Physical-Functional Properties and Characterization of Green Leaves in Nalgonda District, Telangana State: Nontimber Forest Products

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Abstract

Naturally grown green leafy vegetables contribute nutrients, fiber, antioxidants, dietary diversity, household food security, income, and livelihood to rural people. Due to their good vitamin, mineral, and fiber properties, green leaves are considered to be protective foods. The physical-functional properties of four fresh and dried (*Aerva lanata*, *Corchorus olitorius*, *Celosia argentea*, and *Leucas aspera*) uncultivated green leafy vegetables available in Nalgonda District of Telangana State, India, were analyzed and compared. The results of the study reported that fresh *Aerva lanata* has high pH and fresh *Corchorus olitorius* has highest relative reconstitution capacity. It was found that fresh *Celosia argentea* has high shrinkage and dehydration ratio, and the leaves of *Leucas aspera* had high rehydration capacity. Dried leaf powder of *Aerva lanata* has high flowability, cohesiveness, pH, total soluble solids, water-retention capacity, and oil-retention capacity. Dried *Corchorus olitorius* was found to have high bulk density, tapped density, and rehydration capacity on dried weight basis. *Leucas aspera* powder had a high water absorption index and hydrophilic-lipophilic index. It was found that water activity of all the leaf powders is below 0.5 so they can be stored at room temperature. Physical and functional properties of uncultivated greens powders help in development of value-added products, product-specific equipment, and behavior of leaf powders at processing and packing levels.

Globally, uncultivated green leafy vegetables (UCGLVs) are resource of great importance to mankind. There is no particular definition of wild edible plants but they are usually defined as being neither cultivated nor domesticated but available from natural habitat, forest, and savannah areas. UCGLVs are source of food and nutrition and they provide coping strategies during food insecurity in developing countries (Phangchopi et al. 2015). Uncultivated greens leaves are more drought resilient and adaptive, have low management costs, and tolerate adverse climatic conditions (Gupta and Yadav 2016). Nutritional compositions of many green leaves available in different parts of India are still not documented (Saha et al. 2015). Because of a lack of awareness of the nutritional values of many uncultivated greens leaves, they remain underutilized (Gupta and Yadav 2016).

Traditional knowledge is an outcome of several trial-and-error methods over many generations. UCGLVs fulfil many needs of tribal people such as food, fiber, medicine, shelter, and other needs. Village-level doctors, commonly called ''vaidu,'' are aware of UCGLVs' medicinal properties and use them as remedies for several diseases. Because of perceptions of their significance, many studies have been undertaken to collect nutraceutical, pharmaceutical, and other interesting information on the traditional usage of UCGLVs (Lele et al. 2017). Transplanting UCGLVs into

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home gardens has been shown to be an easily incorporated, cost-effective way to improve health and family income (Freedman 2015). Physical properties of powders are important parameters used to evaluate the characteristics of leaf powder during processing, product development, equipment design, handling, and packaging. The aim of the present study is to investigate physical-functional properties of traditional green leafy vegetables grown in Telangana State.

Materials and Methods

Four fresh, commonly used UCGLVs, namely *Aerva lanata*, *Celosia argentea*, *Corchorus olitorius*, and *Leucas aspera*, were collected from three randomly selected villages of Nalgonda District, Telangana State, India (Fig. 1). Edible portions of leaves were cleaned, blanched, shade-dried, and ground to fine powder. The powdered samples were stored in airtight containers at refrigerated temperature (4°C) for further analysis. Materials required for the analysis were procured from the Post Graduate and Research Centre, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The percentages of change in physical-functional properties of fresh and dried leaves were analyzed and compared.

Physical-functional properties

The following characterization methods were used in this study: rehydration capacity (Quintero-Ramos et al. 1992), shrinkage capacity (Yilmaz et al. 2018), relative reconstitution capacity (Fathima et al. 2001), dehydration and rehydration ratio (Sheshma and Raj 2014), bulk density (Stojceska et al. 2008), tapped density (Narayana and Narasinga Rao 1984), flowability and cohesiveness (Jinapong et al. 2008), titratable acidity (Ranganna 2017), total soluble solids (TSS; Kathiravan et al. 2014), color (Hunter Lab 2013), chroma and hue (Pathare et al. 2012), total color difference (Martins and Silva 2002), water solubility and water absorption index (WAI; Anderson et al. 1969), water-retention and oil-retention capacities (Beugre et al. 2014), hydrophilic lipophilic index (Njintang et al. 2001), and water activity (Abramovie et al. 2008).

Statistical analysis

All data were analyzed using analysis of variance in a randomized block design, and significance was tested at probability level $P \leq 0.05$.

Results and Discussion

Physical properties of fresh leaves

Rehydration capacity of fresh *Leucas aspera* leaves (FLAL; 8.67) and fresh *Aerva lanata* leaves (FALL; 8.28) was high compared to fresh *Celosia argentea* leaves (FCAL; 5.09) and fresh *Corchorus olitorius* leaves (FCOL; 5.22). It was perhaps due to the papery, sponge-like texture of leaves and also due to the presence of white cottony hair-like structures present beneath the leaves of FLAL and FALL. A dried product with high rehydration capacity has good quality (Okpala and Ekechi 2014).

Highest relative reconstitution capacity was observed in FCOL (303.70), followed by FALL (212.80), FLAL (184.20), and FCAL (87.80). FCOL has high reconstitution capacity because these leaves produce thick gel when they are placed in water and retain a high amount of moisture. The maximum times taken for reconstitution of FALL, FCOL, FCAL, and FLAL were 35, 45, 30, and 40 minutes, respectively. Among the four leaves, FALL leaves had good reconstitution properties with original color like fresh whereas FCAL were highly affected by the drying process with least reconstitution and color retention properties. Figure 2 shows the relative reconstitution capacity of selected four UCGLVs.

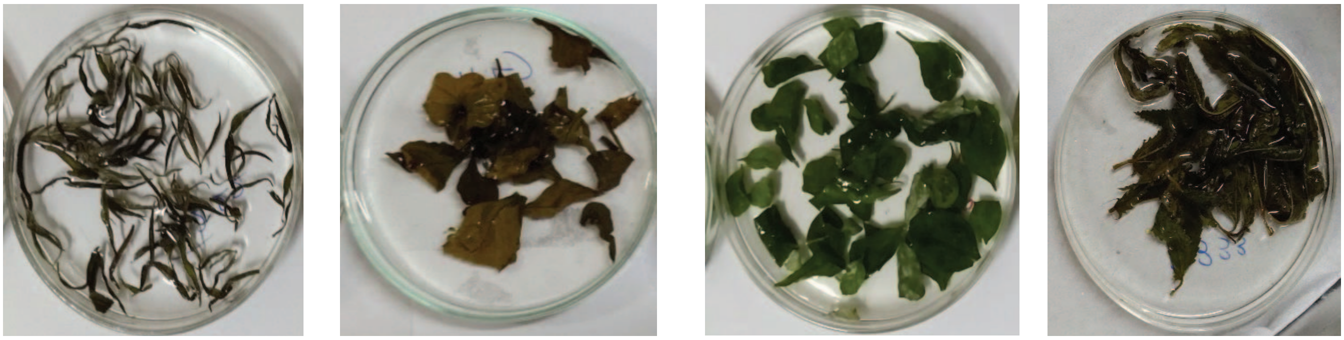
Shrinkage capacity of leaves was directly proportional to moisture content of leaves. FCAL had high shrinkage capacity because it has high moisture content, followed by FLAL and FALL, with the lowest moisture and shrinkage capacity found in FCOL. The pH of UCGLVs ranged from 5.59 in FLAL to 7.13 in FALL. Highest pH was found in FALL (7.13) and the lowest pH was found in FLAL (5.59). Titratable acidity of greens ranged from 0.001 in FCOL to 0.008 in FLAL. It was found that acidity (low pH) and titratable acidity of FLAL was high. TSS content of FALL (0.63) was high and FCOL (0.23) had the lowest content. There was no significant difference found in the TSS content of FCAL and FLAL.

Dehydration ratio of leaves depends on their moisture content. Due to it's high moisture content FCAL (6.53%) had a high dehydration ratio with the lowest in FCOL (3.39%). During the drying process leaves containing high moisture like FCAL and FLAL lost more water and resulted in a high dehydration ratio. The results for the physical properties of fresh UCGLVs are mentioned in Table 1.

Color.—Color is an important quality parameter as it influences the acceptability of the food product. The results for the color values of the fresh leaves are given in Table 2. It was

Aerva lanata *Corchorus olitorius* *Celosia argentea* *Leucas aspera*

Figure 1.—Uncultivated green leafy vegetables.



Leucas aspera *Celosia argentea* *Aerva lanata* *Corchorus olitorius*

Figure 2.—Relative reconstitution capacity of uncultivated green leafy vegetables.

Table 1.—Physical properties of fresh uncultivated green leafy vegetables. Values are expressed as mean ± SD of three determinations. Means within the same column followed by a common letter do not differ significantly at P ≤ 0.05.

Sample[a]	Shrinkage	Relative reconstitution capacity (%)	Rehydration capacity	pH	Titratable acidity (%)	Total soluble solids	Dehydration ratio
FALL	0.24 ± 0.02 B	212.80 ± 0.20 C	8.28 ± 0.13 C	7.13 ± 0.05 D	0.005 ± 00 A	0.63 ± 0.03 C	4.67 ± 0.02 C
FCOL	0.18 ± 0.01 A	303.70 ± 0.30 D	5.22 ± 0.04 B	6.34 ± 0.05 C	0.001 ± 00 A	0.23 ± 0.03 A	3.39 ± 0.22 A
FCAL	0.46 ± 0.02 D	087.80 ± 0.30 A	5.09 ± 0.00 A	6.27 ± 0.02 B	0.002 ± 00 A	0.37 ± 0.03 B	6.53 ± 0.04 D
FLAL	0.31 ± 0.00 C	184.20 ± 0.20 B	8.67 ± 0.05 D	5.59 ± 0.00 A	0.008 ± 00 B	0.37 ± 0.03 B	4.61 ± 0.04 B

[a] FALL = fresh *Aerva lanata* leaves; FCAL = fresh *Celosia argentea* leaves; FCOL = fresh *Corchorus olitorius* leaves; FLAL = fresh *Leucas aspera* leaves.

Table 2.—Determination of color in fresh uncultivated green leafy vegetables. Values are expressed as mean ± SD of three determinations. Means within the same column followed by a common letter do not differ significantly at P ≤ 0.05.

Sample[a]	L*	a*	b*	E*	C*	h*
FALL	−64.02 ± 0.25 D	−9.28 ± 0.28 D	20.33 ± 0.68 C	66.93 ± 0.76 D	18.05 ± 0.09 C	55.93 ± 0.84 A
FCOL	−62.41 ± 0.62 C	−7.38 ± 0.00 C	16.89 ± 0.54 B	65.08 ± 0.45 C	15.18 ± 0.59 B	56.50 ± 0.41 B
FCAL	−57.39 ± 0.34 B	−5.82 ± 0.06 A	15.00 ± 0.69 A	59.49 ± 0.06 A	13.78 ± 0.72 A	58.05 ± 0.47 C
FLAL	−54.64 ± 0.30 A	−6.77 ± 0.21 B	24.69 ± 0.56 D	60.35 ± 0.06 B	23.73 ± 0.61 D	62.35 ± 0.51 D

[a] FALL = fresh *Aerva lanata* leaves; FCAL = fresh *Celosia argentea* leaves; FCOL = fresh *Corchorus olitorius* leaves; FLAL = fresh *Leucas aspera* leaves; L* = lightness; a* = green to red; b* = blue to yellow; E* = total color difference; h* = hue angle; C* = chroma.

observed that lightness (L*) values of fresh UCGLVs ranged from –54.64 in FLAL to –64.02 in FALL. The L* value indicates that the color of FALL was lighter than other samples. The green-to-red (a*) values were found to be high for FALL (–9.28) and lowest in FCAL (–5.82). The color values of a* show that the leaves of FALL were darker green in color than other leaves. The blue-to-yellow (b*) values were found to be high in FLAL (24.69) and lowest in FCAL (15.00). The total color difference (E*) values of leaves ranged from 59.49 in FCAL to 66.93 in FALL. The chroma (C*) value was highest in FLAL (23.73) and lowest in 13.78 (FCAL). E* values were highest in FLAL and lowest in FCAL. The hue angle (h*) values of fresh leaves ranged from 55.93 (FALL) to 62.35 (FLAL).

Physical properties of dried leaves

The bulk densities of dried leaf powders ranged from 0.17 g/cm^3 for dried *Aerva lanata* leaves (DALL) to 0.37g/cm^3 for dried *Corchorus olitorius* (DCOL). Bulk density is an important parameter in determining packing requirements, handling, and applications in wet processing in the food industry (Gull et al. 2015). The results of tapped density of dried leaf powders shows that DCOL (0.45g/cm^3) has high tapped density and it is lowest in DALL (0.36 g/cm^3).

According to the Carr index classification of flowability, DCOL has good flowability (20.00%) and dried *Celosia argentea* leaves (DCAL) have fair flowability (26.00%), whereas dried *Leucas aspera* leaves (DLAL) and *Aerva lanata* (DALL) have bad and very bad flowability, respectively. Lowest flowability properties of DALL and DLAL may be due to presence of white cottony hair-like structures present beneath the leaves as they form clumps and resist free flow of the leaf powders.

Flowability of leaf powders was affected by storage conditions such as moisture, temperature, exposure to air, storage time, and consolidation (Domian and Poszytek 2005). The highest cohesiveness ratio was found in DALL (2.01) and the lowest ratio in DCOL (1.24). Based on the Husner ratio of cohesiveness, DCOL and DCAL have intermediate cohesiveness and DALL and DLAL have high cohesiveness. Table 3 shows the physical properties of powders of UCGLVs.

Percentages of change in physical properties of leaf powders when compared to fresh leaves are given in Figure 3. DALL has high pH (7.14) and the lowest is found in DLAL

Table 3.—Physical properties of dried uncultivated green leafy vegetables. Values are expressed as mean ± SD of three determinations. Means within the same column followed by a common letter do not differ significantly at $P \leq 0.05$.

Sample[a]	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Flowability (Carr index, %)	Cohesiveness (Husner ratio)	pH	Titratable acidity (%)	Total soluble solids
DALL	0.17 ± 0.00 A	0.36 ± 0.00 A	52.77 ± 0.00 D	2.01 ± 0.00 D	7.14 ± 0.03 D	0.039 ± 0.00 D	2.67 ± 0.03 C
DCOL	0.37 ± 0.00 D	0.45 ± 0.00 C	20.00 ± 0.00 A	1.24 ± 0.00 A	6.07 ± 0.02 C	0.002 ± 0.00 A	2.50 ± 0.00 B
DCAL	0.32 ± 0.00 C	0.43 ± 0.00 B	26.00 ± 0.00 B	1.36 ± 0.00 B	5.77 ± 0.03 B	0.007 ± 0.00 C	1.80 ± 0.00 A
DLAL	0.28 ± 0.00 B	0.43 ± 0.00 B	35.00 ± 0.00 C	1.54 ± 0.01 C	5.60 ± 0.05 A	0.006 ± 0.00 B	2.50 ± 0.00 B

[a] DALL = dried *Aerva lanata* leaves; DCAL = dried *Celosia argentea* leaves; DCOL = Dried *Corchorus olitorius* leaves; DLAL = dried *Leucas aspera* leaves.

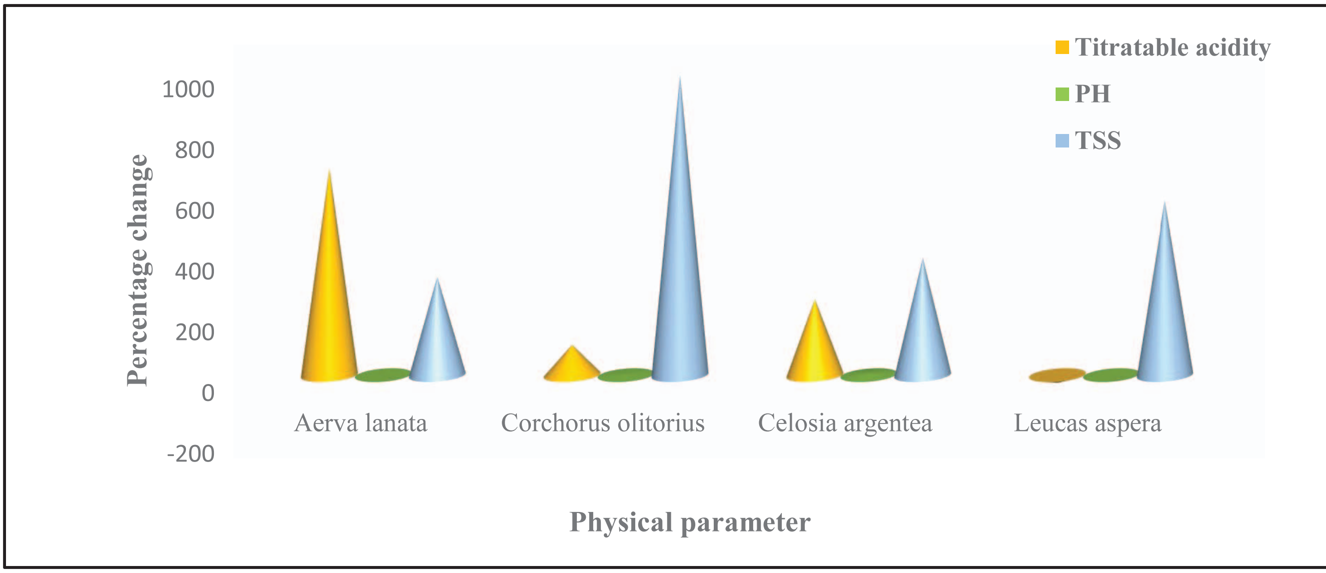


Figure 3.—Percentages of change in physical properties of uncultivated green leafy vegetables after drying.

(5.60). When compared to fresh leaves, the pH values of DALL and DLAL were slightly decreased whereas pH values of DCAL and DCOL increased by 7.97% and 4.26% respectively. Titratable acidity of dried leaves ranged from 0.002% (DCOL) to 0.039% (DALL). When compared to fresh leaves, titratable acidity of DALL, DCOL, and DCAL increased whereas DLAL acidity decreased by 25%. TSS content of dried leaves increased to a great extent compared to fresh leaves (i.e., 323.8% in DALL, 986.95% in DCOL, 386.48% in DCAL, and 575.67% in DLAL).

Color.—The results of color values of dried leaves are reported in Table 4. The L* values were found to be high in DCAL and low in DCOL. The a* values were high in DLAL (1.39) and low in DCOL (–0.47). The b* values of dried leaves ranged from 15.07 (DCAL) to 21.09 (DCOL). E* value was highest in DCOL (56.06) and lowest in DALL (55.81). The C* values were found to be high in DCOL, followed by DLAL, DALL, and DCAL. The h* values of leaf powders ranged from DLAL (74.92) to DCOL (81.47). It was evident from the study that DCOL has high b*, C*, and h* values whereas DCAL has low values for these parameters. The L* and E* values of DALL, DLAL, and DCOL was decreased whereas L*, a*, b*, and E* values were increased in DCAL. The C* and h* values of dried leaves were increased when compared to fresh leaves.

Functional properties of dried leaves

Determination of functional characteristics helps to understand the behavior of special ingredients used during preparation and processing and also determines how the finished product will look, feel, and taste (Godswill et al. 2019). The results for the functional properties of UCGLV powders are given in Table 5.

Table 4.—Color parameters of dried uncultivated green leafy vegetables. Values are expressed as mean ± SD of three determinations. Means within the same column followed by a common letter do not differ significantly at $P \leq 0.05$.

Sample[a]	L*	a*	b*	E*	C*	h*
DALL	−52.00 ± 0.36 B	−0.74 ± 0.26 B	18.10 ± 0.30 B	55.81 ± 0.14 A	18.08 ± 0.30 B	78.52 ± 0.14 C
DCOL	−51.93 ± 0.41 A	−0.47 ± 0.22 A	21.09 ± 0.46 D	56.06 ± 0.28 B	21.08 ± 0.46 D	81.47 ± 0.23 D
DCAL	−62.95 ± 1.99 D	1.07 ± 0.00 C	15.07 ± 0.20 A	67.70 ± 0.14 D	15.10 ± 0.20 A	75.12 ± 0.08 B
DLAL	−53.23 ± 0.23 C	1.39 ± 0.15 D	19.09 ± 0.19 C	56.56 ± 0.33 C	19.14 ± 0.19 C	74.92 ± 0.76 A

[a] DALL = dried *Aerva lanata* leaves; DCAL = dried *Celosia argentea* leaves; DCOL = Dried *Corchorus olitorius* leaves; DLAL = dried *Leucas aspera* leaves; L* = lightness; a* = green to red; b* = blue to yellow; E* = total color difference; h* = hue angle; C* = chroma.

Table 5.—Functional properties of dried uncultivated green leafy vegetables. Values are expressed as mean ± SD of three determinations. Means within the same column followed by a common letter do not differ significantly at P ≤ 0.05.

Sample[a]	Rehydration capacity	WAI (%)	WSI (%)	WRC (g water/g of sample)	ORC (g oil/g of sample)	HLI	a_w
DALL	5.98 ± 0.06 B	1.75 ± 0.04 C	1.19 ± 0.00 B	6.48 ± 0.08 D	5.24 ± 0.06 D	0.27 ± 0.00 A	0.20 ± 0.00 B
DCOL	8.59 ± 0.01 D	1.58 ± 0.04 B	1.27 ± 0.00 C	6.39 ± 0.16 C	3.44 ± 0.09 A	0.25 ± 0.00 A	0.15 ± 0.00 A
DCAL	5.07 ± 0.14 A	1.31 ± 0.03 A	1.31 ± 0.03 C	4.51 ± 0.04 A	3.63 ± 0.06 B	0.29 ± 0.00 A	0.18 ± 0.03 A
DLAL	6.25 ± 0.07 C	1.78 ± 0.03 C	1.14 ± 0.01 A	5.87 ± 0.16 B	3.82 ± 0.05 C	0.30 ± 0.00 B	0.17 ± 0.00 A

[a] DALL = dried *Aerva lanata* leaves; DCAL = dried *Celosia argentea* leaves; DCOL = Dried *Corchorus olitorius* leaves; DLAL = dried *Leucas aspera* leaves; WAI = water absorption capacity; WSI = water solubility index; WRC = water-retention capacity; ORC = oil-retention capacity; HLI = hydrophilic-lipophilic index; a_w = water activity.

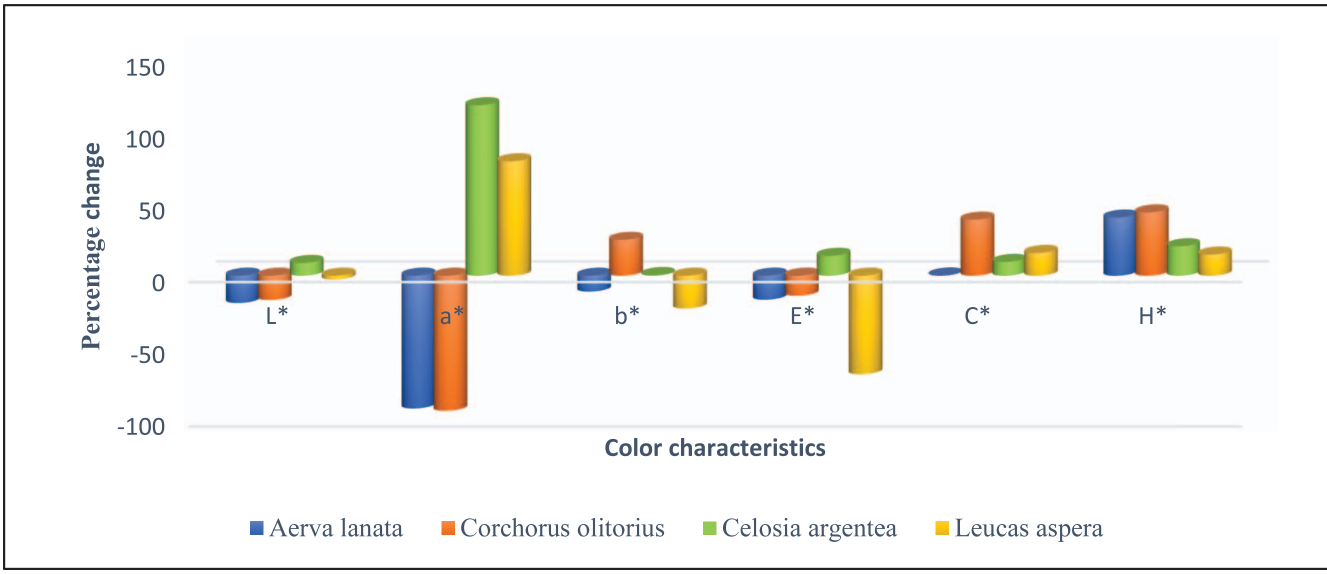


Figure 4.—Percentages of change in color values of uncultivated green leafy vegetables after drying.

Rehydration capacity measures the extent of damage occurred by the dehydration process (Taib et al. 2012). DCOL had highest rehydration capacity whereas DCAL had lowest. Positive correlation found between relative reconstitution capacity and rehydration ratio of leaf powders.

WAI is the measure of amount of water taken up by the sample to get desirable consistency. Very low or excessive water absorption negatively affects the food product's quality (Godswill et al. 2019). The WAI of leaf powders ranged from 1.31 in DCAL to 1.78 in DLAL. DCAL was highly affected by the drying process as it has low relative reconstitution capacity, rehydration ratio, water-retention capacity, and WAI compared to other leaves. High water solubility index was found in DCAL followed by DCOL, DALL, and DLAL.

Water-retention capacity was found to be high in DALL and lowest in DCAL. Cottony structures beneath the leaves of DALL and the gummy nature of DCOL on hydration may be responsible for the high water-retention capacity of these leaves. It was found that DALL (5.24) had high oil retention; this was lowest in DCOL (3.44).

Hydrophilic-lipophilic index values of UCGLV powders were reported based on the water absorption capacity (WAC) and oil-retention capacity values. The hydrophilic-lipophilic indices of the four leaves were almost the same and no significant difference was found between them. The water activity of all the dried leaf powders was less than 0.5, which indicates that all the leaves can be stored at room temperature for long durations.

Pearson correlation coefficient of physical and functional properties of fresh UCGLVs

Results of correlation analyses between physical and functional properties of fresh UCGLVs shows that physical parameter b* values were positively correlated with titratable acidity (r = 0.95112; P = 0.04890) at the 0.05 level of significance whereas they strongly correlate with C* (r = 0.99155; P = 0.00850) at the 0.01 level of significance. The results of the study clearly show positive correlation between shrinkage and dehydration ratio at the 0.05 level of significance. The relative reconstitution capacity of fresh uncultivated green leaves was negatively correlated with dehydration ratio (r = –0.98093; p = 0.0200) at the 0.05 level of significance. It is clear from the study that the value of P is more than 0.05 for all values of r for all other parameters except those discussed above; this shows that no significant correlation was obtained between these parameters.

Conclusion

The present study demonstrated the physical functional properties of UCGLVs grown in Nalgonda District. Impact of dehydration on the physical properties of leaves was determined and compared among the four leaves. Green leafy vegetables are good source of dietary fiber and provide protection against a number of health problems. Characterization of various physical properties of traditional greens helps to find their performance in food product development, handling, and packing properties.

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