Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2301067B
Vol. 68, No. 1, 2023 UDC: 613.26:[635.49:582.991.1
Pages 67-79 Original scientific paper

PROXIMATE, MINERAL, VITAMIN, AND ANTI-NUTRIENT CONTENTS OF THE LEAVES OF *SENECIO BIAFRAE*

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Abstract: Micronutrient malnutrition is a global challenge. However, there are promising opportunities for combating it through the consumption of neglected and underutilized leafy green vegetables. *Senecio biafrae* is an underutilized and nutrient-rich green leafy vegetable with huge nutritional and health potentials that have remained unexploited. The aim of this research was to evaluate the proximate, mineral, vitamin, anti-nutrient contents of the leaves of *Senecio biafrae*. Leaves of *Senecio biafrae* were collected from five communities in Ekiti State and analyzed using standard biochemical methodologies. The results showed that the leaves differed significantly in nutritional and anti-nutritional contents. The leaves were rich in potassium, magnesium, and calcium, and low in fat and anti-nutrient contents for all the groups studied. The Pearson's correlation results showed that most of the nutritional parameters either had inverse or no relationships with anti-nutrients. The crude protein showed significantly positive correlations with dry matter (0.90**) and a negative correlation with cyanogenic glycosides (-0.90**). Cyanogenic glycosides showed significantly negative correlations with potassium (-0.63**), calcium (-0.66**) and dry matter (-0.44*). Nitrate showed no significant relationship with any nutritional parameter. Oxalate and tannin showed no significant relationship with the vitamins. Phytate and tannin showed no significant relationship with the proximate contents and minerals. The results showed that *Senecio biafrae* leaf is nutrient-rich and could help to mitigate the effects of micronutrient deficiencies. The variations and relationships among the nutritional and anti-nutritional parameters could enhance meaningful selection and nutritional quality through breeding.

Key words: nutrient-dense, leafy vegetable, *Senecio biafrae,* minerals, vitamins, proximate, anti-nutrients, micronutrients.

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Introduction

Malnutrition used to be considered a challenge of the resource-poor people alone until the problems of micronutrient ("hidden-hunger") malnutrition became prevalent among the elites and the resource-poor. Green leafy vegetables, however, have huge underexploited potentials for mitigating the effects of hidden-hunger and combating malnutrition. In most parts of the world, the consumption of leafy vegetables is not cherished by the younger generations, especially children. Edema (1987) noted that the dislike for leafy green consumption could be attributed partly to the fact that some leafy vegetables might be bitter. Some have a peculiar aroma and some may not be so tasty. Sub-Saharan Africa, for instance, despite the vast biodiversity of green leafy vegetables, consumes them the least (Remi et al., 2005). Crop biodiversity and the nutritional contents of vegetable crops are particularly important for food and nutrition security on a global scale. Leafy greens are extremely important to one's health and illness prevention (Hanif et al., 2006), and they are some of the cheapest and some of the most accessible sources of protein, carbohydrates, vitamins, minerals, and vital amino acids as well (Aregheore, 2012).

The middle-belt and southern parts of Nigeria, especially the tropical rainforests and the derived guinea savanna agro-ecologies of the country, have a huge biodiversity of green leafy vegetables cherished for their numerous food, nutritional and medicinal advantages. Most of these indigenous green leafy vegetables are harvested directly from the wild, with no serious cultivation or genetic improvement being carried out on them. There is currently massive genetic erosion of the biodiversity of these invaluable vegetables due to little or no conservation and breeding efforts being carried out on them that could enhance their growth, yield, and nutrient qualities. Underexploited and neglected crops are now being explored for nutrition and medicine because of the promising opportunities they offer (Baiyeri et al., 2018).

Senecio biafrae is one of these indigenous green leafy vegetables in the southern part of Nigeria. The consumers' demand for this vegetable is usually by far higher than the supplies, which makes it comparably costlier than the other green leafy vegetables consumed in the region. A major reason for this is that *Senecio biafrae* is still currently harvested from the wild and no serious effort is being put by farmers to include it in their regular traditional cropping systems. In ethno-medicine, it is used in the treatment of hypertension, low-sperm count, pile, dysentery, cough, pulmonary defects and rheumatism (Bello et al., 2018). In spite of the huge nutritional and nutraceutical benefits associated with *Senecio biafrae*, there are limited research projects and little or no funding for research into the various aspects of this vegetable. There is also poor awareness of its dietary and medicinal potentials. Nutrient profiling is one of the strategies for unraveling the nutritional potentials of a crop and could enhance awareness about it. When compared to other commonly consumed vegetables, there are few documented nutritional studies on this vegetable in the literature. The earlier nutritional studies on *Senecio biafrae* used one accession for their nutritional analyses (Ajala, 2009; Nupo et al., 2013; Adeniji, 2014). These studies looked at proximate composition and either minerals or anti-nutrients. Evaluating the nutritional and anti-nutritional qualities of a food crop could unveil the variations in its genotypes with respect to the studied traits. This is a prerequisite for the improvement of such traits through crop breeding. To the best of the writers' knowledge, there are no documented studies on the proximate, mineral, vitamin, anti-nutrient contents and their correlations using a number of accessions in *Senecio biafrae*. Evaluating the nutritional and anti-nutritional composition of crops, especially their correlations using various genotypes could provide useful information to nutritionists, agronomists and crop breeders that will enhance the designing of dietary preparations, crop management and breeding strategies, all of which will ultimately be of immense benefit to the consumers. In order to enhance sustainable food and nutritional security, nutritionists, agronomists, and crop breeders need to look beyond yield and yield-components alone and begin to take into consideration the nutritional and anti-nutritional traits and the inter-relationships among them in vegetables and staple food crops. This study was therefore initiated to evaluate the proximate, mineral, vitamin, anti-nutrient contents and their correlations in *Senecio biafrae* accessions collected in Ekiti State, southwestern Nigeria.

Material and Methods

Leaf collection and preparation: The vines with leaves of *Senecio biafrae* were collected from five communities in Ekiti State: Aba oyo, Ijebu agege, Ijesha isu, Odooro, Okeorin. The accessions were named after the communities where they were collected. The samples were kept in a cooling system and transported to the laboratory. The leaves were detached from the vine and washed carefully with distilled water and drained. The fresh leaf samples were homogenized with a mortar and pestle and weighing was done for the various analyses. Proximate, mineral, vitamin, and anti-nutrient analyses were performed. All biochemical analyses were carried out in quadruplicates.

Proximate analysis: The assays were performed using the established techniques of analysis outlined by AOAC (2005). The crude protein concentration in the samples was determined using the standard semi-micro Kjeldahl method – AOAC (2005) method 988.05. Crude fat in the samples was analyzed using AOAC (2005) method 2003.06. Dry matter and moisture contents of the samples were determined using AOAC (2005) method 967.08. The ash concentrations were determined using AOAC (2005) method 942.05. The crude fibre was analyzed using AOAC (2005) method 958.06. The carbohydrate was determined by difference. This was done by subtracting (% moisture + % crude protein + % ether extract + % crude fiber + % ash) from 100%.

Mineral content determination: The mineral contents (calcium [Ca], zinc [Zn], iron [Fe], magnesium [Mg], copper [Cu], sodium [Na]) of the leaf samples of the *Senecio biafrae* accessions were analyzed using AOAC (2005) method 975.11. The digest of each sample as obtained from sample dissolution was aspirated into the Buck 210 Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combinations. Phosphorus was determined by the vanado-molybdate spectrophotometric method (AOAC, 975.16).

Vitamin analyses: The concentrations of vitamin A, vitamin B1, vitamin B2, vitamin B5, vitamin B6, vitamin C, vitamin E and vitamin K were assayed in the leaf samples of the *Senecio biafrae* accessions using the AOAC (2005) method.

Anti-nutrient determination: The phytate contents of the samples were determined using the AOAC (2006) method. Nitrate in the samples was analyzed using the rapid colorimeteric method by nitrification of salicylic acid (Cataldo et al., 1975). Oxalate concentration was analyzed using the AOAC 2006 method. Tannin contents in the leaf samples were analyzed using the AOAC 2006 method. Cyanogenic glycoside was analyzed in the samples using AOAC (2005) method 915.03.

Statistical analysis: All data collected were analyzed using the *R* statistical analysis package, version 4.1.1. The analysis of variance was done using the library Agricolae. The significance of the treatment means was determined by the Tukey's HSD test at the 5% probability level, and the standard deviation was determined using the library (Psych). Pearson's correlation analysis was done using the library: Hmisc to understand the strength of the relationships among the nutritional and anti-nutritional traits studied in the *Senecio biafrae* accessions.

Results and Discussion

The results of the proximate composition of the *Senecio biafrae* accessions are shown in Table 1. Proximate composition was significantly ($p<0.05$) influenced by accession. Crude protein was significantly affected by accession and ranged from 1.76% in Ijesha isu to 2.29% in Aba oyo that recorded the highest crude protein content. The crude protein levels in these accessions were within the range reported by Nupo et al. (2013) for *Senecio biafrae.* The accessions significantly ($p<0.05$) varied in their crude fat and crude fiber concentrations. Aba oyo had the highest crude fat content (1.34%) while Okeorin (1.18%) had the least fat content. The fat content was within the range reported for *Seneico biafrae, Solanum nigrum and Crassocephalum crepidiodes* by Nupo et al. (2013) and comparable to the crude fat

(0.92%) reported for *Senecio biafrae* by Ajala (2009). The low fat content of these *Senecio biafrae* accessions makes them a promising leafy vegetable in the treatment of overweight and obesity. The crude fibre content was also significantly influenced by the accessions, with Aba oyo (2.52%) having the highest content; followed closely by Ijebu agege (2.40%) while Okeorin (2.25%) had the least crude fiber among the accessions. The results agree with the crude fiber content of commonly consumed fresh vegetables reported by Titchenal and Dobbs (2006). Higher crude fiber contents have been reported for *Senecio biafrae* in dried leaf samples (Famurewa, 2009; Gbadamosi and Okolosi, 2013; Nupo et al., 2013). The consumption of fiber has been associated with a reduction in serum cholesterol levels, lower risks of coronary heart disease, high blood pressure, diabetes, and colon and breast cancers (Ishida et al., 2000; Ramula and Rao, 2003). Okeorin recorded the highest value (2.16%) for the total ash content, while Aba oyo (1.65%) recorded the lowest value for the total ash content. The ash contents of the accessions analyzed were within the values (1.8–2.5%) reported for the same vegetable by Nupo et al. (2013). Aba oyo recorded the least moisture content (90.47%) and the highest dry matter content (9.53%) while Ijesha isu that recorded the highest moisture content (91.23%) also had the least dry matter content (8.76%). The moisture contents of the fresh leaf samples analyzed were equivalent to 89.68% and 89.49% reported for *Senecio biafrae and Solanium nigrum*, respectively (Ajala, 2009).

Table 1. Proximate composition (%) of the fresh leaves of *Senecio biafrae* accessions.

Accession	Crude protein (±SD)	Crude fat (±SD)	Crude fibre (±SD)	Total ash (±SD)	Moisture (±SD)	Dry matter (±SD)	Carbohydrate (±SD)
Aba oyo	2.29±0.07[a]	1.34±0.06[a]	2.52±0.04[a]	1.88±0.03[c]	90.47±0.06[c]	9.53±0.06[a]	1.41±0.12[a]
Ijebu agege	2.01±0.35[abc]	1.23±0.05[b]	2.40±0.06[ab]	2.02±0.07[b]	90.92±0.42[ab]	9.08±0.42[bc]	1.59±0.16[a]
Ijesha isu	1.76±0.16[c]	1.20±0.11[b]	2.24±0.18[b]	2.10±0.07[ab]	91.24±0.06[a]	8.76±0.06[c]	1.28±0.12[b]
Okeorin	1.95±0.17[bc]	1.18±0.05[b]	2.25±0.13[b]	2.16±0.03[a]	90.91±0.45[ab]	9.09±0.45[bc]	1.59±0.13[a]
Orinodo	2.20±0.23[ab]	1.23±0.02[b]	2.37±0.07[ab]	2.10±0.09[ab]	90.61±0.10[bc]	9.39±0.10[ab]	1.59±07[a]

SD = Standard deviation; Means followed by different letters are significantly different by a Tukey's HSD test at $\alpha = 0.05$.

The high moisture contents of the *Senecio biafrae* accessions suggest the need for effective postharvest handling and storage methods with minimal nutrient loss, hence preventing huge postharvest losses associated with leafy vegetables that have high moisture contents. The accessions differed significantly ($p<0.05$) in their carbohydrate contents, which ranged from 1.29 to1.59%. All the accessions were statistically higher than Ijesha isu (1.29%) in their carbohydrate contents.

Vegetables are known for very little carbohydrate and low fat but provide concentrated sources of minerals and vitamins (Titchenal and Dobbs, 2006). The variation in the proximate composition of the *Senecio biafrae* accessions evaluated in this study suggests the possibility of improving these nutritional qualities through crop improvement. The germplasm level of diversity is critical to a successful crop improvement plan (Adebisi, et al., 2001).

The mineral composition: The accessions significantly ($p<0.05$) differed in their iron (Fe), magnesium (Mg), phosphorus (P) contents (Table 2). Orinodo (28.19 mg/kg) recorded the highest value for iron. Okeorin (20.29 mg/kg) had the least iron concentration. The zinc (Zn) contents of the accessions ranged from Ijebu agege (3.88 mg/Kg) and Orinodo (4.01 mg/kg). Calcium (Ca) ranged from Orinodo (574.60 mg/kg) to Okeorin (618.90 mg/kg). Magnesium contents of *Senecio biafrae* ranged from Ijebu agege (425.30 mg/kg) to Orinodo (500.30 mg/kg) which was significantly higher than the rest of the accessions in their magnesium concentrations. Ijesha isu (19.92 mg/kg) was the most prominent accession for phosphorus and was significantly ($p<0.05$) higher than Aba oyo (15.28 mg/kg) that recorded the least phosphorus content. The *Senecio biafrae* accessions were not significantly ($p>0.05$) different in their potassium concentrations. The potassium content ranged from 409.15 mg/kg in Ijesha isu to 427.30 mg/kg in Ijebu agege. The sodium contents were also statistically similar in the accessions. Sodium ranged from 184.60 mg/kg in Aba oyo to 196.70 mg/kg in Ijesha isu. The accessions were statistically similar in their copper concentrations, with Orinodo (4.03 mg/kg) recording the highest value, while Ijebu agege had the lowest concentration of the mineral. The results obtained in this study for the minerals (Fe, Ze, Mg, K, Ca, P, Cu, and Na) were within the range of values reported for minerals in leafy vegetables (Titchenal and Dobbs, 2006; Garcia-Herrera et al., 2020).

Table 2. Mineral composition (mg/kg) of the fresh leaves of *Senecio biafrae* accessions.

Accession	Iron (±SD)	Zinc (±SD)	Minerals Calcium (±SD)	Magnesium (±SD)	Phosphorus (±SD)	Potassium (±SD)	Sodium (±SD)	Copper (±SD)
Aba oyo	$20.82±1.11^{b}$	$3.89±0.33^{a}$	$586.70±1.30^{ab}$	$446.90±8.43^{ab}$	$15.28±0.47^{b}$	$419.40±4.36^{a}$	$184.60±4.50^{b}$	$4.00±1.12^{a}$
Ijebu agege	$23.42±3.98^{b}$	$3.88±0.86^{a}$	$588.10±38.91^{ab}$	$425.30±4.38^{c}$	$18.05±1.48^{a}$	$427.30±29.33^{a}$	$195.20±8.59^{ab}$	$3.62±0.38^{a}$
Ijesha isu	$28.98±0.77^{a}$	$3.98±0.27^{a}$	$575.40±10.94^{b}$	$459.80±29.27^{b}$	$19.92±0.37^{a}$	$409.10±10.60^{a}$	$196.70±4.82^{a}$	$3.73±0.41^{a}$
Okeorin	$20.29±2.57^{b}$	$3.94±1.09^{a}$	$618.90±27.31^{a}$	$435.30±26.27^{ab}$	$18.70±0.23^{a}$	$416.30±5.99^{a}$	$189.30±10.79^{ab}$	$4.39±0.72^{a}$
Orinodo	$28.19±1.90^{a}$	$4.01±0.34^{a}$	$574.60±24.60^{b}$	$500.30±2.15^{a}$	$18.76±2.31^{a}$	$415.10±7.07^{a}$	$185.50±5.34^{b}$	$4.03±0.45^{a}$

SD = Standard deviation; Means followed by different letters are significantly different by a Tukey's HSD test at $\alpha = 0.05$.

The vitamin concentrations: The accessions were similar in their vitamin concentrations except for the concentration of vitamin C, which was significantly ($p<0.05$) influenced by accession (Table 3). Vitamin A ranged from 252.20 mg/100 g in Ijesha isu to 256.70 mg/100 g in Aba oyo. Vitamin B1 ranged from 0.1253 mg/100 g in Orinodo to 0.1328 mg/100 g in Okeorin. Vitamin B2 ranged from 0.1195 mg/100 g in Okeorin to 0.1210 mg/100 g in Aba oyo. Vitamin B5 ranged from 0.2382 mg/100 g in Okeorin to 0.2442 mg/100 g in Ijesha isu. Vitamin B6 ranged from 0.0525 mg/100 g in Aba oyo to 0.0528 mg/100 g in Ijesha isu. Vitamin C concentration was significantly ($p<0.05$) influenced by accession. The highest vitamin C content was found in Ijesha isu (26.35 mg/100 g), which was significantly higher than in Orinodo (23.35 mg/100 g). The vitamin E contents of the accessions ranged from 42.17 mg/100 g in Okeorin to 44.65 mg/100 g in Ijebu agege while vitamin K ranged from 17.23 mg/100 g in Aba oyo and in Ijebu agege to 18.06 mg/100 g in Orinodo. The vitamin A contents in the accessions were higher than the rest of the vitamins analyzed in the samples. A similar result was reported for vitamin A in kale, spinach and duckweed (Natesh et al., 2017). The high vitamin A contents in *Senecio biafrae* are commendable, which can be attributed to the purple pigmentation on the stems and the leaves. The results of the vitamins in this study are within the ranges reported for various commonly consumed green leafy vegetables (Titchenal and Dobbs, 2006; Ojimelukwe and Amaechi, 2019). The results suggest that *Senecio biafrae* is a promising leafy vegetable with huge nutritional potentials that could help in mitigating the effects of vitamin deficiencies.

Table 3. Vitamin composition (mg/100 g) of the fresh leaves of *Senecio biafrae* accessions.

Accession	Vitamin A (±SD)	Vitamin B1 (±SD)	Vitamin B2 (±SD)	Vitamin B5 (±SD)	Vitamin B6 (±SD)	Vitamin C (±SD)	Vitamin E (±SD)	Vitamin K
Aba oyo	256.70 ± 2.02^{a}	0.1305 ± 0.00^{ab}	0.1210 ± 0.00^{a}	0.2425 ± 0.01^{a}	0.0525 ± 0.00^{a}	25.12 ± 0.33^{a}	42.84 ± 2.85^{ab}	17.23 ± 1.26^{a}
Ijebu agege	254.00 ± 1.36^{a}	0.1313 ± 0.01^{ab}	0.1205 ± 0.00^{a}	0.2410 ± 0.00^{a}	0.0527 ± 0.00^{a}	25.82 ± 0.79^{a}	44.65 ± 0.35^{a}	17.23 ± 0.39^{a}
Ijesha isu	252.20 ± 6.59^{a}	0.1293 ± 0.00^{ab}	0.1200 ± 0.01^{a}	0.2442 ± 0.01^{a}	0.0528 ± 0.00^{a}	26.35 ± 0.86^{a}	43.92 ± 0.81^{ab}	18.24 ± 1.04^{a}
Okeorin	253.10 ± 3.71^{a}	0.1328 ± 0.00^{a}	0.1195 ± 0.00^{a}	0.2382 ± 0.00^{a}	0.0527 ± 0.00^{a}	25.83 ± 0.54^{a}	42.17 ± 1.45^{b}	17.79 ± 0.54^{a}
Orinodo	255.20 ± 8.50^{a}	0.1253 ± 0.01^{b}	0.1200 ± 0.00^{a}	0.2427 ± 0.00^{a}	0.0527 ± 0.00^{a}	23.35 ± 1.78^{b}	42.51 ± 0.57^{ab}	18.06 ± 0.53^{a}

SD = Standard deviation; Means followed by different letters are significantly different by a Tukey's HSD test at $\alpha = 0.05$.

Anti-nutrient composition: The results of the analysis of variance for the anti-nutrients are found in Table 4. Accessions significantly ($p<0.05$) affected the anti-nutrient concentrations in the leaf samples except for the phytate and tannin concentrations that were statistically ($p>0.05$) similar. The accessions were generally low in anti-nutrients. The phytate concentration of the accessions ranged from 0.3410% in Ijebu agege to 0.3682% in Okeorin. This result was within the range of 0.1–6% phytate concentration found in food items (Mohammed et al., 2002). The oxalate concentrations were significantly influenced by accession and ranged from 0.2243% in Aba oyo to 0.2495% in Orinodo and were lower than the oxalate concentrations of some commonly consumed leafy green vegetables (Badifu, 2001). Tannin concentrations of the accessions ranged from 0.0052% in Ijebu agege to 0.0058% in both Orinodo and Ijesha isu. The tannin contents of the *Senecio biafrae* accessions were also lower than 7.5% reported in *Amaranthus viridus* (Umar et al., 2011). The accessions differed significantly ($p<0.05$) in their nitrate contents. Ijesha isu (0.1385%) had the highest concentration of nitrate while Ijebu agege (0.1265%) had the least nitrate concentration. The nitrate concentration is lower than 0.33% reported for *Senecio biafrae* (Ajala, 2009). The *Senecio biafrae* accessions significantly varied with respect to cyanogenic glycoside. Ijesha isu (51.63 mg/kg) had the highest concentration of cyanogenic glycoside while Okeorin (48.23mg/kg) had the least concentration of cyanogenic glycosides; these concentrations were lower than 52 mg/100 g reported for cassava leaves and 95.5 mg/100 g reported for *Vernonia amygdalia* (Aregheore, 2012). The levels of the anti-nutrients in this study were lower than the levels reported for phytate, oxalate, nitrate and tannin in the fresh leaf samples of *Senecio biafrae* and *Solanium nigrum* (Ajala, 2009). The anti-nutrients in leafy vegetables like *Senecio biafrae* pose little or no threats to humans that consume them since different food processing methods are capable of reducing them to levels that are non-toxic and facilitate the absorption of other nutrients they would have formed complexes with,thus enhancing their bioavailability. Cooking, drying and boiling have also been reported to reduce anti-nutrients in the leaves to the non-toxic level with appreciable nutrient retention in *Senecio biafrae, Solanium nigrum* and *Vernonia amygdalina* (Fasuyi, 2005; Ajala, 2009; Aregheore, 2012).

Table 4. Anti-nutrient composition (%) of the fresh leaves of *Senecio biafrae* accessions.

Accession	Phytate (±SD)	Oxalate (±SD)	Nitrate (±SD)	Tannin (±SD)	Cyanogenic glycosides (mg/kg) (±SD)
Aba oyo	$0.3505±0.00^{a}$	$0.2243±0.01^{c}$	$0.1378±0.00^{a}$	$0.0056±0.00^{a}$	$48.57±0.35^{bc}$
Ijebu agege	$0.3410±0.05^{a}$	$0.2345±0.01^{bc}$	$0.1265±0.00^{b}$	$0.0052±0.00^{a}$	$49.96±1.65^{ab}$
Ijesha isu	$0.3638±0.00^{a}$	$0.2445±0.01^{ab}$	$0.1385±0.01^{a}$	$0.0058±0.00^{a}$	$51.63±1.48^{a}$
Okeorin	$0.3682±0.00^{a}$	$0.2462±0.01^{ab}$	$0.1333±0.00^{ab}$	$0.0055±0.00^{a}$	$48.20±0.93^{c}$
Orinodo	$0.3568±0.01^{a}$	$0.2495±0.01^{a}$	$0.1378±0.01^{a}$	$0.0058±0.00^{a}$	$50.36±0.60^{a}$

SD = Standard deviation; Means followed by different letters are significantly different by a Tukey's HSD test at $\alpha = 0.05$.

Proximate and anti-nutrient correlations: Crude protein showed significantly ($p<0.01$) positive relationships (0.90**) with dry matter and a significantly negative relationship with moisture (-0.90**) and cyanogenic glycosides (-0.57**). Crude fat had a negatively significant relationship with total ash (-0.63**) and (-0.47*) oxalate. Crude fat showed significantly ($p<0.01$) positive relationships (0.83**) with crude fiber. Oxalate showed a significantly negative relationship with crude fibre (-0.45*). Total ash showed a significant positive relationship with oxalate (0.77**). Dry matter had a significantly negative correlation (-0.44*) with cyanogenic glycosides. Phytate, tannin and nitrate showed no relationship with proximate composition of the *Senecio biafrae* accessions. These results imply that the higher the protein, the lower the cyanogenic glycosides and the higher dry matter. Selecting or breeding for high dry matter implies increased protein and decreased cyanogenic glycosides in *Senecio biafrae*. Agronomic management practices that increase dry matter will decrease the cyanogenic glycosides and increase protein in this leafy vegetable. The inverse relationships between oxalate and crude fiber, and oxalate and fat imply that any crop management practices that enhance crude fiber and/or fat contents in this crop will decrease its oxalate concentration. The strong significant ($p<0.01$) and positive correlation between total ash and oxalate implies that an increase in the total ash in this vegetable simultaneously increases oxalate content. This information should guide the vegetable breeder who would want to improve the nutrient quality of *Senecio biafrae* to select or breed for a nutrient-rich and low anti-nutritional composition of this leafy vegetable. These correlations would also give useful insights to the agronomist for enhanced crop management for optimum nutrient-density. The correlation coefficient could guide food nutritionists and scientists in the processing of this leafy vegetable for enhanced bioavailability of nutrients and better human nutrition and health. (Table 5.).

Table 5. Correlation coefficients among proximate qualities and anti-nutrients in the leaves of *Senecio biafrae* accessions.

	CP	C. fat	C. fibre	T. ash	Moist	Dry M	Phy	Tan	Oxa	Nit	C. gl
CP	1										
C. fat	0.19	1									
C. fiber	0.29	0.83**	1								
T. ash	-0.58**	-0.63**	-0.58**	1							
Moist	-0.90**	-0.34	-0.50*	0.51 *	1						
Dry M	0.90**	0.34	0.50*	-0.51*	-1.00**	1					
Phy	0.07	-0.20	-0.32	0.08	-0.06	0.06	1				
Tan	0.11	0.00	-0.36	0.04	0.04	-0.04	0.10	1			
Oxa	-0.30	-0.47*	-0.45*	0.77**	0.32	-0.32	0.13	0.01	1		
Nit	0.05	0.34	0.14	-0.13	0.06	0.04	0.23	0.45*	-0.18	1	
C. gl	-0.57**	0.09	0.12	0.23	-0.44*	-0.44*	-0.17	-0.09	0.29	0.20	1

*A correlation is significant at the 0.05 level; **A correlation is significant at the 0.01 level, CP = crude protein; C. fat = crude fat; C. fibre = crude fibre; T. ash = total ash; Moist = moisture; Dry M = dry matter; Phy = phytate; Tan = tannin; Oxa = oxalate; Nit = nitrate; C. gl = cyanogenic glycoside.

Minerals and anti-nutrient correlations: Cyanogenic glycosides showed significant (p<0.01) negative correlations with calcium (-0.66**), potassium (-0.63**) and sodium (0.66**), and a positive and significant correlation (p<0.05) with iron (0.54*). Tannin showed a significant (p<0.01) negative correlation with sodium (-0.60**). Oxalate showed significant (p<0.05) positive relationships with magnesium (0.53*). These results imply that any agronomic practices that decrease cyanogenic glycosides in *Senecio biafrae* could result in high calcium and potassium contents. This information is important considering the fact that *Senecio biafrae* is rich in calcium and potassium. The positive relationship between cyanogenic glycosides and iron gives useful information that could guide future *Senecio biafrae* breeding programs to select/breed for low cyanogenic glycosides and high minerals. Interestingly, tannin, phytate and nitrate showed no relationship with minerals in the *Senecio biafrae* accessions. (Table 6.).

Table 6. Correlation coefficients among minerals and anti-nutrients in the leaves of *Senecio biafrae* accessions.

	Fe	Zn	Ca	Mg	P	K	Na	Cu	Phy	Tan	Oxa	Nit	C. gl
Fe	1												
Zn	-0.29	1											
Ca	-0.15	-0.66**	1										
Mg	0.65**	-0.13	-0.11	1									
P	0.45*	0.25	-0.33	0.17	1								
K	0.06	-0.43	0.65**	-0.10	-0.51*	1							
Na	0.20	-0.10	-0.19	-0.12	-0.57**	-0.52*	1						
Cu	-0.27	-0.30	0.27	0.12	-0.09	-0.28	-0.07	1					
Phy	0.20	-0.23	0.30	0.12	0.00	0.16	-0.20	0.00	1				
Tan	0.09	0.03	0.00	0.19	-0.10	0.07	-0.60**	0.40	0.10	1			
Oxa	0.27	0.20	-0.07	0.53*	0.61**	-0.42	0.29	0.24	0.13	0.01	1		
Nit	0.28	-0.10	-0.22	0.21	0.06	-0.30	-0.19	0.04	0.23	0.45	-0.18	1	
C. gl	0.54*	0.07	-0.66**	0.21	0.60**	-0.63**	0.66**	-0.07	-0.17	-0.09	0.29	0.20	1

*A correlation is significant at the 0.05 level; **A correlation is significant at the 0.01 level; Fe = iron; Zn = zinc; Ca = calcium; Mg = magnesium; P = phosphorus; K = potassium; Na = sodium; Cu = copper; Phy = phytate; Tan = tannin; Oxa = oxalate; Nit = nitrate; C.gl = cyanogenic glycoside.

Vitamin and anti-nutrient correlations: Phytate showed a significantly (p<0.05) negative correlation with vitamin B1 (-0.45*). This implies that breeding efforts that improve the vitamin B1 content in *Senecio biafrae* will simultaneously reduce its phytate content. Cyanogenic glycosides showed a positive relationship with vitamin B5 (0.47*). Breeding efforts and selection for enhanced nutritional quality in *Senecio biafrae* should explore the possibilities of identifying *Senecio biafrae* genotypes with reduced cyanogenic glycoside content and increased vitamin B5 content. Oxalate, nitrate and tannin showed no relationship with vitamins in the *Senecio biafrae* accessions. This suggests that breeding efforts or crop management practices that reduce oxalate, nitrate and tannin will not negatively affect the vitamin content of this vegetable. (Table 7.).

Table 7. Correlation coefficients among vitamins and anti-nutrients in the leaves of *Senecio biafrae* accessions.

	VA	VB1	VB2	VB5	VB6	VC	VE	VK	Phy	Tan	Oxa	Nit	C. gl
VA	1												
VB1	0.05	1											
VB2	0.15	-0.39	1										
VB5	-0.21	0.04	-0.61**	1									
VB6	0.09	-0.08	0.49*	-0.38	1								
VC	-0.41	0.59**	-0.23	0.08	-0.02	1							
VE	-0.06	-0.05	0.37	-0.45*	0.26	0.25	1						
VK	-0.18	0.18	-0.77**	0.57**	-0.51*	0.09	-0.46*	1					
Phy	0.00	-0.45*	0.00	-0.10	0.00	-0.04	-0.12	0.10	1				
Tan	-0.01	-0.24	0.35	-0.40	0.04	-0.10	0.46	-0.23	0.10	1			
Oxa	0.22	-0.09	0.11	-0.20	0.30	-0.33	-0.20	0.25	0.13	0.01	1		
Nit	-0.39	-0.25	-0.16	0.15	-0.12	0.05	-0.13	0.28	0.23	0.45*	-0.18	1	
C. gl	-0.30	-0.12	-0.24	0.47*	0.19	0.04	0.14	0.34	-0.17	-0.09	0.29	0.20	1

*A correlation is significant at the 0.05 level; **A correlation is significant at the 0.01 level; VA = vitamin A; VB1= vitamin B1; VB2 = vitamin B2; VB5 = vitamin B5; VB6 = vitamin B6; VC = vitamin C; VE = vitamin E; VK = vitamin K; Phy = phytate; Tan = tannin; Oxa = oxalate; Nit = nitrate; C. gl = cyanogenic glycosides.

Conclusion

The results of this study have revealed that *Senecio biafrae* is a nutrient-rich vegetable with huge potentials for combating malnutrition, especially micronutrient deficiencies and associated health challenges. The high content of vitamins A and E, potassium, magnesium, calcium, low fat and low anti-nutrient concentrations of this leafy vegetable provide some of the basis, and support the claims of the South-western people of Nigeria that greatly cherish it for its nutritional and nutraceutical advantages. The correlation results suggest the possibility to increase nutritional traits in *Senecio biafrae* without necessarily increasing most of the anti-nutrients analyzed in this study. Efforts should therefore be made to domesticate *Senecio biafrae* and include it in traditional cropping systems.

References

Adebisi, M.A., Ariyo, O.J., & Kehinde, O.B. (2001). Variation and correlation studies in Quantitative characteristics in soybean. *Proceeding of the 35th Annual Conference of the Agricultural Society of Nigeria* (pp. 121-125). University of Agriculture, Abeokuta, Nigeria.

Adeniji, P.O. (2014). Nutrient and antinutrient composition of Senecio biafrae. *Nigerian Journal of Nutritional Sciences, 35(2),* 94-98.

Ajala, L. (2009). The effect of boiling in the nutrient and anti-nutrient in two non-conventional vegetables. *Pakistan Journal of Nutrition, 8* (9), 1430-1433.

Aregheore, E.M. (2012). Nutritive value and inherent anti-nutritive factors in four indigenous leafy vegetables in Human nutrition in Nigeria. *Journal of Food Resources Science, 1* (1), 1-14.

AOAC (2005). Official methods of analysis.18th edition USA.

AOAC (2006). Official methods of analysis. 18thEdition. USA.

Badifu, G.I.O. (2001). Effect of processing on proximate composition, anti-nutritional and toxic Contents of kernels from *Cucurbitaceae* species grown in Nigeria. *Journal of Food composition and Analysis*, *14*, 153-161.

Baiyeri, S.O., Uguru, M.I., Ogbonna, P.E., Samuel-Baiyeri, C.C.A., Okechukwu, R., Kumaga, F.K., & Amoatey, C. (2018). Evaluation of the nutritional composition of the seeds of some selected African yam bean (*Sphenostylis stenocarpa* Hochst ex. A. Rich.) Harms accessions. *Agro-Science: Journal of Tropical Agriculture, Food, Environment and Extension*, *17* (2), 36-43.

Bello, O.A., Ayanda, O.I., Aworunse, O.S., Olukanmi, B.I., Soladoye, M.O., Esan, E.B., & Obembe, O.O. (2018). *Solanecio biafrae*: An underutilized nutraceutically-important African indigenous vegetable. *Pharmcognosy Reviews*, *12*, 128-132.

Edema, A.O. (1987). *Production of some common vegetables*. Ibadan: Horticultural Research Institute.

Famurewa, J.A.V. (2009). An assessment of physiochemical properties of *worowo* (*Senecio biafrae*); emphasis on common drying methods. *Journal of Food Processing and Preservation*, *35* (1), 327-330.

Fasuyi, A.O. (2005). Nutrient composition and processing effects on cassava leaf (*Manihot esculenta* Crantz) anti-nutrients. *Pakistan Journal of Nutrition*, *4*, 37-42.

Garcia-Herrera, P. Morales, P., Camara, M. Fernandez-Ruiz, V., Tardio, J., & Sanchez-Mata, M.C. (2020). Nutritional and physiochemical composition of Mediterranean wild vegetables after culinary treatment. *Foods, 9*, 176.

Gbadamosi, I.T., & Okolosi, O. (2013). Botanical galactogogues: Nutritional values and therapeutic potentials. *Journal of Applied Biosciences, 61*, 4460-4469.

Hanif, R., Iqbal, Z., Iqbal, M., Hanif, S., & Rasheed, M. (2006). Use of vegetables as nutritional food role in human health. *Journal of Agricultural and Biological Sciences*, *1*, 18-22.

Ishida, H., Suzuno, H. Sugiyama, N., Innami, S., Tadokoro, T., & Maekawa, A. (2000). Nutritional evaluation of chemical components of leaves, stalks, stems of sweet potatoes (*Ipomaea batatas*). *Food Chemistry*, *68*, 359-367.

Mohammed, A.M., Wolf, W., & Spieb, W.E.L. (2002). Physical, morphological and chemical characteristics, oil recovery and fatty acid composition of *Balanites aegyptiaca* Del. Kernels. *Plant Foods for Human Nutrition, 57*, 179-189.

Natesh, H., Abbey, I., & Asiedu, S.K. (2017). An overview of nutritional and antinutritional factors in green leafy vegetables. *Horticulture International Journal, 1,* (2).

Nupo, S.S., Onigbogi, I.O., Akinlotan, J.V., & Ilori, O.A. (2013). Effect of different processing methods on the nutrients and anti-nutrient composition of *Senecio biafrae, Crassocephalum crepidiodes* and *Solanum nigrum* consumed in south west Nigeria. *American Journal of Food and Nutrition*, *3* (3), 147-154.

Ojimelukwe, P.C., & Amaechi, N. (2019). Composition of *Vernonia amygdalina* and its potential health benefits. *International Journal of Environment, Agriculture and Biotechnology, 4* (6), 1836-1848.

Ramula, P., & Rao, P.U. (2003). Dietary fibre content of fruits and leafy vegetables. *Nutrition News, 24*, 1-6.

Remi, K., Ludovic, T., Pierre, B., & Hubert, D.B. (2005). *Les legumes feuilles des pays tropicaux: Diversité, richesse économique etvaleursantedans un contextetrès fragile (Leafy vegetables from tropical countries: Diversity, economic wealth and health value in a very fragile context)*. Montpellier, France: CIRAD Département Flhor.

Titchenal, C., & Dobbs, J. (2006). *Handbook on food Science, technology and engineering*. New York: Taylor & Francis Group.

Umar, K.J., Hassan, L.G., Dangoggo, S.M., Maigandi, S.A., & Sani, N.A. (2011). Nutritional and anti-nutritional profile of spiny amaranth (*Amaranthus viridus* Linn). *Studia Universitatis "Vasile Goldis", Seria Stiintele Vietii*, *21* (4), 727-737.

Received: June 29, 2022
Accepted: February 13, 2023

NEPOSREDNI MINARALNI, VITAMINSKI I ANTINUTRITIVNI SADRŽAJ LISTOVA BILJKE *SENECIO BIAFRAE*

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R e z i m e

Neuhranjenost usled nedostatka mikronutrijenata je globalni izazov. Međutim, postoje obećavajuće mogućnosti za borbu protiv neuhranjenosti kroz konzumiranje zanemarenog i nedovoljno iskorišćenog lisnatog zelenog povrća. *Senecio biafrae* je nedovoljno iskorišćeno i hranljivim sastojcima bogato zeleno lisnato povrće sa ogromnim nutritivnim i zdravstvenim potencijalima koji su ostali neiskorišćeni. Cilj ovog istraživanja bio je da se procene neposredni mineralni, vitaminski, antinutritivni sadržaji listova biljke *Senecio biafrae*. Listovi biljke *Senecio biafrae* prikupljeni su iz pet zajednica u državi Ekiti i analizirani korišćenjem standardnih biohemijskih metodologija. Rezultati su pokazali da se listovi značajno razlikuju u pogledu nutritivnih i antinutritivnih sastojaka. Pokazalo se da su bogati kalijumom, magnezijumom i kalcijumom, i malim sadržajem masti i antinutritivnih sastojaka za sve ispitivane grupe. Rezultati Pirsonove korelacije pokazali su da većina nutritivnih parametara ima obrnutu ili nikakvu vezu sa antinutiritivnim sastojcima. Sirovi proteini su bili u značajno pozitivnoj korelaciji sa suvom materijom (0,90**) i u negativnoj korelaciji sa cijanogenim glikozidima (-0,90**). Cijanogeni glikozidi su pokazali značajno negativne korelacije sa kalijumom (-0,63**), kalcijumom (-0,66**) i suvom materijom (-0,44*). Nitrat nije pokazao značajnu vezu ni sa jednim nutritivnim parametrom. Oksalati i tanini nisu pokazali značajnu vezu sa vitaminima. Fitati i tanini nisu pokazali značajnu vezu sa mineralima. Rezultati su pokazali da je list biljke *Senecio biafrae* bogat hranljivim materijama i da može pomoći u ublažavanju efekata nedostataka mikronutrijenata. Varijacije i odnosi između nutritivnih i antinutritivnih parametara mogu poboljšati selekciju i nutritivni kvalitet kroz oplemenjivanje.

Ključne reči: bogat nutrijentima, lisnato povrće, *Senecio biafrae,* minerali, vitamini, neposredan, antinutrijenti, mikronutrijenti.

Primljeno: 29. juna 2022.
Odobreno: 13. februara 2023.

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