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EFFECTS OF THERMAL TREATMENTS ON SOME PHYSICOCHEMICAL, MINERAL AND ANTI-NUTRITIONAL PROPERTIES OF SOME INDIGENOUS UNDER-UTILISED VEGETABLES IN SOUTH WEST NIGERIA

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Abstract

This study evaluated the impact of sun drying, oven drying and blanching–oven drying on the nutritional, elemental and some anti-nutritional properties of some under-utilised leafy vegetables commonly consumed in South West Nigeria- Piper guineense (Schum. and Thonn) (Fiperaceae); Ceiba Pentandra (L) Gaestn (Bombacaceae); Struchium sparganophora (L) (Asteraceae piperaceae); Ipomoea batatas and Tuber borchi (Ascomycota). Results obtained revealed that moisture content ranged from 5.0-7.3%, crude proteins 4.2-7.3%, carbohydrates 64.4-70.4%, fat content 2.1-3.6% respectively, while titratable acidity was 0.2-0.8%, ascorbic acid content was 28.2-44.2 and pH 4.6-5.8 respectively. Blanching-oven drying significantly decreased protein, ash, moisture and ascorbic acid contents respectively, and increased the fat and carbohydrate contents. The mineral elements (mg/100g) in these vegetables was appreciably high. Sun dried samples had significantly higher minerals content, while blanching-oven dried samples had significantly decreased mineral levels. Calcium ranged from 64.0-123.2, magnesium 33.0-89.4, phosphorus 41.8-87.0, sodium 62.6-124.6 and iron 2.0-5.6mg/100g respectively. Sun dried samples had higher levels of phytates (6.4-10.2%), tannins (2.6-4.7%), oxalates (4.8-6.8%) and alkaloids (1.9-3.4%) respectively, while these antinutrients were significantly decreased in both oven dried and blanched-oven dried samples. These results indicate that blanching-oven drying processing of these vegetables may be suitable to substantially reduce some antinutrients in these vegetables, although, it might may affect other nutrients and minerals in the vegetables.

Keywords: *Edible plants, Phytonutrients, Food processing, Nutrition*

1.0 Introduction

Nigeria has a vast amount of vegetables, not only consumed as foods, but also used for ethno-medicinal purposes. Vegetables are the edible parts of plants which could be leaves, stems, roots, flowers, seeds, fruits, bulbs, tubers and fungi that are consumed wholly or in parts, raw or cooked as part of main dish (Nnamani *et al.*, 2010). Generally, when the part utilised as vegetable is mainly from the leaves, such vegetables are referred to as leafy vegetables. They are also called potherbs, greens, vegetable greens, leafy greens, or salad greens. Although they come from a very wide variety of plants, some share a great deal with other leafy vegetables in nutrition and processing methods (Nnamani *et al*., 2010; Omara-Achong *et al*., 2012).

Some indigenous vegetables in Nigeria have been identified and classified as under-utilised. Under-utilised vegetables are inexpensive source of cheap and abundant nutrients and fibers which are usually in short supply in people's daily diets (Mohammed & Sharif, 2011; Omara-Achong *et al*., 2012). A great proportion of our indigenous vegetable species are cultivated domestically while some are seen growing in the wild. Some of these vegetables include; *Ipomoea batatas, Ceiba pentandra, Tuber borchi, Struchium sparganophora and Piper guineense schum and Thonn.*

Over 40 indigenous leafy vegetables are eaten in Nigeria, with the South-Western region accounting for over half of them. Local vegetables are useful contributors to rural and urban population diets in Nigeria. They play important roles in traditional-food culture and various ethnic groups consume varieties of different indigenous types of vegetables for different reasons (Antia *et al*., 2006; Mepba *et al*., 2007; Gladys-Oguche, 2012; Omoyemi *et al*., 2015). Approximately half of the leafy vegetables consumed in most Nigeria diets are from indigenous sources and they contribute significant micronutrients (Mepba *et al*., 2007; Mohammed & Sharif, 2011). Green leafy vegetables used for food & soup preparation cuts across different cultures within Nigeria and other parts of West Africa with similar cultural and socio economic background (Mepba *et al*., 2007; Nnamani *et al*., 2010). It is well known that vegetables are rich in various antioxidants, including ascorbic acid and carotenoid compounds that can protect against oxidative stress, and thus play important roles in the chemoprevention of diseases that have their aetiology and pathophysiology in reactive oxygen species (Nnamani *et al*., 2010; Omara-Achong *et al*., 2012; Salisu *et al*., 2019).

Epidemiological studies revealed that the consumption of vegetable and fruit can protect humans against oxidative damages, often associated with an increased risk of cardiovascular disease, cancer and other chronic diseases. Antioxidants prevent oxidative damages by inhibiting the action of free radicals and reactive oxygen species implicated in the aetiology of some pathological conditions related to cardiovascular and other diseases (Ali, 2009; Nnamani *et al*., 2010; Vinala *et al*., 2011; Chandra & Ramalingam 2011). Consumption of dietary antioxidants from vegetables and fruits is beneficial in preventing these diseases. High intake of foods rich in natural antioxidants have been shown to increase the antioxidant capacity of the plasma and reduce risk of some, but not all of cancers, heart diseases and stroke (Chandra & Ramalingam 2011; Asaolu *et al*., 2012; Gupta *et al*., 2013).

In literature, studies abound on the availability and utilization of vegetables in a number of communities in Nigeria (Banwat *et al*., 2012; Chubike *et al*., 2013), however, little information exists on the availability and utilisation of some leafy vegetables in the South West region. This study is aimed at evaluating some under-utilized leafy vegetables cultivated in this region for their nutrients profile with a view to find applications in academic, institutional or domestic catering needs, and also, other possible applications in food processing.

2.0 Materials and methods

2.1 Sample collection and pre-processing

The leaves of freshly harvested, matured and blemish-free *Ipomoea batatas* (Anamo), *Ceiba pentandra* (Araba), *Tuber borchi* (Efunle), *Sparganophorus sparganophora* (Ewuro Odo) and *Piper guineense* seed (Iyere) were collected from local farms around Aba Erinfun area near The Federal Polytechnic Ado-Ekiti main campus, and were identified by a plant taxonomist in the Department of Botany and Plant Science, Afe Babalola University Ado-Ekiti, Ekiti State, Nigeria.

The fresh samples were destalked, washed, each sample was divided into three (3) equal portion of 1kg each.

Table 1: Sample names and coding

Sample name	Local name	Coding
Ipomoea batatas leaves	Anamo	Ib
Ceiba pentandra leaves	Araba	Cp
Tuber borchi leaves	Efunle	Tb
Sparganophorus sparganophora leaves	Ewuro odo	Ss
Piper guineense (seed)	Iyere	Pg

Sample Preparation

The first batch included weighing 1kg of each leafy vegetables and *Piper guineense* seed, respectively, the samples were washed and spread on medium density polythene bags (0.926 – 0.940 g/cc) on a raised platform for sun-drying (5hrs daily for three days at 33-35 ^{0}C and RH, 80-85%). The dried samples was carefully milled using a laboratory mortar and pestle, and then packed in labelled air tight containers.

For the second batch, 1kg each of the vegetables and seed samples were blanched (Mepba *et al*., 2007) in hot water at 100 ^{0}C for 5mins and rapidly refrigerated at 2 ^{0}C. The blanched samples was then oven dried at 45 ^{0}C for 2 days.
For the third batch, 1kg of each vegetable and seed was oven dried at 45 ^{0}C for 2 days.

Chemical Analysis

Ground samples of sun-dried, oven dried and blanched oven dried vegetables were analysed for proximate composition determination (Mepba *et al*., 2007; AOAC, 2005). The moisture content was determined by air-oven drying at 120 ^{0}C for 1 hr, and the crude protein contents by micro Kjeldahl method (% protein = N x 6.25). The lipid content was determined using a soxhlet extraction apparatus and crude fiber content was evaluated by dilute acid and alkali hydrolysis. Carbohydrate contents was calculated by difference (AOAC, 2005; Antia *et al*., 2006; Salisu *et al*., 2019). The titratable acidity was determined as described by Onwuka (2005) and AOAC (2005), while the pH was determined according to the method described by Onitilo *et al*. (2007) with the use of pH meter (Starter 2100 Bench pH Meter) with standardization with buffer solution of pH 4 and 9.

Mineral Composition Analysis

5g of dried powdered sample was dissolved in 6 M HCl solution, the resulting solution was made up to 20ml, and used for the determination of mineral elements. Phosphorus was determined by the phospho-molybdate method [Mepba et al., 2007; Ali, 2009). Sodium and potassium were determined by flame photometer (Jenway, PF 7, Essex UK), while calcium, magnesium, iron and zinc were determined by Atomic absorption spectrophotometer (Unicam Analytical system, Model 919, Cambridge, UK.

Determination of Ascorbic Acid

Vitamin C was determined by taking a 5g sample, grinding it in a mortar using 100ml of 10% trichloroacetic acid. The ascorbic acid was assayed by visual titration with 2,6 dichlorophenol solution (Mepba *et al*., 2007; Pattan & Devi, 2014; Salisu *et al*., 2019).

Determination of some Anti-nutrients

Tannin was determined spectrometrically using tannic acid standard and Folin Denis reagent. Phytates was determined titrimetrically as described using ammonium thiocyanate and standard iron (III) chloride solution (Salazar *et al*., 2006; Pillai & Nair, 2013; Pattan & Devi, 2014). Alkaloids was determined gravimetrically, while the method of titration was used to determine oxalates (Day & Underwood, 1986; Onwuka, 2006; Pattan & Devi, 2014).

Statistical analysis

The statistical differences between the values obtained under different experimental conditions were established by undertaking ANOVA followed by Tukey's HSD multiple - pairwise comparison test using SPSS software (PASW Statistics 17.0, IBM, UK). Differences were considered significant at $P < 0.05$.

3.0 Results and discussion

3.1 Effects of thermal treatments on the proximate composition, ascorbic acid content and pH of some under-utilised vegetables in South West Nigeria.

Table 2 shows the proximate composition, ascorbic acid and pH contents of some sun dried, oven dried and blanched-oven dried underutilized vegetables. Fat content ranges from 2.1–3.6% with blanched-oven dried *Ipomoea batatas* (Ib3) having the highest fat content while oven dried *Ceiba petandra* (Cp2) had the lowest. All the samples had a low fat content. According to Antia *et al*. (2006), dietary fats functions in the increase of palatability of foods by absorbing and retaining flavor, however, excess fat intake has been implicated in atherosclerosis, cancer and ageing. Sun dried samples had higher contents of ash (8.1-10.4%), crude fiber (8.5-12.2%), ascorbic acid (37.4-44.2mg/100g) and moisture (6.2-7.3%) respectively. Ash contents of foods influences its mineral composition (Antia *et al*., 2006; Mepba *et al*., 2007), the ash content of any given food materials is a measure of food quality and identity, it may represent foodstuffs that is carbon free as a result of burning away of organic portion, on the other hand, crude fiber offers a variety of health benefits, and is essential in reducing the risk of chronic disease such as diabetes, obesity, cardiovascular disease and diverticulitis (Nnamani *et al*., 2010; Mohammed & Sharif, 2011; Chandra & Ramalingam 2011; Gupta *et al*., 2013; Salisu *et al*., 2019).

Protein content of blanched-oven dried samples were the least (4.2-6.6%), it was also the same for moisture (5.0-6.4%) and ascorbic acid contents (28.2-38.3mg/100g). Proteins are used for building and repairing of body tissues, regulation of body processes and formation of enzymes and hormones.

As earlier reported (Oladele *et al*., 2009), the decrease in nutrients of vegetables

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could be attributed to leaching of some soluble constituents. Constituents such as nutrients, simple sugars and some anti-nutrients e.g. tannin and phytic acid can be lost by leaching particularly at above ambient temperature.

The ascorbic acid content and pH of some underutilized vegetables as depicted in Table 2 also revealed that the pH ranged from 4.6-5.8, indicating that the samples tended towards weak acid potentials. pH value is used to depict the degree of acidity or alkalinity of a substance. The ascorbic acid content ranged from 28.2-44.2 mg/100g with the sun dried samples having the highest Ascorbic acid content (37.4-44.2 mg/100g) and the blanched oven dried samples having the lowest ascorbic acid content (28.2-38.3 mg/100g) respectively. Ascorbic acid is known to be adversely affected by high temperature (Gladys-Oguche 2012; Gupta *et al*., 2013).

Table 2: Effects of thermal treatments on the proximate composition, ascorbic acid content and pH of some under-utilised leafy vegetables in South West Nigeria.

				% Composition					
Sample	**Fat**	**Protein**	**Ash**	**Moisture**	**C.Fiber**	**Carbohydrates**	**T. acidity**	**Asc. acid (mg/100g)**	**pH**
Ib1	2.7±0.1$_{ab}$	5.4±0.1$_{ab}$	8.3±0.1$_{a}$	6.4±0.2$_{a}$	12.2±0.2$_{e}$	65.0±0.4$_{ab}$	0.4±.0.3$_{a}$	38.2±0.1$_{b}$	5.0
Cp1	2.2±0.4$_{a}$	7.3±0.2$_{d}$	8.1±0.2$_{a}$	7.2±0.4$_{b}$	10.5±0.1$_{c}$	64.7±0.42$_{a}$	0.2±0.2$_{a}$	41.4±0.1$_{d}$	4.9
Tb1	2.8±0.2$_{ab}$	6.2±0.2$_{bc}$	9.2±0.2$_{b}$	6.2±0.4$_{a}$	11.2±0.1$_{cd}$	64.4±0.34$_{a}$	0.5±0.1$_{ab}$	39.2±0.2$_{c}$	5.4
Ss1	2.2±0.2$_{a}$	4.6±0.2$_{a}$	10.4±0.3$_{c}$	7.3±0.2$_{b}$	9.7±0.22$_{b}$	65.8±0.46$_{bc}$	0.6±0.4$_{ab}$	44.2±0.3$_{e}$	5.6
Pg1	3.1±0.4$_{bc}$	6.8±0.1$_{cd}$	9.2±0.3$_{b}$	6.4±0.1$_{a}$	8.5±0.32$_{a}$	66.0±0.35$_{c}$	0.3±0.3$_{a}$	37.4±0.2$_{a}$	5.6
Ib2	2.5±0.1$_{ab}$	5.5±0.1$_{b}$	7.4±0.4$_{a}$	5.8±0.3$_{ab}$	11.9±0.3$_{e}$	66.9±0.43$_{a}$	0.5±0.4$_{ab}$	33.2±0.4$_{a}$	4.7
Cp2	2.1±0.1$_{a}$	7.2±0.1$_{d}$	7.6±0.3$_{ab}$	6.4±0.4$_{bc}$	10.1±0.22$_{c}$	66.6±0.36$_{a}$	0.4±0.3a	39.4±0.2$_{c}$	4.6
Tb2	2.6±0.4$_{ab}$	6.4±0.1$_{bc}$	8.3±0.4$_{bc}$	5.2±0.2$_{a}$	10.8±0.4$_{cd}$	66.7±0.24$_{a}$	0.7±0.1$_{ab}$	37.2±0.3$_{b}$	5.2
Ss2	2.4±0.32$_{a}$	4.8±0.3$_{a}$	8.4±0.3$_{bc}$	6.4±0.4$_{bc}$	9.3±0.28$_{b}$	68.7±0.43$_{b}$	0.8±0.1$_{ab}$	42.1±0.6$_{d}$	5.8
Pg2	2.9±0.2$_{ab}$	6.5±0.2$_{cd}$	8.3±0.2$_{bc}$	5.2±0.3$_{a}$	8.2±0.33$_{a}$	68.9±0.44$_{b}$	0.5±0.2ab	33.4±0.4$_{a}$	5.7
Ib3	3.6±0.3$_{cd}$	4.3±0.2$_{a}$	7.3±0.2$_{a}$	5.6±0.3$_{ab}$	11.6±0.4$_{d}$	67.6±0.36$_{bc}$	0.5±0.2$_{ab}$	31.3±0.4$_{b}$	5.1
Cp3	2.5±0.1$_{ab}$	6.6±0.1$_{c}$	7.4±0.1$_{a}$	6.4±0.4$_{bc}$	10.2±0.24$_{bc}$	66.9±0.25$_{a}$	0.4±0.1$_{a}$	34.4±0.2$_{c}$	4.9
Tb3	3.2±0.1$_{bc}$	4.9±0.1$_{ab}$	8.5±0.2$_{b}$	5.0±0.4$_{a}$	11.1±0.18$_{cd}$	67.3±0.36$_{ab}$	0.6±0.2$_{ab}$	31.4±0.5$_{b}$	5.4
Ss3	2.4±0.2$_{a}$	5.3±0.1$_{bc}$	9.4±0.4$_{bc}$	6.0±0.2$_{bc}$	9.8±0.3$_{b}$	67.1±0.45$_{ab}$	0.6±0.1$_{ab}$	38.3±0.1$_{d}$	5.7
Pg3	3.5±0.2$_{cd}$	4.2±0.2$_{a}$	8.6±0.2$_{b}$	5.0±0.2$_{a}$	8.3±0.2$_{a}$	70.4±0.26$_{d}$	0.4±0.4$_{a}$	28.2±0.4$_{a}$	5.8

***Values are means of triplicate determinations. Values not sharing a common letter are significantly different at P < 0.05.**
Sun dried samples have the prefix 1
Oven dried samples have the prefix 2
Blanched samples have the prefix 3

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3.3: Effect of thermal treatments on anti-nutritional factors in some underutilized vegetables in South West Nigeria

Table 3 shows the anti-nutritional composition of some underutilized vegetables under different thermal processing conditions. Sun dried samples had the highest phytates level (6.4-10.2mg/100g), while there was marked reduction for phytates in blanched-oven dried samples (4.8-8.4mg/100g). This trend was noticeable in all the analysed samples, as blanching-oven drying caused significant decreases in tannins, oxalates and alkaloids contents respectively. Sun dried *Ipomoea batatas* leaves had the highest phytates content, same for sun dried *Sparganophorus sparganophora* leaves, which had higher oxalates and alkaloids content. Oven drying these vegetables resulted in lower levels of these antinutrients, and blanched-oven dried samples, the least levels respectively.

Phytates has been suggested to serve as a store of cations, of high energy phosphoryl groups, and, by chelating free iron, as a potent natural anti-oxidant (Chinma & Igyor, 2007; Pattan & Devi, 2014). Oxalates ranges from 2.5-6.8 mg/100mg while tannins ranges from 1.1-4.7 mg/100g. Tannins are known to be responsible for decreased feed intake, growth rate, feed efficiency and protein digestibility in experimental animals. If tannin concentration in the diet becomes too high, microbial enzyme activities including cellulose and intestinal digestion may be depressed. Tannin is known to evoke growth-depressing effects in rats. In this study, the tannin level (1.1-4.7 mg/100g) were found to be relatively low in comparison with tannic acid in some previous study (Akinyede et al., 2005; Chinma & Igyor 2007). High amount of tannins are well known to form complex with proteins and reduce the solubility of proteins and make protein less susceptible to proteolytic attack than the same proteins alone. However, relatively, some amount of tannins may have a potential role as protective factors against free radical mediated pathologies, such as cancer and atherosclerosis, in humans (Hangen & Bennin, 2002; Onwuka, 2006; Pattan & Devi, 2014).

Anti-nutrients are chemicals which have been evolved by plants for their own defense, among other biological functions and reduce the maximum utilization of nutrients especially proteins, vitamins, and minerals, thus preventing optimal exploitation of the nutrients present in a food and decreasing the nutritive value. Some of these plant chemicals may however be deleterious to health or evidently advantageous to human and animal health if consumed at appropriate amounts. The levels of some of the antinutritional factors as reported in this study is low when compared to that of previous studies (Oladele *et al*., 2009; Ilodibia *et al*., 2016).

Table 3: Some anti-nutritional factors in some sun dried, oven dried and blanched-oven dried underutilized vegetables

	Anti-nutrients (mg/100g)			
Sample	**Phytates**	**Tannins**	**Oxalates**	**Alkaloids**
Ib1	$10.2\pm0.18_d$	$2.6\pm0.08_a$	$5.6\pm0.28_{bc}$	$2.4\pm0.18_{ab}$
Cp1	$8.4\pm0.2_b$	$3.6\pm0.16_b$	$4.8\pm0.48_a$	$2.8\pm0.22_b$

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Sample	Anti-nutrients (mg/100g) Phytates	Tannins	Oxalates	Alkaloids
Tb1	9.3±0.32$_{c}$	2.7±0.22$_{a}$	5.4±0.36$_{ab}$	1.9±0.28$_{a}$
Ss1	8.9±0.24$_{bc}$	3.8±0.42$_{b}$	6.8±0.32$_{d}$	3.4±0.26$_{bc}$
Pg1	6.4±0.08$_{a}$	4.7±0.28$_{c}$	5.2±0.26$_{ab}$	2.2±0.18$_{ab}$
Ib2	9.2±0.08$_{d}$	2.5±0.08$_{a}$	4.6±0.32$_{ab}$	3.2±0.2$_{bc}$
Cp2	7.4±0.22$_{b}$	2.8±0.08$_{a}$	4.2±0.22$_{a}$	2.8±0.32$_{b}$
Tb2	8.4±0.32$_{c}$	2.5±0.28$_{a}$	4.9±0.28$_{ab}$	1.8±0.28$_{a}$
Ss2	7.8±0.26$_{bc}$	3.2.0±0.4$_{ab}$	6.3±0.43$_{c}$	3.8±0.18$_{c}$
Pg2	5.4±0.32$_{a}$	4.2±0.26$_{c}$	4.9±0.48$_{ab}$	2.0±0.14$_{ab}$
Ib3	8.4±0.28$_{cd}$	1.1±0.33$_{a}$	3.8±0.36$_{bc}$	1.4±0.18$_{a}$
Cp3	6.2±0.24$_{b}$	2.2±0.42$_{b}$	3.8±0.28$_{bc}$	2.2±0.2$_{b}$
Tb3	7.6±0.32$_{c}$	1.8±0.2$_{ab}$	3.2±0.28$_{ab}$	1.1±0.24$_{a}$
Ss3	7.5±0.3$_{c}$	2.7±0.16$_{bc}$	4.6±0.34$_{d}$	3.0±0.35$_{c}$
Pg3	4.8±0.42$_{a}$	3.1±0.12$_{c}$	2.5±0.3$_{a}$	1.6±0.31$_{ab}$

***Values are means of triplicate determinations. Values not sharing a common letter are significantly different at P < 0.05.**
Sun dried samples have the prefix 1
Oven dried samples have the prefix 2
Blanched samples have the prefix

3.4 Mineral composition of some sun dried, oven dried and blanched-oven dried under-utilized vegetables in South West Nigeria.

The mineral composition of the leaves in Table 4 revealed a considerably high content of minerals in the sun dried samples in relation to oven dried and blanched-oven dried samples. With the exception of manganese (0.2-1.2 mg/100g), oven and blanching-oven drying processing caused marked reduction in mineral elements in all the samples. Iron ranged from (2.0-5.6mg/100g), with all the blanched-oven dried samples having the least iron contents, it has been reported that iron deficiency reduces work capacity and productivity in adult, and increases the severity and incidence of infection, anaemia, maternal and prenatal mortality (Scrinshaw, 1991; Ilodiba *et al.*, 2016). Zinc content ranged from 2.2-6.8mg/100g, while Calcium content was 64.0-123.2mg/100g. Calcium plays important roles in tissues and bones strengthening, additionally, calcium and phosphorus combine favourably to prevent rickets (Asaolu *et al.*, 2012; Banwat *et al.*, 2012; Chibuke *et al.*, 2013).

The samples had appreciable amounts of sodium and potassium, high K/Na ratio in foods serves as maintenance of a correct osmotic pressure and fluid pH in the body, essential for the movement of metabolites (Lake & Waterworth 1980; Antia *et al.*, 2006; Gupta *et al.*, 2013).
Generally, the reduction in mineral content from blanching-oven drying may be attributed to leaching of some soluble components in these vegetables. However, some of the studied vegetables compared favourably, and had higher mineral contents than those earlier reported for some other plants (Akinhanmi *et al.*, 2008). These vegetables may have a potential to supply sufficient amount of minerals for consumers and microbial media for microorganisms.

Table 4: Elemental composition of sun dried, oven dried and blanched oven dried under-utilised vegetables

Sample	Fe	Mn	Zn	Ca	Na	K	Mg	P
				Minerals (Mg/100g)				
Ib1	5.6±0.3$_c$	0.9±0.2$_{ab}$	6.8±0.22$_e$	98.2±0.1$_c$	124.6±0.1$_e$	56.9±0.24$_b$	67.0±0.1$_b$	68.9±0.1$_c$
Cp1	4.9±0.2$_b$	0.6±0.1$_{ab}$	5.9±0.3$_d$	79.4±0.2$_b$	98.4±0.4$_b$	44.9±0.31$_a$	89.4±0.2$_e$	45.6±0.1$_a$
Tb1	2.4±0.28$_a$	0.2±0.2$_a$	4.3±0.2$_b$	67.5±0.1$_a$	112.0±0.3$_c$	59.8±0.42$_c$	34.9±0.3$_a$	87.0±0.3$_d$
Ss1	2.4±0.3$_a$	0.4±0.1$_a$	2.8±0.2$_a$	123.2±0.2$_e$	66.8±0.1$_a$	44.8±0.18$_a$	67.8±0.2$_{bc}$	45.9±0.2$_a$
Pg1	5.5±0.1$_c$	0.5±0.16$_{ab}$	4.9±0.2$_{bc}$	109.6±0.2$_d$	119.8±0.3$_d$	60.2±0.45$_{cd}$	78.8±0.3$_d$	59.6±0.4$_b$
Ib2	5.4±0.24$_{bc}$	0.9±0.2$_{ab}$	6.5±0.3$_d$	85.3±0.3$_c$	122.8±0.1$_e$	54.8±0.27$_b$	66.2±0.1$_b$	66.1±0.3$_d$
Cp2	4.6±0.16$_b$	0.6±0.2$_{ab}$	5.6±0.2$_c$	75.5±0.4$_b$	95.4±0.3$_b$	43.1±0.31$_a$	88.3±0.2$_d$	44.4±0.4$_{ab}$
Tb2	2.2±0.3$_a$	0.3±0.18$_a$	4.1±0.2$_b$	65.7±0.3$_a$	110.8±0.4$_c$	57.4±0.19$_c$	33.2±0.2$_a$	85.8±0.3$_e$
Ss2	2.1±0.08$_a$	0.3±0.2$_a$	2.5±0.3$_a$	120.3±0.2$_e$	64.6±0.2$_a$	42.8±0.44$_a$	66.3±0.3$_b$	43.7±0.2$_a$
Pg2	5.1±0.22$_{bc}$	0.6±0.2$_{ab}$	4.4±0.1$_b$	105.6±0.3$_d$	117.4±0.3$_d$	58.2±0.25$_{cd}$	77.1±0.3 C	57.4±0.3$_c$
Ib3	4.9±0.34$_{bc}$	1.2±0.1$_{bc}$	6.2±0.2$_e$	82.7±0.1$_c$	120.9±0.1$_e$	52.4±0.31$_d$	65.2±0.1$_b$	64.5±0.4$_d$
Cp3	4.4±0.2$_b$	0.7±0.3$_{ab}$	4.6±0.2$_{cd}$	74.9±0.2$_b$	94.5±0.1$_b$	42.6±0.28$_b$	86.9±0.2$_d$	42.8±0.2$_b$
Tb3	2.1±0.1a	0.2±0.2$_a$	3.5±0.32$_b$	64.0±0.3$_a$	108.6±0.2$_c$	55.3±0.19$_e$	33.0±0.4$_a$	83.4±0.4$_e$
Ss3	2.0±0.2$_a$	0.6±0.27$_{ab}$	2.2±0.3$_a$	116.4±0.4$_e$	62.6±0.3$_a$	38.2±0.32$_a$	65.4±0.2$_b$	41.8±0.2$_a$
Pg3	4.7±0.1$_{bc}$	0.7±0.32$_{ab}$	4.1±0.2$_c$	104.4±0.2$_d$	115.6±0.4$_d$	45.3±0.22$_c$	76.5±0.2$_c$	54.4±0.1$_c$

***Values are means of triplicate determinations. Values not sharing a common letter are significantly different at P < 0.05.**
Sun dried samples have the prefix 1
Oven dried samples have the prefix 2
Blanched samples have the prefix 3

4.0 Conclusion

From the results obtained in this study, blanching-oven dying had a significant influence on the nutrients and anti-nutrients of these vegetables studied. Blanching-oven drying led to increase in fat and carbohydrates contents, while effectively causing significant reduction in other nutrients. The anti-nutritional factors in these vegetables were significantly reduced by blanching-oven drying, while the sun dried samples had significantly higher nutrients levels.

It can be concluded that processing vegetables by sun drying ensures minimal losses in nutrients and minerals levels, while blanching-oven drying may be suitable for processing vegetables, particularly if their anti-nutritional factors are suspected to be high.

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