Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 1987-1992
Received: 16-05-2019
Accepted: 20-06-2019

Dinesha DT
Department, of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Ramachandra CT
Department, of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Uday kumar Nidoni
Department, of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Sharanagouda Hiregoudar
Department, of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Prakash KV
Department, of Farm Machinery and Power Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Correspondence
Dinesha DT
Department, of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

Performance evaluation of roller type aloe vera gel extraction machine

Dinesha DT, Ramachandra CT, Uday kumar Nidoni, Sharanagouda Hiregoudar and Prakash KV

Abstract
Aloe vera (*Aloe barbadensis* Miller) is a perennial, drought-resisting, succulent plant. Aloe vera gel is the colourless mucilaginous gel obtained from the parenchymatous cells in the fresh leaves of Aloe vera (*Liliaceae*). Aloe vera gel is extracted from Aloe vera (*Aloe barbadensis* Miller) leaves using Aloe vera gel extraction machine. The gel extraction machine consisted of two stainless steel rollers arranged in horizontal plane. The front roller had more clearance than the crushing roller. The front roller compressed the leaf while crushing roller helped in extraction of gel. Effect of roller speeds (0.093, 0.123 and 0.153 m/s) and roller clearances (4, 5 and 6 mm) were considered for the extraction process. Maximum gel extraction efficiency of 98.06%, minimum gel extraction loss of 1.58%, maximum gel recovery of 43.57% and extraction capacity of 158.06 kg.h^{-1} were obtained at roller speed of 0.153 m/s with 5 mm of roller clearance. The manual extraction cost of Aloe vera gel was estimated as Rs. 20.67/- per kg with benefit cost ratio of 2.42:1. The extraction cost of Aloe vera gel from Aloe vera gel extraction machine was estimated as Rs.13.36/- per kg with benefit cost ratio of 3.74:1.

Keywords: Aloe vera, gel extraction efficiency, gel extraction loss, gel recovery and gel extraction capacity

Introduction
Aloe vera (*Aloe barbadensis* Miller) is a perennial, drought-resisting, succulent plant. Aloe vera has a number of uses and mainly they are used as a food preservative and herbal medicine. In the food industry, Aloe vera has been utilized as a resource for functional foods, especially for the preparation of aloe soft drinks (with electrolyte), diet drinks, tropical fruit juices with Aloe vera, yogurt and yogurt drinks, Aloe vera jelly desserts with chunks of aloe, instant Aloe vera tea granules (health food drinks) and other beverages, including tea (Ramachandra and Rao, 2008).

The Aloe leaf can be divided into two major parts, namely the outer green rind, including the vascular bundle and the inner colourless parenchyma containing the aloe gel. The physical and chemical composition of Aloe vera differs depending on the species, climate and growing conditions (Nilanjana and Chattopadhay**,** 2004). The main feature of the Aloe vera plant is its high water content ranging from 99.0 to 99.5% (w.b.). The remaining 0.5 to 1.0% solid material is reported to contain over 75 different potentially active compounds including water and fat soluble vitamins, minerals, enzymes, simple and complex polysaccharides, phenolic compounds. (Choi and Chung, 2003) [5]

The leaves of the Aloe vera plants have a relatively dense outer layer, rind or peel surrounding the relatively soft core that is filled within the Aloe vera gel. Aloe vera gel is the colourless mucilaginous gel obtained from the parenchymatous cells in the fresh leaves of Aloe vera (*Liliaceae*) (Chandegara and Varsheny, 2013). The rind constitutes 37.9±2.7% and the gel fillet constitutes 60.2±2.6% from the Aloe vera leaf. The growing commercial importance of Aloe vera has resulted in a need for efficient means for extracting the gel from the leaves of the Aloe vera plants.

The manual extraction method of processing Aloe vera leaves was developed to avoid contaminating the internal fillet with the yellow sap. In this method the rind is removed by sharp knife, keeping anthroquinone level low, but most of the mucilage is left on the working table in this process (Pal *et al.*, 2013) [13]. The hand extraction method is very labour intensive. Owing to this fact, machines have been designed and employed which attempt to simulate the manual extraction techniques.

Materials and Methods

Raw materials

Fresh whole Aloe vera (*Aloe barbadensis* Miller) leaves of 3-year old plant were collected from Agricultural Research Station, Hagari, and Ballari district of India. According to the size, maturity, colour and Homogeneous Aloe *barbadensis* Miller leaves were selected as the raw material for the experiment.

Manual Aloe vera gel extraction process

Freshly harvested Aloe vera leaves were dipped into tap water and washed thoroughly. The leaf trimming process means that the side, tip and base of the leaf were cut away using stainless steel knife (manually) Fig. 1, Trimmed leaves were cut vertically into two half and gel was separated using stainless steel knife and collected in a box.

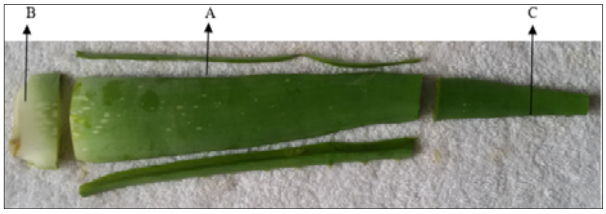

Fig 1: Leaf trimming procedure resulting in A:-, removal of sides, B:-, removal of base and C:-, removal of tip of leaf

Aloe vera gel extraction machine

The Aloe vera gel extraction machine (Fig. 2) developed by M/s. Sanjivani Phytopharma, Pvt. Ltd., India. The gel extraction machine consisted of belt conveyor, knurling rollers, chain pulley, and gel collecting unit, mesh sieve for collection of rind and frame for holding all components. Aloe vera gel extractor was powered by single at three phase. The rotating rollers were fitted inside the extracting chamber. The rotating rollers were directly attached to the chain pulley and power was transmitted from 3 phase electric motor through belt transmission to drive the rotating rollers. The CV100 series Variable Frequency Drive (VFD) used for varying the roller speed of extraction machine. All contact parts were made up of stainless steel (SS304) with the exception of the frame which was made from mild steel.

The trimmed Aloe vera leaves were fed through the knurling mesh conveyor of Aloe vera leaf washing machine. After washing, the Aloe vera leaves were moved through the belt conveyor to the Aloe vera gel extraction machine, here Variable Frequency Drive (VFD) used for varying the speed of rollers (30, 40 and 50 rpm) but operational roller speed of Aloe vera gel extractor (roller speed: 0.093, 0.123 and 0.153 m/s) and the clearance between rollers was adjusted with the help of nuts provided on top frame of the machine (roller clearance: 4, 5 and 6 mm). In this machine, extraction process was carried out through the pressing of leaves by knurling rollers, the front roller had more clearance than the crushing roller. The front roller compressed the leaf and the crushing roller helped for extraction of gel. The Aloe vera gel was sieved through 10 mm diameter openings in the outlet hopper and collected in the bottom outlet (60 mm diameter). The residual waste was collected in sieve outlet (570×570 mm).

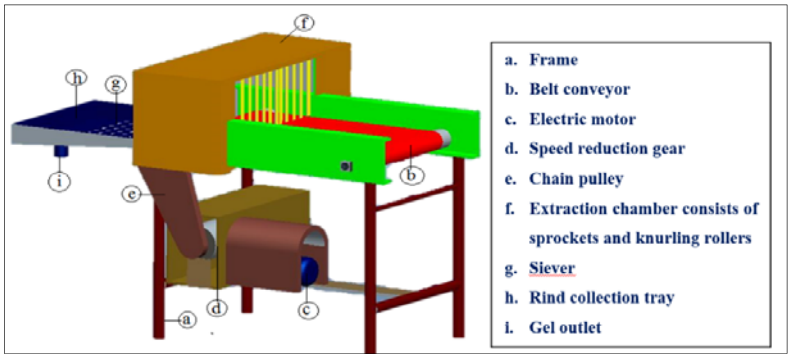

Fig 2: Components of Aloe vera gel extraction machine

Performance test of Aloe vera gel extraction machine

The performance of the Aloe vera gel extraction machine was evaluated at three levels of roller speeds (0.093, 0.123 and 0.153 m/s) and three levels of roller clearances (4, 5 and 6 mm) in terms of gel extraction efficiency (%), gel extraction loss (%), gel recovery (%) and gel extraction capacity (kg.h^{-1}). The trimmed Aloe vera leaves were fed into the belt conveyor then passed through the extraction chamber and the machine was allowed to operate until the material was completely fed and extracted. After that, mass of Aloe vera leaves fed into the machine, mass of gel extracted, mass of rind waste and gel constant value of the Aloe vera leaves were recorded. The gel constant was obtained from the ratio of sum of masses of gel extracted and gel in rind to the mass of trimmed Aloe vera leaves fed in (Ndubisi *et al*., 2013) [11].

Gel Extraction Efficiency (%)

$$\text{Gel Extraction Efficiency: } E_E = \frac{100 \times W_{ge}}{X \times W_{fs}} \quad \ldots (1)$$

Gel Extraction Loss (%)

$$\text{Gel Extraction Loss: } E_L = \frac{100(W_{fs} - (W_{ge} + W_{rw})}{W_{fs}} \quad \ldots (2)$$

Gel Recovery (%)

$$\text{Gel Recovery: } G_R = \frac{100 \times W_{ge}}{W_{ge} + W_{rw}} \quad \ldots (3)$$

Extraction Capacity (kg.h^{-1})

$$\text{Extraction Capacity: } E_C = \frac{W_{fs}}{T} \quad \ldots (4)$$

Where,

Wge = Weight of gel extracted in g
Wfs = Weight of feed sample in g
X = Gel constant (X is calcualated as the ratio of Sum of masses of gel extracted and gel in Rind to the mass of trimmed Aloe vera

Leaves fed in.) (Ndubisi *et al*., 2013) [11].

Wrw = Weight of residual waste in g

T = Time in seconds

Economics of Aloe vera gel extraction process

The cost of extraction of Aloe vera gel by using both Aloe vera washing and gel extraction machine were estimated by considering the fixed, variable costs and other related costs. In operating cost, the energy requirement of Aloe vera leaf washing machine and Aloe vera gel extraction machine were recorded during the operation of machines. The costs of operation were determined by estimating the fixed cost and variable cost. The following assumptions and relationships were used for calculating the cost of extraction of Aloe vera gel. The fixed cost was calculated by using the following relationship (Gritty, 2012) [6].

Fixed cost of the equipment/year = Fixed cost × Capital recovery factor

Where,

Capital Recovery Factor (CRF) was derived by using the equation

$$= \frac{Ri\,(Ri+1)^n}{(Ri+1)^n - 1} \times E$$

Where,

RI = Existing rate of interest for long term (4.5%) bank loans, per cent

n = Life span of the machines, years

The variable costs, which were incurred on wages, electricity Charges, repairs and maintenance, raw materials, *etc*., were calculated by collecting data during the operation of machines and assuming certain data reasonably wherever necessary.

Payback period

Payback period of the evaluated of Aloe Vera gel extractor in terms of number of years was computed by using the following equation (Gritty, 2012) [6]

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net annual return}} = \frac{I}{E}$$

Where,

P- Payback period, years

I- Investment, Rs.

E- Annual net return, Rs.

Statistical Analysis

The experiment in the study was conducted in triplicate and mean values are reported. In this experiment considered 2×3 factorial design (Number of treatments was 9, number of replications was 3 and total no of treatments was 27). The Input variables considered were roller speed (0.93, 0.123 and 0.153 m/s) and roller clearance (4, 5 and 6 mm). The Output variables considered were extraction efficiency, extraction loss, and Gel recovery and extraction capacity. Factorial Completely Randomised Design (FCRD) was used to analyse the data. The experimental design was done with the aid of the Design-Expert software version 7.7.0 (Stat ease Inc., Minneapolis, USA). The experiments were designed according to the general factorial design and the order of experiments was fully randomised. (Montgomery, 2001) [9]

Results and Discussion

Effect of roller speed and roller clearance on gel extraction efficiency (%)

The manually extracted (control) Aloe vera gel was found to be maximum i.e., extraction efficiency (100%) compared to Aloe vera gel extracted from machine (96.08%). This might be due to no loss of Aloe vera gel (Khambalkar, 2007) [8] in the case of manual extraction. The gel extraction efficiency was higher compared to machine extracted Aloe Vera gel are presented in Table 1.

The gel extraction efficiency ranged from 88.61 to 96.08%. Among the treatment combinations, the extraction efficiency (96.08%) was the highest at 0.153 m/s roller speed and roller clearance of 5 mm. whereas, the lowest gel extraction efficiency (88.61%) was recorded at 0.093 m/s roller speed and roller clearance of 4 mm. The mean treatment combination of gel extraction efficiency was 93.66%, the standard deviation of treatment combinations of gel extraction efficiency was 2.25. The interaction effect of 0.153 m/s roller speed and 5 mm roller clearance on extraction efficiency was significant ($p<0.05$) at five per cent level.

From Table 1, it is clear that the gel extraction efficiency (%) increased with increase in roller speed. Due to faster compression force and increase in roller speed the extraction efficiency increased. Gel extraction efficiency (%) increased with increase in roller speed and also increase in roller clearance but in this case the significantly difference affected on 5 mm of roller clearance, the gel extraction efficiency was maximum, because gel recovery was more in 5 mm of roller clearance compare to 4 mm and 6 mm of roller clearance. It was observed that more would be the gel extraction efficiency and less would be the extraction loss. At 5 mm roller clearance as the roller speed increased the extraction efficiency also increased but extraction efficiency was Maximum at 0.153 m/s roller speed. Khambalkar *et al.* (2007) [8] reported that the extraction efficiency of Aloe vera gel was found to be 91.20% of Aloe vera gel (Fillet) extractor. The machine efficiency increased with an increase in peripheral speed. Chandegara and Varsheny (2014) [4] reported that the expulsion efficiency affected by the orientation of leaf in feeding, roller speed, leaf thickness, leaf size and shape. Looking at both roller speed and roller clearance, it might be concluded that the gel extraction of Aloe vera leaves should be carried out at 0.153 m/s roller speed with 5 mm of roller clearance for obtaining maximum extraction efficiency.

Effect of roller speed and roller clearance on gel extraction loss (%)

The extraction loss ranged from 1.58 to 4.50%. Among the treatment combinations, the extraction loss (4.50%) was the highest at 0.093 m/s roller speed and roller clearance of 4 mm. whereas, the lowest extraction loss (1.58%) was recorded at 0.153 m/s roller speed and roller clearance of 5 mm. The mean treatment combination of extraction loss was 2.64%, the standard deviation of treatment combinations of extraction loss was 0.87. From Table 1, it is clear that the gel extraction loss (%) decreased with increase in roller speed and also increase in roller clearance but in this case the significantly difference affected on 5 mm of roller clearance, gel extraction loss was minimum, because gel recovery was more in 5 mm of roller clearance compare to 4 mm (more compression force occurred mixed with both rind and gel, most of the gel remaining in rind itself) and 6 mm of roller clearance (less compression force occurred gel recovery is less)

From Table 1, it is clear that the gel extraction loss (%) decreased with increase in roller speed and also increase in roller clearance but in this case the significantly difference affected on 5 mm of roller clearance, gel extraction loss was minimum, because gel recovery was more in 5 mm of roller clearance compare to 4 mm and 6 mm of roller clearance. It was observed that more would be the gel extraction efficiency and less would be the gel extraction loss. It was observed that the gel extraction loss (%) was minimum (1.58%) at roller speed of 0.153 m/s and at 5 mm roller clearance. This might be due to the faster movement of leaf at less time at higher roller speed, which resulted in higher gel recovery from leaf exudates. Similar finding was reported by Chandegara and Varshney (2014) [4] for expulsion of Aloe vera gel, who reported that the extraction loss was found to be minimum at the particular roller speed, maturity and thickness of leaves for obtaining minimum gel extraction loss (%). Looking at both roller speed and roller clearance, it might be concluded that the gel extraction of Aloe vera leaves should be carried out at 0.153 m/s roller speed with 5 mm of roller clearance for obtaining maximum extraction efficiency.

There was no gel extraction loss in manually extracted (control) Aloe vera gel compared to the Aloe vera gel extracted by the machine (1.58%) are presented in Table 2. This is due to maximum extractability (Khambalkar, 2007) [8] in the case of manual method.

Effect of roller speed and roller clearance on gel recovery (%)

The gel recovery was ranged from 37.93 to 43.57%. Among the treatment combinations, the gel recovery (43.57%) was the highest at 0.153 m/s roller speed and roller clearance of 5 mm. whereas, the lowest gel recovery (37.93%) was recorded at 0.093 m/s roller speed and roller clearance of 6 mm. The mean treatment combination of gel recovery was 40.60 per cent, the standard deviation of treatment combinations of gel recovery was 1.90. The interaction effect of 0.153 m/s roller speed and 5 mm of roller clearance on gel recovery was significant ($p<0.05$) at five per cent level and is presented in Table 1.

From Table 1, it is clear that the gel recovery (%) increased with increase in roller speed. It is observed from Table 2, that the gel recovery (%) was maximum (43.57%) at roller speed of 0.153 m/s and 5 mm of roller clearance. It was observed that as the roller speed increased the gel recovery (%) increased at constant roller clearance. Khambalkar *et al.*, 2007, reported that the recovery of gel was found to be 52% for manually operated Aloe vera gel (Fillet) extractor. Bog Hani *et al.* (2012) [2] reported that the Aloe vera leaves with maximum weight recorded maximum gel recovery (42.73%) whereas the Aloe vera leaves with minimum weight recorded minimum gel recovery (29.18%) in manual extraction for medium trimmed Aloe vera leaves (140 to 200 g). The difference in leaves structure and gel recovery might be due to different growing stages and maturity profiles of Aloe vera leaves. On the basis of the results obtained, it could be suggested that long fully developed Aloe vera leaves should be preferred for extraction of gel for maximum yield. Hussain *et al*. (2010) [7] reported that greater rotational speed and larger diameter of rollers resulted in more pulp recovery in tomato fruit, while roller clearance played an inverse role, yielding less pulp recovery in case of larger clearance. From the above discussion, it might be concluded that more would be the roller speed better would be the crude gel recovery.

Chandegara and Varsheny (2014) [4] reported that the gel recovery was affected by roller speed, leaf weight, leaf size and leaf shape and also leaf thickness. Looking at both roller speed and roller clearance, it might be concluded that the gel extraction of Aloe vera leaves should be carried out at 0.153 m/s roller speed with 5 mm roller clearance to obtained maximum gel recovery (%)

Effect of roller speed and roller clearance on extraction capacity (kg.h^{-1})

The extraction capacity ranged from 104.32 to 158.06 kg.h^{-1}. Among the treatment combinations, the extraction capacity (158.06 kg.h^{-1}) was the highest at 0.153 m/s roller speed and roller clearance of 5 mm. whereas, the lowest extraction capacity (104.32 kg.h^{-1}) was recorded at 0.093 m/s roller speed and clearance of 4 mm. The mean treatment combination of extraction capacity was 125.64 kg.h^{-1}, the standard deviation of treatment combinations of extraction capacity was 18.99. The interaction effect of 0.153 m/s roller speed and 5 mm of roller clearance on extraction capacity was significant ($p<0.05$) at five per cent level.

The effect of roller speed and roller clearance on extraction capacity (kg.h^{-1}) at three levels namely 0.093, 0.123 and 0.153 m/s and 4, 5 and 6 mm are presented in Table. 1. The interaction effect of 0.153 m/s of roller speed and 5 mm of roller clearance on extraction capacity was significant ($p < 0.05$) at five per cent level. From Table 1, it is clear that the extraction capacity (kg.h^{-1}) increased with increase in roller speed. It is observed that the extraction capacity was maximum (158.06 kg.h^{-1}) at roller speed of 0.153 m/s and at 5 mm of roller clearance. Because of faster movement of leaves into gel extractor, less time was consumed, which minimised the gel extraction loss. Khambalkar *et al.* (2007) [8] reported that the extraction capacity of manually operated Aloe vera gel (Fillet) extractor was found to be 3.923 kg.h^{-1} of leaves, whereas the manual extraction method gave very less capacity of 0.654 kg.h^{-1}. It was observed that the rate of work was six times higher than the manual method. Anonymous (2007) reported an Hand operated Aloe vera gel extractor by providing tolerance in between the crushing rollers, so that only the gel was just extracted and over-crushing of the leaves avoided. The capacity of the extractor was 60-80 kg.h^{-1} of Aloe vera leaves. Looking at both roller speed and roller clearance, it might be concluded that the gel extraction of Aloe vera leaves should be carried out at 0.153 m/s roller speed with 5 mm of roller clearance for obtaining maximum extraction capacity.

The manually extracted (control) Aloe vera gel had the maximum gel recovery (57.78%) compared to Aloe vera gel extracted from machine (43.48%). Khambalkar (2007) [8] r eported that the gel recovery obtained from manually extracted Aloe vera gel was 57%. This might be due to maximum extractability and no losses. This gel recovery was higher compared to machine extracted Aloe vera gel and is presented in Table 1.

Table 1: Mean values of gel extraction efficiency (%), gel extraction loss (%), gel recovery (%) and extraction capacity (kg.h^{-1}) obtained at different roller speed and clearance

Treatments	Roller speed (m/s)	Roller clearance (mm)	Gel extraction Efficiency (%)	Gel extraction Loss (%)	Gel Recovery (%)	Extraction capacity (kg.h^{-1})
T_1	0.093	4	88.61	4.50	37.93	104.32
T_2	0.093	5	94.45	2.35	41.08	115.02
T_3	0.093	6	93.79	2.46	38.06	106.09
T_4	0.123	4	92.25	3.25	40.02	114.20
T_5	0.123	5	94.85	2.24	42.28	128.11
T_6	0.123	6	94.42	2.37	41.08	117.19
T_7	0.153	4	92.80	3.10	40.18	141.44
T_8	0.153	5	96.08	1.58	43.57	158.06
T_9	0.153	6	95.23	2.03	41.39	146.32
Range			88.61-96.08	1.58-4.50	37.93-43.57	104.32-158.06
Mean			93.66	2.64	40.60	125.64
SD			2.25	0.87	1.90	18.99
C.V. (%)			2.40	32.85	4.68	15.12

Note: Manual extraction method: gel extraction efficiency (100%), gel extraction loss (0%), gel recovery (57.78%) and extraction capacity (3.15 kg.h^{-1})

Economics of Aloe vera gel extraction process

The machines used for extraction of Aloe vera gel were Aloe vera gel extraction machine and Aloe vera washing machine, the cost of each machines were 4 lakh and 1 lakh respectively. The energy requirement of process machines were calculated as 38.40 and 24.00 kWh/day, respectively.

The fixed cost of Equipments (Gel extraction machine, leaf washing machine, variable frequency drive and electronic balance unit) was 0.68320lakh and also Housing, insurance and taxes of Equipments cost were 0.21620 lakh. The variable cost per year considered both repair and maintenance charge of equipment, cost of energy requirement (Electricity charges Rs. 4 per kWh), labour charges (two labour, 175 Rs per day and per year) and cost of raw material (cost of 1 kg of leaf was Rs. 5) were 0.26275, 0.68640, 0.96250 and 17.39 lakh respectively. Total extraction cost (both fixed and variable) was 20.19 lakh. Total extraction of Aloe vera gel per year for trimmed leaves calculated optimized product of gel recovery and No. of days and per year (1 year considered as 275 days) was 1.512 lakh. The cost of extraction of one kg of Aloe vera gel calculated was the ratio of total cost of extraction to the total quantity of Aloe vera gel extracted. The total extraction cost for 1 kg of Aloe vera gel was estimated to be Rs.13.36/-. The Aloe vera gel can be sold at a cost of Rs. 50/- per kg.

Conclusions

The Aloe vera gel extraction machine had eliminated the manual contact in processing of Aloe vera gel. The bulk quantity of Aloe vera gel is not available in the market round the year, it is essential to extract Aloe vera gel using Aloe vera gel extraction machine. In the present investigation, Aloe vera gel is extracted from Aloe vera (*Aloe barbadensis* Miller) leaves by using Aloe vera gel extraction machine developed by M/s. Sanjivini Phytopharma, Pvt. Ltd., Mumbai. Compared to manual extraction, machine extracted Aloe Vera gel was less time consuming and labour-saving. The different roller speeds of 0.093, 0.123 and 0.153 m/s and roller clearances of 4, 5 and 6 mm were chosen as independent variables to extract Aloe vera gel. It was concluded that for getting maximum gel recovery, maximum gel extraction efficiency, minimum gel extraction loss and the highest extraction capacity, the Aloe vera leaf should be extracted at 0.153 m/s of roller speed and 5 mm of roller clearance. Maximum gel extraction efficiency of 96.08%, minimum gel extraction loss of 1.58%, maximum gel recovery of 43.57% and extraction capacity of 158.06 kg.h^{-1} were obtained at 0.153 m/s roller speed and 5 mm of roller clearance. The total cost of extraction of Aloe vera gel was estimated as Rs. 13.36/- per kg.

References

1. Anonymous. Aloe vera gel extractor. DARE/ICAR Annual Report, 2007-08, ICAR, New Delhi, India, 2007, 80.
2. Bog Hani AH, Abdul R, Hashmi SI. Development and storage studies of blended papaya-Aloe Vera Ready To Serve (RTS) Beverage, J Food Process Technol. 2012; 3(10):1-4.
3. Chandegara VK, Varshney AK. Aloe Vera L. processing and products: A review. Int. J Med. Arom. Plants. 2013; 3(4):492-506.
4. Chandegara VK, Varshney AK, Design and development of leaf splitting unit for Aloe vera gel expulsion machine. J. Food Process Engg. 2014; 37(4):427-437.
5. Choi S, Chung MH A. review on the relationship between Aloe vera components and their biological effects. Sem. Intgr. Med. 2003; 1(1):53-62.
6. Gritty PT, Studies on low temperature drying and grinding of whole leaf Aloe vera (*Aloe barbadensis* Miller) M Tech. Thesis, University of Agricultural Sciences, Raichur, India, 2012, 50-54.
7. Hussain KA, Sabir MS, Iqbal M. Development of a machine for cold pulping of tomato. Pak. J Agri. Sci. 2010; 47(4):383-387.
8. Khambalkar VP, Thakur KB, Sawant A, Dahatonde S, Karale DS. Preservation of Aloe vera leaf juice by different methods. The Asian J Expt. Chem. 2007; 2(1):10-14.
9. Montgomery DC. Design and Analysis of Experiments. John Wiley and Sons, Inc, New York, 2001.
10. Naik R, Annamalai SJK. Gel textural properties of Aloe vera. Madras Agric. J. 2013; 100(1-3):232-235.
11. Ndubisi AA, Abubakar AL, Davou SN, Jesutofunmi B. Development and performance evaluation of a multi-fruit juice extractor. Global. J Engg. Design. Technol. 2013; 2(2):16-21.

12. Nilanjana D, Chattopadhay RN. Commercial cultivation of Aloe. Natural Product Radiance. 2013; 3(2):85-87.
13. Pal S, Sahrawat A, Prakash D. Aloe Vera: composition, processing and medicinal properties. Curr. Discovery. 2013; 2(2):106-122.
14. Ramachandra CT, Rao PS. Processing of Aloe vera leaf gel: A Review. Am. J Agril. Biol. Sci. 2013; 3(2):502-510.