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Assessment of physical properties of fresh aloe leaves and influence of drying temperature on physico-chemical properties of aloe vera

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Abstract
The physical properties of fresh aloe vera leaves were measured and correlated with gel yield and it was found that the leaf weight has direct effect on the gel yield whereas the effect of leaf volume is found to be minimal. The physicochemical properties of the hot air dried aloe vera at four temperatures *viz*. 50, 60, 70 and 80 ºC were investigated. The study showed that the dried product obtained at 70 ºC is superior in quality with higher ash (16.11 %), fibre (16.54 %) and protein content (5.88 %) and lower fat (1.37 %) and carbohydrate content (3.64 %) than that of the products obtained at different drying temperatures.

Keywords: Aloe vera, physical properties, convective drying, biochemical properties

1. Introduction
Aloe barbadensis Miller, the most biologically active species of Aloe group is a semitropical perennial plant, often used in food, pharmaceutical and cosmetic industry [1]. The most usable part of this short-stemmed plant is the modified stem; which is comprised of outer dark green parenchyma entrapping thick mucilaginous colourless gel inside it [2]. Mostly used in pharmaceutical and cosmetic industry, it is very rich in many micro and macronutrients. With around 98.5-99 per cent moisture content, the dry matter incorporates polysaccharides (55 %), sugars (17 %), minerals (16 %), proteins (7 %), lipids (4 %) and phenolic compounds (1 %). The aloe gel also contains many important antioxidant and vitamins *viz*. Vitamin A (retinol), Vitamin B_1 (thiamine), Vitamin B_2 (riboflavin), Vitamin B_3 (niacin), Vitamin B_9 (folic acid), Vitamin C (ascorbic acid) and Vitamin E (tocopherol) [3,4]. Carbohydrates, comprising of mono and polysaccharides, are derived from the mucilage layer of the plant under the rind, surrounding the inner parenchyma or gel. The Egyptians call Aloe vera "The plant of immortality" [5].
The herbal movement initiated by neuropaths, yoga gurus and holistic healers [6] have given recognition to aloe vera. In the food industry, it can be a potential substitute as a food preservative for sulphur dioxide. The leaf powder is used in a number of ayurvedic medicines as it contains antioxidants, dietary fibre, iron, etc. [7].
Aloe vera is a very high moisture commodity, it is essential to know its gel yield in order to access the overall nutritive dry matter. This gel can be found out from the volume and weight of the leaf. Therefore, it has become essential to know the physical properties of the leaf and correlate it with gel yield.
However, aloe gel is an unstable product accounting to its higher water activity and is subjected to discoloration and microbial contamination. Thus it is important to process it in order to enhance its shelf life while maintaining the nutritional qualities. Drying is one of the cheapest and most efficient methods for reducing water activity of aloe vera while inhibiting the growth of microbes and decreasing spoilage reaction. In addition to this, the dried product reduces the cost of packaging, storage and transportation due to its comparatively lower mass and volume. The challenge of aloe vera drying is to maximize the retention of nutrients while minimizing the moisture content of the product to a level where microbiological growth won't occur. This can be achieved by controlled drying keeping in view the quality of the dried product. Therefore the present study was carried out to access influence of different drying temperature on physico-chemical properties of aloe vera.

2. Materials and Methods

2.1 Collection and preparation of sample

Fresh, healthy and matured aloe vera leaves were obtained from Instructional Herbal Garden, IGKV, Raipur. The procured aloe vera leaves were washed under tap water to remove the foreign materials and dirt sticking to it. The spikes and the thick dark green outer skin (epidermis) were peeled out manually from the thick colourless parenchyma (or gel fillet) using a stainless steel knife. The fillets were cut into 50 × 30 × 10 mm slabs with the help of stainless steel cutter and stored in an airtight container, till the experiment was started, to avoid moisture loss and contamination.

2.2 Physical properties Aloe Vera

2.2.1 Leaf size and shape

The axial dimensions *viz*. length (L), width (W) and thickness (T) were measured from twenty randomly selected leaves using a metallic scale having a least count of 1 mm which was later used to calculate the volume of the leaf using the formula given by Hernandez *et al*. (2002). From Fig. 1, the shape of the leaf can be attributed to be conical [8].

$$\text{Volume of leaf (mm}^3) = \frac{\text{L (mm)}}{12} \times \pi \times \text{W (mm)} \times \text{T (mm)}$$

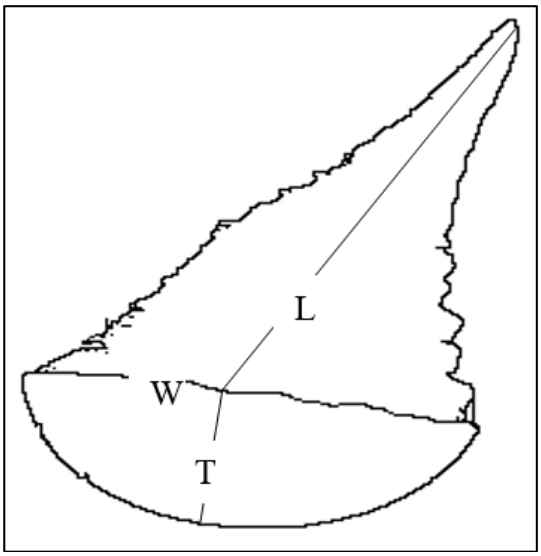

Fig 1: Diagram of the approximate geometry of aloe vera leaf.

2.2.2 Leaf weight and gel recovery

Twenty number of aloe leaves were randomly selected weighed before and after peeling the outer parenchymatus layer. The relationship between leaf weight and leaf volume, leaf weight and gel recovery as well as leaf volume and gel recovery was established.

2.3 Convective drying of Aloe Vera samples

The air drying process is influenced by drying air temperature, air velocity, relative humidity, time of drying, loading density, etc. Among these parameters listed above, the quality of the aloe Vera is most affected by the drying air temperature (T ºC) therefore the variation of nutritional qualities with respect to temperature is considered here. The aloe vera samples were dried in a laboratory tray dryer at 50, 60, 70 and 80 ºC drying air temperatures. The drying process is ceased when constant or no weight reduction is attained. The correct drying air temperature was adjusted by temperature indicator cum controlling unit before one hour starting the experiment to allow the internal environment to stabilize. The aloe vera samples were loaded on the drying trays at a load density of 15 kg m^{-2}.

2.4 Quality Parameters

2.4.1 Yield

The percentage yield of dried product is the amount of dried powder we get from drying 1 kg fresh aloe vera fillets. It can be calculated by,

$$Yield\ (\%) = \frac{\text{Powder obtained (g)}}{\text{Fresh fillet (g)}}$$

2.4.2 pH

The pH of the samples was measured by using pH meter. The sample powder was thoroughly mixed and 1 g and was dissolved in 100 ml of hot distilled water. The mixture was allowed to stand for 5 min at room temperature before the pH and temperature was recorded using a pre-calibrated pH meter [9].

2.4.3 Water activity

The equilibrium moisture content (EMC) values were determined by drying the aloe vera fillets for 24 hours in the convective dryer at all temperature as mentioned above [10, 11] equation was used to model the experimental data for the EMC versus the water activity of aloe vera at different drying temperatures.

$$X_{eq} = B + A \times \left[\frac{a_w}{1 - a_w}\right]$$

Where

X_{eq}- Equilibrium moisture content, g water/ g dry matter
A, B- Iglesias –Chirife parameters
a_w- Water activity

2.4.4 Moisture content

The moisture content was determined by using the method described in AOAC (1990) [12]. The moisture content (db) of the sample was calculated using the following equation.

$$Moisture\ content, db\ (\%) = \frac{\text{Weight of water present (g)}}{\text{Weight of dry matter present (g)}} \times 100$$

2.4.5 Ash content

The ash content of the sample was estimated by the dry ashing method as described in the AOAC (1990) [12]. 2 g of sample was taken into the pre-dried crucible and weighed. It was then kept in the muffle furnace at 600 ºC for 8 hours. After complete ashing is done, the crucible was kept in desiccators and cooled down. The final weight was taken. Total ash content was calculated by using the following formula,

$$\text{Ash content (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

2.4.6 Crude fat content

The crude fat content was calculated by the Soxhlet method using "*Socs Plus*" (Pelican equipment) (AOAC, 1990) [12]. 2 g of sample was poured in pre-weighed oven dried thimble and 80 mL of petroleum ether was added to it. The equipment was run for 1 h at 80 ºC. After the ether is evaporated, the thimble was taken out and kept in oven for 15-20 min in order to remove the remaining ether present in it. The final weight was taken. The amount of fat was calculated by the formula,

$$\text{Crude fat content (\%)} = \frac{(\text{The weight of flask+fat})\ (g) - (\text{Weight of flask})\ (g)}{\text{Weight of sample}\ (g)} \times 100$$

2.4.7 Crude fibre content

To determine fibre content Fibra-Plus (Pelican) equipment was used. The ground material retained after fat estimation was used for fibre content analysis. 1g of dried material was first digested with acid (1.25 % sulphuric acid at 400 ºC for 40 min) and then with alkali (1.25 % sodium hydroxide at 400 ºC for 30 min). After washing with distilled water, the crucible was oven dried until the moisture evaporates and the weight was taken. The crucibles then were kept in a muffle furnace at 600 ºC for 4 hours. After ashing it was cooled in desiccator and final weight was taken. The fibre content was calculated using the given formula.

$$\text{Crude fibre content (\%)} = \frac{\text{Weight of sample before digrstion}\ (g) - \text{Weight of ash}\ (g)}{\text{Weight of sample}\ (g)} \text{ x } 100$$

2.4.8 Protein content

Protein of the aloe vera powder was determined by Kjeldahl method with a conversion factor of 6.25. Ground sample of 0.5 g was digested in 10 ml conc. H_2SO_4 along with catalyst mixture of sodium sulphate and copper sulphate for 2.30 hours. The digest was cooled and then distilled with 40 per cent sodium hydroxide and 4 per cent boric acid. Then it was titrated against 0.1N hydrochloric acid till light blue color turns into light pink. The nitrogen content was calculated using the given formula:

$$N\ content\ \left(\frac{g}{kg}sample\right) = \frac{(\text{ml}_{\text{HCl}} - \text{ml}_{\text{blank}}) \times \text{N HCl} \times 14.01}{\text{W}}$$

Crude protein content = 6.25 × Nitrogen content

2.4.9 Carbohydrate content

Total carbohydrate content was calculated by using Anthrone Method. 100 mg of the sample was weighed into a boiling tube and hydrolysed by keeping it in a boiling water bath for three hours with 5 mL of 2.5 N HCl. It was then cooled to room temperature and neutralised with solid sodium carbonate until the effervescence ceases. The volume was made up to 100 mL and was centrifuged. The supernatant was collected. 0.5 mL of aliquot, 4 mL of anthrone reagent was added and heated for 8 min in a boiling water bath. After rapid cooling, the intensity of green to dark green colour was read at 630 nm in a spectrophotometer.

2.5 Statistical Analysis

The properties were analysed using SAS (Statistical Analysis System) 9.3 software. The completely randomised design was used to investigate the significance of data.

3. Results and Discussion

3.1 Physical characteristics of Aloe Vera leaf

The mean values of physical properties length, width, thickness, apparent volume, leaf weight, gel weight and gel recovery is shown in Table 1. It has been observed from the data that the length of the leaf is about 23-25 times of its thickness. The similar result was given by Wang and Strong (1993) [8]; Chandegara and Varshney (2007) [13]. The shape of aloe vera leaf may be classified as conic- tapered towards apex as per classification given by Mohsenin (1980) [14].

Table 1: Physical parameters of fresh cut aloe vera leaf.

Particulars	Average	Range
Length, mm	551.65 ± 28.18	495-590
Width, mm	87.75± 9.41	66-100
Thickness, mm	23.2± 3.05	18-29
Apparent volume, cm^3	291.88± 38.64	217.602-353.692
Leaf weight, g	344.185 ±35.31	295.2-417.6
Gel weight, g	177.13 ±18.39	151.6-215.1
Gel recovery, %	51.46± 0.07	51.336-51.575

During experimentation, it was also observed that leaf weight, apparent volume and gel yield had some relationship. Hence, apparent volume could be taken as a parameter for the estimation of fresh weight and gel yield, and vice versa. The relationship between apparent volume - fresh weight, leaf weight – gel yield and apparent volume – gel yield of aloe leaves is shown in Fig 2, 3 and 4 respectively.

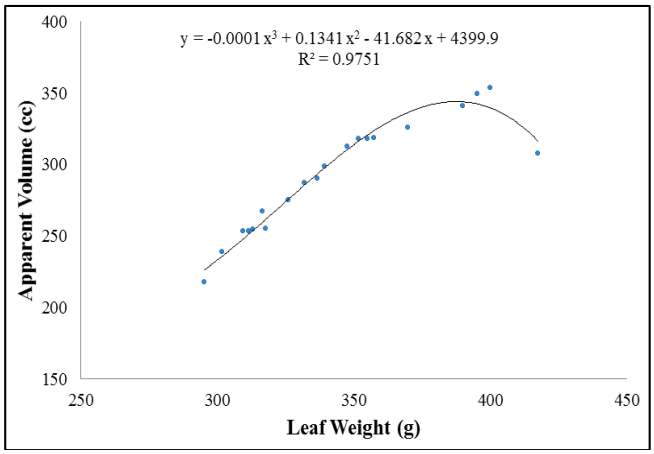

Fig 2: Relationship between apparent volume and fresh weight of aloe vera leaf

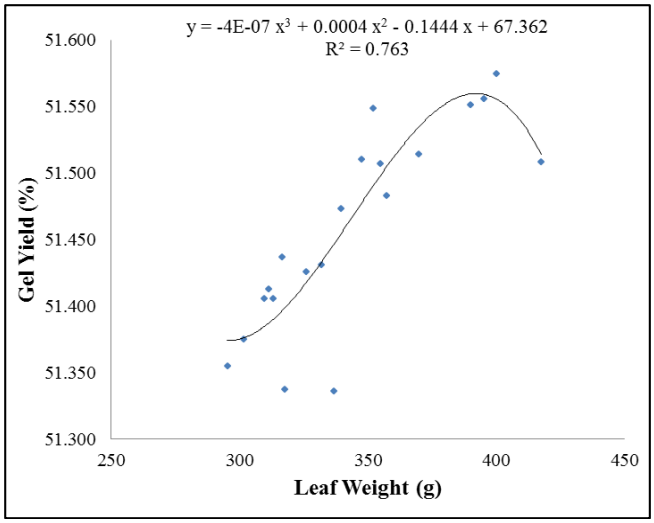

Fig 3: Relationship between weights of aloe vera leaves and gel recovery of aloe vera leaf

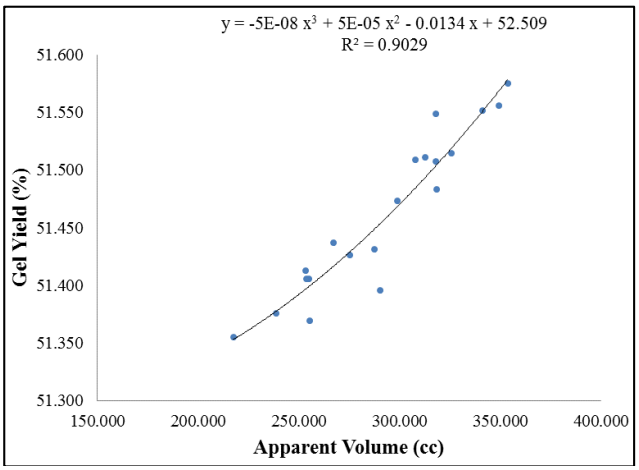

Fig 4: Relationship between apparent leaf volume and gel recovery of aloe vera leaf

3.2 Biochemical Analysis of aloe vera dried at different temperatures

The air drying behavior of aloe vera slabs were analyzed by a hot air oven drier. The percent yield of the dried samples was decreased (2.67-2.51 %) with increase in drying temperature (50-80 ºC). Since Aloe vera has very high moisture content, the drying yield is very low. The similar result was reported by Gulia *et al.* (2010) [7]. The water activity (Table 2) of all the dried samples were found to be less than 0.32 implying to a product with higher stability and lower susceptibility to microbial and enzymatic spoilage which enhances the storability of the product [15, 16]. It was observed that with increase in temperature the water activity of the product decreased as a result of lower EMC.

The proximate analysis of aloe vera dried at different temperatures is shown in Table 2. It was observe that the final moisture content of aloe vera samples significantly decreased with increase in drying air temperature. Similar types of results have been reported by various researcher *viz.* Vega – Galvez *et al.* (2007) [17], Pisalkar *et al.* (2011) [18] and Pattali *et al.* (2015) [19] for air drying of aloe vera gel slabs.The pH (Table 2) of oven dried powder aloe vera samples (1 % solution) was in mild acidic range (from 3.68 to 3.72). Significant difference was found in the pH of the dried sample. The total ash content of a food sample gives an idea of the mineral elements present in the food sample. The ash content (Table 2) of the dried samples varied from 15.56 per cent to 16.11 per cent (db) respectively as an effect of temperature rise from 50 to 80 ºC with highest amount obtained in the sample dried at 70 ºC. The ash content of aloe vera falls in the range of 15-17 per cent as reported by Gautam and Awasthi (2007) [4], Gulia *et al.* (2010) [7] and Miranda *et al.* (2009) [16] for dried aloe vera powder. Crude fat content (Table 2) in the aloe powder sample decreased significantly with increase in drying temperature from 50 to 80 ºC. This decrease in the fat content may be attributed to enzymatic hydrolysis during first falling period of drying [16, 20]. The same trend was also Gautam and Awasthi (2007) [4], Miranda *et al.* (2009) [16] and Gulia *et al.* (2010) [7] for aloe vera.

Table 2: Quality parameters of dried aloe vera at different level of temperature

Drying Temperature (ºC)	Yield (%)	pH	Water activity	Moisture content (%)	Ash content (%)	Crude fat (%)	Crude Fibre (%)	Protein content (%)	Carbohydrate content (%)
50	2.67^{a}	3.68^{c}	0.32^{a}	21.84^{a}	15.56^{c}	2.29^{a}	13.92^{d}	5.01^{c}	4.12^{a}
60	2.60^{b}	3.704^{b}	0.27^{b}	19.95^{b}	15.74^{b}	2.24^{b}	16.02^{b}	5.39^{b}	3.87^{b}
70	2.54^{c}	3.71^{ab}	0.25^{c}	17.95^{c}	16.11^{a}	1.37^{d}	16.54^{a}	5.88^{a}	3.64^{c}
80	2.51^{d}	3.72^{a}	0.21^{d}	16.52^{d}	15.82^{b}	1.44^{c}	15.00^{c}	4.85^{c}	4.08^{a}
F value	84.16	19.25	297.41	115.19	20.60	866.69	119.96	89.40	10.08
Pr>F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0003

*For particular parameter means with the same letter were not significantly different

*Probability value Pr<.0001 implies significant and Pr>.0001 shows non-significant at 5 per cent level of significance

The presence of fibre in diet increases the bulk of faeces, which has a laxative effect in the gut. Drying temperature was significantly affected on fibre content (Table 2). The crude fibre content was observed to be 13.92, 16.02, 16.54 and 15.00 per cent for drying temperature of 50, 60, 70 and 80 ºC which is the second most abundant component of the powder mainly composed of pectic substances, cellulose and hemicelluloses. The values recorded are in accordance with the findings of Gautam and Awasthi (2007) [4], Miranda *et al.* (2009) [16] and Gulia *et al.* (2010) [7]. The loss of protein (Table 2) at 80 ºC may be due to denaturation or change in solubility during drying. Another cause of release of amino acids from the product may be via Millard's reaction where the amino acids react with other compounds like sugars to produce melanoidines, a dark brown-colored polymer (Lee and Shibamoto, 2002; Perera, 2005, Miranda, 2009) [21, 20, 16]. Previous studies by Gautam and Awasthi, 2007) [4], Miranda *et al.* (2009) [16] and Gulia *et al.* (2010) [7] also supported this range of values for aloe vera. Total available carbohydrates (Table 2) were not significantly affected by drying temperature. Very less or no reducing sugar was found. The starch was found to be nearly equal to the total carbohydrate value.

4. Conclusion

The physical properties of aloe vera suggested that the weight of the aloe vera has direct relationship with the gel yield irrespective of the leaf volume. It is a well-established fact that the stability of the nutritional parameters greatly dependent on temperature. In this study also it has been observed that the nutritional qualities of aloe vera powder started to degrade at the temperature of 80 ºC whereas the powder obtained by drying at 60 and 70 ºC are found with superior quality. Thus it can be suggested that, to obtain a product of acceptable commercial quality, the fresh gel should be dried at a temperature between 60 and 70 ºC.

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