



## Development of Continuous Feed Equipment for Aloe Vera Whole Gel Extraction

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Continuous feed Aloe vera whole gel extraction equipment comprises of six major components, (a) Outer frame to hold functional components; (b) Conveyor belt; (c) Drive mechanism for gel extraction system; (d) Whole gel extraction mechanism; (e) Collection trays for extracted gel and rinds; (f) Motor. Leaf base and sharp spines of matured Aloe vera leaves are removed before feeding into equipment. Combination action of sliding bearing (4 numbers) mechanism and pressure springs (4 numbers) helps to adjust gap between pressure roller assembly and flatten curvature of Aloe vera leaves. Two high carbon steel blades one each, just above bottom set of rollers and just below top set of rollers, simultaneous peels off both top and bottom rind in a single pass. To obtain whole gel recovery of more than  $98.13 \pm 0.52$  % and residual gel percentage of below  $1.87 \pm 0.27$  %, speed of the rollers was optimized at 100 rpm for three levels of leaves thickness (<25 mm, 25–30 mm and >30 mm). Capacity of equipment is  $215.00 \pm 9.08$  kg/h. Percentage saving in cost and time of operation is 55.56 and 70 %, respectively. Quality parameters of whole Aloe vera gel were at par with preferred hand filleting method of gel extraction. Equipment is suitable to be adopted as a rural technology specially in the Aloe vera catchment area.

**Keywords:** Aloe vera, Gel extraction efficiency, Hand filleting, Quality parameters

### Introduction

Aloe vera a traditional medicinal plant is used in food, pharmaceutical and cosmetic industries. The innermost part of the leaf is a clear, soft, moist and slippery tissue that consists of large thin-walled parenchyma cells in which water is held in the form of viscous mucilage.<sup>1-5</sup> Thick fleshy leaves of Aloe plants contain not only cell wall carbohydrates such as cellulose and hemicellulose, but also acetylated mannans which is a storage carbohydrates.<sup>5,6</sup> Aloe has antitumor and anti-tyrosine properties in addition to efficacy in healing wounds and burns and in treatment of gastric ulcers.<sup>1,5,7</sup>

Due to improper processing procedures, Aloe vera products contain very little or virtually no active ingredients.<sup>4,5,8</sup> So, it has become very important to evolve a better processing method for increasing shelf life and maintaining quality of Aloe vera whole gel. The raw pulp of Aloe vera is approximately 98.5% water, while the mucilage or gel is about 99.5% water<sup>5,9</sup> and remaining 0.5–1.5% solid material consists a range of compounds, including water-soluble and fat-soluble vitamins, minerals, enzymes, polysaccharides, phenolic compounds and organic

acids.<sup>1,5,10,11</sup> Many beneficial effects of this plant have been attributed to polysaccharides present in the pulp.<sup>5,12,13</sup> At present Aloe vera gel extraction is done by any one of the methods viz., traditional hand filleted Aloe vera processing, whole leaf Aloe vera processing and mechanical extraction of Aloe vera gel in a crushing roller.<sup>5</sup> Leaves start losing its biological activity six hours after harvesting when they are stored at ambient temperature.<sup>5,8,14</sup> In order to avoid contamination of internal fillet with yellow sap, traditional hand-filleting method of processing Aloe vera leaves is widely adopted. In this method, lower 25 mm of the leaf base, tapering point of leaf top and short, sharp spines located along leaf margins are removed by a sharp knife. The knife is then introduced into mucilage layer below green rind on both the surfaces, avoiding the vascular bundles to obtain the Aloe vera whole gel. Hand-filleting method is very labour intensive, and due to this fact, machines have been designed which attempt to simulate the hand-filleted technique.<sup>5,8</sup> In whole leaf Aloe vera processing, base and tip of the leaf are removed and then leaf is cut into sections and ground into particulate slurry. Material is then treated with special chemical products that break down the hexagonal structure of fillet, releasing the constituents. Rind particles are removed using a series of coarse and

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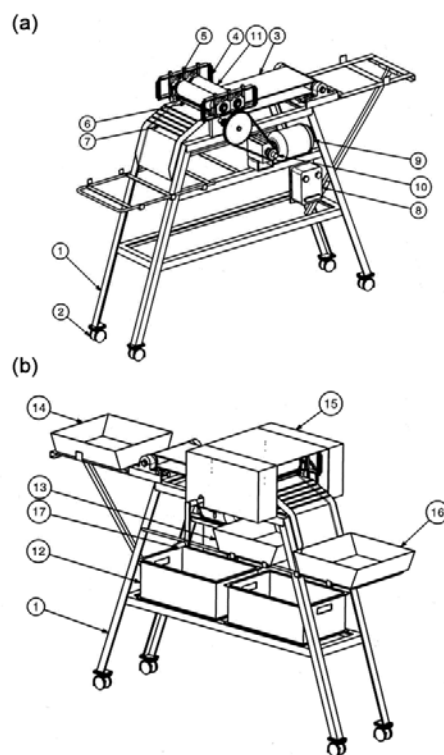
screening filters, to remove the undesirable laxative agents.<sup>5,8,1</sup> In process of extraction of gel in crusher roller, Aloe vera gel in liquid form is extracted from Aloe vera leaves by crushing the leaves in between a pair of rollers arranged in horizontal plane. Front roller compressed the leaf, while crushing roller helped in extraction of gel in liquid form.<sup>5,15</sup> During the crushing of Aloe vera gel, parameters like roller speeds and roller clearance were considered for the extraction process. The gel could be obtained at 0.153 m/s with 5 mm of roller clearance, but again it was obtained in the collapsed form and not in the much desired whole gel form as in hand filleting method. Further to get maximum gel extraction, leaves should be splitted prior to feeding into the roller type gel extraction unit, where again the gel is obtained in crushed form<sup>15</sup>.

Present method of gel extraction is carried out manually using knife in unhygienic manner and there is no control to avoid contamination during manual handling. Also, this is slow in operation and low in output. Moreover, it is tedious in operation as person has to sit down and work in bending position. In the whole leaf Aloe vera processing or by using the crushing roller method, undesirable content available in leaf also gets mixed with gel being extracted, thereby making it unsuitable for human consumption.<sup>16</sup> Care should be taken to see that only pure whole gel material is extracted in whole form without unwanted material present in the form of aloin/ Aloe emodin and extracts present in outer rind of leaves.<sup>5,8,14</sup> In total process of Aloe vera extraction is a combination of hand filleting and whole leaf processing. In this process, Aloe vera is hand filleted by traditional method. Then the green rinds and the mucilage pulp are processed separately. A combination of the products obtained by these two procedures produces a product called as Total Process Aloe. But there is an urgent need to develop a mechanical method to achieve safe extraction of edible Aloe vera whole gel and to reduce human drudgery involved in this operation, a safe and faster mechanism for Aloe vera whole gel extraction is need of the hour and is being reported upon. Motivation of this study was to develop equipment where in a safe and faster mechanism can be developed where the gel can be extracted in the whole form. So far, no equipment has been developed for mechanical extraction of the whole gel. Present investigation was aimed to remove drawback/ difficulties in existing methods and extract Aloe vera gel in the whole form.

## Materials and Methods

### Material

About 16–18 months matured Aloe vera (*Aloe barbadensis Miller*) leaves of Dindigul local variety were selected for the experiment. Leaves were collected from field of M/s C P Plantation, Kottampatty, Madurai, Tamil Nadu, India a leading Aloe vera processing unit. To avoid bio-degradation of Aloe vera leaves, each leaf was harvested early in morning by gloved hand with knife and pulled carefully from mother plant so as not to break the rind. The leaves were transported to working place in a covered polyethylene bag to avoid oxidation or contamination.<sup>4,17</sup> Aloe vera leaves under investigation were divided into three groups based on average thickness of leaves viz., less than 25 mm, 25–30 mm and more than 30 mm. All experiments were conducted at ambient room temperature of  $33 \pm 2^\circ\text{C}$  (RH =  $65 \pm 5\%$ ).



1= Outer frame; 2 = Castor Wheel; 3 = Continuous feed conveyor; 4=Pressure spring ;5= Sliding bearing; 6= Cutting blade; 7= Whole gel diversion rod; 8= Starter;9= Motor (1hp; 3 phase); 10=Drive Mechanism;11= Top roller Assembly; 12= Whole Gel Collecting tray;13 = Bottom rind collecting tray; 14= Inlet feeding tray;15=Safety Cover;16= Top rind collecting tray;17= Operating handle

Fig. 1 — Isometric view of continuous feed equipment for aloe vera whole gel extraction

**Equipment for Whole Gel Extraction of Aloe vera**

The equipment (Fig. 1) consists of an outer frame to hold all functional parts, conveyor belt, drive mechanism to operate the feeding belt, gel extraction mechanism, collection trays for extracted whole gel and a power source to move all parts through gear transmission mechanism. The design of the equipment was done using Solid work software 2018 (version 26). The software was used to select the standard components for commercial production of the equipment developed. Healthy mature Aloe vera leaves after harvesting was washed thoroughly two or three times to remove dirt and other foreign material adhering on the surface of leaves. From mature clean Aloe vera leaves, lower 25 mm of the leaf base (the white part attached to large rosette stem of the plant), tapering point (50–100 mm) of leaf top was cut using a sharp stainless steel knife. Short, sharp spines located along the leaf margins were removed by a sharp knife. Aloe vera leaves from which whole gel is to be extracted is placed on the conveyer which is moving at a constant preset speed. Conveyer has a gripping effect (as it is dimpled in nature), which partially holds the Aloe vera leaves during the extraction process. Aloe vera leaves are passed through a set of two pressure rollers on the top and a set of two rollers at bottom, to flatten the Aloe vera leaf fed between rollers to make it devoid of curvature (Fig. 2). Sliding bearing (4 no’s) arrangements were provided to adjust gap between the two set of pressure rollers based on average thickness of Aloe vera leaf. Four numbers of pressure springs were provided between top set of rollers and bottom set of rollers for fine adjustment of the gap between the rollers to match curvature of the leaves. Two blades made of high carbon steel were provided, one each, just above the bottom set of rollers and just below top set of rollers. Upper blade was fixed on spring loaded top roller, so that the blade was positioned just below top layer of leaf. Peeling of upper rind of Aloe vera leaf takes place simultaneously as that of bottom rind as the leaf moved forward by means of conveyer belt. There is a set of



Fig. 2 — Continuous feed equipment for Aloe vera whole gel extraction a) without cover b) with cover

stainless steel rods which are provided at the outlet of gel extraction mechanism, which allows top rind of leaves and whole gel to be separated during extraction process. Extracted whole gel is directly collected in food grade tray, which is partially filled with clean potable water. This enables hygienic collection of extracted Aloe vera whole gel. Top and bottom rinds are collected separately. Thus there are three outlets viz., for top rind, bottom rind and whole gel. Power source for moving parts is obtained by a Motor (One hp; three phase) through a gear transmission mechanism. Alternatively, a handle (manually operated) can be used as source of power transmission. The specification of the equipment is given in Table 1. The sound generated by the equipment during the evaluation was recorded by the sound level meter (Make-Lutron Electronic Enterprises Co., LTD; Model-SL-4012; least count of 0.1 dB)

**Measurement of Selected Textural Properties of Aloe vera Leaves**

Selected textural properties 25 numbers of Aloe vera leaves for all levels of thickness viz., below 25

Table 1 — Technical specification of continuous feed equipment for aloe vera whole gel extraction

S No	Particulars	Dimension
1	Overall Frame ( Medium steel ) (L × B × H)	1900 mm × 800 mm × 1350 mm
2	Rubber Rollers Big, 2 Nos a) Length and OD of shaft b) Length and OD of Rubber layer	410 × 20 mm 0 × 280 mm
3	Rubber Rollers small, 2 Nos a) Length and OD of shaft b) Length and OD of Rubber layer	410 × 16 mm 50 × 260 mm
4	Rubber Grip Conveyor Belt (L × B × T)	140 × 245 × 3 mm
5	Stainless Steel Knife, 2 nos (L × B × T)	290 × 20 × 2 mm
6	Motor	1440 RPM, 3 phase, 0.5HP Power, Flange mount
7	Gearbox	15:1 Ratio Gearbox, Aluminum body, Flange Mount
8	Stainless Steel Collection Trays (L × B × T) a) Top skin collection tray b) Top skin collection tray c) Whole Gel Collecting tray	420 × 360 × 2 mm 420 × 360 × 2 mm 800 × 340 × 2 mm
9	Transport wheel a) Locking type b) Non locking type	360 degree plastic, 90 mm 360 degree plastic, 90 mm

mm, 25–30 mm and more than 30 mm were recorded using texture analyzer (Stable Microsystems, UK, with load cell capacity of 50 kg). Surface hardness of leaves were measured using with 2 mm dia. stainless steel probe. Initial force in compression, corresponding to insertion of probe through surface, was taken as the surface hardness (N) of the leaves.<sup>4,18,19</sup> Warner Bratzler blade was used to measure the cutting force (N).<sup>20,21</sup> Operating conditions of the texture analyzer was selected as pre-test speed: 1.5 mm/s, test speed: 0.5 mm/s, post-test speed: 10.0 mm/s and trigger force: 0.10 N.

The selected Null Hypothesis  $H_0$  for the experiment was assumed as  $R_1=R_2=R_3=R_4$  and alternative hypothesis  $H_1 = R_1 \neq R_2 \neq R_3 \neq R_4$ , where in  $R_1, R_2, R_3$  and  $R_4$  were the roller speed of 50, 75, 100 and 125 rpm respectively, where it was assumed that roller speed had no effect on various parameters like efficiency of whole gel extraction, percent wastage and capacity of whole gel extraction.

#### Optimization of Speed of Operation

Optimization of speed of operation of Aloe vera whole gel extraction equipment was done by rotation of the rollers at different rpm (50, 75, 100 and 125 rpm) which in turn provided the linear motion to conveyer belt on which the Aloe vera leaves were fed.

#### Performance Evaluation of the Equipment

The performance of equipment was evaluated as follows

##### i) Efficiency of whole gel extraction

Efficiency of whole gel extraction is the amount of whole gel that can be recovered by equipment from total amount of gel present in leaf. It is calculated by using equation

$$\text{Whole gel extraction efficiency} = \frac{\text{Wt. of whole gel extracted from leaf, g}}{\text{Total wt. of gel present in leaf, g}} \times 100 \quad \dots (1)$$

##### ii) Per cent gel wastage

Per cent gel wastage is amount of gel remaining along with rind after the gel extraction is completed. It is calculated using equation

$$\text{Per cent gel wastage} = \frac{\text{Wt. of gel left in rind after extraction, g}}{\text{Total wt. of gel present in leaf, g}} \times 100 \quad \dots (2)$$

##### iii) Capacity of Aloe vera whole gel extraction equipment

Capacity of equipment was calculating by amount of whole gel extracted per unit time

$$\text{Capacity (kg/h)} = \frac{\text{Wt. of aloe vera whole gel extracted, kg}}{\text{Operating time, h}} \quad \dots (3)$$

#### Selected Chemical properties of Aloe vera gel

Some of the properties of Aloe vera whole gel was recorded using standard equipment /standard methods and compared with Aloe vera gel extracted by hand filleting method.

Sl No	Properties analyzed	Method/ equipment used
1	Moisture content	Hot air oven method as per AOAC. <sup>22</sup>
2	Crude fibre	Procedure as followed by as per AOAC. <sup>23</sup>
3	Acidity	Titration method as per standard procedure 2310B of ASTM 1067. <sup>(24)</sup>
4	Refractive index	By Abbe Refractometer (range 1.3000 to 1.7000; Accuracy = 0.0002)
5	Specific gravity	By Pycnometer as per procedure laid under ASTM D1840-15. <sup>(25)</sup>
6	Optical density	By using Spectrophotometer Model Spectronic™ Meter at 400nm
7	pH	By using microprocessor based pH meter (Model 1012 E).
8	Total soluble solids	Standard procedure of TSS measurement. <sup>26</sup>
9	Total Sugars	By Phenol-sulphuric acid method. <sup>27</sup>
10	Reducing sugar	Nelson-Somogyi method. <sup>28</sup>

#### Cost Economics of the Equipment

Cost economics of developed equipment for whole gel extraction of Aloe vera leaves was calculated by considering cost of raw materials, overhead charges, labor charges and other operating parameters. Cost of operation, saving in cost, saving in time and breakeven point was calculated as per Regional Network for Agricultural machinery test code for farm machinery<sup>29</sup> with the following assumptions

- 1) Initial cost of Aloe vera gel extraction equipment = Rs.50,000.00
- 2) Annual usage for equipment (240 days @ 6 h/day) = 1440 h say 1500 h
- 3) Total life of equipment = 5 years
- 4) Salvage value = 10 % of initial cost of equipment

#### Statistical analysis

Data was analyzed as per Completely Randomized Design (CRD) using SPSS (Version 17.0.2). Experiment was conducted to check performance of 4 roller speeds i.e 50, 75, 100, 125 rpm with three leaf thickness separately, making a total of four treatment.<sup>30</sup> Each treatment was replicated 5 times under each leaf thickness. Care was taken to keep the sufficient error degrees of freedom. Statistical significance was determined at  $p < 0.05$  by ANOVA and the pair wise

means were compared using Least significant difference test (LSD) which is also called as CD.

**Results and Discussion**

Aloe vera whole gel extraction equipment developed (Fig. 2) was evaluated for its performance at four levels of roller speeds (50, 75,100 and 125 rpm) and three levels of leaf thickness (<25 mm, 25–30 mm and >30 mm). Results were recorded in terms of whole gel recovery, residual gel percentage and whole gel extraction efficiency (Fig. 3).

**Effect of Thickness of Aloe Vera Leaves on the Compression Force for Rupturing**

During compression test using the textural analyser, it was found that about 159.41±8.32 N rupture force was required for less than 25 mm thick leaf; 196.2 ± 10.64 N for the leaf thickness of 25-30 mm and 343.35 ± 15.34 N for leaf having thickness of more than 30 mm. This data indicated that increase in leaf thickness increased the force required for rupturing of leaf. The results are in lines with earlier reported work<sup>3</sup>. This parameter was considered while designing top pair of roller of the equipment. Weight of rollers selected was about 20 percent of the least force of 159.41 ± 8.32 N, which is below the point where rupturing of the leaves starts. Thus weight of pair of top roller was fixed at 3.20 kg which was required for flattening curvature of Aloe vera leaves from which whole gel had to be extracted, without rupturing. Rollers were made of hardened rubber, thereby giving a cushioning effect to leaves which were flattened before coming in contact with pair of knives for removing top and bottom rinds to extract Aloe vera whole gel.

**Effect of Thickness of Aloe Vera Leaves on the Cutting Force for Rind Removing**

Removing of spikes and outer rind is an important and essential step in processing of Aloe vera leaves

for gel extraction.<sup>31</sup> Rinds can be removed either in vertical or horizontal position. Cutting force exerted by textural analyzer was recorded for Aloe vera leaves of less than 25 mm, 25–30 mm and more than 30 mm thickness under investigation. Cutting force for initiating to remove the outer rinds at 25 mm and 25–30 mm leaf and 30 mm thickness of Aloe vera leaves were 9.54 ± 1.94 N, 7.69 ± 1.19 N and 5.76 ± 0.81 N load, respectively. It was observed that as leaf thickness increased, force required for removing of outer rind of Aloe vera leaves decreased. This may be due to the fact that lower cutting force was required when the thickness of leaves was higher, due to presence of higher gel content. Moreover, the gel was softer when compared to outer rind. Results are in lines with reported earlier work.<sup>5</sup>This was taken as criteria for designing two knives for removing the outer rind of Aloe vera leaves during whole gel extraction process.

**Performance Criteria for Continuous Feed Equipment for Whole Gel Extraction of Aloe vera**

*Aloe vera Whole Gel Extraction Efficiency*

Whole gel recovery efficiency was calculated as ratio of weight of whole gel extracted to the weight of whole gel available in leaf fed into equipment. It is observed that irrespective of thickness of the Aloe vera leaf fed, whole gel extraction efficiency increased with speed of roller from 50 rpm (95.65 ± 0.83%) to 100 rpm (98.13 ± 0.52%), and reduced when the speed was further increased from 100 to 125 rpm (94.78 ± 1.13%). During the investigation, it was further observed that both roller speed and leaf thickness have significant effect on whole gel extraction efficiency. Maximum whole gel extraction of 98.65 ± 0.57% was recorded at the roller speed of 100 rpm for leaf thickness of more than 30 mm. The minimum whole gel recovery 93.75 ± 1.31% was recorded at 125 rpm speed when the leaves of less

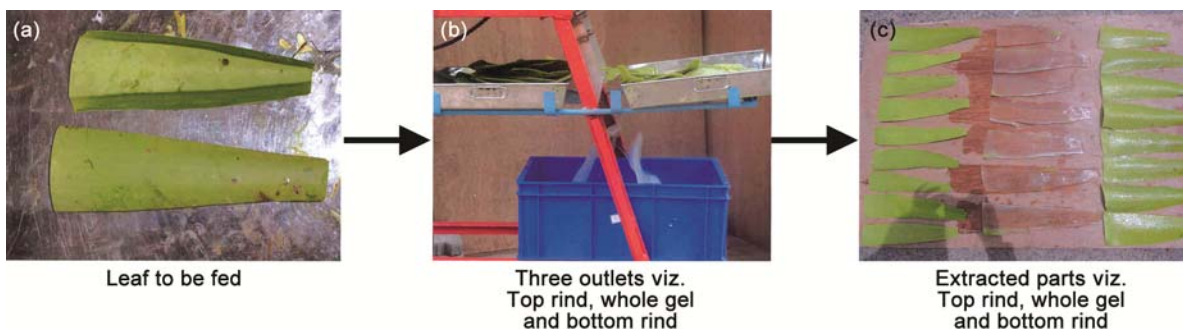


Fig. 3 — Extraction process of continuous feed equipment for aloevera whole gel extraction: a) Leaf to be fed b)Three outlet viz., top rind, whole gel and bottom rind c) Extracted part viz., top rind, whole gel and bottom rind

Table 2 — Performance evaluation of continuous feed equipment for aloe vera whole gel extraction at various speed of roller and leaf thickness

Parameters	Whole gel extraction efficiency, %				Residual gel, %				Whole gel extraction Capacity, kg/h			
	<25mm	25-30mm	> 30mm	Mean	<25mm	25-30mm	> 30mm	Mean	<25mm	25-30mm	> 30mm	Mean
Leaf thickness												
Roller speed, Rpm												
50	94.75 ±0.80 <sup>b</sup>	96.00 ±0.83 <sup>b</sup>	96.20 ±0.87 <sup>b</sup>	95.65 ±0.83	5.25 ±0.28 <sup>b</sup>	4.00 ±0.29 <sup>b</sup>	3.80 ±0.31 <sup>b</sup>	4.35 ±0.29	93.5 ±5.70 <sup>a</sup>	112.5 ±7.50 <sup>a</sup>	137.5 ±9.50 <sup>a</sup>	114.50 ±7.57
75	95.00 ±0.76 <sup>b</sup>	96.25 ±0.79 <sup>b</sup>	96.45 ±0.81 <sup>b</sup>	95.90 ±0.79	5.00 ±0.26 <sup>b</sup>	3.75 ±0.31 <sup>b</sup>	3.55 ±0.34 <sup>b</sup>	4.10 ±0.30	143.5 ±6.40 <sup>b</sup>	162.5 ±7.50 <sup>b</sup>	188.5 ±8.70 <sup>b</sup>	164.83 ±7.53
100	97.25 ±0.46 <sup>c</sup>	98.50 ±0.53 <sup>c</sup>	98.65 ±0.57 <sup>c</sup>	98.13 ±0.52	2.75 ±0.24 <sup>c</sup>	1.50 ±0.27 <sup>c</sup>	1.35 ±0.29 <sup>c</sup>	1.87 ±0.27	193.5 ±7.95 <sup>c</sup>	212.5 ±9.50 <sup>c</sup>	239.0 ±10.25 <sup>c</sup>	215.00 ±9.08
125	93.75 ±1.31 <sup>a</sup>	95.10 ±1.87 <sup>a</sup>	95.50 ±2.20 <sup>a</sup>	94.78 ±1.13	6.25 ±0.93 <sup>a</sup>	5.90 ±0.83 <sup>a</sup>	4.50 ±0.81 <sup>a</sup>	5.55 ±0.87	212.5 ±10.25 <sup>d</sup>	262.5 ±11.75 <sup>d</sup>	280.0 ±12.23 <sup>d</sup>	251.67 ±11.41
CD (0.05)	0.831	0.674	0.617		0.691	0.845	0.590		10.351	12.263	13.132	
Mean	95.19 ±0.84	96.46 ±1.41	96.70 ±0.77		4.81 ±0.43	3.79 ±0.42	3.30 ±0.44		160.75 ±7.58	187.50 ±9.06	211.25 ±10.12	

Each observation is a mean ± CD (n=5)

than 25 mm leaf thickness were fed in the equipment (Table 2). Decrease in whole gel recovery after 100 rpm was due to the fact that at higher speed of operation, lesser time was available for scrapping action of blades on to the leaves, which lead to higher residual gel in leaf. It could be seen from results that as the leaf thickness increased, whole gel recovery also increased significantly. These results are in line to that reported by earlier workers<sup>15,32</sup>, where compression force was used for gel extraction. In present case, the whole gel extraction process is by scrapping action of pair of adjustable blades. From the results, it can be considered that for maximum whole gel recovery of above 98.50%, feeding of Aloe vera leaves need to be done at roller speed of 100 rpm with leaf thickness of 25 mm and above.

#### Residual Gel Percentage

Residual gel percentage was obtained as difference between theoretical quantity of gel available and actual gel recovery from Aloe vera leaves fed into the equipment. It is observed that irrespective of thickness of Aloe vera leaf fed, residual gel percentage reduced with the increase in speed of roller from 50 rpm (4.35 ± 0.29 %) to 100 rpm (1.87 ± 0.27%), and increased when speed was further increased from 100 to 125 rpm (5.55 ± 0.87%). During the investigation, it was observed that both roller speed and leaf thickness have significant effect on residual gel percentage. Minimum residual gel percentage of 1.35 ± 0.29% was recorded at roller speed of 100 rpm for leaf thickness of more than 30 mm. Maximum residual gel percentage of 6.25 ±

0.93% was recorded at roller speed of 125 rpm and when the leaves of less than 25 mm thickness was fed in the equipment (Table 2). Increase in residual gel percentage after 100 rpm may be due to the fact that at higher speed, lesser time was available for scrapping action of pair of blade on the leaf from which whole gel was to be extracted. This leads to lower whole gel extraction efficiency and thereby higher residual gel in leaf. It could be seen from results that as the leaf thickness increased, the residual gel percentage also reduced significantly. These results are in line to that reported by earlier workers<sup>32</sup>, where in compression force was used for gel extraction. In present case, whole gel extraction process is by action of pair of adjustable scrapping blades. Lower leaf thickness may not have assisted in proper contact of the scrapping blades on the leaves and whole gel to be extracted. From the above results, it can be considered that to obtain residual gel percentage of below 1.50 %, feeding of Aloe vera leaves need to be carried out at 100 rpm roller speed with leaf thickness of more than 25 mm (25–30 mm and above 30 mm thickness of leaves).

#### Capacity of the Aloe vera Whole Gel Extraction Equipment

Capacity of the whole gel extraction equipment was calculated as weight of whole gel extracted per unit time. During the investigation, it was observed that both roller speed and leaf thickness have significant effect on capacity of whole gel extraction. It is observed that irrespective of thickness of Aloe vera leaf fed, capacity of equipment increased with speed of roller from 50 rpm (114.50 ± 7.57%) to 125 rpm

(251.67 ± 11.41%). Further based on thickness of Aloe vera leaves fed, capacity of equipment was recorded as 160.75 ± 7.58, 187.50 ± 9.06 and 211.25 ± 10.12 kg/h for Aloe vera leaves of thickness of less than 25mm, 25–30 mm and more than 30 mm, respectively. Interaction effect depicted that maximum whole gel extraction of 280.0 ± 12.23 kg/h was observed at the speed of 125 rpm for leaf thickness more than 30 mm. Minimum whole gel recovery 93.5 ± 5.70 kg/h was recorded at 50 rpm roller speed and leaves of less than 25 mm leaf thickness (Table 2). But at higher roller speed i.e 125 rpm, although whole gel extraction capacity was highest (Mean value of 251.67 ± 11.41 kg/h), the corresponding gel extraction efficiency was lowest (Mean value of 94.78 ± 1.13 %) and the residual gel was highest (Mean value of 5.55 ± 0.87%). The decrease in gel recovery after 100 rpm roller speed may be due to the fact that at higher operating speed, lesser time is available for scrapping action of blades on to the leaf, which resulted in higher residual gel in leaf exudates. Since whole gel extraction capacity increased with lower residual gel percentage till 100 rpm, the speed of operation of the equipment was optimized as 100 rpm roller speed. The mean whole gel extraction capacity at 100 rpm roller speed was 215.00 ± 9.08 kg/h with extraction efficiency of 98.13 ± 0.52 % and residual gel percentage of 1.87 ± 0.27%. Similar results were obtained by earlier workers<sup>32</sup>, when roller type Aloe vera gel extraction equipment was used. From the above results, it was considered that for maximum whole gel recovery, feeding of Aloe vera leaves

need to be done at 100 rpm roller speed with preferable leaf thickness of leaf 25 mm or more. For agricultural machines, the noise level is an important ergonomically aspect as it has effects on the hearing ability of the workers. As per the Occupational Safety and Health Administration (OSHA; www.osha.gov/laws-regs/regulations/standard number/1910/1910.95)<sup>33</sup>, the permissible exposure limit (PEL) is 90 dB for all workers for an 8-hour day. During the evaluation, the maximum sound level was in the range of 82.21 ± 0.21 to 85.44 ± 0.19 dB, and the minimum sound level was in the range of 80.51 ± 0.30 to 81.19 ± 0.62 dB, which was well within the permissible accepted limit and hence acceptable.

Thus it is seen that Null hypotheses is rejected as it was observed that overall model for treatments was found to be significant at 5% level of significance (p ≤0.05). Further pair wise comparisons of treatment means were done using CD and found that at roller speeds 50 and 75 were non-significant while 75 and 100 were found to be significant under all 3 leaf thickness for 3 different dependent variables i.e whole gel, residual gel and whole gel capacity.

**Quality Parameters of Extracted Aloe vera whole Gel**

Quality of whole gel extracted either manually or mechanically depends on various quality parameters like moisture content, crude fibre, acidity, refractive index, specific gravity, pH, total soluble solids, total sugars, reducing sugars etc. The values of quality parameters for machine extracted whole gel operated

Table 3 — Quality parameters of machine extracted aloevera whole gel in comparison with whole gel extracted by hand filleting method

Parameters	Moisture content, %	Crude fibre,%	Acidity, %	Refractive index	Specific gravity	Optical density, abs	pH	Total soluble solids, Brix	Total sugars, %	Reducing sugar, %
Machine extracted whole gel										
<25mm	99.10 ±0.17 <sup>a</sup>	0.09 ±0.006 <sup>a</sup>	0.07 ±0.007 <sup>a</sup>	1.352 ±0.021 <sup>a</sup>	1.083 ±0.026 <sup>a</sup>	0.398 ±0.049 <sup>a</sup>	4.27 ±0.22 <sup>a</sup>	0.79 ±0.17 <sup>a</sup>	1.61 ±0.19 <sup>a</sup>	0.03 ±0.007 <sup>a</sup>
25–30mm	99.20 ±0.27 <sup>a</sup>	0.10 ±0.002 <sup>a</sup>	0.07 ±0.011 <sup>a</sup>	1.342 ±0.017 <sup>a</sup>	1.103 ±0.083 <sup>a</sup>	0.365 ±0.091 <sup>a</sup>	4.31 ±0.12 <sup>a</sup>	0.77 ±0.34 <sup>a</sup>	1.62 ±0.42 <sup>a</sup>	0.03 ±0.009 <sup>a</sup>
> 30mm	99.33 ±0.31 <sup>a</sup>	0.10 ±0.016 <sup>a</sup>	0.08 ±0.009 <sup>a</sup>	1.349 ±0.086 <sup>a</sup>	1.064 ±0.023 <sup>a</sup>	0.359 ±0.033 <sup>a</sup>	4.32 ±0.43 <sup>a</sup>	0.78 ±0.11 <sup>a</sup>	1.60 ±0.17 <sup>a</sup>	0.03 ±0.006 <sup>a</sup>
Hand filleting method										
<25mm	99.21 ±33 <sup>a</sup>	0.09 ±0.023 <sup>a</sup>	0.07 ±0.033 <sup>a</sup>	1.351 ±0.191 <sup>a</sup>	1.097 ±0.062 <sup>a</sup>	0.371 ±0.021 <sup>a</sup>	4.33 ±0.31 <sup>a</sup>	0.78 ±0.29 <sup>a</sup>	1.63 ±0.19 <sup>a</sup>	0.03 ±0.008 <sup>a</sup>
25–30mm	99.20 ±29 <sup>a</sup>	0.09 ±0.035 <sup>a</sup>	0.07 ±0.051 <sup>a</sup>	1.349 ±0.196 <sup>a</sup>	1.083 ±0.047 <sup>a</sup>	0.366 ±0.057 <sup>a</sup>	4.29 ±0.56 <sup>a</sup>	0.80 ±0.41 <sup>a</sup>	1.61 ±0.22 <sup>a</sup>	0.03 ±0.003 <sup>a</sup>
> 30mm	99.28 ±36 <sup>a</sup>	0.09 ±0.045 <sup>a</sup>	0.07 ±0.089 <sup>a</sup>	1.353 ±0.019 <sup>a</sup>	1.091 ±0.123 <sup>a</sup>	0.369 ±0.044 <sup>a</sup>	4.31 ±0.33 <sup>a</sup>	0.79 ±0.22 <sup>a</sup>	1.62 ±0.33 <sup>a</sup>	0.03 ±0.005 <sup>a</sup>
CD (0.05)	0.841	0.003	0.021	0.246	0.197	0.171	0.435	0.236	0.271	0.0107

Each observation is a mean ± CD (n=5)

at 100 rpm roller speed are compared in Table 3 with that of hand filleting method for various leaf size viz., below 25 mm, 25 to 30 mm and above 30 mm fed into the equipment. Pair wise comparisons of leaf thickness means using CD for different quality parameters of machine extracted Aloe vera whole gel in comparison with whole gel extracted by hand filleting method was found to be non-significant (Table 3). This depicts that quality parameters assessed were on par at both the treatment viz. machine extracted and hand filleting method irrespective of size of leaves fed into the machine. This clearly depicts that the developed equipment can be an effective alternative to much preferred hand filleting method of whole gel extraction, which is being followed in most of the Aloe vera gel processing industries.

#### Cost Economics of Aloe Vera Whole Gel Extraction Equipment

Cost economics of developed equipment by following the standard method of calculation gave that fixed cost of operation is Rs 12.50/h and operating cost is about Rs 151.50/h. Percentage saving in cost of operation over the traditional hand filleting method is 55.56% with the saving in time of about 70%. The breakeven point of the equipment is about 200 hours.

#### Conclusions

Study relates to development of equipment for safely removing whole gel from Aloe vera leaves. At present, Aloe vera gel is extracted either by hand filleting method which is unhygienic, unsafe and tedious or extracted mechanically. The mechanical methods although faster, does not extract gel in whole form. Developed Aloe vera whole gel extraction equipment eliminated the manual contact in Aloe vera whole gel extraction and prevented contamination. Problem of mixing of gel with chemical compound from Aloe vera leaf rind as in crushing and roller extraction method was eliminated. It was observed that overall model for treatments were found to be significant ( $p \leq 0.05$ ). Further pair wise comparisons of treatment means were done using LSD test and found that at roller speeds 50 and 75 rpm were non-significant while 75 and 100 rpm were found to be significant under all 3 leaf thickness for 3 different dependent variables i.e whole gel, residual gel and whole gel capacity. It is found that for maximum whole gel recovery and minimum residual gel percentage in rind, the equipment should be operated at 100 rpm roller speed and preferable with Aloe vera leaves of

more than 25 mm thickness. Capacity of equipment is  $215.00 \pm 9.08$  kg/h with whole gel extraction efficiency of  $98.13 \pm 0.52\%$  and residual gel of  $1.87 \pm 0.27\%$ . Quality of extracted whole gel is on par with traditional hand filleting method of gel extraction. Percentage saving in cost of operation was 55.56% with saving in time of operation of 70 %. Equipment can be adopted as an effective alternative to existing hand filleting method, especially in Aloe vera catchment area without compromising on quality parameters.

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