Effect of processing methods on the nutritional content of three traditional vegetables leaves: Amaranth, black nightshade and jute mallow

Korotimi Traoré1,2 | Charles Parkouda1 | Aly Savadogo2 | Fatoumata Ba/Hama1 | Regine Kamga3 | Yves Traoré2

1Institut de Recherche en Sciences Appliquées et Technologies, Département Technologie Alimentaire O3 BP 7047, Ouagadougou, Burkina Faso
2Laboratoire de Biochimie et d’Immunologie Appliquée, Department of Biochemistry-Microbiology, Université Ouaga 1 Pr Joseph Ki-ZERBO, Ouagadougou, Burkina Faso
3Asian Vegetable Research and Development Center, Liaison office Cameroon, Messa, Yaoundé, Cameroon

Correspondence
Charles Parkouda, Institut de Recherche en Sciences Appliquées et Technologies, Département Technologie Alimentaire O3 BP 7047, Ouagadougou, Burkina Faso. Email: cparkouda@yahoo.fr

Funding information
Conseil Ouest et Centre Africain pour la Recherche et le Developpement Agricole / West and Central African Council for Agricultural Research and Development

Abstract
The study assessed changes in nutritional content of some commonly consumed traditional vegetables subjected to postharvest processes. Amaranth (Amaranthus cruentus L.), black nightshade (Solanum scabrum Mill.) and jute mallow (Corchorus olitorius L.) leaves used as vegetables were subjected to blanching, boiling and drying. The proximate composition and β-carotene content of fresh and processed leaves were determined. Amaranth, black nightshade and jute mallow leaves had 25.21%, 39.74% and 29.18% of protein, respectively. The β-carotene levels were 16.40, 25.25 and 27.74 mg/100 g for black nightshade amaranth and jute mallow leaves, respectively. The ash content was 10.57% for black nightshade, 12.40% for jute mallow and 16.33% for amaranth. Processing methods caused decreases of β-carotene and crude lipid content. Boiling for 30 min or more resulted in large loss of β-carotene. Drying under shade resulted in less loss of β-carotene than drying in cabinet at 50 and 60°C.

KEYWORDS
Amaranthus cruentus, Corchorus olitorius, nutrient, processes, Solanum scabrum

1 | INTRODUCTION

Traditional African vegetables have values and properties that make them useful for farmers and consumers. Leafy vegetables are important sources of minerals, vitamins, fiber, amino acids and health-promoting phytochemicals with antioxidant, antibiotic and anticancer and other nutraceutical properties (Grubben, 1976; Ihekoronye & Ngoddy, 1985; Oyenuga & Fetuga, 1975; Yang & Keding, 2009). Several of these vegetables are subjected to postharvest treatments of drying, Blanching, or cooking to improve organoleptic properties and remove potential toxic components and for preservation purposes. Some processing techniques alter nutrient content of plants (Causseret, 1986; Frances, Thomas, & Gabriel, 2013; Shashi & Sali, 1996). Traditional vegetables have been neglected by consumers because of introduction of exotic vegetables into markets (Remi, Ludovic, Pierre, & Hubert, 2005). In sub-Saharan Africa, there is a diversity of leafy vegetables that are consumable (Remi et al., 2005). Despite this diversity, sub-Saharan Africa has the lowest level of vegetable consumption in the world (AVRDC, 2003), and the highest level (15%) of malnutrition (FAO, 2015). Among these vegetables, amaranth (Amaranthus cruentus L.), black nightshade (Solanum scabrum Mill.) and jute mallow (Corchorus olitorius L.) are thought to benefit the human diet (Grubben et al., 2014; Mulokozi & Svanberg, 2003; Waliou, 2011). Promotion of traditional vegetables consumption can help reduce food insecurity and improve nutrition (Shashi and Sali, 1996; Kouame, Batchep, & Kamga, 2013; Grubben et al., 2014). Before consumption amaranth, black nightshade and jute mallow undergo postharvest processing that can affect their nutrient contents (Oboh, 2005). It is necessary to ensure that the processes applied do not affect the quality of the vegetables. Urbanization in developing countries and globalization have created a need for larger...
scale production of processed traditional vegetables with consistent quality since householders allocated less time to growing or preparation of vegetables for consumption (Kang et al., 2013). Postharvest processes applied by producers is uncontrolled and leads to variation in product stability and quality. Despite the importance of traditional vegetables in the diet, understanding of postharvest processing of traditional vegetables is limited. The objectives of this study were to determine the nutritional content of traditional African vegetables and to assess effects of processing method on chemical composition of amaranth, black nightshade and jute mallow leaves.

2 | MATERIAL AND METHODS

Ready to use fresh leaf samples were collected with producers from three production sites in Ouagadougou (Burkina Faso), and immediately transported to the laboratory for preparation. Samples were washed three times with tap water and drained. The leaves were subjected to the processing techniques of blanching, or boiling for 30 or 60 min, or shade drying and drying at 50 or 60°C using a gas convection dryer.

For blanching, 30 g of sample were immersed in hot water, 90-92°C for 2 min as described by James and Kuipers (2003). After treatment leaves were rinsed with cool tap water, drained, packaged in plastic bottles and kept frozen at −20°C, until analyses.

For boiling, 30 g of sample were subjected to boiling in 2 L of tap water and sub-samples obtained at 30 and 60 min during boiling. The samples were cooled, packaged into plastic bottles and kept frozen at −20°C until analyses.

For drying, samples were dried in the shade and in a gas convection dryer at 50 and 60°C. During shade drying, temperature varied from 25.8 to 31.4°C, with a relative humidity value varied from 63% to 97%. Dried samples were packaged in opaque bottles and stored at laboratory temperature until analysis.

Content of moisture, ash, lipid, protein, carbohydrate and crude fiber in samples were performed according to international standards (NF V03-707, 2000; ISO 2171, 2007; ISO-659, 1998; NF V03-050 NF, 1970; Montreuil & Spik, 1969; Deymie et al., 1981). β-carotene content was determined by High Performance Liquid Chromatography as described by Craft (1992). Analyses were performed in triplicate for each sample.

The data were subjected to one-way analysis of variance (ANOVA). Means were separated by the Tukey test based on the honest significant difference (HSD) test using the XLSAT software (ver. 7.5.2, Addinsoft. Paris, France).

3 | RESULTS

The nutritional content of amaranth, black nightshade and jute mallow leaves differed (Table 1). Moisture content was similar for amaranth, black nightshade and jute mallow. There was less protein in leaves of amaranth and jute mallow and the highest value was in leaves of black nightshade. Crude lipid and total carbohydrates contents where similar for the crops. Fiber content was lowest for black nightshade and highest for jute mallow. The β-carotene content of the black nightshade leaves was lower than for amaranth and jute mallow.

Blanching affected nutritional content of amaranth, black nightshade, and jute mallow (Table 2). Moisture content of leaves increased due to blanching. There was no difference in the moisture content of the amaranth and black nightshade and jute mallow leaves, compared to the raw leaves. The ash content decreased by 2.61%, 1.73% and 3.83% for amaranth, black nightshade and jute mallow, respectively. There was no difference in protein content in amaranth and black nightshade leaves due to blanching. There was a difference between raw and blanched jute mallow leaves. Total carbohydrate content increased after blanching for amaranth and black nightshade. There was a decrease for jute mallow leaves. Blanching did not affect crude lipid content. There was a decrease in β-carotene content due to blanching.

Boiling affected nutritional content of amaranth, black nightshade, and jute mallow leaves (Table 3). Moisture content increased from the onset until 30 min for all crops and decreased at 60 min. The values were higher than the moisture content in raw leaves for all crops. There was no difference between ash content in boiled and raw leaves. The ash content in leaves boiled for 30 min was lower than leaves boiled for 60 min.

There was no change in protein content in amaranth, black nightshade and jute mallow leaves and black nightshade leaves boiled for 30 min. The protein content of jute mallow leaves had decreased by boiling for 30 min. There was no difference between protein content of raw and amaranth leaves boiled for 60 min. For black nightshade and jute mallow leaves protein content in raw leaves was higher than for those boiled for 60 min. Carbohydrate content increased through the boiling process for amaranth and black nightshade leaves after 30 and 60 min. There was no difference between carbohydrate content

### TABLE 1 Nutritional content of raw amaranth, black nightshade and jute mallow leaves (dry matter basis)

| Crop               | Moisture (%) | Ash (%)   | Lipid (%) | Protein (%) | Carbohydrate (%) | Fiber (%) | β-carotene (mg/100 g) |
|--------------------|--------------|-----------|-----------|-------------|-------------------|-----------|-----------------------|
| Amaranth           | 84.33 ± 1.26a| 16.33 ± 1.27a| 7.56 ± 0.37b| 25.21 ± 2.63b| 25.68 ± 2.36b| 16.35 ± 2.29b| 24.25 ± 2.29b |
| Black nightshade   | 87.71 ± 1.61b| 10.57 ± 1.12b| 7.11 ± 1.22b| 39.74 ± 1.92a| 25.94 ± 5.05a| 14.07 ± 0.39b| 16.40 ± 0.08b |
| Jute mallow        | 84.49 ± 1.76a| 12.40 ± 1.44b| 6.64 ± 1.46a| 29.18 ± 0.47b| 27.88 ± 3.76a| 20.86 ± 3.30a| 27.71 ± 1.75a |

*p-value: .05 or < .01. ns, * nonsignificant or significant at p < .05 or p < .01.
of raw and boiled leaves of jute mallow. There was a loss of β-carotene content due to boiling. For amaranth and jute mallow leaves, no β-carotene was detected in boiled leaves. For black nightshade leaves loss of β-carotene was lower for 30 min of boiling than for 60 min.

Drying led to reduced leaf moisture content (Table 4). The loss was similar for all leaves dried in the shade and at 50 or 60°C. There were few variations in ash content in dried compared to raw leaves. The crude lipid content decreased with the drying process. There were no differences in crude lipid content in all crops regardless of drying method. There was no difference in protein content between raw and dried leaves of amaranth and black nightshade. For jute mallow there were decreases in protein content due to drying in the shade and drying at 50 or 60°C between raw and dried leaves. For all crops, carbohydrate content decreased during the drying processes. Drying reduced β-carotene content of the leaves of all crops.

### DISCUSSION

Some nutritional content reported here are close to that reported by Odhav, Beekrum, Akula, and Bajnath (2007). Schönfeldt and Pretorius (2011) reported a lower moisture content for jute mallow leaves.

### TABLE 2 Impact of blanching process on the nutritional content of the vegetables (dry matter basis)

| Crop       | Condition | Moisture (%) | Ash (%) | Protein (%) | Carbohydrate (%) | Lipid (%) | β-carotene (mg/100 g) |
|------------|-----------|--------------|---------|-------------|------------------|-----------|----------------------|
| Amaranth   | Raw leaves| 84.33 ± 1.26a| 16.33 ± 1.27a| 25.21 ± 2.63a| 25.68 ± 2.36a| 7.56 ± 0.37a| 24.25 ± 2.29b |
|            | Boiled 30 min| 88.51 ± 1.39a| 13.72 ± 0.72b| 26.86 ± 2.75a| 42.35 ± 9.83a| 5.75 ± 0.16a| 14.85 ± 0.09b |
| p-value    |      | .070       | .144     | .496       | .046          | .086      | .003     |
| t test     |      | ns         | ns       |           |              |           |           |
| Black nightshade | Raw leaves | 87.71 ± 1.61a| 10.57 ± 1.12b| 39.83 ± 2.04a| 29.04 ± 5.05b| 7.60 ± 0.83a| 16.39 ± 0.83a |
|            | Boiled 30 min| 91.50 ± 1.57a| 8.84 ± 1.63a| 40.60 ± 3.58a| 60.69 ± 13.44a| 7.28 ± 1.38a| 11.86 ± 0.05b |
| p-value    |      | .023       | .204     | .764       | .013          | .750      | .000     |
| t test     |      | *          | ns       |           |              |           |           |
| Jute mallow | Raw leaves | 83.73 ± 1.64b| 12.40 ± 1.44a| 28.98 ± 0.45a| 26.63 ± 4.36a| 6.64 ± 1.46a| 27.71 ± 1.75a |
|            | Boiled 30 min| 91.68 ± 0.11a| 8.57 ± 1.56a| 27.09 ± 0.49a| 46.69 ± 2.0a| 16.39 ± 0.08a| 27.71 ± 1.75a |
| p-value    |      | .003       | .036     | .003       | .017          | .952      | .0001    |
| t test     |      | *          | ns       |           |              |           |           |

Values in columns followed by the same letter are not significantly different. ns, *, ** nonsignificant or significant at p < .05 or p < .01.

### TABLE 3 Effect of boiling on nutritional content of the vegetables (dry matter basis)

| Crop       | Condition | Moisture (%) | Ash (%) | Proteins (%) | Carbohydrates (%) | β-carotene (mg/100 g) |
|------------|-----------|--------------|---------|--------------|-------------------|----------------------|
| Amaranth   | Raw leaves| 84.63 ± 0.70a| 16.54 ± 0.77a| 25.21 ± 2.63a| 25.68 ± 2.36a| 24.25 ± 2.33a |
|            | boiled 30 min| 95.67 ± 0.24b| 14.27 ± 1.64a| 25.94 ± 4.95a| 46.69 ± 2.0a| 0b |
|            | boiled 60 min| 92.57 ± 1.45b| 18.20 ± 3.00a| 26.75 ± 3.92a| 47.72 ± 7.66a| 0b |
| p-value    |      | .0001       | .460     | .906       | .002          | .0001     |
| t test     |      | *          | ns       |           |              |           |
| Black nightshade | Raw leaves | 87.13 ± 1.39a| 10.57 ± 1.12b| 39.83 ± 204a| 26.94 ± 5.04c| 16.39 ± 0.08a |
|            | boiled 30 min| 95.81 ± 0.56b| 7.32 ± 0.87a| 39.39 ± 2.12a| 57.47 ± 0.20a| 5.37 ± 0.18b |
|            | boiled 60 min| 93.44 ± 0.59c| 8.80 ± 2.18a| 32.28 ± 1.59b| 50.54 ± 0.22b| 2.30 ± 0.12c |
| p-value    |      | .0001       | .233     | .006       | .0001          | .0001     |
| t test     |      | *          | ns       |           |              |           |
| Jute mallow | Raw leaves | 83.73 ± 1.64c| 12.39 ± 1.44a| 29.18 ± 0.47a| 27.88 ± 4.36dc| 27.71 ± 1.75a |
|            | boiled 30 min| 96.90 ± 0.63a| 9.37 ± 2.66c| 20.09 ± 022c| 32.04 ± 3.36e| 0b |
|            | boiled 60 min| 94.18 ± 0.32b| 11.43 ± 0.70a| 26.32 ± 0.69b| 19.88 ± 3.36b| 0b |
| p-value    |      | .0001       | .190     | .0001      | .102          | .0001     |
| t test     |      | *          | ns       |           |              |           |
compared to values in the present study. These differences might be due to leaf maturity stage, environmental factors and harvesting method (Jain & Sutarno, 1996). Higher moisture content constitutes an alteration of leaves, which can lead to postharvest losses.

Idirs et al. (2009) reported different ash content for jute mallow leaves than found here. Differences in ash content may be due to leaf age at harvest, or the mineral fertilizer used in culture (Sossa-Vihotogbe, 2013). Variation in ash content in vegetables can be due to cultural practices (Agbo, Kouamé, Mahyao, N’Zi, & Fondio, 2009; Nordeide, Hailtov, Folling, Lied, & Oshaug, 1996), soil mineral composition and the proportion of individual mineral absorption by each plant (Anjorin, Ikokoh, & Okolona, 2010; Asaolu & Asaolu, 2010). In this study, differences might be explained by diversity of sample collection site, or by the cultural practice of each farmer.

The crude lipid content for amaranth, black nightshade, and jute mallow leaves were higher than reported by Grubben et al. (2014). Idirs et al. (2009) found a higher crude lipid content in jute mallow leaves. The crude lipid content could make these crops contribute to meeting the daily lipid requirement of consumers. However, a higher crude lipid content would make the product highly susceptible to rancidity (Odibo, Ezeaku, & Ogbo, 2008).

The crops investigated are an important source of protein. For amaranth protein content was lower than reported by Ocho-Anin, Lénifiére, Christophe, Edith, and Kouakou (2012) and Grubben et al. (2014). For black nightshade leaves, the average found here was lower than that reported by Ocho-Anin et al. (2012). For jute mallow leaves, Idirs et al. (2009) and Grubben et al. (2014) reported lower protein values. Ocho-Anin et al. (2012) reported higher protein levels of jute mallow leaves. The differences in protein content could be due to fertilizer used and soil composition (Agbo et al., 2009).

Carbohydrate content of leaves were lower than reported by Grubben et al. (2014) for amaranth, black nightshade and jute mallow leaves, or by Tchiegang and Kitikil (2004) for black nightshade leaves. Differences may be attributed to analysis method, plant age, farming and environmental conditions, plant species, or cultivar (Jain & Sutarno, 1996).

The crops are sources of β-carotene. Various values of β-carotene have been reported for amaranth leaves (Moshia, Gaga, Pace, Laswai, & Mtebe, 1997; Negi & Roy, 2001), black nightshade (Mibe & Ojjio, 2011) and jute mallow (Choudhary et al., 2013). The differences may be attributed to analysis methods (Jain & Sutarno, 1996). In previous works (Mibe & Ojjio, 2011; Moshia et al., 1997; Negi & Roy, 2001) β-carotene was determined by titration while in the present study β-carotene was determined by High Performance Liquid Chromatography.

Increase in moisture content in blanched leaves can be attributed to disruption of cell walls and membranes allowing water to fill spaces. Reduction in ash content can be explained by minerals leaching during blanching and cooling processes. Blanching led to increased protein content for amaranth and black nightshade leaves. Protein content of jute mallow decreased. This difference could be explained by the nature and form of protein of each specific leaf. Increase in carbohydrate content could be attributed to hydrolyzation of complex glucidic chains (Nafir-Zenati, Gallon, & Faver, 1993) freeing sugar molecules. Blanching leaves induced loss of β-carotene. The loss could be due to

### Table 4: Effect of drying on nutritional content of the vegetable (dry matter basis)

| Crop × Condition | Moisture (%) | Ash (%) | Lipid (%) | Protein (%) | Carbohydrates (%) | β-carotene (mg/100 g) |
|------------------|--------------|---------|-----------|-------------|-------------------|----------------------|
| Amaranth         |              |         |           |             |                   |                      |
| Raw leaves       | 84.63 ± 0.70<sup>a</sup> | 16.54 ± 0.77<sup>a</sup> | 7.56 ± 1.37<sup>a</sup> | 25.21 ± 2.63<sup>a</sup> | 25.68 ± 2.36<sup>a</sup> | 24.25 ± 2.33<sup>a</sup> |
| Shade drying     | 11.82 ± 3.58<sup>b</sup> | 16.43 ± 1.61<sup>b</sup> | 3.96 ± 0.41<sup>b</sup> | 23.24 ± 4.44<sup>b</sup> | 13.97 ± 0.73<sup>b</sup> | 0.63 ± 0.12<sup>b</sup> |
| Cabin drying at 60°C | 7.29 ± 2.14<sup>b</sup> | 15.14 ± 1.17<sup>b</sup> | 3.57 ± 0.39<sup>b</sup> | 23.62 ± 0.82<sup>b</sup> | 12.94 ± 2.09<sup>b</sup> | 0.11 ± 0.00<sup>b</sup> |
| Cabin drying at 50°C | 7.38 ± 3.84<sup>b</sup> | 16.31 ± 1.94<sup>b</sup> | 3.64 ± 0.63<sup>b</sup> | 24.10 ± 6.33<sup>b</sup> | 10.20 ± 3.52<sup>b</sup> | 0.19 ± 0.06<sup>b</sup> |
| p-value          | .0001        | .734    | .004      | .939        | .000              | .0001                |
| t test           | **           | ns      | **        | ns          | **                | ns                   |
| Black nightshade |              |         |           |             |                   |                      |
| Raw leaves       | 87.71 ± 1.61<sup>a</sup> | 10.57 ± 0.83<sup>a</sup> | 7.11 ± 1.22<sup>a</sup> | 39.74 ± 1.92<sup>a</sup> | 26.94 ± 5.04<sup>a</sup> | 16.39 ± 0.08<sup>a</sup> |
| Shade drying     | 11.82 ± 3.5<sup>b</sup> | 12.34 ± 1.7<sup>b</sup> | 4.03 ± 0.92<sup>b</sup> | 38.24 ± 1.63<sup>b</sup> | 17.09 ± 1.86<sup>b</sup> | 1.76 ± 0.00<sup>b</sup> |
| Cabin drying at 60°C | 6.47 ± 1.24<sup>c</sup> | 11.51 ± 0.53<sup>c</sup> | 4.05 ± 0.36<sup>c</sup> | 36.34 ± 1.39<sup>c</sup> | 13.98 ± 0.88<sup>c</sup> | 1.09 ± 0.00<sup>c</sup> |
| Cabin drying at 50°C | 10.18 ± 3.98<sup>bc</sup> | 11.67 ± 0.69<sup>bc</sup> | 4.14 ± 0.53<sup>bc</sup> | 36.07 ± 2.24<sup>bc</sup> | 16.60 ± 1.58<sup>bc</sup> | 1.11 ± 0.01<sup>bc</sup> |
| p-value          | .0001        | .352    | .001      | .136        | .006              | .0001                |
| t test           | **           | ns      | **        | ns          | **                | **                   |
| Jute mallow      |              |         |           |             |                   |                      |
| Raw leaves       | 83.73 ± 1.64<sup>a</sup> | 12.39 ± 1.44<sup>a</sup> | 6.64 ± 1.46<sup>a</sup> | 29.18 ± 0.47<sup>a</sup> | 27.88 ± 3.76<sup>a</sup> | 27.71 ± 1.75<sup>a</sup> |
| Shade drying     | 9.32 ± 1.42<sup>b</sup> | 11.20 ± 1.04<sup>b</sup> | 4.11 ± 0.94<sup>b</sup> | 25.69 ± 0.76<sup>b</sup> | 19.14 ± 5.86<sup>b</sup> | 0.69 ± 0.01<sup>b</sup> |
| Cabin drying at 60°C | 7.09 ± 0.74<sup>b</sup> | 7.96 ± 0.63<sup>b</sup> | 5.32 ± 1.36<sup>b</sup> | 23.46 ± 1.26<sup>b</sup> | 22.35 ± 3.25<sup>b</sup> | 0<sup>b</sup> |
| Cabin drying at 50°C | 7.48 ± 1.36<sup>b</sup> | 11.96 ± 0.23<sup>b</sup> | 4.59 ± 0.37<sup>b</sup> | 24.39 ± 2.4<sup>b</sup> | 23.58 ± 2.10<sup>b</sup> | 0<sup>b</sup> |
| p-value          | .0001        | .028    | .049      | .001        | .136              | .0001                |
| t test           | **           | *       | *         | *           | **                | ns                   |

Values in columns followed by the same letter are not significantly different. ns, *, ** nonsignificant or significant at p < .05 or p < .01.
blanching temperature. The loss of β-carotene in leaves were higher than those reported by Negi and Roy (2000) in amaranth leaves. Differences may be due to blanching time and use of potassium metabisulfite applied by others. Metabisulfite is used to retain leaf color and carotenoids compounds including β-carotene. It is understandable that leaves that have been cooked for 30–60 min loose more compounds that those which have been blanched for 1 min.

Boiling leads to increased leaf moisture content because of water absorption during the cooking process. The lower ash content in boiled leaves compared to raw leaves could be explained by a transfer of minerals from leaves to the boiling water. Loss is less pronounced in leaves cooked for 30 than for 60 min. There was an increase in carbohydrates content of boiled leaves. These results may be explained by the hydrolyzation of glucidic polymers to free sugar molecules during boiling. (Nafir-Zenati et al., 1993).

Boiling affected leaf β-carotene content. Loss was more pronounced for amaranth and jute mallow than for black nightshade leaves. The loss can be attributed to temperature effect on β-carotene. Chandler and Schwartz (1988) reported that loss of carotenoids during cooking is due to oxidation reactions and isomerization. They reported that during cooking treatment time is associated with transformation of the trans-configurations of carotenoids to cis-configuration, which are less active.

The reduction in moisture content of leaves during drying was due to evaporation by convection. Moisture content of leaves dried in a drying cabinet at 50 or 60°C was different than that reported by James and Kuipers (2003) for dried vegetable leaves. This is likely due to an insufficient drying (short time) or an inadequate drying method.

The drying process induced loss in β-carotene content that can be attributed to drying temperature (Negi & Roy, 2000). They reported that drying at moderate temperature (30 ± 2°C) allowed for better retention of β-carotene. This loss could be reduced by bleaching and sulfur treatment prior to drying (James & Kuipers, 2003).

Amaranth, black nightshade and jute mallow leaves have very high nutrient, mineral and β-carotene potential. Postharvest processes affect nutritional content of these vegetables, particularly β-carotene loss, which is pronounced following blanching and boiling of amaranth and jute mallow leaves. Black nightshade leaf exhibited the highest β-carotene retention during all processes. Protein and ash content were relatively stable regardless of the process. Blanching appeared to preserve more leaf nutrients. Time and temperature of treatments should be taken into account during postharvest processes to preserve nutrients. To minimize qualitative and nutritive losses, vegetables should be cooked for a shorter time, cooking in less water, and consuming the water used for cooking as a part of the diet.

ACKNOWLEDGMENTS

This study was supported in part by a commissioned project granted to The World Vegetable Center by CORAF/WECARD (grant number CW/CP/03/PCN/NSC/02/2012 AVRDC10000224) and funded through the World Bank by a Multi Donor Trust Fund composed of the European Union and the Canadian International Development Agency.

REFERENCES

Agbo, E., Kouamé, C., Mahyao, A., N’Zi, J. C., & Fondo, L. (2009). Nutritional importance of indigenous leafy vegetables in Côte d’Ivoire. Acta Horticulturae, 80(1), 361–366.

Anin, L. O. A. A., Léniféré, C. S., Christophe, K., Edith, A. A., & Kouakou, K. A. K. (2012). Valeur nutritionnelle des légumes feuilles consommés en Côte d’Ivoire (Nutritional value of leafy vegetables consumed in Côte d’Ivoire). International Journal of Biological and Chemical Sciences, 6(1), 128–135.

Anjorin, T. S., Ikokoh, P., & Okolona, S. (2010). Mineral composition of Moringa oleifera leaves, pods and seed from two region in Abuja, Nigeria. International Journal of Agriculture and Biology, 12, 431–434.

Asaolu, S. S., & Asaolu, M. F. (2010). Trace metal distribution in Nigerian leafy vegetables. Pakistan Journal of Nutrition, 9(1), 91–92.

AVRDC (2003). Vegetables for life: Confronting the crisis in Africa, AVRDC 03-564. Tainan, Taiwan: Asian Vegetable Research and Development Center.

Carole Nadia Adjouavi Sossa-Vihotogbe, C. N. A. (2013). Food and nutritional quality of four traditional leafy vegetables consumed in Benin: Ceratotheca sesamoides, Sesamum radiatum, Acmella uliginosa et Justicia tenella. University Of Abomey Calavi Bénin.

Causseret, J. (1986). L’alimentation humaine. Evolution et tendances (Human food: Evolution and trend). Documents. Dijon, France: National Institute of Agricultural Research.

Chandler, L. A., & Schwartz, S. J. (1988). Isomerization and losses of trans-β-carotene in sweet potatoes as affected by processing treatments. Journal of Agriculture and Food Chemistry, 36, 129–133.

Choudhary, S. B., Hariom, K. S., Pran, G. K., Saha, A. A. K. A. R., Pranab, H., & Bikas, S. M. (2013). Nutritional profile of cultivated and wild jute (Corchorus) species. Australian Journal of Crop Science, 7(13), 1973–1982.

Craft, N. E. (1992). Carotenoid reversed-phase high performance liquid chromatography methods: reference compendium. Methods Enzymology, 213, 185–205.

Deymie, B., Mutton, J. L., & Simon, D. (1981). Techniques of analyses and controls in the food industries, Vol. 4. Analysis of food components. Paris: Aparia.

Food and Agriculture Organization, International Fund for Agricultural Development and World Food Program (2015). L’état de l’insécurité alimentaire dans le monde 2015. Objectifs internationaux 2015 de réduction de la faim: Des progrès inégaux. (The state of food insecurity in the world 2015. International goals for reducing hunger 2015: Uneven progress). Rome: Food and Agriculture Organization, International Fund for Agricultural Development and World Food Program.

Frances, I. O., Thomas, M. O., & Gabriel, I. O. (2013). Effect of processing methods on the chemical composition of Vitex doniana leaf and leaf products. Food Science and Nutrition, 1(3), 241–245.

Gruppen, G. J. H. (1976). Communication in the Department of Agricultural Research, No. 67. Amsterdam, The Netherlands: Royal Tropical Institute.

Gruppen, G., Klaver, W., Nono-Wondim, R., Everaarts, A., Fondu, L., Nugteren, J. A., & Corrado, M. (2014). Vegetables to combat the hidden hunger in Africa. Chronica Horticulturae, 54(1), 24–32.

Idris, S. I., Yisa, J., & Ndamitso, M. M. (2009). Nutritional composition of Corchorus olitorius leaves. African Journal Online, 5(2), 83–86.

Ihekoronye, A. I., & Ngoddy, P. O. (1985). Integrated food science and technology. New York: Macmillan Publishers.

ISO 2171 (2007). Cereals, pulses and by-products Determination of ash yield by incineration, 11 p. Geneva, Switzerland: International Organization for Standardization.

ISO 659 OldN (1998). Grains oligomères - Détermination de la teneur en huile (Méthode de référence), (Oliginous grains - Determination of oil content. Reference method), 13 p. Geneva, Switzerland: International Organization for Standardization.
Jain, S. K., & Sutarno, H. (1996). Amaranthus L. (grain amaranth). In G. J. H. Grubben & S. Partoohardjono (Eds.), Plant resources of south-east Asia., No 10. Cereals (pp. 130–136). Leiden, The Netherlands: Backhuys Publishers.

James, I. F., & Kuipers, B. (2003). La conservation des fruits et des légumes (Fruits and vegetables conservation). Fondation Agromisa. Agrodok No. 3. Wageningen. The Netherlands.

Kamba, R., Kouamé, C., & Akyeampong, E. (2013). Vegetable consumption patterns in Yaoundé, Cameroon. African Journal of Food, Agriculture, Nutrition and Development., 13(20), 7399–7414.

Kouame, C., Batchep, R., & Kamba, R. T. (2013). Évaluation des pertes post-récolte dans la chaine de production et de commercialisation des légumes feuilles traditionnels à Yaoundé (Cameroon) (Evaluation of post-harvest losses in the production and marketing of traditional leafy vegetables in Yaoundé, Cameroon). Agronomie Africaine., 25(1), 61–70.

Mibei, E. K., & Ojjo, N. K. O. (2011). Effects of processing on chemical composition of four african leafy vegetables. Electronic Journal of Environmental. Agricultural and Food Chemistry, 10(11), 3121–3131.

Montreuil, J., & Spik, G. (1969). Microdosage de sucres. Méthodes colorimétriques de dosage des sucres totaux. [Microdose of carbohydrates. Colorimetric methods for the determination of total carbohydrates], Lille, France: Faculty of Sciences, Université de Lille France.

Mosha, T. C., Gaha, H. E., Pace, R. D., Laswai, H. S., & Mtebe, K. (1997). Effect of traditional processing practices on the content of total carotenoid, β-carotene, α-carotene and vitamin A Activity of selected Tanzanian vegetables. Plant Foods for Human Nutrition, 50, 189–201.

Mukokazi, G., & Svanberg, U. (2003). Effect of traditional open sun-drying and solar cabinet drying on carotene content and vitamin A activity of green leafy vegetables. Plant Foods for Human Nutrition, 58, 1–15.

Nafir-Zenati, S., Gallon, G., & Favier, J. C. (1993). Effet de la cuisson sur la teneur en minéraux des épis d’œufs. [Effect of cooking on the minerals content of spinach], Office de la Recherche Scientifique et Technique Outre-Mer. Fonds Documentair, 36(445), 1–7.

Negi, P. S., & Roy, S. K. (2000). Effect of blanching and drying methods on β-carotene, ascorbic acid and chlorophyll retention of leafy vegetables. Lebensmittel-Wissenschaft and -Technologie, 33, 295–298.

Negi, P. S., & Roy, S. K. (2001). Effect of drying conditions on quality of green leaves during long term storage. Food Research International, 34(4), 283–287.

NF V03 50 NF (1970). Directives générales pour le dosage de l’azote avec minéralisation selon la méthode Kjeldahl (produits agricoles alimentaires), 3 p. Agence Française de Normalisation. 3p. Paris, France.

NF V03 707 (2000). Céréales et produits céréaliers: Détermination de la teneur en eau. Méthode de référence pratique Agence Française de Normalisation. 8p. Paris, France.

Nordide, M. B., Hatloy, A., Folling, M., Lied, E., & Oshaug, A. (1996). Nutrient composition and nutritional importance of green leaves and wild foo resources in an agricultural district. Koutiala, in southen Mali. International Journal of Food Science and Nutrition, 47, 455–468.

Oboh, G. (2005). Effect of some post-harvest treatments on the nutritional properties. Pakistan Journal of Nutrition, 4(4), 226–230.

Odnhav, B., Beekrum, S., Akula, U., & Baijnath, H. (2007). Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal. South Africa. Journal of Food Composition and Analysis, 20, 430–435.

Odibo, F. J. C., Ezekwu, E. O., & Ogbo, F. C. (2008). Biochemical change during the fermentation of Prosopis africana seeds for ogiri-okpe production. Journal of Industrial Microbiology and Biotechnology, 35, 947–952.

Oyenuga, V. A., & Fetuga, B. L. (1975). Chemical composition, digestibility and energy values of some varieties of yam, Cassava, sweet potatoes and cocoyams for pigs. Nigerian Journal of Science, 9(1), 63–110.

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

Schönfeldt, H. C., & Pretorius, B. (2011). The nutrient content of five traditional South African dark green leafy vegetables—A preliminary study. Journal of Food Composition and Analysis, 24, 1141–1146.

Shashi, K. Y., & Salil, S. (1996). Effect of home processing and storage on ascorbic acid and β-carotene content of Bathua (Chenopodium album) and fenugreek (Trigonella foenum graecum) leaves. Plant Foods for Human Nutrition, 50, 239–247.

Tchiegang, C., & Kitikil, A. (2004). Données ethno nutritionnelles et caractéristiques physico- chimiques des légumes feuilles consommés dans la savane de l’Adamaoua (Cameroon) (Ethno-nutritional data and physicochemical characteristics of leafy vegetables consumed in the savanna of Adamaua Cameroon). Tropicuitura, 22(1), 11–18.

Waliou, B. A. A. H. (2011). Evaluation du potentiel de couverture des besoins en vitamine A des jeunes enfants à partir des sauces accompagnant les aliments de base consommés au Bénin (Evaluation of the potential to cover the vitamin A requirements of young children from the sauces accompanying the staple foods consumed in Benin). Thèse de doctorat en nutrition santé à l’école doctorale en Science des procédés-Science des aliments. Montpellier, France: Université de Montpellier 2.

Yang, R.-Y., & Keding, G. B. (2009). Nutritional contributions of important African indigenous vegetables. African indigenous vegetables in urban agriculture. In C. M. Shackleton, M. W. Pasquinii & A. W. Dresche (Eds.), African indigenous vegetables in urban agriculture (pp. 105–143). London: Earthscan.

How to cite this article: Traoré K, Parkouda C, Savadogo A, Ba/Hama F, Kamba R, Traoré Y. Effect of processing methods on the nutritional content of three traditional vegetables leaves: Amaranth, black nightshade and jute mallow. Food Sci Nutr. 2017;5:1139–1144. https://doi.org/10.1002/fsn3.504