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Multivariate analysis of the sensory changes in the dehydrated cowpea leaves

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Abstract

Processing of foods, especially dehydration is known to result in alteration of sensory and nutritional qualities. Cowpea leaves is one of the common leafy vegetables consumed in Kenya that contain high levels of pro-vitamin A compounds and has good carotene retention during processing. A tasting panel was trained using a quantitative descriptive analysis (QDA) test that was developed and used to characterize the sensory properties of dehydrated cowpea leaves. The panel identified sensory attributes in dehydrated cowpea leaves that were important in discriminating the dehydrated samples from the fresh material. Principal component analysis (PCA) was used to analyze the QDA scores. The first principal component (PC1) which accounted for 85% of the variance was an index of the interrelationship among variables in differentiating the samples while PC2, which accounted for the remaining variance measured the attributes influence in discriminating samples. The results of the sensory attributes mean scores showed that aroma, texture and appearance had high influence in discriminating between the fresh, the sun-dried and the solar-dried samples. The solar dried products were close to the fresh material, which was characterized, as soft and tender with an appealing dark green color, than the sun dried product. The sun dried products differed from the other products more on appearance.

Keywords: Dehydrated cowpea leaves; Sensory attributes; Panel training; Principal component analysis

1. Introduction

In the African diet dark green leafy vegetables (DGLV) are the most variable vegetables because they are the major source of essential dietary nutrients such as carotenes, Vitamin C, protein, calcium and iron. They also provide crude fiber, color and flavor as well as variety to the diet. [1,2]. Many green leafy vegetables widely consumed in Kenya include cowpea leaves, kale, nightshade, African herb and East African spinach [3]. However, the availability and consumption of these vegetables depend on the seasonal changes and this affects the nutritional status of the people [4]. During rainy season fruits and vegetables are consumed fresh in large quantities but become scarce or not available during dry season. This is partly responsible for the micronutrient deficiency such Vitamin A and iron in many developing countries. Simple and cheap preservation methods are essential to make such foods available in times of shortage and out of season, and at places far from the site of production. There preservation and distribution methods that are being promoted as intervention programs for Vitamin A deficiency [5,6]. Such methods can also minimize the high losses incurred in vegetable production.

Dehydration is the best preservation method suited for developing countries where facilities for other methods are poorly established [4,7–9]. The method prevents the growth and reproduction of microorganisms causing spoilage and reduces many of the deteriorative reactions by reducing the moisture content to a low level. The dehydrated products are substantially reduced in weight and volume that minimizes packing, storage and transportation costs [10]. Jayaraman and Das Gupta [11] reviewed the recent developments in the principles and techniques of dehydration of fruits and vegetables.

Though sun drying by open air is the most common, cheap and easiest dehydration method it experiences many shortcomings such as contamination by dirt or rodents, infestation by insects, easy spoilage from exposure to weather

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elements and animals, and uncontrolled drying conditions leading to low quality products [4,12]. Due to this and other reasons considerable interest has been focused in recent years on solar dehydration; a method of using solar energy for hot air dehydration [13]. With improvements, solar dehydration would provide an appropriate preservation technique for vegetables in the tropics [14].

Dehydration is accompanied by many changes, including chemical reaction and physical and structural changes which affect both nutritional and sensory qualities. In foods dehydration generally involves a series of interdependent unit operations like blanching, pasteurization, pre-concentration and drying, all of which contribute to the overall quality of the final product. For vegetables in particular, dehydration processes affect, to a varying degree, the quality attributes of color, texture and nutritional retention. The loss of nutritional and sensory attributes depends on both the type of dehydration process and the sensitivity of specific food components [15]. The aim of this study was to train a panel of assessors and use it to investigate the effect of dehydration on the sensory qualities of the dark green leafy vegetables. A QDA test was developed during training and used to characterize the sensory attributes of cowpea leaves. The changes in the sensory qualities were analyzed by principal component analysis (PCA). PCA reduces attributes to fewer dimensions without loss of information to account for the variance within a set of data by providing linear combinations of correlated variables that maximize the variance of the weighed sum [16]. It identifies which attribute or combinations of attributes are important in discriminating samples.

2. Materials and methods

2.1. Materials

Cowpea leaves (*Vigna unguiculata*) used for the study were purchased from local markets in Nairobi. The leaves were thoroughly washed, and stalks and all inedible parts removed before shredding. After blanching in boiling water for three minutes the material was drained and divided into two equal portions, one for sun drying and the other for solar drying. A panel was trained on the products and used to evaluate the sensory attributes. Training and tasting sessions were carried out using a room improvised into a taste panel area by constructing booths.

2.2. Dehydration

The samples for solar-drying were evenly and loosely spread in a wire mesh tray in a load capacity of less than 2.0 kg m^{-2} to give a single layer and allowed to dry for 4–6 h. Spreading was done such that lumping together of many leaves was minimized. The layer thickness was kept below 0.7 cm, with the average thickness being about 0.4 cm. An indirect solar dryer was constructed and used to solar dry the samples. Loading of similar density was done in sun drying as that for solar dehydration on a tray exposed to the sunrays placed adjacent to the solar dryer. The dehydrated products were then packed in opaque polyethylene bags and stored until used.

2.3. Sensory evaluation

The dehydrated samples were reconstituted for tasting by cooking them in a limited amount of boiling water (about 8–10 times the weight of the samples) for 10–15 min. The control fresh sample was pre-treated by thoroughly washing under tap water, removing inedible parts, shredding and blanching for 3 min. The blanched samples were kept refrigerated until used the following day. Before use the blanched samples were cooked in boiling water (volume, one fifth the weight of the blanched material) for 5 min and designated as freshly cooked. The sensory attributes of solar and sun dried cowpea leaves were determined using quantitative descriptive analysis (QDA).

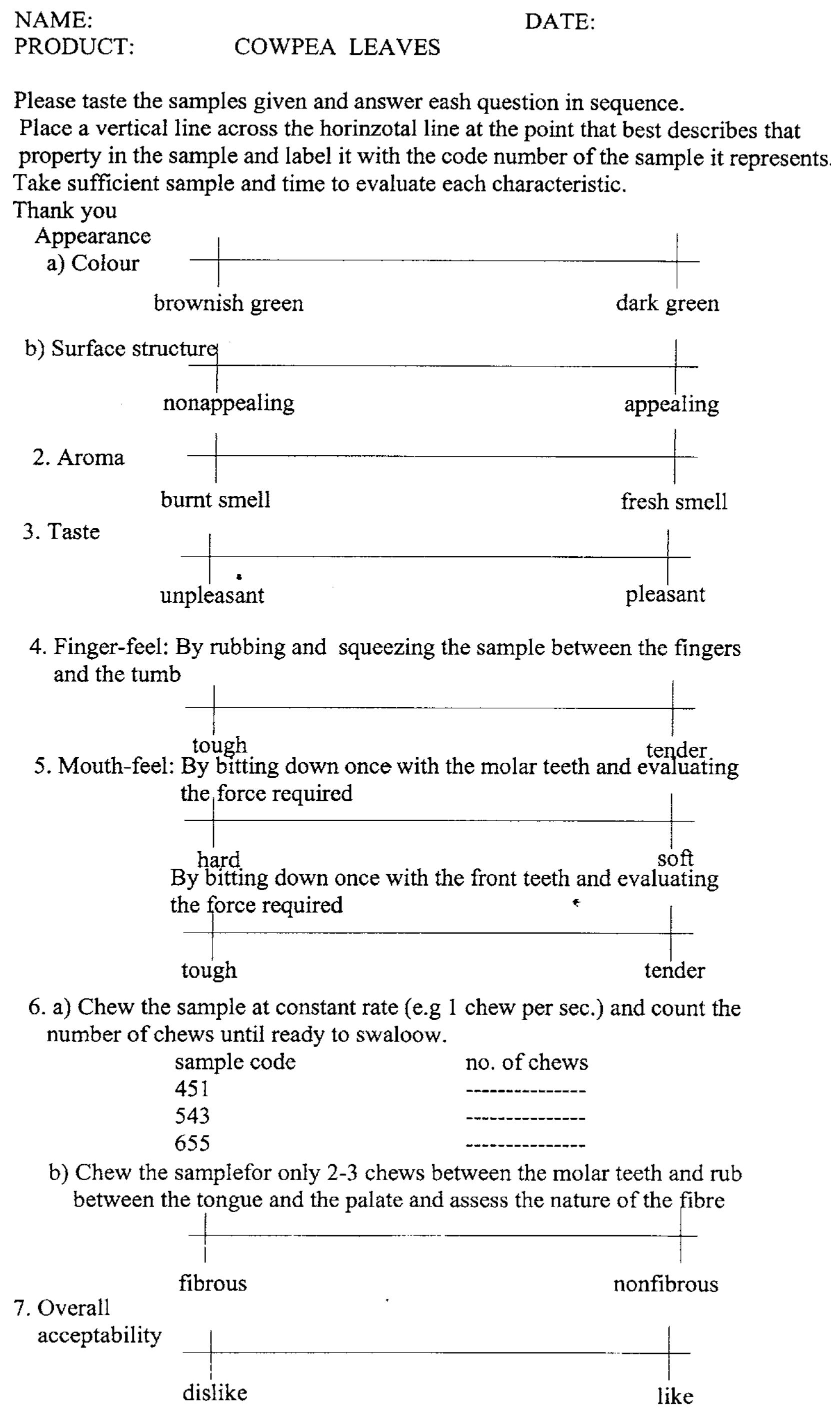
2.4. Development of QDA test

A quantitative descriptive analysis (QDA) test was developed and used to investigate the effect of dehydration on specific attributes of dehydrated cowpea leaves. A range of sensory descriptive terms were obtained from the remarks and comments given by the panelists in a triangle test, described during training and used in structuring the test. Three samples of fleshly cooked and reconstituted solar and sun dried cowpea leaves were served to the trained panelists who indicated their response by marking on horizontal lines given for each attribute (Fig. 1). The lines had anchor descriptors at the ends (10 cm apart), with the left anchor representing the lowest intensity (non-appreciable) and the right anchor the highest intensity (appreciable). The marks were transformed into data by taking measurements (in cm) from the left anchor, representing zero on a scale of 0 and 10. The data was then treated to analysis of variance (ANOVA) and principal component analysis (PCA).

2.5. Panel training

The sensory qualities of the solar and the sun dried cowpea leaves were determined using a trained panel. The purpose of training was to develop familiarity with the product and its sensory characteristics, to develop common language to describe the characteristics and to improve the panel ability to make consistent judgment. Training makes panelists disregard personal preferences and make evaluation objective.

Twenty-seven trainees were recruited, out of which 20 were selected using a triangle test to participate in the training. In the triangle test the participants were served with three samples of fresh and solar dried cowpea leaves and asked to identify the odd one out. Those who correctly identified the odd, were frequent consumers of cowpea



NAME: DATE:
PRODUCT: COWPEA LEAVES

Please taste the samples given and answer eash question in sequence.
Place a vertical line across the horinzotal line at the point that best describes that property in the sample and label it with the code number of the sample it represents.
Take sufficient sample and time to evaluate each characteristic.
Thank you

Appearance
a) Colour — brownish green / dark green

b) Surface structure — nonappealing / appealing

2. Aroma — burnt smell / fresh smell

3. Taste — unpleasant / pleasant

4. Finger-feel: By rubbing and squeezing the sample between the fingers and the tumb — tough / tender

5. Mouth-feel: By bitting down once with the molar teeth and evaluating the force required — hard / soft

By bitting down once with the front teeth and evaluating the force required — tough / tender

6. a) Chew the sample at constant rate (e.g 1 chew per sec.) and count the number of chews until ready to swaloow.

sample code	no. of chews
451	---------------
543	---------------
655	---------------

b) Chew the samplefor only 2-3 chews between the molar teeth and rub between the tongue and the palate and assess the nature of the fibre — fibrous / nonfibrous

7. Overall acceptability — dislike / like

Fig. 1. A QDA test questionnaire for sensory evaluation of fresh, solar-, and sun-dried cowpea leaves.

leaves and were willing to participate in the training were selected. The trainees also indicated the characteristics and qualities causing the difference among the samples and these characteristics and qualities formed the basis in the training. During training participants were presented with a set of samples and a questionnaire to indicate their response, followed by discussion of the results after each session.

Samples of fresh and dehydrated cowpea leaves with extreme properties were used to act as reference points for the attributes. The fresh material was overcooked in boiling water to make it soft and less chewy to indicate the hard and firm texture properties and the solar dried product was further dried in the oven at 150 °C for 2 h and then undercooked to alter its appearance, aroma and chewy properties.

Table 1
Definition of sensory attributes used in profiling of cowpea leaves

Attribute	Definition	
	Low intensity	High intensity
Aroma	Burnt smell	Fresh smell
Taste	Unpleasant	Pleasant
Color	Brownish	Green
Surface structure	Non-appealing	Appealing
Finger-feel toughness	Tough	Tender
Mouth-feel hardness	Hard	Soft
Mouth-feel toughness	Tough	Tender
Fibrousness	Fibrous	Non fibrous
Overall acceptability	Dislike	Like

A number of training sessions were held in which the tasting procedures, development of appropriate sensory terms and scoring procedures were emphasized. The participants learned on how to differentiate samples, communicate their perceptions and comprehend tasting procedures in order to increase homogeneity of response. From the initial training sessions, some sensory attributes that indicated the difference between fresh and dry samples, and their reference points were agreed upon and were used in subsequent training and tasting (Table 1). These attributes were categorized to cover four basic properties; appearance, aroma, finger-feel and mouth-feel properties. Some attributes would not however be described easily even when identified. For example, aroma for the fresh was only described as fresh smell and that for the dry samples as burnt smell. The training sessions were also meant to enable participants to master scoring the attributes in the QDA test so as to give reproducible results.

At the end of the training period, which lasted for five months, 12 participants were finally selected to form the panel but ten of them were available during tasting. The ten trained panelists participated twice in the QDA test on the blanched, solar and sun dried cowpea leaves. The samples were served in petri dishes at random to the panelists who indicated their response in a QDA questionnaire (Fig. 1). The mean of the QDA scores was used in PCA analysis.

3. Results

3.1. The performance of the trained panelists

The mean scores for the panelists were used to determine the relationship among the panelists in scoring the attributes (Table 2). The results indicate that scoring among panelists was inconsistent across some attributes, especially taste that ranged from 1.4 (unpleasant) to 8.1 (pleasant), the number of chews that ranges from chewy to less chewy, and mouth-feel hardness that ranged from soft to hard. This indicated that despite training some panelists had problems in scoring the sample; they disagreed with the rest of the panel.

The mean scores were analyzed by (ANOVA) and PCA to determine the relationship among panelists in scoring the attributes. ANOVA results indicated that some panelists (3, 5, 6, 7) had high F-ratio than the mean F-ratio, suggesting that their scores disagreed with the whole panel [17]. Although some panelists were inconsistent in scoring the attributes the fact that some preferred hard textured vegetables to soft may explain this scoring behavior.

The results for PCA had the loadings for the first two principal components accounting for 97% of the variance (Table 3). The first principal component (PC1) accounts for 91.9% and the loadings have similar sign and magnitude, except for panelists 7 and 8 whose score was slightly low. PC1 is a measure of the scoring dispersion of the panelists and shows that all panelists except 7 and 8 were scoring consistently. On the other hand, PC2 focuses mainly on panelists 7, 8 and 9 by contrasting panelist 8 with panelists 7 and 9 so that if all other scores are accounted for the major variation in the scores was between high scores for panelists 7 and 9 compared with the low score in many attributes for

Table 2
The panelists' mean scores on the attributes of the fresh, solar- and sun-dried cowpea leaves and the F-ratios

Panelist	Mean scores										
	A	T	C	SS	F-T	M-H	M-T	*F*	OA	NC	*F*-ratio
1	4.6	5.3	5.4	5.3	6.4	5.1	5.9	6.0	6.0	17.0	0.23
2	4.9	4.6	5.2	3.7	4.4	5.1	3.9	3.1	5.2	36.7	1.35
3	4.6	3.4	4.9	3.5	4.8	2.7	4.3	4.3	4.3	15.6	6.90
4	6.7	5.4	4.9	5.5	4.7	4.3	4.5	4.4	5.2	21.7	0.74
5	7.6	8.0	6.3	6.7	6.3	8.8	7.0	8.2	7.2	26.0	3.12
6	5.5	5.1	4.2	4.4	4.7	4.9	5.1	4.9	5.5	14.0	6.81
7	4.6	1.8	5.9	5.2	4.8	3.5	5.9	5.2	6.2	10.0	3.17
8	4.6	8.1	6.6	6.9	7.8	4.3	5.5	4.5	4.4	13.7	0.29
9	4.0	1.4	4.0	3.8	3.9	4.7	4.5	5.1	5.3	15.7	2.13
10	6.4	5.4	4.3	4.4	5.1	5.0	5.3	4.4	4.5	21.7	0.14
Mean *F*-ratio											2.47

A: aroma; T: taste; C: color; SS: surface structure; F-T: finger-feel toughness; M-H: mouth-feel hardness; M-T: mouth-feel toughness; *F*: fibrousness; OA: overall acceptability; NC: number of chews.

Table 3
PCA component coefficients for the panelists on and the variance contribution for the first and second principal components of the fresh, sun- and solar-dried cowpea leaves

Panelist	PC1	PC2
1	−0.33	−0.00
2	−0.33	−0.08
3	−0.33	−0.05
4	−0.33	−0.10
5	−0.32	−0.11
6	−0.33	−0.05
7	−0.27	0.74
8	−0.28	−0.55
9	−0.32	0.32
10	−0.33	−0.13
Eigenvalue	9.19	0.51
Variance contribution (%)	91.9	5.1

panelist 8 or vice versa. The analysis on the performance of the trained panel showed that the general scoring ability of the panelists was consistent, perhaps due to the training, although there are variations due to the personal preferences [18].

3.2. Sensory attributes of the cowpea leaves

The mean score for the attribute of the fresh, solar dried and sun dried samples was determined (Table 4). There were apparent differences between the fresh, solar dried and the sun-dried products in most attributes. The fresh product was more appreciable (mean score 6.1) than dehydrated products on a scale of 0 (non-appreciable) to 10 (appreciable). The dehydrated products had below average mean score for most attributes except for color in the solar dried and mouth-feel hardness in the sun dried products, suggesting that the acceptability of solar and sun dried product was medium to low. The difference between the solar dried and the sun-dried product was on color, surface structure and mouth-feel hardness. From the mean scores of the number of chews and the mouth-feel hardness the solar dried products were chewier than the fresh and the sun dried products. The softer texture and the less chewy of the sun-dried product relative to the solar-dried may be attributed to the effect of direct exposure to sunlight, which destroys the cellular structure of the leaves [19].

The sensory attributes were analyzed by ANOVA and PCA in order to investigate the relationship among the samples and the attributes and between the attributes and the samples. This was necessary to identify the attributes that are important in discriminating the samples. ANOVA results indicated that highly significant difference existed among the samples in most attributes. Significance difference among the samples was greatest in color (*F*-ratio, 113.2) and least in overall acceptability (*F*-ratio, 5.6) at 95% significant level (Table 4).

Principal component analysis (PCA) was performed on the correlation matrix of the mean scores to identify the attributes that were important for discriminating the samples (Table 5). The first principal component (PC1) accounted for 85% of the total variance, with the loadings having the same sign and almost similar magnitude except for the mouth-feel hardness and the number of chews. PC1 is an index of the interrelationship among the attributes in differentiating the samples and shows that all attributes were equally important at discriminating the samples, though less for mouth-feel hardness and the number of chews.

The second principal component (PC2), which accounts for the remaining variance is a measure of the attributes' influence in discriminating the samples. It contrasts mouth-feel hardness with the number of chews, implying that the main source of variance if all other attributes are accounted for was in samples with hard texture as felt by the mouth in relation with low number of chews and the samples with soft texture in relation the high number of chews. ANOVA results indicated that that some panelists scored the reverse order relative to the rest of the panel.

The scatter plot of the loading coefficients of the attributes and the scores of the samples for the first and the second principal components is shown in Fig. 2. The scatter display

Table 4
Mean values (and standard deviations) and the *F*-ratios for the sensory attributes of blanched, sun- and solar-dried cowpea leaves

Attribute	Fresh	Solar dried	Sun dried	*F*-ratios
Aroma	7.9 (1.47)	4.5 (2.23)	3.8 (2.39)	13.6*
Taste	6.6 (3.4)	3.9 (3.01)	3.9 (2.74)	3.7
Color	8.9 (0.71)	5.1 (1.79)	1.6 (1.02)	113.2*
Surface structure	8.2 (1.23)	4.6 (2.46)	2.0 (1.27)	36.6*
Finger-feel toughness	8.4 (1,12)	4.4 (2.52)	3.2 (2.23)	17.8*
Mouth-feel hardness	6.7 (2.82)	2.6 (2.51)	5.1 (2.00)	7.9*
Mouth-feel toughness	7.1 (2.65)	3.8 (2.62)	4.7 (2.77)	3.3
Fibrousness	6.1 (2.99)	4.6 (2.69)	4.4 (2.56)	1.8
Overall acceptability	7.5 (2.38)	3.9 (2.12)	4.9 (2.56	5.6*
Number of chews	17.9 (6.43)	21.2 (7.42)	18.3 (11.94)	1.1

* Attributes with significant difference ($P = 0.05$), critical value = 4.26.

Table 5
PCA component coefficients for the attributes on and the variance contribution for the first and second principal components of the fresh, sun- and solar-dried cowpea leaves

Attribute	PC1	PC2
Aroma	−0.34	−0.04
Taste	−0.34	0.09
Color	−0.32	−0.31
Surface structure	−0.33	−0.26
Finger-feel hardness	−0.34	−0.09
Mouth-feel hardness	−0.25	0.56
Mouth-feel toughness	−0.32	−0.30
Fibrousness	−0.34	0.00
Overall acceptability	−0.34	0.31
Number of chews	−0.25	−0.56
Eigenvalue	8.5	1.5
Variance contribution (%)	85.2	14.8

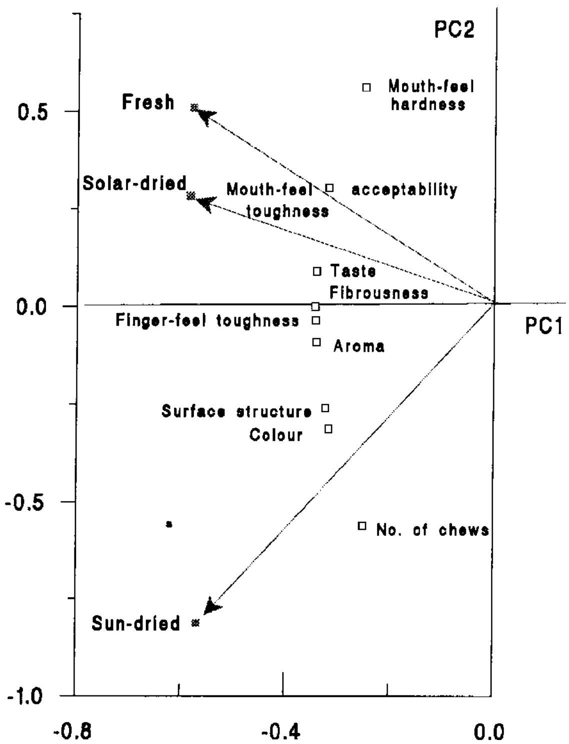


Fig. 2. PCA scatter plot the first and the second principal components on cowpea leaves.

represents 100% of the total variation of the attributes and shows that finger feel toughness, aroma, fibrousness and taste contribute more to PC1 than the rest of the attributes. Mouth feel hardness and the number of chews contributed mainly to PC2. The sun-dried samples are characterized by appearance (color and surface structure), the attribute that discriminated the sample from the other samples. ANOVA confirmed that high significant difference was recorded in appearance between the sun dried and the fresh material (Table 4).

The scatter-plot shows that the sensory characteristics of solar-dried products were much closer to the fresh than to those of the sun-dried products. The fresh products are characterized by mouth-feel toughness and overall acceptability, implying that fresh products were liked due to the soft texture. The sun-dried products had their appearance altered more than the solar dried products.

4. Discussion

The trained panel was able to evaluate objectively and characterize solar dried cowpea leaves. The attributes score were texture oriented (hardness, toughness and chewness) and appearance oriented (color and surface structure). Results indicated that dehydration affected aroma, texture and appearance properties of cowpea leaves and discriminated the fresh, the solar- and the sun-dried products. Dehydration is known to cause physical, chemical and biochemical changes in plant tissues and the change extend depends on the mode of dehydration and the nature of the product [19]. The solar dried product was closer to the fresh than to the sun-dried product. Fresh material was characterized as being soft and tender with an appearing dark green color. The sun dried product differed from other products more on appearance.

Dehydration has a strong impact on the texture of the foods. Adequately blanched vegetables lose texture due to the chemical changes such as crystallization of cellulose and the degradation of pectin, and the localized variations in the moisture content during dehydration that set up internal stress, distorting the relatively rigid cells and give the food a shrunken appearance [20]. Textural damage depends on moisture content, composition of food, variety, pH, product history such as maturity and sample dimensions [15]. The rate and temperature of drying also have substance effect on texture of food; rapid drying and high temperature cause greater changes than do moderate rates of drying at lower temperature. Changes in texture depend on the method of moisture removal, whereby freeze drying produces a texture similar to that achieved by sample freezing, hot air dehydration results in case hardening when high temperature are used.

Drying also changes surface characteristics such as color due to degradation of chlorophyll and carotenoids, and from browning reactions caused by heat and oxidation during drying [20]. Chlorophyll degrades to form pheophytin causing color change, depending on the degree of blanching and the amount of acids produced within the system during processing [21]. The dehydrated products were characterized as appealing dark green color for fresh material, light green for solar dried and non-appealing brownish green color for sun-dried products. Aroma change is attributed to degradation of plant pigments (carotenoids) that produce volatile compounds [22]. Volatile organic compounds responsible for aroma and flavor are lost during drying, its extent depending on temperature, solid concentration of the food, the flavor pressure of the volatiles and the solubility of the volatiles in water vapor [15].

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