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Influence of Different Drying Methods and Storage on the Quality of Indian Spinach (*Basella rubra* L.)

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Abstract: This study reports the effects of drying methods on nutrient retention in a leaf vegetable during storage. The leaves of Indian Spinach were dried to 3.50-4.0% moisture content in the sun (35°), shade (28°C) and oven (45°C) and then stored in polyethylene wrappers. Their moisture, ascorbic acid, minerals and total chlorophyll contents were determined after drying and during storage. There was minimal moisture gain during the twelve week storage period being less than 1% in all three drying methods. Ascorbic acid decreased by 43-48% as a result of drying but storage for twelve weeks did not result into much further loss. Shade-dried leaves retained ascorbic acid in the least. Chlorophyll and minerals contents also decreased slightly with drying and storage. Shade-dried leaves were lowest in Ca, Mg, K, Na, Fe, Mn and Zn. The contents of Ca and Mg in shade dried leaves increased in storage while K, Mn and Zn decreased. Manganese was the most critically reduced element by both drying and storage with shade dried leaves losing 73.2, 81.6% at drying and 12 weeks later. Comparative figures for sun and oven dried leaves were 49.2, 47.6, 50 and 62.6% for the same periods. The greatest reduction in Zn content also occurred with shade drying. Sun drying resulted into more nutrient retention while there was only marginal difference in ascorbic acid content by the three techniques. Chlorophyll content was not much affected by both drying and storage and shade dried leaves retained chlorophyll more than those dried in the sun and oven.

Key words: Drying techniques, storage, nutrient retention

INTRODUCTION

Vegetables are popular in human diet for the vitamins and minerals they supply, their medicinal value, taste and texture especially when fresh. Their processing may however lead to loss of some of the characteristics which initially made them consumer delights. Spinach is a succulent deep-green leaf vegetable that is consumed cooked. It was noted to be a good source of vitamins A and C (Bakr and Gawish, 1997). Indian Spinach is one of the most cultivated of all Spinachs in Africa and *Basella rubra* L. with purple stems and pale pink flowers is one of the two commonest in Nigeria while *Basella alba* with green stems and white flowers is the other. Typical storage life of the leaf is less than seven days at ambient conditions. Attempt to process and preserve the leaves by blanching and freezing results into sliminess which is undesirable for consumers. Drying for preservation then offers a good alternative processing method especially since *Talinum triangulare* a vegetable that is similar to spinach is traditionally preserved by sun-drying alone or in combination with osmotic dehydration in Nigeria.

There are many techniques of drying but the cheapest and most commonly used in Nigeria is sun-drying. This method however results into contamination with dust and microorganisms and is sometimes too slow to accomplish the desired purpose especially in wet weather. Improved drying methods include oven, solar, osmotic and freeze drying (Adom *et al*., 1997).

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Loss of nutrients has been reported for various food processing techniques (Brar *et al*., 2006; Uhlig, 1998; Svanberg and G-L Nyman, 1997). Drying vegetables result into both nutrient and culinary losses. The losses however vary with the drying technique employed (Negi and Roy, 2001). Other reports however indicate that certain advantages exist in addition to slowing down or preventing microbial deterioration. Total carotene and ascorbic acid contents were reported to have been maximally retained by drying African spinach in enclosed solar drier with shade (Maeda and Salunkhe, 1981). The present study was undertaken to compare the effects of three drying techniques on the nutritional quality and appearance of *Basella rubra*.

MATERIALS AND METHODS

Preparation

This study was conducted in 2005 at the Federal University of Technology, Akure, Ondo State, Nigeria. The vegetable was asexually propagated through the stem in a vegetable garden with good supply of water. The leaves were harvested ninety days after planting. The mature leaves were immediately dried after harvest in the sun, shade and oven at 35, 28 and 45°C, respectively. The leaves were kept in a single layer on trays and dried on the house roof (sun), on laboratory bench (shade) and in a Gallenkamp oven. After drying, the leaves were stored in clean black Low Density Polyethylene (LDPE) bags and the bags were tied.

Estimation of Various Nutrients in Leaves

The moisture and ascorbic acid contents were determined in triplicates using standard analytical procedures (AOAC, 1990; Pearson, 1976).

The mineral elements namely calcium, magnesium, sodium, potassium, iron, manganese and zinc were determined using standard atomic absorption spectrophotometric procedure.

Chlorophyll Determination

Two grams each of fresh and dried samples were used for analyses. The leaves were separately ground in mortar and the chlorophyll was then extracted with acetone/water mixture (80:20) using small volumes in successive stages until no trace of green remained in the ground pulp. The total chlorophyll content was estimated according to the formula below (MacKinney, 1941).

$$\text{Total chlorophyll} = 20.2A_{645}+8.02A_{663} \times V/1000 \times W$$

Where:

A_{645} = Absorbance at 645 mm
A_{663} = Absorbance at 663 mm
W = Weight of sample extracted
V = Final volume (cm^2) of extract

Mean values and Standard Deviation (SD) were calculated for each drying technique using the values obtained from three replicates.

Screening for Microorganisms and Insects

Microbial presence was detected by using Nutrient Agar (NA) and acidified Potato Dextrose Agar (PDA) as isolation media for bacteria and fungi, respectively. The leaf samples randomly selected from each bag was immersed in sterile water. The wash water was plated in the respective media using pour-plate technique. The bacteria and moulds present were identified using morphological and biochemical characteristics (Barnett and Hunter, 1960; Holt *et al*., 1994). Whole insects or their eggs, fragments, cocoons and droppings were screened for in fresh, dried and stored dry samples.

RESULTS AND DISCUSSION

All the leaves were dried to approximately 4% moisture content before storage at 28°C. The samples gained some moisture during storage but the moisture gain was negligible (Table 1). Both bacteria and fungi were found on the dried leaves but there was no rottenness in the dried samples. Associated microorganisms were *Aspergillus niger*, *Aspergillus flavus*, *Penicillium* sp., *Mucor mucedo*, *Fusarium* sp., *Proteus mirabilis*, *Staphylococcus aureus*, *Bacillus subtilis*, *Lactobacillus* sp. and *Serratia* sp. before drying. The dried samples did not have *Fusarium* sp. and *Proteus mirabilis* (Table 2). All the organisms detected are common contaminants in the environment. The *Aspergillus* and *Penicillium* species are commonly reported in association with various dried food materials. The presence of *Aspergillus*, *Penicillium* and *Fusarium* was also reported on dried cassava products (Wareing *et al*., 2001). *Lactobacillus* sp. and *Serratia* sp., were present only on shade dried samples in addition to fresh samples.

Chlorophyll content was highest in fresh samples. It decreased with drying and also with storage but the decrease was slight, occurring by the twelfth week in all drying methods (Table 1).

Although drying reduced the ascorbic acid content by 43-48%, the drying method did not matter much. Shade dried leaves retained 52%, while sun and oven dried retained 57 and 55%, respectively (Table 1). Subsequent storage had negligible effect on the same nutrient. Vitamins and minerals loss have been reported with various processing methods including shredding and drying (Oboh and Akindahunsi, 2004; Ozcan *et al*., 2004; Asami *et al*., 2003; Negi and Roy, 2001). The observed values of 47.70-51.50 mg ascorbic acid/100 g sample immediately after drying, which reduced slightly by the twelfth week in storage show that sufficient ascorbic acid was still retained. The Recommended Nutrient Intake (RNI) of the nutrient is 45 mg day^{-1} for adults (Anonymous, 2004). It was reported that indigenous vegetable in Tanzania had 249.6 mg/100 g (Lyimo *et al*., 2003).

Table 1: Composition of dried Indian Spinach (*Basella rubra*) before and during storage at 28°C

Sample type	Ca	Mg	Na	K	Fe	Mn	Zn	Ascorbic acid (mg/100 g)	Moisture content (%)	Chlorophyll (mg/100 g)
	----------(μg 100 g^{-1})----------									
Sun										
Fresh	262.30	90.60	336.10	140.04	34.10	12.00	2.30	92.00±4.05	90.00±0.00	1.42±0.00
Dried	250.30	80.20	316.11	92.04	32.00	6.10	1.41	51.50±7.10	3.50±0.40	1.17±0.12
Six weeks	240.30	70.20	306.11	82.04	30.00	5.10	1.39	51.00±7.05	3.80±0.36	1.17±0.30
Twelve weeks	239.30	69.20	305.11	81.04	29.00	5.09	1.38	50.50±7.00	4.45±0.00	1.15±0.00
Shade										
Fresh	262.30	90.60	336.10	140.04	34.10	12.00	2.30	92.00±4.05	90.00±0.00	1.42±0.00
Dried	240.00	70.20	250.11	90.40	22.10	3.22	0.60	47.70±6.90	4.00±0.85	1.19±0.15
Six weeks	230.00	60.20	290.11	80.04	24.10	2.22	0.58	47.20±6.90	4.20±0.14	1.19±0.15
Twelve weeks	292.08	95.20	289.11	79.04	23.10	2.20	0.57	46.70±6.87	4.70±0.00	1.17±0.12
Oven										
Fresh	262.30	90.60	336.10	140.04	34.10	12.00	2.30	92.00±4.05	90.00±0.00	1.42±0.00
Dried	245.10	78.20	312.00	92.04	31.50	6.00	1.30	50.50±7.07	3.70±5.05	1.17±0.12
Six weeks	235.10	68.20	302.00	82.04	29.50	5.00	1.38	50.00±7.04	3.90±0.38	1.17±0.30
Twelve weeks	234.10	67.20	301.00	81.04	28.50	4.49	1.37	49.50±7.07	4.50±0.00	1.15±0.20

Copper (Cu), Lead (Pb) and Cadmium (Cd) were not detected. Values are for immediately after drying (dried), six weeks in storage (six weeks) and twelve weeks in storage (twelve weeks). Values for ascorbic acid, moisture content and chlorophyll are means of three replicates±standard deviation of the mean

Table 2: Occurrence of bacteria and fungi on Indian spinach (*Basella rubra*)

	Before dying	After dying		
Sample	FPS	SPS	APS	OPS
Fungal isolate				
A. niger	+	+	+	+
M. mucedo	+	-	+	-
A. flavus	+	+	+	+
F. oxysporum	+	-	-	-
Penicillium sp.	+	+	+	+
Bacterial isolate				
S. aureus	+	+	+	+
B. subtilis	+	+	+	+
Lactobacillus sp.	+	-	+	-
Serratia sp.	+	-	+	-
P. mirabilis	+	-	-	-

FPS = Freshly harvested; SPS = Sundried; APS = Shade dried; OPS = Oven dried; + = Present; - = Absent

Ramallo and Mascheroni (2004) reported maximum retention of ascorbic acid when drying temperature was fixed at 45°C. Contrary to their report however, Maeda and Salunkhe (1981) noted that direct sun exposure of vegetables as often practiced in the tropics resulted in marginal retention of the nutrient. Oboh and Akindahunsi (2004) also reported a significant decrease in vitamin C content of some sun dried leafy vegetables although they did not investigate other drying techniques. The converse was observed in the present comparative study where shade dried spinach had the least retention of ascorbic acid while the sun dried had slightly more retention although samples from both sun and oven did not differ much from it.

Drying and storage caused a reduction in Ca, Mg, Na, K, Fe, Mn and Zn (Table 1). Shade dried sample was lowest in Ca, Mg, K, Na, Fe, Mn and Zn immediately after drying. There was drastic reduction in sun and oven dried samples by the 12th week of storage, but the contents of Ca, Mg, Na and Fe increased in shade dried leaves during storage. Sun drying technique retained Ca more than the other two techniques (Table 1). The recommended nutrient intake (RNI) of Ca is 1000-1300 mg day^{-1} while that of Mg is 220-270 mg day^{-1} (Anonymous, 2004). The observed 250 and 80 mg/100 g, respectively of both elements immediately after sun drying and further reduction during storage suggest that there may be a lack of both when the dried leaves are consumed. Usually however, the vegetable is not cooked alone but with other ingredients which may provide additional quantities of nutrients required.

Total chlorophyll content decreased with both drying and storage but the decrease was negligible. This indicates a high potential for the acceptability of the dried leaves because they are desired by consumers in the green state. An earlier report stated that chop and dry vegetables retained substantial amounts of chlorophylls (Adebooye *et al*., 2006). It was however reported that the method used to dry fruits and vegetable materials significantly affected the three colour parameters with air drying causing extensive browning (Krokida *et al*., 2001). Browning was not observed in any of the samples in this study, only a little fading of the green colour was noticed in the dried leaves. Drying by any of the three methods here reported will therefore produce dried leaves of acceptable colour while sun drying seemed to result in more nutrient retention than the other two techniques. The rehydration characteristics and culinary qualities of dried Indian spinach should be investigated in future studies.

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