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Impact of Shadow Drying on Nutritive and Antioxidant Properties of Leafy Vegetables Consumed in Southern Côte D'Ivoire

Florentin Acho[a], Lessoy Zoué[b]*, Sébastien Niamké[c]

[a,b,c]*Biotechnology Laboratory, Biosciences Faculty, Felix Houphouet Boigny University, 22 BP 582 Abidjan 22*

[a]*Email: conxty977@gmail.com*

[b]*Email: y.lessoy@yahoo.fr*

[c]*Email: niamkes@yahoo.fr*

Abstract

The abundance of leafy vegetables during the rainy seasons and poor transport and storage systems lead to their post-harvest losses in dry seasons. Effective preservation and storage of these plants would not only reduce their post-harvest losses but make them available throughout the year. Therefore a study was conducted on shadow drying effect on the nutritive and antioxidant properties of five selected leafy vegetables consumed in Southern Côte d'Ivoire. Experiment was conducted as follow: portions of washed and drained fresh leafy vegetables (500 g) were spread on clean filter paper and kept in a well-ventilated room of the laboratory at 25°C for 5, 10 and 15 days. The results of the proximate composition after 15 days of drying were: moisture (14.16 – 20.51%), ash (8.30 -19.16%), crude fibres (11.43 – 21.27%), proteins (9.13 – 19.05%), lipids (3.29 – 7.97%) and carbohydrates (32.45 – 51.74%). The minerals concentration increased with respective values after 15 days of shadow drying: calcium (78.23-337.26 mg/100g), magnesium (70.41-208.46 mg/100g), phosphorus (50.73-184.81 mg/100 g), potassium (363.56-776.73 mg/100g), iron (12.14-63.57 mg/100g) and zinc (12.57-33.95 mg/100g). During shadow drying, vitamin C and carotenoids were subjected to losses estimated to 65.52 – 91.07% and 39.66 – 95.23%, respectively. Contrary to these losses, antioxidant activity increased and ranged from 66.10 to 74.33% after 15 days of shadow drying. All these results suggest that the considerable nutrient contents of shade dried leafy vegetables make them good source of food when supplemented with sources of vitamin C and carotenoids in order to meet the nutritional requirements of Ivorian population.

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* Corresponding author.

Keywords: food preservation; leafy vegetables; nutritive composition; shadow drying.

1. Introduction

Leafy vegetables are herbaceous plants whose leaves are eaten as supporting food or main dishes and they may be aromatic, bitter or tasteless [1]. The utilization of leafy vegetables is part of Africa cultural heritage and these plants play important roles in the customs, traditions and food culture of the African household. The nutrient content of different types of leafy vegetables varies considerably and they are not major sources of carbohydrates compared to the starchy foods but contain vitamins, essential amino acids, as well as minerals and antioxidants [2]. According to [3], leafy vegetables are the cheapest and most available sources of important proteins, vitamins, minerals and essential amino acids. However, there is seasonal variation in the availability of many of these vegetables. In general leafy vegetables grow abundantly during the rainy season and are most readily available than in the dry season [4].

Due to their high moisture content (70 – 90%), leafy vegetables are perishable and have a short self-life (1-3 days) after harvesting [5]. Indeed, during the wet season, the leaves of these plants which are either cultivated or grow naturally are abundant but without post-harvest preservation, the excess after consumption goes to waste. To avoid post-harvest losses, drying processing has been documented as an appropriate method for preserving leafy vegetables in order to ensure that they are available in other seasons [6]. By definition, food dehydration is the process of removing water from food by circulating hot air through it, which prohibits the growth of enzymes and bacteria [7]. According to [8], drying removes moisture and the food becomes smaller and lighter in weight.

Because of increasing consumption rate of dried leafy vegetables during the dry season, there is a need to investigate the effect of different drying methods on the nutritive value of common edible African Leafy Vegetables (ALVs). In rural areas of Southern Côte d'Ivoire (Ivory Coast) were population are not provided by refrigerator, shadow drying is the method often used for the preservation of leafy vegetables before their consumption through recipes made of sauces and starchy staples foods [9]. Five (5) leafy vegetables (*Basella alba* "epinard", *Colocasia esculenta* "taro", *Corchorus olitorius* "kplala", *Solanum melongena* "aubergine" and *Talinum triangulare* "mamichou") mostly consumed in Southern Côte d'Ivoire are subjected to this traditional drying method. Earlier reports have highlighted the nutritive potential of these fresh leafy vegetables [10] and the focus of the present research was to establish the effect of shadow drying method on their nutritive and antioxidant properties.

2. Material and Methods

2.1. Material

Leafy vegetables (*Basella alba*, *Colocasia esculenta*, *Corchorus olitorius, Solanum melongena* and *Talinum triangulare*) were collected fresh and at maturity from cultivated farmlands located at Dabou (latitude: 5°19′14″ North; longitude: 4°22′59″West) (Abidjan District, Côte d'Ivoire). Samples were harvested at the early stage (between one and two weeks of the appearance of the leaves). These plants were previously authenticated by the

National Floristic Center (University Felix Houphouët-Boigny, Abidjan-Côte d'Ivoire).

2.2. Drying processing

The collected leafy vegetables were rinsed with deionized water and the edible portions were separated from the inedible portions. The edible portions were allowed to drain at ambient temperature and separated into two portions of 500 g each. The first portion was spread on clean filter paper and kept in a well-ventilated room of the laboratory at 25°C for 5, 10 and 15 days. Natural current of air was used for shadow drying and the leaves were constantly turned to avert fungal growth [11]. The second 500 g portion of leafy vegetables was not subjected to any form of drying and used as the control (raw). After drying period, the dried leaves were stored in air-tight containers for further analysis.

2.3. Nutritive analysis

Proximate analysis was performed using official methods [12]. The moisture content was determined by the difference of weight before and after drying samples (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by the incineration of dry matter sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. For crude fibres, 2 g of dry matter sample were weighed into separate 500 mL round bottom flasks and 100 mL of 0.25 M sulphuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 100 mL of 0.3 M sodium hydroxide solution was added and the mixture were boiled again under reflux for 30 min and filtered through Whatman paper. The insoluble residue was then incinerated, and weighed for the determination of crude fibres content. Proteins were determined through the Kjeldhal method and the lipid content was determined by Soxhlet extraction using hexane as solvent. Carbohydrates content and calorific value were calculated and expressed on dry matter basis using the following formulas [13]:

Carbohydrates: 100 – (% moisture + % proteins + % lipids + % ash + % fibres)

Calorific value: (% proteins x 2.44) + (% carbohydrates x 3.57) + (% lipids x 8.37)

Minerals contents were determined by the ICP-MS (inductively coupled argon plasma mass spectrometer) method [14]. The crushed samples (5 g) were burned to ashes in a muffle furnace (Pyrolabo, France). The ashes obtained were dissolved in 10 mL of HCl/HNO_3 and transferred into 100 mL flasks and the volume was made up using deionized water. The mineral composition of each sample was determined using an Agilent 7500c argon plasma mass spectrometer. Calibrations were performed using external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

The titration method as described by [15] was performed for oxalate determination. One (1) g of crushed sample was weighed into 100 mL conical flask. A quantity of 75 mL of sulphuric acid (3 M) was added and stirred for 1 h with a magnetic stirrer. The mixture was filtered and 25 mL of the filtrate was titrated while hot against $KMnO_4$ solution (0.05 M) to the end point.

Phytates contents were determined using the Wade's reagent colorimetric method [16]. A quantity (1 g) of crushed sample was mixed with 20 mL of hydrochloric acid (0.65 N) and stirred for 12 h with a magnetic. The mixture was centrifuged at 12000 rpm for 40 min. An aliquot (0.5 mL) of supernatant was added with 3 mL of Wade's reagent. The reaction mixture was incubated for 15 min and absorbance was measured at 490 nm by using a spectrophotometer (PG Instruments, England). Phytates content was estimated using a calibration curve of sodium phytate (10 mg/mL) as standard.

2.4. Antioxidant properties evaluation

Vitamin C contained in analyzed samples was determined by titration using the method described by [17]. About 10 g of crushed leaves were soaked for 10 min in 40 mL metaphosphoric acid-acetic acid (2%, w/v). The mixture was centrifuged at 3000 rpm for 20 min and the supernatant obtained was diluted and adjusted with 50 mL of bi-distilled water. Ten (10) mL of this mixture was titrated to the end point with dichlorophenol-indophenol (DCPIP) 0.5 g/L.Carotenoids content was carried out according to [18]. Two (2) g of crushed leaves were mixed three times with 50 mL of acetone until loss of pigmentation. The mixture obtained was filtered and total carotenoids were extracted with 100 mL of petroleum ether. Absorbance of extracted fraction was then read at 450 nm by using a spectrophotometer (PG Instruments, England).

Total carotenoids content was subsequently estimated using a calibration curve of β-carotene (1 mg/mL) as standard. Polyphenols content was determined using the method reported by [19]. A quantity (1 g) of crushed sample was soaked in 10 mL of methanol 70% (w/v) and centrifuged at 1000 rpm for 10 min. An aliquot (1 mL) of supernatant was oxidized with 1 mL of Folin–Ciocalteu's reagent and neutralized by 1 mL of 20% (w/v) sodium carbonate. The reaction mixture was incubated for 30 min at ambient temperature and absorbance was measured at 745 nm by using a spectrophotometer (PG Instruments, England).

The polyphenols content was obtained using a calibration curve of gallic acid (1 mg/mL) as standard.Antioxidant assay was carried out using the 2,2-diphenyl-1-pycrilhydrazyl (DPPH) spectrophotometric method outlined by [20]. About 1 mL of 0.3 mM DPPH solution in ethanol was added to 2.5 mL of sample solution (1 g of crushed sample was mixed in 10 mL of methanol, filtered through filter paper and was allowed to react for 30 min at room temperature. Absorbance values were measured with a spectrophotometer (PG Instruments, England) set at 415 nm. The average absorbance values were converted to percentage antioxidant activity using the following formula:

Antioxidant activity (%) = 100 – [(Abs of sample – Abs of blank) x 100/Abs positive control]

3. Results and Discussion

3.1. Nutritive properties

Table 1 shows the proximate composition of fresh and shade dried leafy vegetables. Moisture content was significantly ($p < 0.05$) higher (74.38 – 90.20%) for fresh leafy vegetables than dried ones (14.16 – 20.51%) after 15 days of shadow drying. The high moisture content in the fresh leafy vegetables was expected since it has been reported that leafy vegetables in their fresh state contain basically 85% of water [21]. The maximum moisture content varies between leafy vegetables because of structural differences and cultivation conditions [22]. High moisture content in leafy vegetables is indicative of their freshness as well as easy perish-ability [23]. Higher moisture content in leafy vegetables also suggests that they will not store for long time without spoilage since higher water activity could enhance microbial activity and food spoilage [24,25]. The lower moisture content of shade dried leafy vegetables is not surprising since [26] reported that drying involves lowering the amount of water to below 1 – 55% in vegetables. Moisture content of a food is very important for shelf-life and any food prepared from dried leafy vegetables has more keeping quality than the fresh one [27].

Generally, the removal of moisture, according to [28] leads to an increase in concentration of nutrients as indicated after 15 days of shadow drying by the contents of ash, crude fibres, proteins, lipids and carbohydrates (Table-1). The ash contents (8.30 -19.16%) of shadow dried samples were similar to that reported by [29] for tomatoes, okra, pepper and onions subjected to the same preservation treatment. Ash content indicates the mineral content of food substances and shade dried leafy vegetables could be considered as valuable sources of minerals in human nutrition.

Crude fiber contents were significantly higher ($p < 0.05$) for 15 days shade dried leaves (11.43 – 21.27%) than those (1.37– 4.23%) of fresh vegetables. Dietary fiber may be classified into three major groups (cellulose, non-cellulose and lignin) according to structure and properties. Foods containing high amount of dietary fiber are very low in caloric content. Thus, high fiber diets as dried leafy vegetables could be recommended for weight reducing regimes [30]. Dietary fiber in vegetables reduces food transit time in the alimentary canal and the incidence of constipation and other related diseases [31]. Therefore, adequate intake of the studied dried leafy vegetables could be useful for maintaining bulk, motility and increasing intestinal tract which is also necessary for healthy condition.

The protein content of 15 days dehydrated leaves was in the range of 9.13 – 19.05 g per 100 g. The protein content of 15 days dehydrated leafy vegetables increased by 3 to 12-fold compared to the fresh samples. The author [32] observed that increase in protein content of dried leafy vegetables compared to fresh ones may occur as a result of loss of moisture which in turn has an influence on dry matter. These results are also in agreement with the studies done by [33] which showed that dried leaves retained good amounts of protein. Thus, shadow dried leafy vegetables could be good and affordable sources of protein for poor community of developing countries in order to fight against protein deficiency.

The fat content (3.29 – 7.97%) of 15 days dried leaf samples were also higher than their fresh counter parts (0.48 – 1.47%) but leafy vegetables could not be considered as a rich source of fat, which is in agreement with the fact that green leafy vegetables are “heart friendly food”.

As far as carbohydrates are concerned, leafy vegetables are not considered as a good source of carbohydrate but after 15 days of dehydration, the carbohydrate content of the leaves (32.45 – 51.74%) was higher than vegetables such as potato (22.6%) and turnip greens (9.4%) [34]. However, low carbohydrates contents of leafy vegetables show that they could supply little or no energy when consumed except when supplemented with other foods [35].

Table 1: Proximate composition of shade dried leafy vegetables consumed in Southern Côte d'Ivoire

	Moisture (%)	Ash (%)	Fiber (%)	Proteins (%)	Lipids (%)	Carbohydrates (%)	Energy (kcal /100g)
C. esculenta							
Raw	82.35 ± 2.83a	2.65 ± 0.00d	4.23 ± 0.01d	1.72 ± 0.00d	1.47 ± 0.00d	7.56 ± 0.07d	44.53 ± 0.04d
5 days	74.45 ± 0.47b	3.42 ± 0.00c	5.45 ± 0.00c	2.30 ± 0.00c	2.05 ± 0.00c	9.31 ± 0.00c	56.06 ± 0.00c
10 days	43.29 ± 0.74c	8.71 ± 0.00b	14.13 ± 0.00b	5.88 ± 0.00b	5.13 ± 0.00b	22.82 ± 0.00b	138.90 ± 0.00b
15 days	15.09 ± 2.69d	14.05 ± 0.01a	21.27 ± 0.00a	9.13 ± 0.01a	7.97 ± 0.00a	32.45 ± 0.00a	204.93 ± 0.01a
B. alba							
Raw	89.82 ± 1.24a	2.01 ± 0.00d	1.67 ± 0.00d	1.00 ± 0.00d	0.69 ± 0.00d	4.78 ± 0.01d	25.36 ± 0.02d
5 days	81.48 ± 1.75b	3.68 ± 0.00c	3.07 ± 0.00c	1.90 ± 0.00c	1.33 ± 0.00c	8.50 ± 0.00c	46.19 ± 0.00c
10 days	58.48 ± 0.52c	8.48 ± 0.00b	6.99 ± 0.00b	4.35 ± 0.00b	3.57 ± 0.00b	18.09 ± 0.00b	105.15 ± 0.00b
15 days	18.06 ± 3.27d	16.90± 0.01a	13.96± 0.00a	9.47± 0.00a	7.93± 0.00a	51.74± 0.01a	209.72± 0.05a
S. melongena							
Raw	74.38 ± 0.72a	5.20 ± 0.01d	3.50 ± 0.00d	3.16 ± 0.00d	0.69 ± 0.00d	13.04 ± 0.02d	71.11 ± 0.09d
5 days	65.47 ± 3.36b	7.23 ± 0.00c	4.87 ± 0.00c	4.35 ± 0 .01c	1.08 ± 0.00c	16.96 ± 0.01c	80.28 ± 0.01c
10 days	24.40 ± 1.40c	16.44 ± 0.00b	11.21 ± 0.00b	10.02 ± 0.00b	2.50 ± 0.00b	35.38 ± 0.00b	171.83 ± 0.00b

15 days	14.16 ± 1.89d	18.81 ± 0.00a	12.97 ± 0.00a	12.40 ± 0.00a	3.29 ± 0.00a	38.32 ± 0.00a	194.72 ± 0.01a
T. triangulare							
Raw	90.20 ± 0.21a	2.17 ± 0.00d	1.37 ± 0.00d	1.68 ± 0.00d	0.48 ± 0.00d	5.17 ± 0.00d	26.58 ± 0.01d
5 days	80.39 ± 3.80b	3.85 ± 0.00c	2.37 ± 0.00c	2.92 ± 0.00c	0.82 ± 0.00c	6.63 ± 0.00c	37.70 ± 0.02c
10 days	54.91 ± 1.47c	10.73 ± 0.00b	6.74 ± 0.00b	8.03 ± 0.00b	2.40 ± 0.00b	17.16 ± 0.00b	101.01 ± 0.00b
15 days	20.51 ± 3.97d	19.16± 0.01a	12.21 ± 0.00a	14.76± 0.01a	4.37± 0.00a	49.50± 0.01a	249.30± 0.05a
C. olitorius							
Raw	84.28 ± 0.34a	1.34 ± 0.00d	1.80 ± 0.00d	3.32 ± 0.00d	0.51 ± 0.00d	8.73 ± 0.00d	43.60 ± 0.00d
5 days	73.50 ± 0.66b	2.32 ± 0.00c	3.21 ± 0.00c	5.76 ± 0.00c	0.88 ± 0.00c	14.31 ± 0.00c	72.54 ± 0.01c
10 days	23.41 ± 0.11c	6.99 ± 0.00b	9.71 ± 0.00b	16.90 ± 0.00b	2.82 ± 0.00b	40.14 ± 0.00b	208.22 ± 0.00b
15 days	14.83 ± 1.23d	8.30 ± 0.00a	11.43 ± 0.00a	19.05 ± 0.00a	3.33 ± 0.00a	43.03 ± 0.00a	228.01 ± 0.00a

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly ($p<0.05$) for each leafy vegetable.

Mineral composition of dehydrated leafy vegetables is given in Table 2. There was a significant ($p < 0.05$) increase in the mineral content during shadow drying. Minerals contents after 15 days of shadow drying were as follow: calcium (78.23-337.26 mg/100g), magnesium (70.41-208.46 mg/100g), phosphorus (50.73-184.81 mg/100 g), potassium (363.56-776.73 mg/100g), iron (12.14-63.57 mg/100g) and zinc (12.57-33.95 mg/100g). All the minerals contents increased manifolds in the dehydrated samples and this fact could be beneficial because micronutrient deficiency also referred as “hidden hunger” is a major problem in the developing countries. With regards to the recommended dietary allowances (RDA) as mg/day/person for minerals, the level of iron and zinc in the samples could cover RDA [36].

Iron is known to be an essential part of red blood cells (haemoglobin) and consumption of these leafy vegetables could reduce considerably the risk of anaemia [37].

The drying processing used in this study increased by 2 to 9-fold the contents of oxalates and phytates compared to the contents of fresh leafy vegetables (Figure 1). Oxalates and phytates are considered as anti-nutritional factors which reduce minerals bioavailability. In order to predict adverse effects of phytates and oxalates, anti-nutritional factors/minerals ratios were calculated (Table 3).

The calculated phytates/calcium ratios of the dried leafy vegetables were below the critical level of 0.5 [38]. This implies that phytates contents of the dried leaves would not have deleterious effects on calcium bioavailability.

Table 2: Mineral composition (mg/100g) of shade dried leafy vegetables consumed in Southern Côte d'Ivoire.

	Ca	Mg	P	K	Fe	Na	Zn
C. esculenta							
Raw	103.64 ± 0.01d	61.29 ± 0.00d	139.08 ± 0.02d	402.70 ± 0.06d	25.30 ± 0.00d	6.96 ± 0.00d	6.58 ± 0.00d
5 days	134.99 ± 0.01c	80.44 ± 0.01c	142.66 ± 0.02c	420.28 ± 0.00c	33.59 ± 0.00c	7.68 ± 0.00c	8.38 ± 0.00c
10 days	159.53 ± 0.00b	92.55 ± 0.00b	171.94 ± 0.00b	517.99 ± 0.00b	42.02 ± 0.00b	8.69 ± 0.00b	9.80 ± 0.00b
15 days	194.51 ± 0.22a	110.81 ± 0.23a	184.81 ± 0.11a	594.45 ± 0.06a	47.62 ± 0.10a	13.25 ± 0.10a	12.57 ± 0.01a
B. alba							
Raw	76.38 ± 0.00d	76.74 ± 0.00d	39.71 ± 0.00d	275.31 ± 0.02d	7.88 ± 0.00d	56.50 ± 0.07d	6.84 ± 0.00d
5 days	81.63 ± 0.18c	84.85 ± 0.02c	64.84 ± 0.02c	304.08 ± 0.02c	8.79 ± 0.03c	64.41 ± 0.08c	9.04 ± 0.00c
10 days	103.76 ± 0.03b	92.57 ± 0.03b	87.48 ± 0.01b	339.72 ± 0.02b	10.16 ± 0.00b	81.81 ± 0.01b	12.20 ± 0.00b
15 days	122.17± 0.24a	97.62 ± 0.22a	98.77 ± 0.09a	363.56 ± 0.13a	12.14 ± 0.04a	103.13 ± 0.16a	20.70 ± 0.01a
S. melongena							

Raw	204.07 ± 0.00d	123.46 ± 0.00d	95.93 ± 0.00d	578.01 ± 0.01d	35.73 ± 0.00d	82.78 ± 0.02d	16.58 ± 0.00d
5 days	281.52 ± 0.00c	169.87 ± 0.00c	104.62 ± 0.00c	683.50 ± 0.00c	52.65 ± 0.00c	96.89 ± 0.00c	25.35 ± 0.00c
10 days	326.86 ± 0.01b	204.94 ± 0.00b	120.50 ± 0.01b	728.48 ± 0.02b	60.09 ± 0.00b	99.98 ± 0.00b	29.58 ± 0.00b
15 days	337.26 ± 0.06a	208.46 ± 0.05a	128.82 ± 0.15a	776.73 ± 0.02a	63.57 ± 0.00a	129.23 ± 0.09a	33.95 ± 0.00a
T. triangulare							
Raw	58.93 ± 0.00d	74.08 ± 0.00d	23.47 ± 0.00d	495.21 ± 0.00d	10.02 ± 0.00d	25.50 ± 0.00d	3.53 ± 0.00d
5 days	62.16 ± 0.35c	76.31 ± 0.04c	33.73 ± 0.10c	542.53 ± 0.08c	18.34 ± 0.07c	35.29 ± 0.09c	8.14 ± 0.00c
10 days	62.81 ± 0.10b	82.77 ± 0.01b	41.87 ± 0.06b	601.15 ± 0.03b	27.89 ± 0.02b	40.40 ± 0.04b	12.19 ± 0.00b
15 days	78.23 ± 0.42a	88.07 ± 0.11a	50.73 ± 0.13a	619.00 ± 0.09a	29.34 ± 0.07a	45.60 ± 0.16a	19.99 ± 0.01a
C. olitorius							
Raw	58.00 ± 0.00d	36.86 ± 0.00d	49.80 ± 0.00d	412.26 ± 0.05d	15.34 ± 0.00d	4.36 ± 0.00d	3.88 ± 0.00d
5 days	65.4 7± 0.01c	65.21 ± 0.06c	55.64 ± 0.02c	421.49 ± 0.03c	18.45 ± 0.01c	9.48 ± 0.00c	9.15 ± 0.00c
10 days	74.01 ± 0.00b	68.40 ± 0.00b	60.90 ± 0.00b	443.62 ± 0.00b	21.78 ± 0.00b	18.19 ± 0.00b	11.37 ± 0.00b
15 days	80.84 ± 0.03a	70.41 ± 0.02a	63.74 ± 0.00a	490.00 ± 0.17a	23.09 ± 0.00a	24.26 ± 0.04a	19.65 ± 0.00a

Data are represented as Means ± SD (n = 3). Means in the column with no common letter differ significantly ($p<0.05$) for each leafy vegetable.

Table 3: Anti-nutritional factors/mineral ratios of shade dried leafy vegetables consumed in Southern Côte d'Ivoire.

	Phytate/Ca	Phytate/Fe	Oxalate/Ca
C. esculenta			
Raw	0.04	0.18	0.99
5 days	0.03	0.12	0.99
10 days	0.02	0.08	0.99
15 days	0.02	0.05	1.07
B. alba			
Raw	0.03	0.26	0.87
5 days	0.01	0.07	0.89
10 days	0.01	0.04	0.89
15 days	0.00	0.01	0.86
S. melongena			
Raw	0.05	0.30	0.12
5 days	0.01	0.06	0.13
10 days	0.01	0.04	0.14
15 days	0.01	0.02	0.15
T. triangulare			
Raw	0.05	0.29	0.86
5 days	0.01	0.03	0.89
10 days	0.00	0.02	0.90
15 days	0.00	0.02	0.94
C. olitorius			
Raw	0.11	0.40	2.11
5 days	0.03	0.11	1.87
10 days	0.02	0.09	1.83
15 days	0.02	0.07	1.81

3.2. Antioxidant properties

Most common antioxidants in leafy vegetables and spices are vitamin C, E, phenolic compounds and carotenoids [39]. The contents of vitamin C and carotenoids in the shade dried leafy vegetables are shown in Figure-2. In all the samples, vitamin C and carotenoids contents were depleted during shadow drying. Indeed, losses of these antioxidants components were 65.52 – 91.07% and 39.66 – 95.23%, respectively after 15 days of shadow drying.

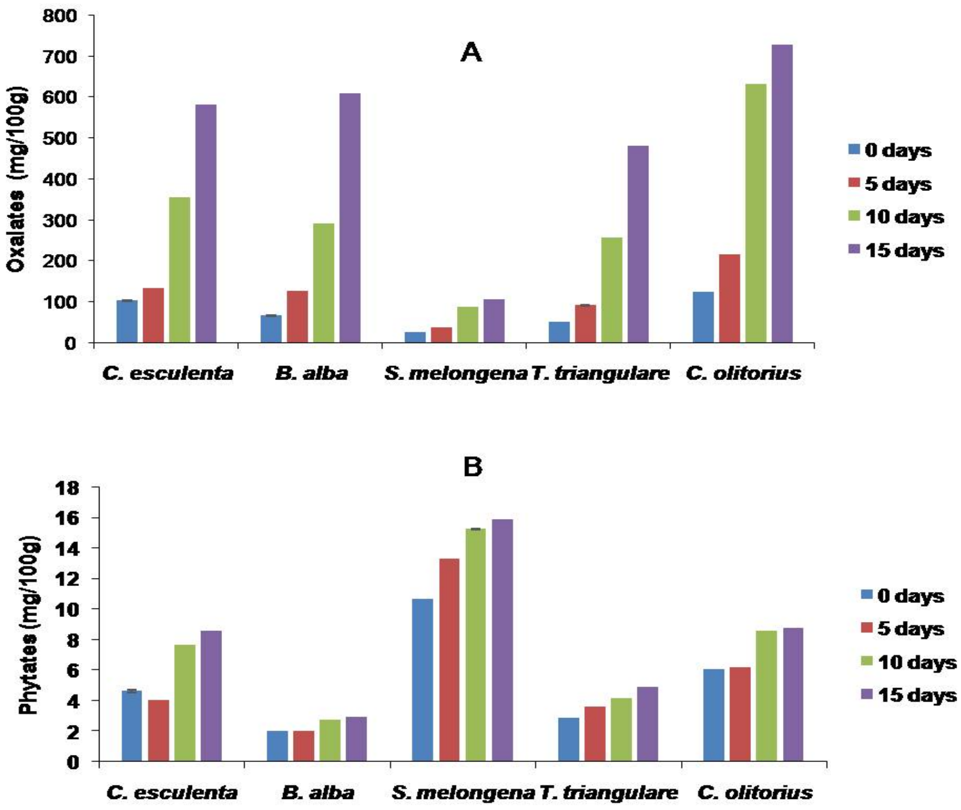

Figure 1: Effect of shadow drying on oxalates (A) and phytates (B) contents of leafy vegetables consumed in Southern Côte d'Ivoire.

Vitamin C and carotenoids losses were directly dependent on the method of drying leafy vegetables. Indeed, shadow drying generally leads to lower vitamin C and carotenoids contents due to the oxidation phenomenon [40]. In addition, the registered losses in vitamin C and carotenoids were higher than those (8 – 26%) of pretreated (blanching and sulphiting) and dried leaves. Therefore, this justifies the fact that several authors have applied different pretreatments before solar and sun-drying processes in order to improve the quality and nutritional parameters of dried products [41]. The phenolic contents of the samples increased during shadow drying (Figure-3). The values were in the range of 156.28-340.24 mg/100 g at 15 days of drying. These values were 6 to 12-fold higher than those (13.31 – 51.07 mg/100g) of the fresh ones. Increase in phenolics compounds may be due to the concentration effect of drying on nutrients. Phenolics components are secondary metabolites synthesized by plants both during normal development and in response to stress conditions (infection, wounding, UV radiation and others) [42]. They also have antioxidant properties that enable them to quench free radicals which lead to beneficial effect on human health by reducing the occurrence of coronary heart diseases [43]. Furthermore, increasing in phenolics contents caused the increase of antioxidant activity (Figure-3) because there is a direct correlation between the concentration of antioxidant compounds and the antioxidant activity [44]. Antioxidant activity ranged from 66.10 ± 0.00 % to 74.33 ± 0.00 % after 15 days of shadow drying. Thus, this increase in phenolics contents and antioxidant activity could be explored for nutraceutical recipes confection including shadow dried leaf powder.

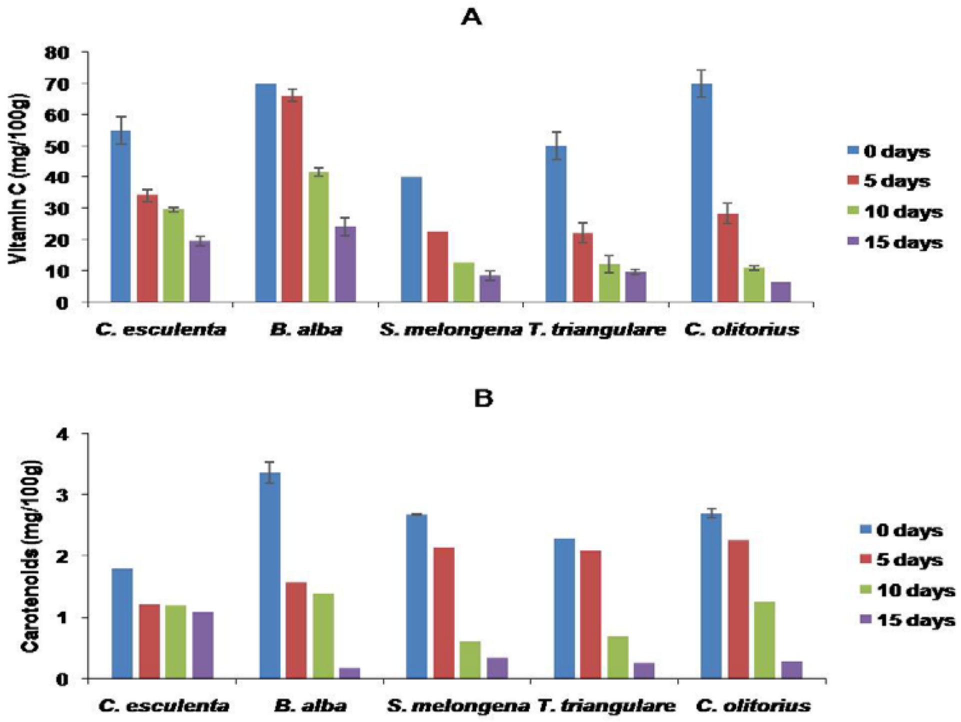

Figure 2: Effect of shadow drying on vitamin C (A) and carotenoids (B) contents of leafy vegetables consumed in Southern Côte d'Ivoire

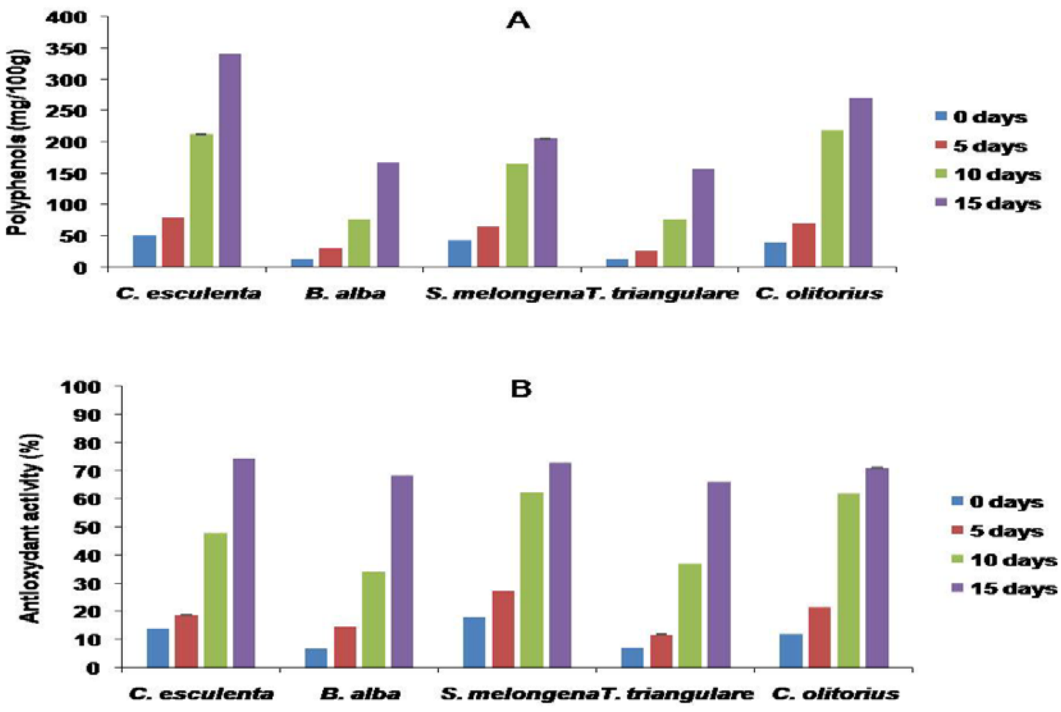

Figure 3: Effect of shadow drying on polyphenols contents (A) and antioxidant activity (B) contents of leafy vegetables consumed in Southern Côte d'Ivoire

4. Conclusion

The results of the present study showed that shadow drying of leafy vegetables consumed in Southern Côte d'Ivoire is an effective method of food preservation and could be used to close the seasonal gaps. This drying processing leads to concentration of nutrients per unit. This is an indication that use of a relatively small amount of the dried leaves could significantly raise the content of minerals and phenolics components in the diet and enables the population to meet the RDAs for these micronutrients. This study recommends the use of shadow drying as a viable strategy to address the seasonality gaps while ensuring retention of these essential nutrients.

References

[1] A.O. Edema. "Production of some common vegetables". Hort Res Inst, vol. 5 (2), pp. 1-5, 1987.

[2] A.O. Fasuyi. "Nutritional potentials of some tropical vegetable leaf meals: chemical characterization and functional properties" Afr J Biotechnol, vol. 5 (1), pp. 49-53, 2006.

[3] J.C. Okafor. "Horticulturally promising indigenous wild plant species of the Nigerian forest zone". Acta Hort, vol. 123, pp. 165-177, 1983.

[4] J.K. Mensah, K. Eifediyi, J.O. Ohaju-Obodo, and R.I. Okoli. "Phytochemical, nutritional and medical properties of some leaf vegetables consumed by Edo people of Nigeria". Afr J Biotechnol. vol. 7 (14), pp. 2304-2309, 2008.

[5] S.A. Gupta, A. Lakshmi A. "Nutritional and sensory quality of micronutrient-rich traditional products incorporated with green leafy vegetables". Int Food Res J. vol. 18 (2), pp. 456-58, 2011.

[6] M. Masarirambi, M. Mavuso, V. Songwe, T. Nkambule, and N. Mhazo. "Indigenous Post-Harvest Handling and Processing of Traditional Vegetables in Swaziland: A Review". Afr J Agric Res, vol. 5 (24), pp. 3333-3341, 2010.

[7] L. Medeiros, and D. Remley. "Drying fruits and vegetables". Ohio State University Extension, Ohio State, 2009.

[8] J.A. Harrison, and E.L. Andress. "Preserving food: Drying Fruits and Vegetables". University of Georgia cooperative Service, 2 p, 2000.

[9] L. Fondio, C. Kouamé, J.C. N'zi, A. Mahyao, E. Agbo, and A.H. Djidji. "Survey of indigenous leafy vegetable in the urban and peri-urban areas of Côte d'Ivoire". Acta Hort, vol. 752, pp. 287-289, 2007.

[10] F.C Acho, L.T. Zoué, E.E. Akpa, V.G. Yapo, and L.S. Niamké. "Leafy vegetables consumed in Southern Côte d'Ivoire: a source of high value nutrients". J Anim Plant Sci, vol. 20, pp. 3159-3170, 2014.

[11] P. Vanderhulst, H. Lanser, P. Bergmeyer, and R. Albers. "Solar energy: small scale applications in developing countries". Int Food J, vol. 8, pp. 138-145, 1990.

[12] AOAC. "Official methods of analysis". Association of Official Analytical Chemists Ed., Washington DC, 684, 1990.

[13] FAO. "Food energy-methods of analysis and conversion factors". FAO Ed, Rome, 97 p, 2002.

[14] CEAEQ. "Mineral determination". Argon plasma spectrometry method, MA 200 – Met 1.2, Rev 4. Quebec, 24 p, 2013.

[15] R.A. Day, and A.L. Underwood. "Quantitative analysis". 5th ed. Prentice Hall. 701 p, 1986.

[16] M. Latta, and M. Eskin. "A simple method for phytate determination". J Agric Food Chem, vol. 28, pp. 1313-1315, 1980.

[17] G. Pongracz, H. Weiser, and D. Matzinger. "Tocopherols- Antioxydant". Fat Sci Technol, vol. 97, pp. 90-104, 1971.

[18] D.B. Rodriguez-Amaya. "A guide to carotenoids analysis in foods". ILSI Press, Washington DC, 64 p, 2001.

[19] V.L. Singleton, R. Orthofer, and R.M. Lamuela-Raventos. "Analysis of total phenols and other oxydant substrates and anti-oxydants by means of Folin-Ciocalteu reagent". Methods Enzymol, vol. 299, pp. 152-178, 1999.

[20] C.W. Choi, S.C. Kim, S.S. Hwang, B.K. Choi, H.J. Ahn, M.Z. Lee, S.H. Park, and S.K. Kim. "Antioxydant activity and free radical scavenging capacity between Korean medicinal plant and flavonoids by assay guided comparison". Plant Sci, vol. 163, pp. 1161-1168, 2002.

[21] I.O. Fakeye. "Nigerian Leafy Vegetable". Nig J Food Sci. vol. 1, pp. 55-59, 2009.

[22] J.W. Florkowski, L.S. Robert, B. Bernhard, and E.P. Stanley. "Postharvest Handling: A Systems Approach". Second Edition. Elsevier Inc. Academic Press, 2009.

[23] O.T. Adepoju, and O.E. Oyewole. "Nutritional importance and micronutrient potential of two non-conventional indigenous green leafy vegetables from Nigeria". Agric J, vol. 3 (5), pp. 365-368, 2008.

[24] R.A. Ejoh, D.V. Nkonga, G. Inocent, and M.C. Moses. "Nutritional Components of Some Non-Conventional Leafy Vegetables Consumed in Cameroon". Pak J Nutr, vol. 6 (6), pp. 712-717, 2007.

[25] O.M. Kolawale, R.M. Kayode, and J. Aina J. "Effect of solar drying on the proximate and microbial composition of Abelmoschus esculentus". J Agric Sci, vol. 2, pp. 214-224, 2010.

[26] H. Dupriez and P. Coener. "African garden and orchards growing vegetables and fruits". Macmillan Press Limited, London, pp. 35- 46, 1992.

[27] S.K. Chou and K.J. Chua. "New hybrid technologies for heat sensitive foodstuffs". Trends in Food Science and Technology: A Handbook of vegetables and vegetable processing. Academic Press, pp. 185-195, 2001.

[28] A. Morris, A. Barnett, and O. Burrows. "Effect of processing on nutrient content of foods: A handbook of vegetables and vegetable processing". Asian J Biochem, vol. 37 (3), pp. 160-164, 2004.

[29] G.I. Onwuka, C.C. Nwabara, P.M. Nwokedi, C.A. Echendu, U. Asumugha, and M.U. Igboekwe. "Comparative studies of the efficacy of sun drying, solar dryer and hot air oven in the preservation of tomatoes, okra, pepper and onion". Nig Food J, vol. 20, pp. 10-14, 2002.

[30] M. Komal, and A. Kaur. Reviews: "Dietary Fibre". Dieteticians, Adipostat Clinic, Tata Medical Centre, Bombay, 1992.

[31] E.T. Ifon, O. Bassir, and G.O. Latunde-Dada. "The nutritive value of some Nigeria leafy vegetables". Part 1, Vitamin and mineral content. Food Chem, vol. 3, pp. 267-350, 2009.

[32] Elegbede J. A. 1998. Legumes. Nutritional quality of plant foods. In: Post Harvest Research Unit. Osagie AU, Eka, QU (Eds).

[33] B. Lakshmi, and V. Vimla. "Nutritive value of dehydrated green leafy powders". J Food Sci Technol, vol. 37 (5), pp. 465-471, 2000.

[34] P. Joshi, and D. Mehta. "Effect of dehydration on the nutritive value of drumstick leaves". J Metabol System Biol, vol. 1: pp. 5-9, 2010.

[35] C. Rossello, A. Berna, and A. Mulet. "Solar drying of fruits in a Mediterranean climate". Drying Technol, vol. 8 (2), pp. 305 – 321, 2000.

[36] FAO. "Human vitamin and mineral requirements". FAO. Ed. 361 p, 2004.

[37] K.O. Soetan, C.O. laiya, and E.O. Oyewole. "The importance of mineral elements for humans, domestic animals and plants: A review". Afr J Food Sci, vol. 4, pp. 200-222, 2010.

[38] S.W. Hassan, R.A. Umar, H.M. Maishanu, I.K. Matazu, U.Z. Faruk and A.A. Sani. "The effects of drying method on the nutrients and non-nutrients composition of leaves of Gynandropsis gynandra (Capparaceae)". Asian J Biochem, vol. 5 pp. 349-353, 2007

[39] L. Priecina, and D. Karklina. "Natural antioxidant changes in fresh and dried spices and vegetables". Int J Biol Vet Agric Food Eng, vol. 8, pp. 480-484, 2014.

[40] V.A. Aletor and O.A. Adeogun. "Nutrient and anti-nutrient components of some tropical leafy vegetables". Food Chem, vol. 53, pp. 375-379, 1995.

[41] P.S. Negi and S.K. Roy. "Effect of drying conditions on quality of green leaves during long term storage". Food Res Int, vol. 34, pp. 283–287, 2001.

[42] M. Naczk and E. Shahidi. "Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis". J Pharm Biomed Anal, vol. 41, pp. 1523-1542, 2006.

[43] S. John, N. Haseeb, P. Joseph, M. Gauri, K. Yukio and J. Yueming. "Extraction polyphenolics from plant material for function foods-engineering and technology". Food Review Int, vol. 21, pp.139-166, 2005.

[44] W. Lan. "Effect of chlorogenic acid on antioxidant activity of Flos lanicerae extracts". J Zhejiang Univ Sci Biol, vol. 8, pp. 673-679, 2007.