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Effect of Different Processing Conditions on Proximate and Bioactive Contents of *Solanum aethiopicum* (Shum) Powders, and Acceptability for Cottage Scale Production

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Abstract The purpose of this study was to investigate the effects of different processing conditions for production of dried *Solanum aethiopicum* (S.) leaf powder by comparing solar drying and cabinet drying processing techniques. Four (4) pre-treatments were done on *S. aethiopicum* leaves to inhibit enzyme action and prolong storage life. Treatments included dipping in; 10% saline solution, 10% vinegar solution, water (as the control), and steam blanching; done for both whole and sliced *S. aethiopicum* leaves. Each of the resultant samples were dried in both solar and cabinet dryers for a period of 24 hours. The dried leaf samples were grounded into powder using a coffee grinder and subjected to different laboratory analyses including; catalase activity, moisture content, vitamin C retention capacity and phytate content analyses. The results obtained were analysed using MINITAB version 16.0 at 5% significance level. The results showed that there was a reduction in catalase activity after pre-treatment and drying from 5.0±0.0 cm^3 for the fresh un-treated leaves to a range of 4.5±0.7 – 3.0±0.0 cm^3 for whole solar dried; 4.5±0.7-4.0±0.0 cm^3 for sliced solar dried; 4.0±0.0 - 3.0±0.0 cm^3 for whole cabinet dried and 3.5±0.7-2.3±0.7 cm^3 for sliced cabinet dried leaf powder. Solar dried *S. aethiopicum* leaf powder contained significantly high moisture content than hot air cabinet dried one (24.9±0.5 % for saline treated sliced leaves to 8.9±0.8 % for blanched sliced leaves, than hot air cabinet dried one with 9.3±0.0 % for sliced plain water treated leaves to 7.0±0.2 % for sliced vinegar treated leaves; respectively). Cabinet dried *S. aethiopicum* contained significantly more vitamin C content (1.1±0.2 mg for whole blanched leaves compared to 0.6±0.1 mg for sliced vinegar treated leaves) than the solar dried one (1.0±0.2 mg for sliced plain water treated leaves to 0.6±0.1 mg for sliced vinegar treated leaves). There was no significant difference in phytate content between the hot air cabinet dried and solar dried i.e. 0.7±0.1 - 0.2±0.1 mg for solar and 0.7±0.1 - 0.3±0.3 mg for cabinet dried. Solar dried *S. aethiopicum* powder contained significantly higher catalase than the hot air cabinet dried one (4.5±0.7 - 3.0±0.0 and 4.0±0.0 - 2.5±0.7 cm^3; respectively). However, in terms of acceptability, there was high preference for saline treated leaf powder soups compared to other soups. It can be concluded that High activity of catalase, moisture retention and high loss of Vit.C occurs in the solar drier than in cabinet drier. Whole leaf saline pretreated leaf powder soup is rated high compared to other dried soups. Therefore, the best method for production of dried *S. aethiopicum* powder is by slicing, dipping it in plain water and drying using a cabinet dryer. Under circumstances where cabinet drying is not achievable, solar drying is recommended using whole leaf, pretreated with saline water to promote preservation and consumption of the vegetable.

Keywords: *Solanum aethiopicum, powder, pre-treatments, solar, cabinet, drying*

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1. Introduction

Vegetables have received considerable attention, as they have proved to be essential for a balanced diet. Studies have associated diets rich in vegetables with reduced risks of cardio-vascular diseases [1], as they contain a wide array of phytochemicals which are claimed to exert many health benefits including antioxidant activity [2]. For a long time, African indigenous vegetables including *Solanum aethiopicum* (S.) have been integrated in a community culture for use as food [3]. There is now increasing awareness of their nutritional value as well as demand by consumers even in dynamic markets such as supermarkets [4]. World Health Organization recommends daily intake of 400g per capita (WHO, 2005); which the Sub Saharan region does not even meet half of it [5]. Children, especially the school going and the elderly are more affected by low intake because of their poor meal frequency [6].

Fresh vegetables are known to be highly perishable due to the high moisture content (around 80%) and can deteriorate over a short period of time if not properly handled [7]. Drying of vegetables is a means of removing water to halt the growth of spoilage microorganisms, as well as stop the occurrence of enzymatic or non-enzymatic browning reaction [8] thus; preserving its structure, sensorial characteristics and nutritional value. Drying therefore appears as a necessary step to enabling later use of vegetables [9]. Many researchers have reported the effect of different methods and influence of drying conditions on the vitamin C content [10], how high dietary intakes of phytate reduces bioavailability and causes poor retention of zinc.

Seasonality in intake is also noted which is matched with the rainfall patterns in the country [11]. Scarcity is therefore characteristic of this relish in times of limited rainfall but coupled by the fact that there is limited or no collection at all from the wild, exacerbated by high postharvest losses. Preservation can serve the purpose of evening out seasonality of vegetables, and thus improve availability and utilization. But doing all the above needs proper control of physical, chemical and biological processes that lead to deterioration. Among the ways of preservation is dehydration which can be done by solar drying and use of a convectional hot air oven. Solar drying is more feasible and adaptable in most areas in Uganda due to ready availability of solar energy.

Dried fruits and vegetables are widely used by the confectionary, bakery, sweet and distilling industries in various sauce, teas, puddings, garnishments and food for infants and children. Applications particularly include fruits and vegetables powders used as intermediate products in the beverage industry, as functional food additives improving the nutritional value of foodstuff, as flavoring agent (in ice creams, yogurts, fruit bars) or also as natural colorants [12]. Vegetable powders likewise serve as ingredients in instant noodles, dried soups and other food recipes [4,8,13]. However [14], recommended that in the drying of vegetables, the performance of solar driers be evaluated and compared with other drying technologies for effectiveness. Electrical cabinet driers and conventional oven driers are known to produce high quality products [15] and can therefore provide a good benchmark for evaluating the applicability of solar drying in production of dried *S. aethiopicum* powder, especially in rural conditions where use of the two conventional methods can be limited.

This study therefore aimed at investigating the effect of different processing conditions in the production of dried *S. aethiopicum* powder, comparing solar drying and convectional hot air oven techniques of processing. The resultant powder was assessed for nutritional quality, which in the long run could act as a process for control of food and nutrition insecurity. Developing the dried *S. aethiopicum* powder will provide the community with a cheap, convenient nutritious product for households that will provide all year round availability and combat micronutrient deficiencies. The dried powder may also be important for consumption by the children and the elderly in particular who often times find the texture of greens to be stringy and difficult to chew.

1.1. Materials and Method

Different bunches of fresh S. aethiopicum were selected randomly from a garden in Gayaza, Kampala. The vegetables were removed from the garden in the morning around 9am to avoid any sun drying on the day they were pre-treated. Samples of fresh *S. aethiopicum* were selected randomly to reduce any bias in sampling. During the picking process (i.e. the process of separation of leaves from the main stocks), well-looking soft leaves were picked and the ones that looked infected by pests were discarded.

Figure 1. *Solanum aethiopicum* being harvested in the garden

1.2. Sample Treatment

The leaves were destalked and washed under running water to remove any dirt and contaminants. Fresh leaves were divided into two lots, that is; whole fresh leaves and the other sliced into uniform sizes using a stainless steel knife, now termed as sliced leaves. After separating into these two lots, both were subjected to separate enzyme treatments which included; steam blanching for two minutes (at 100° C), dipping in 10% saline solution, dipping in 10% vinegar solution, and dipping in water to act as a control, to stop enzyme action and prolong storage life. The resultant enzyme treated leaf samples were subjected to drying under two different drying conditions including the solar drying and electrical cabinet hot air drying, and kept in these dryers for a period of 24 hours. The solar dried and hot air dried samples were later milled to a powder using a coffee grinder, packaged in air-tight polythene bags, sealed and stored at ambient conditions for laboratory analyses. The study profile is presented on Figure 2.

2. Laboratory Analysis

2.1. Catalase Activity

Test for the activity of the catalase enzyme was done following the procedure described by [16]. To 2-3g of each sample, 8ml of 1% hydrogen peroxide was added. The observations for catalase activity were recorded immediately after 3 minutes since the reactions were all generally slow and did not last long. The extent of bubbling for 3 minutes and a Likert scale was used to rate the catalase activity. The height of the rate of effervescence was taken with a metre ruler and results were recorded in cm^3. A scale of 1 – 5 was used for rating the catalase activity where 1 was no observable change and 5 was: highest effervescence.

2.2. Moisture Content

Moisture content was determined according to [17]. Two (2) g of each sample were weighed out in an aluminium dish. The dishes containing samples were placed in a convection oven (Gallenkamp convection oven, size 2, SG93/08/850, United Kingdom) and dried for around 14 hours. When drying was complete, samples were removed and placed in a desiccator to cool for 30 minutes. The dry samples were weighed. The moisture content (%) was calculated as;

$$\text{Moisture content } (\%) = \frac{W2 - W3}{W2 - W1} x100$$

Where;
W1 = weight of container with lid;
W2 = weight of container with lid and sample before drying; and
W3 = weight of container with lid and sample after drying.

2.3. Vitamin C retention Capacity

The total vitamin C content in the samples was determined by spectrophotometric method following [19] procedure in which the two forms of the vitamin C, ascorbic acid and its oxidized form dehydroascorbic acid were measured. A spectrophotometer (Genesys 10uv, Thermo Electron Corporation Madison W 153711 USA) was used to measure absorbance of each sample preparation in triplicates, at a wavelength of 521nm using a 1 cm glass quartz cuvettes.

Sample preparation

Two (2) g of each sample was homogenized with 50 ml of 5% metaphosphoric acid- 10% acetic acid solution, and transferred into a 100 ml volumetric flask through glass wool in funnel to trap solid particles, then shaken gently to a homogeneous dispersion. This was diluted up to the mark with the 5% metaphosphoric acid-10% acetic acid solution. The resultant solution was then used for the determination of vitamin C content. For the standard solution, stock standard solution containing 0.5 mg/ml (500-ppm) of ascorbic was prepared in water by dissolving 0.05 g of AA in 100 ml of water and stored in a glass stoppered bottle. Solutions of variable concentrations were prepared by diluting the stock solution in water. Standard solutions of ascorbic acid dilutions were as follows; 0.025mg, 0.05mg, 0.1mg, 0.15mg, 0.2mg, 0.25mg, 0.3mg. A sample solution (500mg) was pipetted out in triplicates into clean dry test tubes. Two drops of Bromine water was added to the sample solution to oxidize the ascorbic acid to dehydroascorbic acid and then a few drops of thiourea were added to remove the excess bromine. To both the sample and standard solutions, 1 ml of 2, 4- DNPH solution was added and mixed thoroughly. For the completion of the reaction, all the standards, samples and blank solution were kept at temperature of 37°C for 3 hours in a water bath (thermostatic). After this incubation all of those were cooled in an ice bath and treated with 5 ml of 85% sulphuric acid and vortex. As a result, a coloured red solution was obtained whose absorbance was read at 521 nm.

2.4. Phytate Content

Phytic acid content was determined according to procedures developed by [20]. To 1.0g of each of the sample powders, 2.4% HCl and 4% NaCl were added and thoroughly mixed to extract out the phytate. The extracted sample was placed in a 100ml volumetric flask. This was left to stand for 30 minutes. Ten (10) ml of the resultant solution was removed and placed in a 50mls volumetric flask which was topped up with water. About 13ml were then put in falcon tubes and centrifuged for 15 minutes. One (1) ml was then removed and put in a test tube which was topped up with 9mls of water and vortexed. The solution was divided into 3 samples of 3 mls each, put in test tubes, and had 1ml of wading reagent (0.3g of 5-sulfosalicylic acid dehydrate puriss and 0.03g of $FeCl3$ Hexahydrate) in 100mls of water added and vortexed. A series of calibration standards containing 0, 1.12, 2.24, 3.36, 5.6, 7.84, or 11.2 mg L^{-1} PA-P were prepared from sodium phytate (Sigma, St. Louis, MO), the P content of which was estimated at 18.38%.

2.5. Sensory Evaluation

The sensory attributes including colour, aroma, texture, thickness, taste, aftertaste, appearance and overall acceptability were evaluated using the 9-point hedonic scale score card by a panel of 33 judges. Each attribute was scored based on its intensity scaled on the 9-point hedonic scale (1= Dislike extremely, 2= Dislike very much, 3= Dislike moderately, 4= Dislike slightly, 5= Neither like nor dislike, 6= Like slightly, 7= Like moderately, 8= Like very much, 9= Like extremely). This was only done for the solar dried samples.

2.5.1. Cooking Procedures

Each recipe was standardized with 20g of tomato and 5g onion, which were fried together as ingredients and added into 15mls of oil. This mixture was designated as the ‘basic recipe’ for the formation of soups from the various samples of dried flours and fresh *S. aethiopicum* (as control). The decision not to vary the methods of cooking so much was so as to examine the contribution of each of the respective flours to the sensory attributes. The soups from various powders was cooked for a period of 15 minutes, cooled and served to the panelists. Altogether, eight (8) samples of dried flours of *S. aethiopicum* coded using three digit codes were evaluated including;

444= fresh leaf (as control),
321= dried sliced with vinegar,
355= dried whole in water,
511= dried whole blanched,

146= dried sliced in water,
198= dried sliced in saline,
261= dried whole in vinegar,
423= dried whole in saline, and
635= dried sliced blanched; were evaluated.

3. Data Analysis

Data was analyzed using MINITAB version 16.0. Descriptive statistics were carried out for moisture content, vitamin C retention and phytate content. One way ANOVA tests and Duncan's multiple range test ($P<0.05$ level) were used to compare between means.

4. Findings

4.1 Catalase Activity

The effect of pre-treatment of *S. aethiopicum* on catalase activity and on the chemical properties of the powder.

The results for the effect of pre-treatment on catalase activity indicated a general decline in activity, with drying and pre-treatment (Table 1).

The fresh sample had an activity value of 5.0 ±0.0 cm^3, and there was a general decline from this value following different pre-treatment methods. The lowest values attained were 3.0 ±0.0 and 2.3 ±0.7 cm3 for solar and cabinet dried samples; respectively. Pre-treatment and drying therefore have an impact on catalase activity, which is key to keeping quality in vegetables.

4.2. Moisture, Vitamin C and Phytate Content

The results of this study showed that after pre-treatments and drying, there was a significant reduction in moisture content ranging between 24.87±0.45 % for saline treated sliced leaves to 8.90±0.84 % for blanched sliced leaves in solar drying, compared to 9.28±0.04 % for sliced plain water treated leaves to 6.99±0.16 % for sliced vinegar treated leaves in cabinet drying; respectively). This reduction in moisture content is good because it can lead to reduced susceptibility to microbial contamination in the dried leaf powder.

After pre-treatments and drying, there was a reduction in vitamin C content, with cabinet dried *S. aethiopicum* containing more vitamin C content (1.08±0.22 mg for whole blanched leaves to 0.63±0.08 mg for sliced vinegar treated leaves) than the solar dried one (1.04±0.20 mg for sliced plain water treated leaves to 0.61±0.07 mg for sliced vinegar treated leaves). Findings also revealed a significant reduction in phytate content following pre-treatment and drying with a range of 0.68±0.11 - 0.24±0.06 mg/100g for the solar dried and 0.68±0.11 - 0.31±0.07 mg/100g for cabinet dried *S. aethiopicum* leaf powder.

Table 1. The trends of catalase activity of dried *S. aethiopicum* upon reduction in size and pre-treatment

Method of drying	Size reduction method	Pre-treatment method	Catalase activity Average rate (cm^3)
Solar drying	Whole	Saline	4.0±0.0
		Vinegar	4.5±0.7
		Blanched	3.5±0.7
		Plain water	3.0±0.0
	Sliced	Saline	4.0±0.0
		Vinegar	4.5±0.7
		Blanched	4.0±0.0
		Plain water	4.5±1.4
Cabinet dryer	Whole	Saline	3.0±0.0
		Vinegar	4.0±0.0
		Blanched	3.0±0.0
		Plain water	3.0±0.0
	Sliced	Saline	3.0±0.0
		Vinegar	2.3±0.7
		Blanched	3.5±0.7
		Plain water	2.5±0.7
	Fresh	Un-dried, no pre-treatment	5.0±0.0

Where; 1: no observable change; 2: very low effervescence; 3: low effervescence; 4: moderate effervescence; 5: highest effervescence.

Table 2. Moisture, vitamin C and phytate content in the dried *S. aethiopcum* leaf powder

Method of drying	Size reduction method	pre-treatment method	Moisture content (%)	Vitamin C content (mg/100)	Phytate content (mg/100)
Solar dryer	Whole	Saline	15.86±0.51[b]	0.62±0.11[e]	0.46±0.11[ab]
		Vinegar	10.07±0.44[fg]	0.68±0.17[de]	0.68±0.11[a]
		Blanched	11.81±0.50[cd]	0.63±0.09[e]	0.37±0.08[b]
		Plain water	12.23±0.75[c]	0.66±0.11[de]	0.41±0.08[b]
	sliced	Saline	24.87±0.45[a]	0.62±0.12[a]	0.24±0.06[b]
		vinegar	10.38±0.68[ef]	0.61±0.07[e]	0.40±0.07[b]
		Blanched	8.90±0.84[h]	0.81±0.03[cde]	0.40±0.07[b]
		Plain water	11.02±0.38[de]	1.04±0.20[ab]	0.39±0.09[b]
Cabinet dryer	Whole	Saline	8.93±0.08[h]	0.64±0.06[e]	0.41±0.14[b]
		Vinegar	7.78±0.21[j]	1.00±0.19[abc]	0.68±0.11[a]
		Blanched	7.92±0.12[ij]	1.08±0.22[a]	0.31±0.07[b]
		Plain water	8.65±0.36[hi]	0.82±0.11[bcde]	0.41±0.34[b]
	sliced	Saline	7.82±0.11[j]	0.67±0.15[de]	0.45±0.13[b]
		vinegar	6.99±0.16[k]	0.63±0.08[e]	0.41±0.04[b]
		Blanched	8.66±0.31[hi]	0.88±0.16[abcd]	0.31±0.26[b]
		Plain water	9.28±0.04[h]	1.04±0.13[a]	0.35±0.09[b]

Note: - Means of values for the different treatments are significantly different ($p<0.05$) i.e. moisture content, vitamin C and phytate, - Means that do not share a letter for the same treatment are significantly different.

4.3. Acceptability of the Dried *S. aethiopicum* Leaf Powder Products

The overall acceptability score for the dried samples was 5.12 (ranging from 4.06 to 6.30); which clearly indicated that the dried samples were slightly liked by the panelists as compared to the score of 8.21 for fresh vegetable, which was highly rated (as liked very much) by the panelists.

Based on the mean acceptability score, the most acceptable of the dried samples was 423 (whole vegetable dipped in saline solution), followed by 198 9dried sliced in saline) and the least being 635 (sliced and blanched sample).

Table 3. Overall acceptability of the solar dried *S. aethiopicum* soups and the difference between groups (n=8)

		Sum of Squares	df	Mean Square	F	Sig.
Overall acceptability - 321	Between Groups	9.34	3	3.11	1.24	.313
	Within Groups	72.84	29	2.51		
	Total	82.18	32			
Overall acceptability - 423	Between Groups	33.56	3	11.19	5.65	**.004****
	Within Groups	57.45	29	1.98		
	Total	90.97	32			
Overall acceptability – 261	Between Groups	14.63	3	4.88	1.93	.147
	Within Groups	73.43	29	2.53		
	Total	88.06	32			
Overall acceptability – 511	Between Groups	16.32	3	5.44	1.44	.249
	Within Groups	109.01	29	3.76		
	Total	125.33	32			
Overall acceptability – 198	Between Groups	20.54	3	6.85	2.38	**.090***
	Within Groups	83.52	29	2.88		
	Total	104.06	32			
Overall acceptability - 146	Between Groups	11.43	3	3.81	1.26	.301
	Within Groups	86.63	29	2.99		
	Total	98.06	32			
Overall acceptability - 635	Between Groups	9.35	3	3.12	0.82	.494
	Within Groups	102.52	27	3.80		
	Total	111.87	30			

Where, 444= fresh leaf (as control), 321= solar dried sliced with vinegar, 355= solar dried whole in water, 511= solar dried whole blanched, 146= solar dried sliced in water, 198= solar dried sliced in saline, 261= solar dried whole in vinegar, 423= solar dried whole in saline, and 635= solar dried sliced blanched. **. P≤0.05, *. P≤0.1.

Table 4. 'Overall acceptability' of the various dried samples (n=33)

		N	Mean	Std. Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Overall acceptability - 321	Dislike slightly	1	2.00	.	.	.
	Like moderately	4	4.75	0.96	3.23	6.27
	Like very much	13	4.85	1.21	4.11	5.58
	Like extremely	15	4.20	1.93	3.13	5.27
	Total	**33**	**4.45**	**1.60**	**3.89**	**5.02**
Overall acceptability - 423	Dislike slightly	1	1.00	.	.	.
	Like moderately	4	6.25	2.22	2.72	9.78
	Like very much	13	6.08	1.44	5.21	6.95
	Like extremely	15	6.87	1.13	6.24	7.49
	Total	**33**	**6.30**	**1.69**	**5.71**	**6.90**
Overall acceptability - 261	Dislike slightly	1	1.00	.	.	.
	Like moderately	4	5.25	1.26	3.25	7.25
	Like very much	13	4.62	1.50	3.71	5.52
	Like extremely	15	4.60	1.72	3.65	5.55
	Total	**33**	**4.58**	**1.66**	**3.99**	**5.16**
Overall acceptability - 355	Dislike slightly	1	6.00	.	.	.
	Like moderately	4	4.75	1.71	2.03	7.47
	Like very much	13	5.62	1.50	4.71	6.52
	Like extremely	15	4.60	2.26	3.35	5.85
	Total	**33**	**5.06**	**1.90**	**4.39**	**5.74**
Overall acceptability - 511	Dislike slightly	1	2.00	.	.	.
	Like moderately	4	6.50	2.38	2.71	10.29
	Like very much	13	5.62	1.26	4.85	6.38
	Like extremely	15	5.73	2.28	4.47	7.00
	Total	**33**	**5.67**	**1.98**	**4.96**	**6.37**
Overall acceptability - 198	Dislike slightly	1	2.00	.	.	.
	Like moderately	4	6.50	2.65	2.29	10.71
	Like very much	13	6.08	1.50	5.17	6.98
	Like extremely	15	6.60	1.59	5.72	7.48
	Total	**33**	**6.24**	**1.80**	**5.60**	**6.88**

		N	Mean	Std. Deviation	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Overall acceptability - 146	Dislike slightly	1	7.00	.	.	.
	Like moderately	4	5.50	0.58	4.58	6.42
	Like very much	13	4.54	1.05	3.90	5.17
	Like extremely	15	4.20	2.27	2.94	5.46
	Total	**33**	**4.58**	**1.75**	**3.96**	**5.20**

Where, 444= fresh leaf (as control), 321= dried sliced with vinegar, 355= dried whole in water, 511= dried whole blanched, 146= dried sliced in water, 198= dried sliced in saline, 261= dried whole in vinegar, 423= dried whole in saline, and 635= dried sliced blanched.

Table 5. Comparison of the attributes for the different flour sample with those of the fresh sample

Sample	Attributes	F - value	P - value
321	Colour	1.32	0.287
	Aroma	0.68	0.612
	Texture	1.84	0.139
	Thickness	1.95	0.119
	Taste	0.77	0.555
	Aftertaste	1.93	0.122
	Overall appearance	0.49	0.741
423	Colour	2.01	0.120
	Aroma	3.51	0.019**
	Texture	1.56	0.205
	Thickness	2.07	0.101
	Taste	2.94	0.038**
	Aftertaste	2.76	0.039**
	Overall appearance	3.92	0.012**
261	Colour	1.23	0.321
	Aroma	1.48	0.236
	Texture	5.73	0.001**
	Thickness	1.58	0.119
	Taste	1.02	0.414
	Aftertaste	1.56	0.205
	Overall appearance	1.31	0.289
355	Colour	0.60	0.666
	Aroma	1.11	0.373
	Texture	1.51	0.221
	Thickness	1.05	0.411
	Taste	1.20	0.334
	Aftertaste	0.77	0.578
	Overall appearance	0.23	0.920
511	Colour	1.04	0.402
	Aroma	1.24	0.318
	Texture	5.78	0.001**
	Thickness	3.16	0.023**
	Taste	2.47	0.067*
	Aftertaste	1.27	0.305
	Overall appearance	2.81	0.044**
198	Colour	2.17	0.099
	Aroma	1.83	0.152
	Texture	2.42	0.062*
	Thickness	3.29	0.019**
	Taste	2.34	0.080*
	Aftertaste	1.30	0.293
	Overall appearance	3.81	0.013**
635	Colour	0.50	0.735
	Aroma	0.67	0.617
	Texture	1.44	0.244
	Thickness	1.65	0.185
	Taste	1.16	0.351
	Aftertaste	0.89	0.500
	Overall appearance	1.05	0.402
146	Colour	0.80	0.535
	Aroma	1.268	0.306
	Texture	1.197	0.337
	Thickness	1.515	0.218
	Taste	1.305	0.292
	Aftertaste	0.959	0.460
	Overall appearance	0.990	0.429

Where, 444= fresh leaf (as control), 321= dried sliced with vinegar, 355= dried whole in water, 511= dried whole blanched, 146= dried sliced in water, 198= dried sliced in saline, 261= dried whole in vinegar, 423= dried whole in saline, and 635= dried sliced blanched.
** Sig at 0.05; *. Sig at 0.1.

A table showing the comparison of the means of samples for overall acceptability with the overall acceptability for the fresh vegetable sample.

The attributes for the fresh vegetable (which was ranked as the best) were as follows; colour 7.82; aroma 7.85; texture 7.09; thickness 7.15; taste_8.33; aftertaste 7.88; overall appearance 7.97; and overall acceptability 8.21. Table 3 shows how the solar dried samples were scored (for overall acceptability only) in comparison with the fresh sample.

A comparison of 'overall acceptability' of the solar dried samples processed under different pre-treatment conditions is presented (Table 4).

5. Discussion

African leafy vegetables including *S. aethiopicum* are very useful in the diets of the population because they add variety into the human diet and contribute significantly to improving the food security situation [20]. Although Uganda is a home to many over 600 species [21]; of these vegetables, their overall potential is hardly realized especially for purposes of food and nutrition insecurity mitigation. Majority of Ugandans do not actually consume adequate amounts of these vegetables to meet their nutritional needs [11]. Even of what is consumed, a large part (20-50%) of the nutrients are lost from garden to table [20], either physically, biochemically or nutritionally; which in the end contributes to micronutrient deficiencies. In Uganda, anemia prevalence is estimated to be 49 % and 23 % in children and women respectively [22], with the prevalence of iron deficiency being estimated at 2 to 2.5 times the prevalence of anemia. Vitamin A deficiency (VAD) affects 20 % of children and 19 % of women in Uganda. The general prevalence of zinc deficiency in Uganda is still not well defined, but is assumed to be high due to limited access to zinc-rich foods.

Solanum aethiopicum, although rich in some of these micronutrients is known to undergo some deteriorative changes immediately after harvest that are undesirable to farmers and consumers [21]. These changes may be in terms of but not limited to colour, appearance and texture [23]. To reduce the effects of deterioration, and thus increase shelf life and promote availability of the vegetable in times of scarcity, these changes need to be controlled through processing techniques that can easily be promoted, adopted and used locally at home. Such techniques include pre-treatment and drying.

Pre-treatment, although not commonly used for *S. eathiopicum* has been used since time immemorial in the preservation of foods. Sodium bicarbonate (baking soda) has been employed in the cooking of vegetables, largely because of the decreased cooking time required and because its use is attended by retention of the normal color of green vegetables (most especially *Vigna unguiculata*).

Drying of vegetables (particularly *S. aethiopicum*) is a new idea in Uganda, as vegetables are often consumed in their fresh unprocessed form. Uganda has been regarded as the food basket due to the high dietary diversity. The rainy seasons are usually characterized by production of plenty of vegetables, some of which go to waste due to lack of preservation techniques. Consumption of these vegetables is also high both in households and restaurants [4], but often production surpasses consumption at this peak period. Vegetables are seasonal with high (30 - 40 %) post-harvest losses which can lead to high nutritional and economic losses [24]. One way of reducing high post-harvest losses and ensuring year-round availability is through processing of the vegetables into dried and value added products. Year-round availability and utilization of vegetables will improve micronutrient intake resulting in significant reduction in vitamin A, iron and zinc deficiencies in children.

Drying therefore allows one to choose the best and tastiest varieties that can be picked or bought fresh from the garden during the rainy season and preserve them for off-season use, bringing enjoyment when these are not available in the gardens, groceries or markets. Unlike canning in which precise instructions have to be adhered to, vegetable drying is flexible and decisions about the pieces/ sizes, mixtures and pre-treatments to undertake are personal. For this reason, such simple processing methods should be promoted and adopted by the local communities to ensure constant supply of seasonal vegetables.

5.1. Effect of Different Processing Techniques on Moisture Content, Vitamin C Retention and Phytate Content

Moisture content is implicated in deteriorative activities in vegetables. From studies, it is revealed that *S. aethiopicum* has very high moisture content which ranges between 88.31±0.23% and 91.94±0.11% [25] in the fresh leaves. African eggplant fruits generally have high moisture content (about 75%) and low dry matter. The moisture content of any food is an index of its water activity and is used as a measure of stability and the susceptibility to microbial contamination. However, the fibrous nature of the skin of eggplants makes it a bit difficult for microorganism to access. This high moisture content also implies that dehydration would increase the relative concentrations of the other food nutrients and improve the shelf-life/preservation of the vegetables [25].

Studies also indicate that the amount of Vitamin C content of fresh leaves is high, ranging from 8-15mg/100g, [26]. Maintaining such a high content can be challenging especially while using the rudimentary methods of processing. In this current study, there was a significant reduction in vitamin C when the vegetables were cabinet dried and solar dried with a significantly greater reduction in the sample that was solar dried. This is probably because of the direct exposure of the solar rays (ultra violet rays) to the vegetables. Vitamin C undergoes faster oxidative deterioration especially in the presence of conducive factors such as oxygen, light, enzymes, moisture and metal ions [20]. Studies have also found that the phytate content in fresh leaves of *S. aethiopicum* is as high as 28.73±0.80mg/ 100g [25,26]. The findings of this study reveal that the content of phytate is reduced with processing, following pre-treatment and drying irrespective of the methods used which enhances bioavailability of nutrients in the vegetable. This should be promoted in the communities to make better use of the vegetables

5.2. The Effect of the Different Drying Methods on Chemical Properties (Moisture and Phytate Content, Vitamin C Retention, and Catalase Activity) of *S. aethiopicum* Powder

Solar dried leaf powder contains a significantly higher amount of moisture content than hot air cabinet dried leaf powder. However, there was no significant difference in the percent moisture content between the two size reduction methods of whole and sliced, within the drying method. The leaf samples dipped in saline solution contained significantly higher percentage of moisture content followed by those dipped in plain water, followed by the blanched and then those dipped in vinegar contained the least amount of moisture content.

Hot air cabinet dried leaf powder generally retained more vitamin C content than the solar dried powder, irrespective of the size reduction method. Sliced leaf powder had significantly more vitamin C content than whole leaf powder, which seems to make slicing a better method of processing these vegetables. The powder formed from the dipped-in plain water leaf sample had the highest vitamin C content followed by blanched one. The powder from the dipped-in saline and vinegar leaf samples had the least amounts of vitamin C. Besides the high instability in pro-vitamin A and vitamin C under high conditions of heat, light, (Ultra violet radiation), oxygen, enzymes, moisture and metal ions, Osborne and Voogt [27] also suggest reduced stability of these two compounds in aqueous state than in the dry state. It might explain why there was more loss of vitamin C in solar drying than in cabinet drying.

Phytic acid (PA) is the primary storage compound of phosphorus in seeds accounting for up to 80% of the total seed phosphorus and contributing as much as 1.5% to the seed dry weight. The negatively charged phosphate in PA strongly binds to metallic cations of Ca, Fe, K, Mg, Mn and Zn making them insoluble and thus unavailable as nutritional factors. It's often considered an anti-nutrient because it binds minerals in the digestive tract, making them less available to our bodies. In this study, there was no significant difference in phytate content between the hot air cabinet dried and solar dried samples.

Solar dried leaf powder contains more catalase than the hot air cabinet dried one. Sliced leaf sample contained significantly more catalase enzyme than whole powder, which promotes faster deteriorative action in the vegetables. A significant difference in catalase enzyme activity in the different pre-treatments of the leaf samples was also observed.

5.3. Acceptability

Sensory evaluation is considered to be a valuable tool in solving problems involving food acceptability [28]. It is useful in product improvement, quality maintenance and more importantly in new product development. Dried soups should therefore possess desired quality, representing dominant flavor and aroma of the ingredients used.

Overall acceptability for the eight samples indicated that they were liked (slightly) by the panelists, compared to the fresh sample of *S. aethiopicum*. This level of liking could be attributed to the nature of the product. Most vegetables in Uganda are consumed fresh and unprocessed. So because the panelists are familiar with the taste of the fresh vegetable, they were bound to rate it lower than the fresh sample.

The nearest of the samples in terms of acceptability showed that aroma, taste, aftertaste overall appearance were important factors that determined acceptability for the product. Colour is one of the most important attributes of vegetable products [29], as it attracts consumers to a product and can also help in impulse purchases. In this study however, the green color did not seem to be a hindrance to acceptability. Aroma, taste and aftertaste however took precedence over colour where by, for the most acceptable sample and the one next, use of saline water could have served the role of preserving the aroma, taste and aftertaste of the samples. Saline water (salt water made from sodium chloride) is a compound that people use on a daily basis, and therefore once used on a new product, these attributes are not expected to deviate so much from the usual. This is likely to have caused the observed acceptability test results in the two samples, which were significantly comparable to those of the fresh vegetable sample.

6. Conclusion

Pre-treatment of *S. aethiopicum* in saline solution, vinegar solution, blanching and plain water leads to reduction of catalase enzyme activity in the vegetable, pre-treatment also leads to reduction in the chemical properties of *S. aethiopicum* that include moisture content, vitamin C, and phytate. Fresh *S. aethiopicum* contains more catalase, more moisture content, more vitamin C and more phytate content than the pre-treated one. It can be concluded that; more catalase, more moisture content retention and more loss of Vitamin C content occurs in the solar drier than cabinet drier. Whole leaf saline pretreated leaf powder soup is highly rated compared to other dried soups. Therefore, the best method for production of dried *S. aethiopicum* powder is by slicing, dipping it in plain water and drying using a cabinet dryer. Considering local conditions where cabinet drying is not achievable, solar drying is advised using whole leaf, pretreated with saline water to promote preservation and consumption of the vegetable.

7. Recommendations

Hot air cabinet dryers are expensive to venture and use may not be practically possible at the local level without research and initiatives to make them available. Technological innovations are therefore necessary to make these available to the rural poor for use in the production of dried products. Solar drying however, which seems to be a cheaper method comes with a compromise in the nutritional quality of heat and light sensitive nutrients like vitamin C. The recommended method of pre-treatment is therefore dipping whole leaves in saline solution, then subjected to hot air cabinet drying or solar drying in the absence of a cabinet dryer.

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