds and the cooking water were cooled in a plastic container. Subsequently, the cooked seeds and cooking water were dried in a cabinet drier (SM 9053, Uniscope Inc., Chard, Somerset, UK) at 45–50°C. The dried sample was stored in a plastic container prior to analysis.

2.4 Boiling at elevated pressure (BEP)

Pressure boiling was performed using a domestic pressure cooker (Binatone PC-5001, Binatone Lifestyle, Lagos, Nigeria) at about 80±8 KPa. Fivefold distilled water was added to the legume seeds (500 g) as described under atmospheric boiling in a glass flask, which was covered with aluminium foil. The content of the flask was brought to boiling on a hot plate. The seeds in boiling water were placed in a pre-heated pressure cooker with 2,500 cm^3 of boiling water, and the lid was locked in place. The cooking time was counted from when steam began to spurt out from the pressure lid. Cooking time was determined by the tactile method (Ojo *et al*., 2018). When the seeds have been boiled under pressure, the cooker was then removed from the heat source and the pressure released. Boiling water and the boiled seeds were cooled to room temperature and dried at 45-50°C in a cabinet drier (SM 9053, Uniscope Inc., Chard, Somerset, UK). The dried sample was then stored in a plastic container before analysis.

2.5 Steaming at atmospheric pressure (SAP)

Steaming was carried out at normal atmospheric pressure in a steam cooker (Binatone PC-5001, Binatone Lifestyle). The legume seeds (500 g by weight) were placed on a tray in the steam cooker covered with a lid and were steamed over 2,500 cm^3 of boiling water. Steaming time was determined by the tactile method

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(Ojo *et al.*, 2018). After the steaming process, the seeds were cooled and dried at 45-50°C in a cabinet drier (SM 9053, Uniscope Inc., Chard, Somerset, UK). The dried sample was then stored in a plastic container before analysis.

2.6 Steaming at elevated pressure (SEP)

Steaming under pressure was performed using a pressure cooker (Binatone PC-5001, Binatone Lifestyle) at about 80±8 KPa. The legume seeds (500 g by weight) were placed on a tray in a pressure cooker and steamed over boiling water at high pressure (80±8 KPa). Steamed seeds were placed in a plastic container, cooled and then dried at 45-50°C in a cabinet drier (SM 9053, Uniscope Inc., Chard, Somerset, UK). The dried sample was stored in a plastic container before analysis.

2.7 Determination of proximate composition

The raw and the processed samples were analysed for the proximate constituents. The moisture content was determined using air-oven (SM9053, Uniscope, UK). At 105˚C. Total ash content was determined at 550˚C with a muffle furnace (Carbolite 301). Analysis was carried out for crude fibre by treating the sample with concentrated tetraoxo sulphate vi acid, sodium hydroxide and petroleum ether (40˚C). Extraction of the crude oil content was done with petroleum ether (40˚C) using the Soxhlet apparatus. The protein content was determined using the macro Kjeldahl method (N × 6.25). The total carbohydrate was estimated by difference (AOAC., 2010).

2.8 Determination of mineral elements

Mineral elements of the seeds of *V. racemosa* were determined before and after hydrothermal processing using atomic absorption spectrophotometer, Buck 205 (Joslyn, 1970; A.O.A.C, 2010). These mineral elements were Potassium (K), Calcium (Ca), Magnesium (Mg), Zinc (Zn), Sodium (Na), Phosphorus (P) and Iron (Fe). The milled sample was weighed and ashed properly in a muffle furnace (Carbolite 3000) at 550˚C. The ash was dissolved in 100 cm^3 solution of HCl (10% v/v) which was subsequently used in the mineral content determination. Resonance line radiation of each element was supplied by the hollow cathode lamp. Standard calibrations were employed in the analysis.

2.9 Statistical analysis

Data obtained in three replicates were subjected to one-way analysis of variance (ANOVA) using a statistical package for social science (SPSS, 2005) to determine the significant differences among the means at $p<0.05$. The means were separated using Duncan's multiple range test.

3. Results and discussion

3.1 Effect of hydrothermal techniques on cooking times of Vigna racemosa

The water absorption curve for *V. racemosa* is presented in Figure 2 while Table 1 shows the effect of soaking at varying hydration levels followed by hydrothermal processing on cooking times of *V. racemosa.* The curve gives the indication of hydration levels attainable for the legume seeds over twenty-four hours. The corresponding volume of water required for each processing operation is also shown in Table 1. In general, the volume of water used for each cooking operation decreases with an increase in hydration level. The raw seed of the legume took 180 mins to cook by boiling at atmospheric pressure. The longer length of time of 238 mins was recorded for the cooking by steaming the raw seeds at elevated pressure. However, a decrease of 51.11% was recorded when the raw seeds were boiled at elevated pressure. At higher hydration levels of 50% and 75%, boiling at elevated pressure caused 57.22% and 58.33% reduction of cooking times, respectively. The highest percentage reduction in cooking times was recorded at 100% hydration level when the seeds were boiled at elevated pressure. For each of the hydrothermal techniques, boiling, especially at elevated pressure, appeared to have a comparative advantage when cooking time is of importance during processing. Boiling at higher pressure has been reported to cause a reduction in cooking time (Ojo *et al.,* 2017b). This is because the increase in pressure causes an increase in temperature. If the temperature is increased, foods get cook faster (Kivosto *et al.,* 2006; Ojo *et al.,* 2017b).

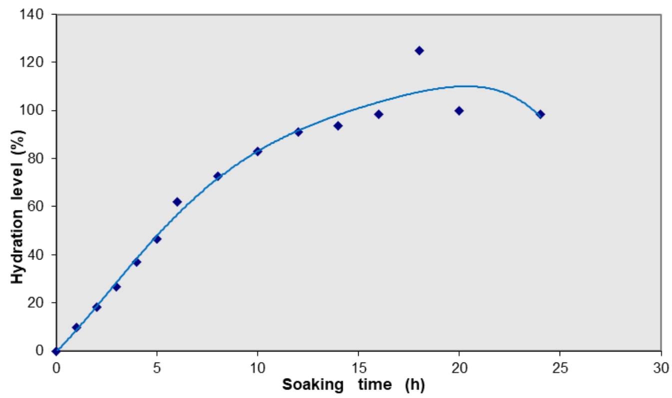

Figure 2. Water absorption curve for *Vigna racemosa* (*Gbomagungi*)

3.2 Proximate components of V. racemosa as influenced by hydrothermal techniques

The effects of hydrothermal processing techniques

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Table 1. Effect of soaking at varying hydration levels followed by hydrothermal processing on cooking times of *Vigna racemosa*

Hydration level	Volume of H_2O used (cm^3)				Cooking time (min)			
	BAP	SAP	BEP	SEP	BAP	SAP	BEP	SEP
0%	3250±7.07^c	4200±14.14^d {22.62}*	1500±0.00^a {53.85}	1850±14.12^b {43.08}	180±0.00^c	238±3.00^d {24.37}*	88±1.00^a {51.11}	110±2.00^b {38.89}
10%	3250±70.60^c {0.00}	4200±0.00^d {22.62}*	1500±0.00^a {53.85}	1850±70.10^b {43.08}	180±0.00^c {0.00}	238±1.41^d {24.37}*	88±1.41^a {51.11}	110±0.00^b {38.89}
25%	3250±42.64^c {0.00}	4150±14.14^d {21.69}*	1430±70.07^a {56.00}	1760±70.07^b {45.85}	180±2.12^c {0.00}	230±1.41^d {21.74}*	83±1.41^a {53.89}	101±0.71^b {43.89}
50%	3000±0.00^c {7.69}	3800±0.00^d {14.47}*	1400±70.71^a {56.92}	1700±14.14^b {47.69}	175±0.00^c {2.78}	230±0.00^d {21.74}	77±0.00^a {57.22}	94±1.41^b {47.78}
75%	3000±91.92^c {7.69}	3680±56.57^d {11.68}*	1400±0.00^a {56.92}	1700±21.21^b {47.69}	175±0.00^c {2.78}	209±2.12^d {13.88}	75±0.00^a {58.33}	90±0.00^b {50.00}
100%	2550±21.21^c {21.54}	3200±14.42^d {1.54}	1000±0.00^a {69.23}	1280±14.14^b {60.62}	160±0.00^c {11.11}	154±2.12^d {14.44}	62±1.41^a {65.56}	75±1.41^b {58.33}

Values are means±standard deviation (n = 3) on dry basis. Values with different superscripts within the same row are significantly different (p<0.05). Values in parenthesis represent percentage reduction. Values with * represent percentage increase.

BAP = boiling at normal atmospheric pressure; SAP = steaming at normal atmospheric pressure; BEP = boiling at elevated pressure; SEP = steaming at elevated pressure.

on the proximate components of *V. racemosa* at 0% hydration level (i.e., before processing) are shown in Figure 3A while Figure 3B-3F show the effects of varying hydration levels, ranging from 10-100%, followed by hydrothermal processing on the proximate components of the seeds of *V. racemosa.* All the hydrothermal techniques employed had significant effects (p<0.05) on the proximate composition of the legume. As presented in Figure 3A, the crude protein content of the raw seeds was 21.30%. Boiling of the seeds, without soaking at atmospheric pressure reduced the protein content by 9.48 and 9.53%, respectively. At 10% hydration level, the percentage reduction in protein content ranged from 9.48% for boiling at elevated pressure to 12.86% for boiling at normal atmospheric pressure. All the hydrothermal techniques have a significant (p<0.05) effect on the protein content of the legume seeds. A decrease in protein content as recorded for *V. racemosa* during hydrothermal processing agrees with an earlier study on *Canavalia ensiformis* when hydrothermal processing resulted in varying decreases in protein content of the seeds (Ojo *et al*., 2018). Also, boiling of *Albazzia lebbeck* seeds for 15, 30, 60 mins reduced the crude protein content by 36.88, 35.90 and 33.88% (Abdullahi, Silas and Anwa, 2007).

The reduction of protein during hydrothermal processing was partly caused by leaching. Soaking and/ or boiling predisposes soluble contents of protein to leach (Fagbemi, 2007; Ojo, 2015). Moreover, reduction of protein could also be attributed to probable denaturation caused by unzipping of the hydrophobic forces which results in partial disruption of the primary structure of protein molecules. Unlike boiling, toasting or steaming, fermentation and germination have been reported to cause an increase in protein content (Kyler and Mcready, 2005; Ojo *et al*., 2018). The oil content of the seed before and after hydrothermal processing is low. Hence, the seed cannot be described as an oil-bearing seed.

The hydrothermal techniques had a significant effect (p<0.05) on the ash content of the seed. At varying hydration levels, the seed showed varying degrees of percentage reduction in the ash content. This agreed with an earlier result on *Vigna unguiculata* when the seeds were processed by boiling (Ojo and Ajayi, 2005). Each of the hydrothermal techniques caused a decrease in the crude fibre content of the seed. The pattern of decrease was similar to that of *Senna occidentalis* as reported by Abdullahi, Tanko and Bankosi (2007). The decrease in the fibre contents of the seed as observed in this study could be attributed to the modification of texture of plant tissues during hydrothermal processing occasioned by the change in pectin formation, mostly in the middle lamella of the cell walls (Alba-Villareal *et al.*, 2001; Ojo *et al.,* 2018). Unlike hydrothermal techniques, sprouting has been reported to cause an increase in ash and crude fibre contents. In a study, the ash and fibre content of unsprouted flour samples of *Vigna subterranean w*hich were 3.67 and 4.10%, respectively increased to 4.59% ash and 4.83% crude fibre, respectively after 72 hrs of sprouting (Akinjayeju and Francis, 2007).

3.3 Effects of hydrothermal processing on the mineral elements in Vigna racemosa

The mineral element components of *V. racemosa* at varying hydration levels followed by hydrothermal

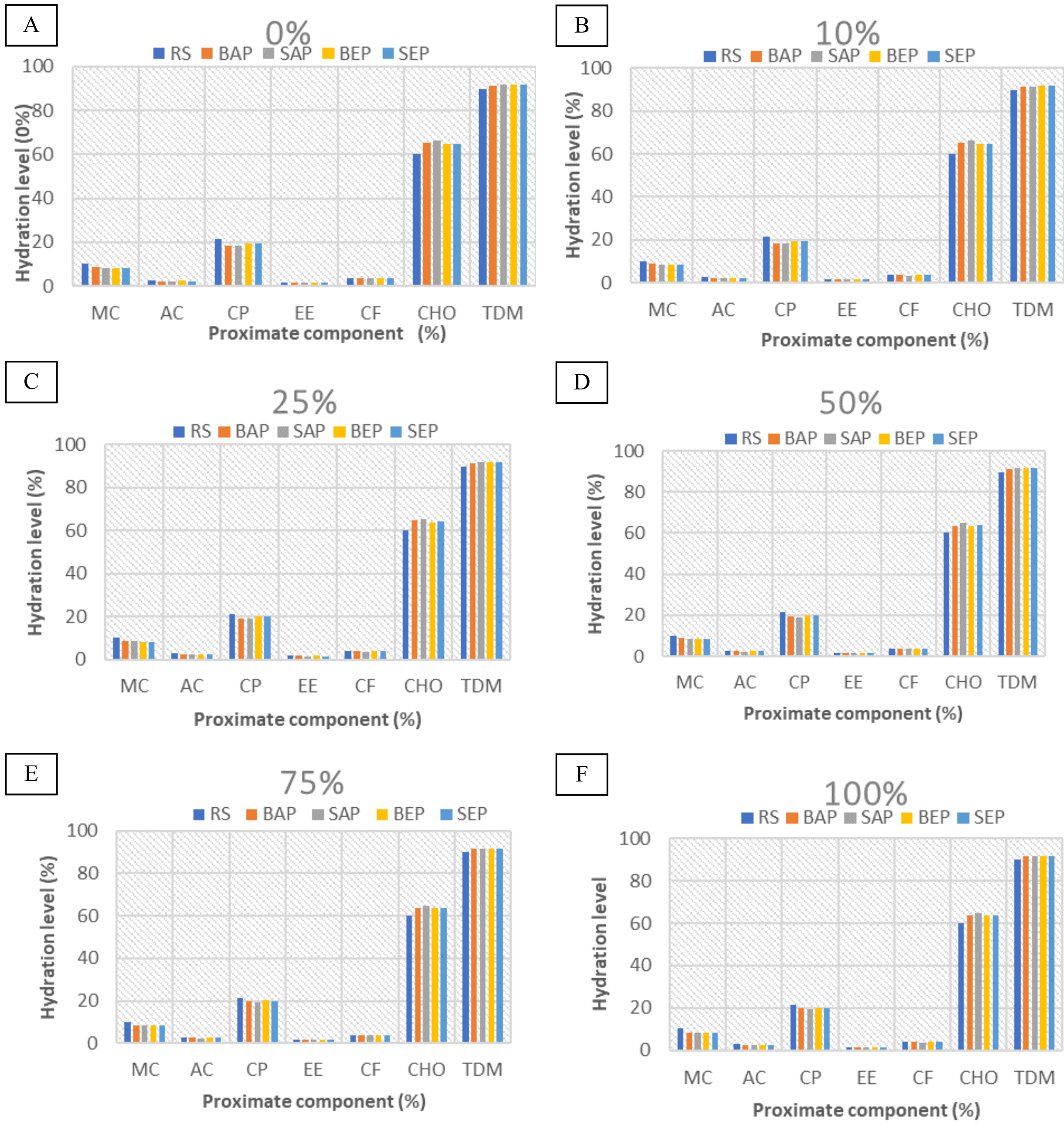

Figure 3. Effect of hydrothermal processing techniques on proximate composition of *V. racemosa* at varying hydration levels. MC = moisture content; AC = ash content; CP = crude protein; EE = ether extract; CF = crude fibre; CHO = total carbohydrate; TDM = total dry matter. RS = raw dried sample; BAP = boiling at atmospheric pressure; SAP = steaming at atmospheric pressure; BEP = boiling at elevated pressure; SEP = steaming at elevated pressure.

processing are presented in Figures 4A-4F. All the hydrothermal processing methods had significant effects (p<0.05) on the mineral elements. The specific effects of processing on the mineral element composition depend on the hydration levels and methods of processing.

The potassium content of the raw sample was 675.24 mg/100 g. Without soaking, boiling and steaming at atmospheric pressure reduced the potassium content to 492.76 and 490.06 mg/100 g, respectively while boiling and steaming at elevated pressure reduced it to 527.00 and 526.48 mg/100 g, respectively. Potassium helps to regulate the acid and water balances as well as transmission of nerve pulses and contraction of muscle tissues (Sunetra, 2009). *Vigna racemosa* also contained appreciable quantities of magnesium 180.21 mg/100 g and phosphorus 460.20 mg/100 g. At 100% hydration level, the concentrations of magnesium and phosphorus were reduced to 123.98 mg/100 g and 308.78 mg/100 g respectively, when the seed was processed by steaming at atmospheric pressure. Calcium is another nutritionally important element present in the seed of *V. racemosa.* The raw seed contained 138.00 mg/100 g. All four hydrothermal methods caused a varying degree of seepage in calcium. It has been reported that a diet containing high quantities of magnesium, calcium and potassium reduce the incidence of cardiovascular disease by reducing high blood pressure (Sunetra, 2009; Ojo *et al.,* 2016). Iron in the legume seed also experienced leaching after processing. The concentration of iron in the dried raw sample was 6.30 mg/100 g. Boiling at an

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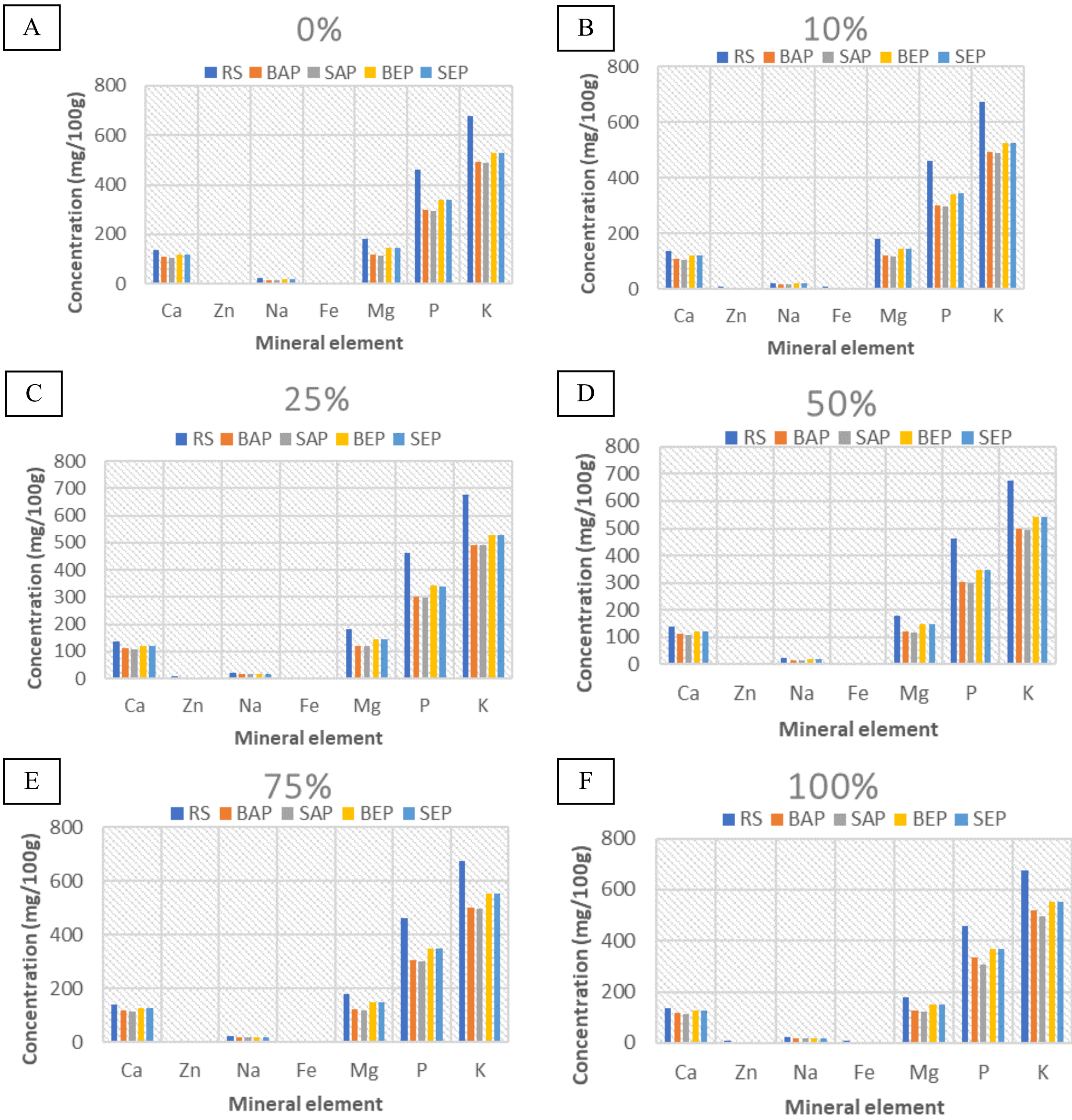

Figure 4. Effect of hydrothermal processing techniques on mineral element composition of *V. racemosa* at varying hydration levels. RS = raw dried sample; BAP = boiling at atmospheric pressure; SAP = steaming at atmospheric pressure; BEP = boiling at elevated pressure; SEP = steaming at elevated pressure.

elevated temperature at 0, 10 and 25% hydration levels reduced the iron content to 5.73, 5.73 and 5.75 mg/100 g, respectively while reductions of 5.75, 5.75 and 5.86 mg/100 g were observed at 50, 75 and 100% hydration levels, respectively. Unlike water-soluble electrolytes such as sodium and potassium, iron is less prone to leaching during thermal processing. A similar result was observed during the processing of *Canavalia ensiformis* when the iron content was observed to decrease from 10.42 mg/100g in the raw seed to 9.30 mg/100 g after soaking to 100% hydration levels followed by pressure boiling (Ojo *et al.*, 2016).

Unlike hydrothermal processing, sprouting was reported to increase the mineral contents of flour of *Vigina subterranean* while fermentation reduced the iron content (Akinjayeju and Francis, 2007). The use of iron cooking ware could be a source of dietary iron in foods during hydrothermal processing. Boiling of *Vigna unguiculata* seeds using iron cooking ware increase their iron content from 20.20 mg/100 g to 25.25 mg/100 g (Ojo and Ajayi, 2005). Iron helps to build up blood cells. For a normal healthy human, daily intake of iron ranges between 10-18 mg/100 g (Robert 1981, Sunetra, 2009). The seeds of *V. racemosa* is a good source of non-heam iron even after hydrothermal treatment. Although all the hydrothermal methods employed were observed to cause varying degrees of leaching of the mineral elements, the seed of the legume was still considered to be a good source of these elements even after processing. In general, cooking of the legume seed at higher hydration levels caused better retention of the mineral elements.

4. Conclusion

All four hydrothermal methods have significant effects on the proximate composition and mineral element status of *Vigna racemosa*. There was a varying degree of seepage of the nutrients during hydrothermal processing but the nutrients components were not

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degraded beyond the normal requirements necessary to meet physiological needs. The seeds of *Vigna racemosa* is a good source of nutritionally important nutrients. Consumption of this underutilised legume will make critically important nutrients such as potassium, magnesium, calcium and protein available for the large segment of the underprivileged populations in many developing nations at affordable prices. Regular consumption of legume seeds has health-promoting effects. Hydration of the legume seed followed by application of hydrothermal techniques, particularly boiling at elevated pressure, has the potency to decrease the cooking time and hence encourage utilisation. Hence, increasing the utilisation of this legume will foster economic utility and strengthen healthy eating habits.

Conflict of interest

The authors declare no conflict of interest.

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