

**PERFORMANCE EVALUATION OF ROLLER TYPE ALOE VERA  
GEL EXTRACTION MACHINE**

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**PERFORMANCE EVALUATION OF ROLLER TYPE ALOE VERA  
GEL EXTRACTION MACHINE**

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University of Agricultural Sciences, Raichur  
In partial fulfillment of the requirements for the  
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**By**

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DEPARTMENT OF PROCESSING AND FOOD ENGINEERING**

**CERTIFICATE**

This is to certify that the thesis entitled “**PERFORMANCE EVALUATION OF ROLLER TYPE ALOE VERA GEL EXTRACTION MACHINE**” submitted by **Mr. DINESHA, D. T.** for the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **PROCESSING AND FOOD ENGINEERING** to the University of Agricultural Sciences, Raichur, is a record of research work carried out by him during the period of his study in this University, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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**AFFECTIONATELY DEDICATED**  
**TO**  
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## LIST OF ABBREVIATIONS

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ANOVA	:	Analysis of Variance
AOAC	:	Association of Official Analytical Chemists
CI	:	Confidence of Interval
CEG	:	Cold Extracted Gel
C.V.	:	Coefficient of Variation
DE	:	Dextrose Equivalent
d.b.	:	Dry basis
d.m.	:	Dry matter
FCRD	:	Factorial Completely Randomised Design
FI	:	Factorial Interaction
HEG	:	Hot Extracted Gel
IU	:	International units
IASC	:	International Aloe Science Council
L	:	Length
RI	:	Refractive Index
SD	:	Standard Deviation
SEm	:	Standard Error mean
TSS	:	Total Soluble Solids
TV	:	Titre Value
VFD	:	Variable Frequency Drive
w.b.	:	Wet basis
w.m.	:	Wet matter

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## LIST OF SYMBOLS

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$a^*$	:	Redness or greenness
$a_w$	:	Water activity
$b^*$	:	Yellowness or blueness
Cm	:	Centimetre
$m.min^{-1}$	:	Metre per minute
$m.h^{-1}$	:	Metre per hour
%Brix	:	Percentage Brix
$^{\circ}C$	:	Degree Celcius
<i>et al.,</i>	:	and others
Fig.	:	Figure
G	:	Gram
$g.cc^{-1}$	:	Gram per cubic centimetre
$g.ml^{-1}$	:	Gram per millilitre
$g.min^{-1}$	:	Gram per minute
$g.cm^{-3}$	:	Gram per cubic centimetre
H	:	Hour
Hp	:	Horse power
$m^{-3}$	:	Per cubic meter
Kg	:	Kilogram
kg m	:	Kilogram Metre
Kcal	:	Kilo calorie
$kcal.mol^{-1}$	:	Kilo calorie per mole
$kg.m^{-3}$	:	Kilogram per cubic metre
$kg.h^{-1}$	:	Kilogram per hour
kPa	:	Kilo Pascal
$kg.cm^{-2}$	:	Kilogram per centimetre square
$kg.min^{-1}$	:	Kilogram per minute
$kg.s^{-1}$	:	Kilogram per second
kW	:	Kilo Watt
$L^*$	:	Lightness or darkness
$l.h^{-1}$	:	Litre per hour
$l.min^{-1}$	:	Litre per minute
M	:	Metre

mg	:	Milligram
min	:	Minute
mg.100g <sup>-1</sup>	:	Milligram per 100 gram
mm	:	Millimetre
mm <sup>3</sup>	:	Millimetre cube
mm.s <sup>-1</sup>	:	Millimetre per second
ml	:	Millilitre
ml.min <sup>-1</sup>	:	Millilitre per minute
ml.h <sup>-1</sup>	:	Millilitre per hour
kW.t <sup>-1</sup>	:	Kilo Watt per tonne
m.s <sup>-1</sup>	:	Metre per second
µm	:	Micrometer
mPa.s	:	Milli Pascal second
N	:	Newton
No.	:	Number
ppm	:	Parts per million
rpm	:	Revolutions per minute
s	:	Second
V	:	Volts
viz.	:	Namely
Var.	:	Variety
wt.	:	Weight
%	:	Per cent
w/v	:	Weight by volume
w/w	:	Weight by weight
<	:	Less than
>	:	Greater than
@	:	at the rate
±	:	Plus or minus sign
\$	:	Dollar
₹	:	Indian National Rupees (INR)

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## *Introduction*

## I. INTRODUCTION

Aloe vera (*Aloe barbadensis* Miller) is a perennial, drought-resisting, succulent plant. The name, Aloe, is derived from the Arabic "alloeh" or Hebrew "halal" meaning bitter shiny substance. It has a vast traditional role in indigenous system of medicine like Ayurveda, Siddha, Unani and Homoeopathy (Karkala and Bidya, 2014 and Sharma *et al.*, 2014). Several species of the genus aloe has been in use under the common name of Aloe *viz.*, *Aloe vera*, *Aloe barbadensis* Miller, *Aloe ferox*, *Aloe chinensis*, *Aloe indica*, *Aloe peyrrii* *etc.* Amongst these, *Aloe barbadensis* Miller is accepted unanimously as the correct botanical source of Aloe (Nilanjana and Chattopadhyay, 2004).

Aloe vera is a member of the lily (*Liliaceae*) family which is a native to warm dry regions. It is popularly grown as indoors plant and cultivated almost everywhere in the world, both as a houseplant and for its medicinal qualities. There are about 300 identified species. 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 recent resurgence of herbal products as a part of 'green movement', Aloe vera is witnessing a new renaissance across the world. Emphasis on agricultural diversification has led to a search for alternatives that are profitable and environmental friendly. It is known by many grateful laymen as "Medicinal Plant", "Burn Plant", "First Aid Plant" or "Miracle Plant". It is mentioned both in the Holy Bible and by the ancient Egyptians. Since Aloe has naturalised throughout the warm regions around the world, it is difficult to correctly establish its origin. It is supposed to be native of North Africa or the Nile regions in Sudan (Bozzi *et al.*, 2007).

*Aloe barbadensis* Miller or Aloe vera, a semi tropical plant is commonly used for its medicinal properties. The plant has lance-shaped, sharp pointed and jagged and edged leaves. Aloe vera is found as the wild herb along the coast of South India. It is under cultivation in fairly large areas in many parts of India *viz.*, Tamil Nadu, Gujarat, Maharashtra *etc.* Aloes are often thought to only grow in hot and dry climates but they actually grow in a variety of climates including desert, grassland and coastal or even alpine locations (Jyotsna, 2009).

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 gel possesses some biological activities such as promotion of wound healing, antifungal activity, hypoglycaemic or antidiabetic effects, as well as antiinflammatory, anticancer, immunomodulatory and gastro-protective properties (Pal *et al.*, 2013).

The main constituents of the Aloe vera leaf are: (i) Aloin: It is an irritant laxative contained in the yellow sap of aloe, which is a constituent of the anthraquinone complex, (ii) Methanol Precipitable Solids (MPS): When alcohols are added to aloe solutions about 20 to 25% of the total solids come out of solution or 'precipitate'. The chemical constituents of *Aloe barbadensis* Miller consists of mainly polysaccharides, glycoprotein and salts of organic acids. The polysaccharides represent about one-half to two-thirds of the MPS or about 10 to 15% of the total solids. (iii) Polysaccharides: There are over 200 constituents in Aloe vera, the single most important constituent being the polysaccharides. Aloe vera gel contains 98.5% water having pH of 4.5 and also contains many polysaccharides such as Glucomannan, Acemannan, *etc.* in active form in the leaves of Aloe vera. Glucomannan is a good moisturizer and mainly used in many cosmetic products. Whereas, Acemannan is the major carbohydrate fraction in the gel and is water soluble long chain mannose polymer which accelerates wound healing, modulates immune function and antiviral effects (Chandegara and Varshney, 2013).

The physical and chemical composition of Aloe vera differs depending on the species, climate and growing conditions (Briggs, 1995). 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 and organic acids. Aloe vera gel contains highly nutritious bioactive constituents including anthraquinones, alkaloids, enzymes, glycoproteins, vitamins and polysaccharides along with mucilaginous polysaccharides which are the major constituents required for effective treatment of skin care as well as other therapeutic and cosmetic applications (Choi and Chung, 2003).

Aloe vera has a number of uses and mainly they are used as a food preservative and herbal medicine. Commercially, aloe can be found in pills, sprays, ointments, lotions, liquids, drinks, jellies and creams. Numerous aloe species around the world are used for conditions ranging from dermatitis to cancer. Various studies have revealed that Aloe vera leaf possesses many pharmaceutical activities including antimicrobial, anticancer, antioxidant, antidiabetic, antiulcer, hepatoprotective, immunomodulatory and many more activities. Many of the health benefits associated with aloe vera have been attributed to the polysaccharides contained in the gel of the leaves (Karkala and Bidya, 2014).

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. Aloe gel is commercialized as a powdered concentrate for use in a wide range of food products. Aloe beverages are also very popular in Korea, Singapore and Malaysia (Jyotsna, 2009). The amount of Aloe vera that finds its application in the pharmaceutical industry is not negligible as far as the manufacturing of topical ointments, gel preparations, tablets and capsules are concerned. Aloe vera gel also finds its application in the cosmetic and toiletry industries, where it is used as a base for the preparation of creams, lotions, soaps, shampoos and facial cleaners (Ramachandra and Rao, 2008).

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. The rind constitutes  $37.9 \pm 2.7\%$  and the gel fillet constitutes  $60.2 \pm 2.6\%$  from the Aloe vera leaf. The rind weight decreases to 30% of the leaf where as the gel fillet increases to 70% in leaf base of 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 (Robert, 1997). Nevertheless, the Aloe crop is still often processed by hand (Thomas, 1984).

The current global turnover of raw Aloe vera leaves amount is estimated up to 70 to 80 million US dollars. For processed derivatives and value added products, it is estimated around 1 billion and 25 billions US dollars, respectively. USA supplies the major bulk of Aloe in world market having a share of 60 to 65%. Whereas, Latin American countries supply 20 to 25% and Australia, China and India combined together have a market share of only 10% (Jyotsna, 2009).

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 using sharp knife, keeping anthraquinone level low, but in this process the most of the mucilage is left on the working table. During processing operation, the lower 25 mm of the leaf base (the white part attached to the large stem of the plant), the tapering point (50 to 100 mm) of the leaf top and the short, sharp spines located along the leaf margins are removed with the help of sharp knife. The knife is then introduced into the mucilage layer below the rind to remove top rind and similarly the bottom rind is removed (Pal *et al.*, 2013). 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.

Extraction of Aloe vera gel by machines is difficult as the leaves differ in shapes and have thorny outer edge. The manual gel extraction of Aloe vera leaves is time consuming,

tedious and also not hygienic. In the crushing method of Aloe vera leaves, ingress of other chemical compounds (high level of anthroquinone level) deteriorates the quality. The growing commercial importance of Aloe vera has resulted in the need for an efficient means of extracting the gel from the leaves of the Aloe vera plants. Advanced extraction process must emphasize cleanliness with respect to the collected gel and provision for efficient disposal of rind remaining after the extraction process.

In order to ease the processing and to reduce material loss, effective method for extraction of gel at production level was developed by M/s. Sanjeevani Phytopharma Pvt. Ltd., Mumbai, Maharashtra. The gel extraction machine consisted of two stainless steel rollers arranged in horizontal plane. The front roller has more clearance than the crushing roller. The front roller compresses the leaf while crushing roller helps in extraction of gel. The clearance between rollers can be adjusted with the help of nuts provided on top frame according to the thickness of leaves. Aloe vera gel extraction machine involves the process of crushing of trimmed Aloe vera leaves in order to obtain the gel and reduce bulkiness of the Aloe vera to obtain gel and rind. The Aloe vera gel extraction machine has high gel recovery and is fast running process that greatly reduces the manual labour. The merits of using machine for extraction are time saving, improved efficiency, increased capacity and reduction of extraction loss. Keeping in view the importance of a machine for taking out gel from the leaves of Aloe vera plant, the present investigation has been undertaken with the following objectives.

- To evaluate the performance of roller type Aloe vera gel extraction machine
- To analyze the quality characteristics of Aloe vera gel obtained from Aloe vera gel extraction machine

*Review of Literature*

## II. REVIEW OF LITERATURE

A comprehensive review is mandatory in any research endeavour. This requires thorough efforts on the part of investigator to select relevant subject matter, to organize and to report it systematically. This chapter deals with brief account of literature, which has direct and indirect bearing on the specific objectives of the investigation.

- Aloe vera plant and leaf gel
- Physical and chemical properties of Aloe vera
- Aloe vera gel extraction machine
- Gel extraction from Aloe vera pulp
- Development and performance evaluation of extraction machines
- Economics of extraction process

### 2.1. Aloe vera plant and leaf gel

According to Femenia *et al.* (1999) Aloe vera (*Aloe barbadensis* Miller) was a traditional medicinal plant, used in food, pharmaceutical and cosmetic industries. Aloe vera leaves were formed by a thick epidermis (skin) covered with cuticle surrounding the mesophyll, which can be differentiated into chlorenchyma cells and thinner walled cells forming the parenchyma (inner layer). The parenchyma cells contain a transparent mucilaginous jelly, which is referred to as Aloe vera gel. Gel contains 97 to 98% of water and more than 60% of dry matter is made up of polysaccharides. The gel is a colourless, odourless, hydrocolloid with several natural beneficial substances. Aloe vera is an industrial crop and in the food industry, it has been utilized for the preparation of health food drinks, beverages like tea, milk, ice-cream and confectionary.

Efterpi and Panagiota (2010) revealed that Aloe vera is a plant for many uses. Aloe leaves can be separated into two basic products: the latex, a bitter yellow liquid beneath the epidermis of the leaf and the gel, a colourless and tasteless substance in the inner part of the leaf. Both of them have many biologically active components, mainly anthraquinones and polysaccharides (the most active is acemannan), which might act alone or in synergy. Scientific studies provide support for the application of Aloe vera in cosmetic-moisturizers, toothpastes and food as flavouring compounds or preservative of fresh products and in medicine of humans or animals. Aloe vera seems to treat a variety of conditions because of its

wound healing, anti-inflammatory, immunity, antidiabetic, antioxidant, laxative, antibacterial, antifungal, antiviral and antitumor effects.

Urvashi and Raju (2012) and Gomathi *et al.* (2014) stated that *Aloe barbadensis* Miller was used for human nutrition, health, cosmetic and medicinal purposes like confection, lotion and juice, useful remedies for curing various diseases. Aloe contains mixture of glucosides collectively called 'aloin' which is the active constituent of various drugs. Indian Aloe (*Aloe barbadensis* Miller) is a rich source of over 200 naturally occurring nutrients such as vitamins, minerals, sugars, amino acids, enzymes and acids, which helps in digestion. Aloe vera juice has cooling properties, is anabolic in action, a fighter of 'pitta', storehouse of phytochemicals and guards against fever, skin diseases, burns, ulcers, boils eruptions *etc.* Commercially, Aloe can be found in pills, sprays, ointments, lotions, liquids, drinks, jellies and creams, to name a few of the thousands of products available.

Karkala and Bidya (2014) revealed that the Aloe vera plant is grown today commercially with *Aloe barbadensis* Miller and *Aloe arborescens* being the most popular. *Aloe barbadensis* Miller has been medicinally used for an array of ailments such as mild fever, wounds and burns, gastrointestinal disorders, diabetes, sexual vitality and fertility problems to cancer, immune modulation, AIDS and various skin diseases. In the pharmaceutical industry, it has been used for the manufacture of topical products such as ointments and gel preparations, as well as in the production of tablets and capsules.

Aloe vera has medicinal properties, is a tropical and subtropical plant that has been used from ancient time. The gel of Aloe vera leaves is the colourless mucilaginous, obtained from the parenchymatous cells. Application of Aloe vera gel in the food industry is increasing day by day as resource of drinks, beverages and ice creams (Chauhan *et al.*, 2014). Aloe vera gel (5.0% and 10.0%) treatments led to grapes with better freshness without browning symptoms and lower decay incidence after 40 days of cold storage. Aloe vera gel contains bioactive molecules present in Aloe vera such as Aloe-emodin and Aloenin have shown antifungal activity against *Aspergillus*, *Cladosporium* and *Fusarium* (Chauhan *et al.*, 2014a).

## **2.2 Physical and chemical properties of Aloe vera**

Gowda (1979) reported that after harvest of Aloe vera leaf, the viscous pseudoplastic nature of Aloe vera gel, mainly due to the presence of polysaccharides composed of a mixture of acetylated glucomannans was lost shortly after extraction, apparently due to enzymatic degradation. This shows there are some biological activities, which related to the visco-elastic behaviour of gel.

According to Reynolds and Dweck (1999), Femenia *et al.* (1999) and Basmatker *et al.* (2011), Aloe vera contains more than 200 compounds and about 75 of which have biological activity. The prominent components are anthraquinones, aloin, aloemodine, polysaccharides, enzymes, reducing sugars, organic acids and metallic cations. The Aloe vera gel or fillet, which is stored in the inner portion of the leaves, contains 99.50% water and 0.50% solid matter.

Wang and Strong (1993) studied the physical properties of Aloe vera leaves and reported that the average weight of the individual leaves was ranging from 387 to 704 g, length 48 to 60 cm, width 8.9 to 11.5 cm and optical density 1.020 to 1.437 (abs).

Joshi (1998) had given the chemical constituents of Aloe vera barbadensis. The aloe plant contains 99 and 99.5 per cent water, with an average pH of 4.5. The remaining solid material contains over 75 different ingredients including vitamins, minerals, enzymes, sugars, anthraquinones or phenolic compounds, lignin, saponins, sterols, amino acids and salicylic acid.

Active components with its properties: Aloe vera contains 75 potentially active constituents: vitamins, enzymes, minerals, sugars, lignin, saponins, salicylic acids and amino acids. The details of the different constituents of Aloe vera as reported by Atherton (1998) and Basmatker *et al.* (2011) is explained hereunder.

- Vitamins: It contains vitamins A (beta-carotene), C (ascorbic acid) and E (Tocopherol), which are antioxidants. It also contains vitamin B12 (Cyanocobalamin), folic acid and choline. Antioxidant neutralizes free radicals.
- Enzymes: It contains eight enzymes: amylase, alkaline phosphatase, bradykinase, carboxypeptidase, catalase, cellulase, lipase and peroxidase. Bradykinase helps to reduce excessive inflammation when applied to the skin topically, while others help in the breakdown of sugars and fats.
- Minerals: It contains calcium, chromium, copper, selenium, magnesium, manganese, potassium, sodium and zinc. They are essential for the proper functioning of various enzyme systems in different metabolic pathways and few are antioxidants.
- Sugars: It contains monosaccharides (glucose and fructose) and polysaccharides (glucomannans/polymannose). These are derived from the mucilage layer of the plant and are known as mucopolysaccharides. The most prominent monosaccharide is mannose 6-phosphate and the most common polysaccharides are called glucomannans

[ $\beta$  (1, 4) acetylated mannan]. Acemannan, a prominent glucomannan has also been found. Recently, a glycoprotein with antiallergic properties called as alprogen and novel anti-inflammatory compound, glucosyl chromone, has been isolated from Aloe vera gel.

- Anthraquinones: It contains 12 anthraquinones, which are phenolic compounds traditionally known as laxatives. Aloin and emodin act as analgesics, antibacterials and antivirals.
- Fatty acids: It contains 4 plant steroids; cholesterol, campesterol,  $\beta$ -sisosterol and lupeol. All these have anti-inflammatory action and lupeol also possesses antiseptic and analgesic properties.
- Hormones: Auxins and gibberellins that helps in wound healing and have anti-inflammatory action.
- Others: It contains 20 of the 22 human required amino acids and 7 of the 8 essential amino acids. It also contains salicylic acid that possesses anti-inflammatory and antibacterial properties. Lignin, an inert substance, when included in topical preparations, enhances penetrative effect of the other ingredients into the skin. Saponins that are the soapy substances form about 3% of the gel and have cleansing and antiseptic properties.

Femenia *et al.* (1999) have examined the compositional features of polysaccharides from Aloe vera (*Aloe barbadensis* Miller) plant tissue. They reported that Aloe plant portions contained high amount of water. The skin and fillet fractions contained approximately 90 and 98% of water, respectively, the extracted gel containing over 99% of water. Extraction with ethanol of lyophilised aloe fractions, allowed concentrating the major fraction composed of polysaccharides upto 80%. Mannose and cellulosic glucose were the major polysaccharide components, significant amounts of pectic polysaccharides were detected, sequential extraction of polysaccharides present in Aloe vera plant portions, revealed that two main types of mannose-containing polymers were present in the Aloe vera plant.

Hernandez *et al.* (2002) conducted a study on Aloe vera response to plastic mulch and nitrogen. In this study, the fresh weight of leaf and shape of Aloe vera leaf was estimated. Leaf volume was calculated by using an empirical equation containing leaf length, width and thickness. Leaf geometry was considered to be a cone with elliptical shape rather than circular

cross section. Volume was calculated as  $L/12(\pi wt)$  where L, w and t are length, width and thickness of leaf, respectively. The study found that average leaf weight was 228 g.

Hu *et al.* (2003) carried out the experiments on evaluation of antioxidant potential of Aloe vera (*Aloe barbadensis* Miller) extract and reported that the three year old Aloe vera had 4.70 g per kg flavonoid content, which was significantly higher than that of two year old Aloe vera at 3.36 g per kg and also three-year old Aloe vera possessed significantly higher contents of polysaccharide and flavonoids than those of two and four year old Aloe vera.

Choi and Chung (2003) wrote a review on relationship between the isolated Aloe vera components (*i.e.*, glycoproteins, anthraquinones, saccharides, low-molecular weight substances and their presumed pharmacological activities). They concluded that Aloe vera contains many physiologically active substances that have effective anti-inflammatory, immunomodulatory and wound healing effects.

Eshun and He (2004) reviewed the chemical and physiological properties of Aloe vera gel and concluded that the further research needs to be done to unravel the myth surrounding the biological activities and the functional properties of Aloe vera. They also concluded that appropriate processing techniques should be employed during the stabilization of the gel in order to affect and extend its field of utilization.

Qian *et al.* (2005) developed the various steps for quality assurance in Aloe vera juice processing. The study revealed that the various critical control points for quality assurance were addition of vitamin-C, citric acid and pasteurization apart from raw materials, filleting operation, drying, grinding or homogenization, pectolytic enzyme addition, filtration, deaeration, flash cooling and storage.

Chang *et al.* (2006) conducted the research on the gel juice from Aloe vera to investigate the effect of heat treatment on bioactive substances including polysaccharide and barbaloin and concluded that the polysaccharide from Aloe vera exhibited a maximal stability at 70 °C decreasing either at higher or lower temperatures and heating promoted a remarkable decrease in barbaloin content depending on temperature and time, more affected than polysaccharide of the gel juice from Aloe vera.

Gautham and Awasthi (2007) standardized the process for making Aloe vera leaf powder and its nutrition and physico-chemical characteristics were assessed. They concluded that Aloe vera leaf powder contained many nutrients, antioxidants, dietary fibre and iron and other physico-chemical properties. The recovery of Aloe vera leaf powder on drying of fresh

Aloe vera leaves was 3.2%. Aloe vera leaf powder contained 18.5% of crude fibre, 4.8% of crude protein, 2.2% of crude fat, 14.0% of polysaccharides and 231 kcal energy values. They stated that, the Aloe vera leaf powder could be used as a functional ingredient in many food preparations by food processing industries which will provide medical and therapeutic value to food.

Ramachandra and Rao (2008) investigated processing techniques for producing best quality aloe products since end aloe products contained very little or virtually no active ingredients, so it has become very important to evolve a better method of preservation for increasing the shelf life and maintaining the quality of Aloe vera gel. Hence, to extend the use of Aloe vera gel, appropriate processing techniques should be employed during processing. This review has revealed Aloe vera as a highly potential functional and valuable ingredient that exhibit relatively impressive biological functions of great interest in cosmetic, pharmaceutical and food industries.

Margarita *et al.* (2009) carried out the investigation on total polysaccharides content, physico-chemical, nutritional properties and antioxidant capacity of Aloe vera (*Aloe barbandensis* Miller) gel. It was also suggested that the stability of various nutritional and functional quality parameters in rehydrated Aloe vera gel depended mostly on the temperature used during the drying process, with increased nutrient loss observed at 80 and 90 °C. Colour variation in dehydrated Aloe vera gel in terms  $L^*$  and the chromatic coordinates  $a^*$  and  $b^*$ . They concluded that at a drying temperature of 80 or 90 °C, the amount of colour variation was greater than that in the sample dried at 50, 60 and 70 °C. The samples dehydrated at 80 or 90 °C, showed the highest total colour variation compared to the fresh samples, due to the effect of temperature on the heat sensitive compounds such as carbohydrates, proteins and vitamins, which cause colour degradation in fresh foods. The optimized drying temperature for Aloe vera gel was in between 60 and 70 °C. They reported that the content of crude fibre, calcium, vitamin C and the antioxidant capacity were decreased in the rehydrated samples compared to fresh Aloe vera gel.

Elena *et al.* (2010) carried out the investigation on Aloe vera as a functional ingredient in foods. Aloe vera gel contained mannose polymers with some glucose and other sugars, among which the most important was Acemannan. They reported that a wide variety of nutrients and nutrient compounds were present in low concentrations such as vitamins, minerals, phenolics and organic acids in Aloe vera. There are many factors which influence the chemical composition of Aloe vera gel and therefore the efficiency depends on species or

subspecies or varieties, climate and exposure to light, land and irrigation and cultivation methods.

Lad and Murthy (2013) reported the rheological characteristics of native Aloe vera gel and juice under dynamic and steady shear. The damping of the elastic moduli and viscous moduli at various temperatures for the Aloe vera gel under oscillatory shear tests have been reported, for the first time, which were observed due to the presence of weak, fibrous and random structure of polysaccharides in it. The complete deformation of the structure of polysaccharides present in the pulp of Aloe vera leaves has been found responsible for such kind of rheological properties of the Aloe vera gel and juice. This is also confirmed by viscosity tests which showed the decrease of viscosities of the gel and juice at various temperatures. It is found that the gel and juice exhibited the shear thinning behaviour at comparatively low shear rates before reaching to the plateau region. The moduli for gel increased with increasing temperature and that for juice decreased with temperature. Prior to attaining the plateau region after certain shear rate, Aloe vera gel and juice exhibited shear thinning behaviour. The flow behaviour index for Aloe vera gel samples was found to be 0.1 in the shear thinning region.

Haque *et al.* (2014) conducted an experiment to evaluate the amount of dietary inclusion of Aloe vera leaves. Many of the health benefits associated with Aloe vera have been attributed due to the presence of protein, carbohydrate, fat *etc.* in the gel of the leaves. Proximate analysis of the dried Aloe vera leaves revealed fat (1.83%); protein (10.50%); ash (19.50%); carbohydrate (56.27%); phosphorous (1.90 mg. g<sup>-1</sup>) and energy (290.08 kcal).

### **2.3 Aloe vera gel extraction machine**

Thompson (1983) developed an Aloe vera gel separator and obtained a patent on it (Fig.1). The machine was designed to transport the leaf on a first endless belt conveyor on which the leaf is laid lengthwise and flat on the conveyor belt. A second endless belt travels in the same direction and at the same speed as the first endless belt conveyor but is disposed at a right angle to the first endless belt conveyor at the feed end of the apparatus. With the leaf standing on its edge between the two endless belt conveyor, the same was fed into the apparatus where the leaf will be cut into two half sections and thereafter the gel within the leaf will be squeezed and the gel was recovered.

Thomas (1984) developed a method and apparatus for extracting the gel from aloe leaves without contaminating the gel with toxic juices. The Aloe vera leaves are washed, trimmed and fed to the hopper. The leaves will undergo to and through motion of a blade, which longitudinally bisects through pressing rollers, which advance the rind but retain the

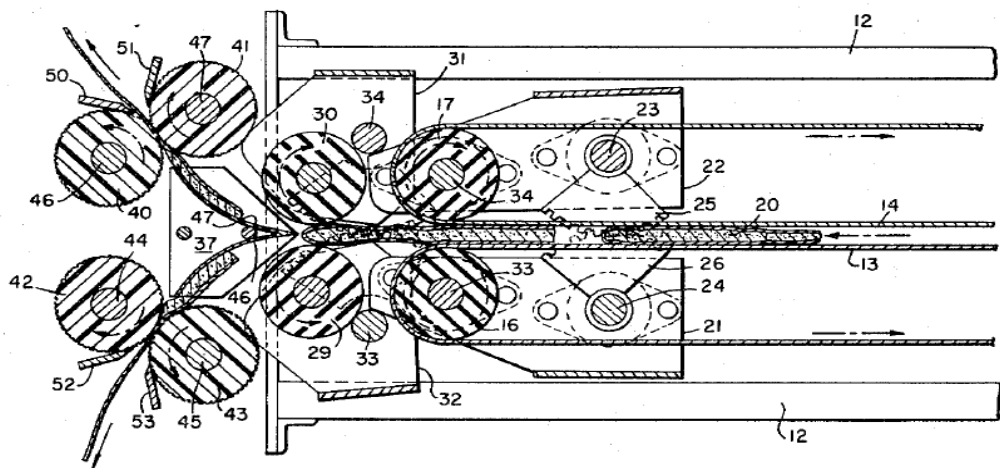


Fig. 1 Aloe vera gel separator

gel that falls from the pressing rollers into a collection pan. The unique mechanized action was suited to permit frequent cleaning of the machinery as shown in Fig. 2.

Larry (1985) obtained a patent on “method and apparatus for extraction of Aloe vera gel”, (Fig. 3). In which, the harvested leaves of the Aloe vera leaves are placed between a pair of endless moving belts. The leaves are passing through a number of crushing rollers arranged in a desired pattern. The rollers first crush the core of the leaf to enable the gel to flow internally while a second set of rollers extrudes the gel from the leaf. The crushed leaf and extruded gel is then fall on a drain grate to enable gravity flow for the separation of gel from the crushed leaves. The proper slope is provided to the drainage grate, so that the leaves will slowly move across the drain grate to enable separation of the gel. The leaves are removed from the gel collection area before it mixes with the flowing aloin to avoid contamination.

William (1986) obtained an US patent on “Aloe vera leaf processor”, (Fig. 4) in which an elongated conveyor assembly was provided upon which an Aloe vera leaf advances lengthwise from one end of the conveyor to the other end. The edge cutting, rind panel peeling and gel removal operations were carried out during continuous movement of the leaf along the conveyor assembly at a substantially constant rate.

Anonymous (2007) developed an Aloe vera gel extractor by providing tolerance in between the crushing rollers, so that only the gel is just extracted and over-crushing of the leaves is avoided. The capacity of the extractor was 60 to 80 kg.h<sup>-1</sup> of leaves. The machine is shown in Fig. 5.

Khambalkar *et al.* (2007) developed Aloe vera gel extractor. It consisted of shaft cum roller, bearing and housing frame, discharge chute and a transmission unit. The cleaned leaf was fed between the roller and rotation of the handle causes the gradual expression of the gel. Extraction capacity of the machine was found to be 3.923 kg.h<sup>-1</sup> of leaves giving 91.2% extractability and recovery of gel was found to be 52%.

#### **2.4 Gel extraction from Aloe vera leaf**

Anon (1967) carried out the gel extraction from Aloe vera leaves, remaining after the removal of its exudates were cut upon and its mucilage was scraped out with blunt edged knife. This mucilage was stirred vigorously in a blender to make it uniform. This solution was strained through a muslin cloth and filtered. This uniform solution was extracted for Cold-Extracted Gel (CEG) and Hot Extracted Gel (HEG).





**Fig. 5 Aloe vera gel extractor**

Waller *et al.* (1978) reported the gel extraction process. As Aloe leaves rapidly lose their medicinal properties, the material used was either fresh or lyophilized and stored at  $-15\text{ }^{\circ}\text{C}$ . *Aloe barbadensis* leaves (35 g equivalent of dry material) were macerated and extracted with water-acetone (1:1) and then acetone at room temperature. The combined extracts (2:1) were concentrated in a rotary evaporator ( $35\text{ }^{\circ}\text{C}$ ) and the acetone free residue was extracted three times with diethyl ether (250 ml per each time).

Yaron (1993) extracted gel from full sized mature leaves and half size young leaves picked from the same shrub. After removal of the 'peel' the colourless hydroparenchyma was ground in a blender and centrifuged at 10,000 rpm for 30 min at  $4\text{ }^{\circ}\text{C}$  to remove the fibres. Leaves weighing 800 g produced about 300 ml of gel.

Shafi *et al.* (2000) developed a commercially viable process for preparing a stable and pharmacological active crystalline substance from the fresh whole leaf meal and tested the product on experimental animals and volunteers for wound healing remedy for all kinds of all damaged skin conditions.

Chandegara and Varshney (2014) studied on effect of centrifuge speed on gel extraction from Aloe vera leaves. centrifuge speed, *i.e.*, 2000, 5000 and 10,000 rpm at different temperature *i.e.*,  $5\text{ }^{\circ}\text{C}$ ,  $10\text{ }^{\circ}\text{C}$  and  $32\text{ }^{\circ}\text{C}$  (ambient) ) and centrifuge holding duration *i.e.* 10, 20 and 30 min, on gel recovery and quality parameters like, viscosity of gel, refractive index of gel, was studied. An effort was made to optimize the centrifuge speed for gel extraction from Aloe vera leaves. It was concluded that the extraction of gel from Aloe vera should be carried at 10000 rpm speed,  $5\text{ }^{\circ}\text{C}$  temperature and 30 min duration, which yielded higher gel recovery and better quality of gel. Higher centrifuge speed resulted in more separation of gel molecules and fibres from Aloe vera pulp to get clear gel.

## **2.5 Development and performance evaluation of gel and juice extraction machines**

Hendrex (2005) conducted an experiment on development of low-cost fruit juice extraction technologies. On-station performance evaluation showed that two simple hand-operated fruit juice extractors; Horizontal Extractor and Vertical Extractor were developed to increase fruit utilization and minimize post harvest losses in Malawi. The two treatments were machine type-horizontal versus vertical ( $T_1$ ) and fruit type ( $T_2$ ) in which 12 kg of fruit sample was used in turns. Comparative performance between the two machines showed that horizontal scored 7 to 35  $\text{l}\cdot\text{h}^{-1}$  at 61 to 82% and vertical ranged 10 to 36  $\text{l}\cdot\text{h}^{-1}$  at 63 to 85%, extraction capacity and efficiency, respectively. On-farm evaluation showed that 1256 farmers practiced both machines using a total fruit quantity handled of 121 metric

tonnes (50% of which was handled by each machine) up on which a mean volumetric throughput  $180 \text{ kg.h}^{-1}$  was obtained. The results above concluded that with the fruit extraction technology, it is possible and very sustainable to extract fruit juice for small-scale fruit juice production under both urban and rural conditions.

Kailappan *et al.* (2005) fabricated and tested a tomato seed extractor. The unit consisted of a fruit squeezing chamber parts such as feed hopper, rotor shaft, screw auger, outer cover, power transmission system, motor and frame and also seed separation unit. The performance of the machine was tested by varying parameters such as feed water flow rate (5, 7.5 and  $10 \text{ l.min}^{-1}$ ), rotor shaft speed (50, 100, 150 and 200 rpm) and auger length (240 and 340 mm). The highest seed extraction efficiency (98.8%) was at  $7.5 \text{ l.min}^{-1}$  water flow rate, 340 mm auger length and 150 rpm shaft speed. A tomato seed extractor having a capacity of 180 kg of fruits per hour or 1.8 kg of tomato seed per hour.

Kasozi and Kasisira (2005) designed and evaluated a banana juice extractor. Banana juice extractor machine used to extract the juice from peeled bananas (*Mussa sp.*) mixed with spear grass was designed and constructed. This extractor can either be manual or motorized with a designed power requirement of 0.23 kW. The amount of banana taken was 5 kg. Results indicated that the volume of juice concentrate obtained was 1.38 l and time taken was 8.54 min in case of machine juice extraction, whereas for manual extraction the juice concentrate obtained was 0.81 l and time taken was 35.3 min. The machine extraction efficiency was about 47% as compared to about 69% for traditional manual method. However, the manual juice extraction time was 4 times that of the machine but extraction machine is time saving as compare to manual method.

Balakrishnan *et al.* (2006) developed and tested a chilli seed extractor. The chilli seed extraction machine consisted of a feed hopper, beater with auger assembly, concave with cover, stand and electric motor. It was operated by a 1 hp single-phase electric motor. Seed extraction was carried out for feed rates of 50, 60 and  $80 \text{ kg.h}^{-1}$  and peripheral speeds of 480, 520 and  $560 \text{ m. min}^{-1}$  of the beater. The test results of the machine showed that optimum peripheral speed of  $480 \text{ m.min}^{-1}$  and feed rate of  $60 \text{ kg.h}^{-1}$  was selected to obtain a maximum extraction efficiency of 94% with 91% of germination.

Thirupathi *et al.* (2006) developed and tested a tomato pulper cum strainer. The pulper cum strainer unit consisted of components such as feed hopper, stainless steel rotor shaft, outer stainless steel cylinder, inner stainless steel perforated cylinder, stainless steel blade and nylon brush, discharge outlet and motor. Electric motor of 1 hp was selected to drive the rotor

shaft. The maximum pulp extraction efficiency for local variety was 91.0% by hot pulping at a peripheral speed of  $47.1 \text{ m.s}^{-1}$ . The maximum pulp extraction efficiency for hybrid variety was 92.3% by hot pulping at a peripheral speed of  $47.1 \text{ m.s}^{-1}$ . The capacity of the unit was  $110 \text{ kg.h}^{-1}$ .

Abulude *et al.* (2007) designed, developed and evaluated electrically operated orange and pineapple juice extractor. The electrically operated extractor was simple but the epileptic power supply is a limiting factor for its use. Performance evaluation was carried out with the production of orange and pineapple juices. The results showed that the machine produced efficiencies of 83.86 and 83.38% and extraction capacities of  $1.29 \text{ kg.h}^{-1}$  and  $1.23 \text{ kg.h}^{-1}$  for orange and pineapple juices, respectively.

Oyeleke and Olaniyan (2007) evaluated a small scale multi-fruit juice extractor to determine the juice yield of orange, grape, tamarind, water melon and pine apple. The washed and sliced (2, 3, 4, 5 and  $6 \text{ cm}^2$  sizes) fruits were processed by using fruit juice extractor. The slices were processed by the extractor at 1.5 kg per batch to extract the juice. Results obtained that percentage of maximum juice yields of orange, grape, tamarind, water melon and pineapple were 76.00, 83.30, 82.75, 96.00 and 71.40%, respectively. Extraction efficiencies of orange, grape, tamarind, water melon and pineapple was 86.30, 95.20, 94.10, 98.00 and 81.30% with corresponding extraction losses of 3.30, 20.00, 3.30, 10.00 and 6.70%, respectively for slices size of  $2 \text{ cm}^2$ . The juice extracted from orange, tamarind, water melon and pineapple showed acid contents of 7.71, 7.08, 27.02, 6.20 and  $11.52 \text{ mg.ml}^{-1}$ , respectively with corresponding pH of 3.23, 4.21, 4.00 and 4.07, respectively and juice temperature ranged between 30 to  $32 \text{ }^\circ\text{C}$  for all the juice extracted. To achieve efficient extraction,  $2 \text{ cm}^2$  size of fruit slices was recommended for multi fruit juice extractor.

Ajao *et al.* (2009) designed, fabricated and evaluated the performance of a groundnut oil expelling machine. The machine components were speed reduction gear, expellant unit, drains collector, driving and driven pulleys and the hopper. The expelling unit consists of a screw expellant shaft with expellant barrel. The expeller is driven by a 3 hp electric motor via a reduction gear. The machine gave a better performance at the speed of 60 revolutions per minute (rpm).

Hussain *et al.* (2010) developed a machine for cold pulping of tomato, the study was taken up to investigate the existing methods of tomato processing for pulp and fabricate an indigenous machine which might operate under room temperature to isolate pulp, seed and peel from fresh tomato without heating activity. The machine consists of a hopper, 2 stainless

steel serrated rollers (26 cm diameter and 30 cm length), gear shaft, stand frame, variable speed gear electric motor (0.746 kW (900 rpm)), casing with screen spinner. Machine parameters, such as the roller surface (flat and serrated), variation in roller clearance and rotational speed were employed for experimentation of cold pulping of tomato. The quality and recovery of pulp and seed were tested to establish the performance of the machine for cold pulping. Greater pulp rate (483.71 g.min<sup>-1</sup>; 90% pulp approx.), 8% seed and 2% peel were obtained in case of red ripe tomatoes because of their lower rupture strength than the ripe once. Greater rotational speed and larger diameter of rollers resulted in more pulp recovery while roller clearance played an inverse role, yielding less pulp recovery in case of larger clearance. Higher pulp production was achieved by serrated rollers rather than that with flat or plain rollers.

Olaniyan (2010) developed a small scale orange juice extractor. The essential components of the machine were feeding hopper, top cover, worm shaft, juice sieve, juice collector, waste outlet, transmission belt, main frame, pulleys and bearings. The worm shaft conveys, crushes, presses and squeezes the fruit to extract the juice. The juice extracted is filtered through the juice sieve into juice collector while the residual waste is discharged through waste outlet. Result showed that the average juice yield and juice extraction efficiency were 41.6 and 57.4%, respectively. Powered by a 2 hp electric motor, the machine has a capacity of 14 kg.h<sup>-1</sup>, with a machine cost of about US\$100.

Olaoye (2011) developed a small scale sugarcane juice extractor. It was a simple mechanical device for extraction of sugarcane juice. The machine efficiency increased with an increase in peripheral speed. The functional performance and economics operations of the machine were evaluated. The output capacities of 10.50, 12.00 and 14.25 kg.h<sup>-1</sup> were obtained at operating speeds of 0.25, 0.3 and 0.36 m.s<sup>-1</sup>. The extraction efficiency of the machine ranged between 40 and 61% at operating speeds of 0.25 and 0.36 m.s<sup>-1</sup>.

Raji and Olofin (2011) designed and developed a machine for extraction of protein juice from a highly proteinous leaf and fruit. The machine is family-sized with low power requirement, easy to operate and fast. The percentage of juice obtained from the leaf and pineapple fruit, respectively 38.6% and 63.6%, with about 2.1% and 1.1% materials retained within the machine. The machine has extraction efficiencies of 97.9 and 98.9% for leaf and pineapple. Because of pineapple has higher moisture content and is softer to compress than leaves.

Aye and Ashwe (2012) developed a manually operated household orange juice extractor. The dimensions are 160 mm diameter and 350 mm height. The machine combines the actions of chopping and beating, often by macerating. It consists of two main parts such as goblet (1 mm thickness of mild steel sheet) and a manually operated mechanical unit (consists of a pair of bevel gears, two bearings and two shafts). The bevel gear casing was constructed using 2 mm thickness of mild steel sheet. Small sharpened blades were then made and fixed onto the impeller shaft. A bearing was then fixed underneath and a shaft passed through. A dynamic seal was put between the shaft, bearings and goblet to prevent leakage. The connection between the gear casing and goblet was done by means of an Oldham coupling designed for misalignment. The machine can extract the juice of about 180 to 220 oranges per hour. It can be easily operated and its efficiency is very high.

Akkinnuli *et al.* (2013) designed, developed and evaluated the performance of an indigenous honey extractor. It contains chain driven system (sprockets) of small diameter of 55 mm and big diameter of 343 mm and teeth number of 18 and 113, respectively with chain pitch of 99.525 mm. The chain system was mounted on a vertical central solid shaft of diameter 25 mm to this shaft was the honey comb net bucket of hexagon shape with six segments was welded. A full turn will give the net bucket housed in a cylindrical container (drum) speed of 200 rpm when loaded, while driven force is 0.7054 N. The volume of honey collected was 9.0 litres while the one collected from imported honey extractor was 11.0 litres when 15 kg of honey comb was used to till their net baskets under the same number of turns. This proved the local fabricated extractor to be 82% relative efficient. The cost of production was 25000 Naira (US\$155.28).

Ndubisi *et al.* (2013) developed and evaluated a multi fruit juice extractor. The extractor was designed to extract juice based on the principle of compression and shear due to the action of conveyor housing and screw conveyor. Performance analysis showed that type of fruit and peel condition significantly influenced the performance indices at 1% level of significance. Results showed that percentage of juice yield for peeled and unpeeled pineapple, orange and water melon was 79.1 and 68.7%, 77 and 69.2% and 89.5 and 89.7%, respectively. Extraction efficiency was respectively, 96.9, 94.3 and 96.6% for peeled pineapple, orange and water melon and their respective unpeeled value was 83.6, 84.2 and 97.1%. The extraction loss of peeled and unpeeled fruits was respectively, 2.1 and 2.7% (pineapple), 2.1 and 2.5% (orange) and 2.9 and 2.6% (water melon). The machine was found to be efficient in extracting juice from water melon, pine apple and orange.

Naik and Annamalai (2013) studied the relation between textural properties like penetration and cutting force with respect to gel distribution in Aloe vera leaves. The gel distribution percentage was 24.11, 27.30 and 38.40%, respectively in top, middle and bottom regions of Aloe vera plant, indicating that leaves from bottom region of the plant only needs to be harvested for increased gel extraction. The study using the textural analyzer revealed that during the process of removal of the spikes from the Aloe vera leaves, the cutting of outer spikes in vertical direction required only 9 to 11% of cutting force when compared to the horizontal direction, which would be helpful in developing a suitable cutting tool for mechanization. Low temperature storage of  $5\pm 1$  °C for 24 h made the Aloe vera leaves harder requiring greater penetration and cutting forces.

Adebayo *et al.* (2014) designed, developed and evaluated motorized pineapple juice extractor. The two operating factors used for evaluating this machine were extraction speed (S) at three levels (*i.e.*,  $S_1=565$  rpm,  $S_2=478$  rpm and  $S_3=380$  rpm) and feed rate (F) at three levels (*i.e.*  $F_1=0.5$  kg.min<sup>-1</sup>,  $F_2=1.0$  kg.min<sup>-1</sup> and  $F_3=1.5$  kg.min<sup>-1</sup>). Each of these factors was replicated thrice, which resulted into 3×3×3 factorial experimental design. The performance evaluation results obtained from this experimental design shows an optimum juice extraction efficiency of 87.50%, juice extraction capacity of 26.70 l.h<sup>-1</sup> with juice extraction losses of 12.50%. The optimum output of motorized juice extractor was compared with that of manual extraction method which was evaluated to have manual juice extraction efficiency of 97.00%, manual juice extraction capacity of 5.25 l.h<sup>-1</sup> and manual juice extraction losses of 3.08%. Hence, motorized juice extractor was rated to be five times faster than human method of extracting juice from fruits. Although, the extraction losses of motorized juice extractor type was observed to be slightly higher than that of manual extraction method.

Olaniyan and Obajemihi (2014) designed, developed and tested a small scale mango juice extraction machine. The major components of the machine included hopper, perforated drum, screw conveyor, juice outlet, waste outlet, frame, electric motor and motor stand. Other components included screw shaft, the juice collector, top cover and the transmission system. Results obtained showed an average juice yield, extraction efficiency and extraction loss of 34.56%, 55.14% and 10.15%, respectively. The extraction machine was powered by a 2.5 hp single-phase electric motor and machine has a production cost of US \$565 with the construction materials being locally available at affordable costs.

Chandegara and Varshney (2014a) designed and developed an Aloe vera gel expulsion machine. The leaf splitting unit consists of grip roller, reciprocating blade, rotary disc and

eccentric drive. The leaf was inserted between two grip rollers and splitting into 2 halves carried out by reciprocating knife. The splitting unit was tested for its performance at seven levels of roller speeds (45, 60, 75, 90, 105, 120 and 135 rpm) and three levels of leaf thickness (<25 mm, 25-30 mm and >30 mm) for gel recovery, residual gel percentage and gel expulsion efficiency. The developed Aloe vera leaf splitting unit had eliminated the manual contact in processing of Aloe vera gel and prevented contamination during gel expulsion process. The problem of mixing of gel with chemical compound from Aloe leaf skin in crushing method was reduced. It was concluded that for getting maximum gel recovery, minimum residual gel percentage, highest expulsion efficiency and output capacity, the leaves should be split in splitting unit and the Aloe vera gel expulsion should be carried out at 75 rpm roller speed for 25 to 30 mm thickness of Aloe vera leaves.

Kehinde (2015) developed and tested a sugarcane juice extraction machine. The machine consists of the housing, shaft, bearings, keys, pulleys, rollers, hopper, v-belt, adjusters and gears electric motor *etc.* The performance tests carried out on the developed machine showed an efficiency of 65%. A sugarcane crushing and squeezing machine with a capacity of 360 kg.h<sup>-1</sup>. The development machine possesses simplicity in operation and maintenance costs and with reliable efficiency.

## **2.6 Economics of extraction process**

Kehinde *et al.* (2015) developed a sugarcane juice extractor for small scale industries. A sugarcane crushing and squeezing machine with a capacity of 360 kg.h<sup>-1</sup> was developed and tested; the production cost of the machine is \$520 at an exchange rate of #197:00 to a dollar. The development machine possess simplicity in operation and maintenance, as well as being affordable with low running and maintenance costs and with reliable efficiency.

## *Material and Methods*

### **III. MATERIAL AND METHODS**

This chapter deals with the approach followed to accomplish the objectives of the present investigation on 'Performance evaluation of roller type Aloe vera gel extraction machine'. The materials used in the experimentation, instruments, method used for performance evaluation of roller type Aloe vera gel extraction machine, methodology for measurement of various quality parameters for Aloe vera gel were described in this chapter.

#### **3.1 Selection of raw material**

Fresh whole Aloe vera (*Aloe barbadensis* Miller) leaves of 3-year old plant were collected from Agricultural Research Station, Hagari, Ballari district of Karnataka. Homogenous leaves were selected according to the size, ripeness, colour and freshness, which were then used as the raw material for the experimentation.

#### **3.2 Instrumentation**

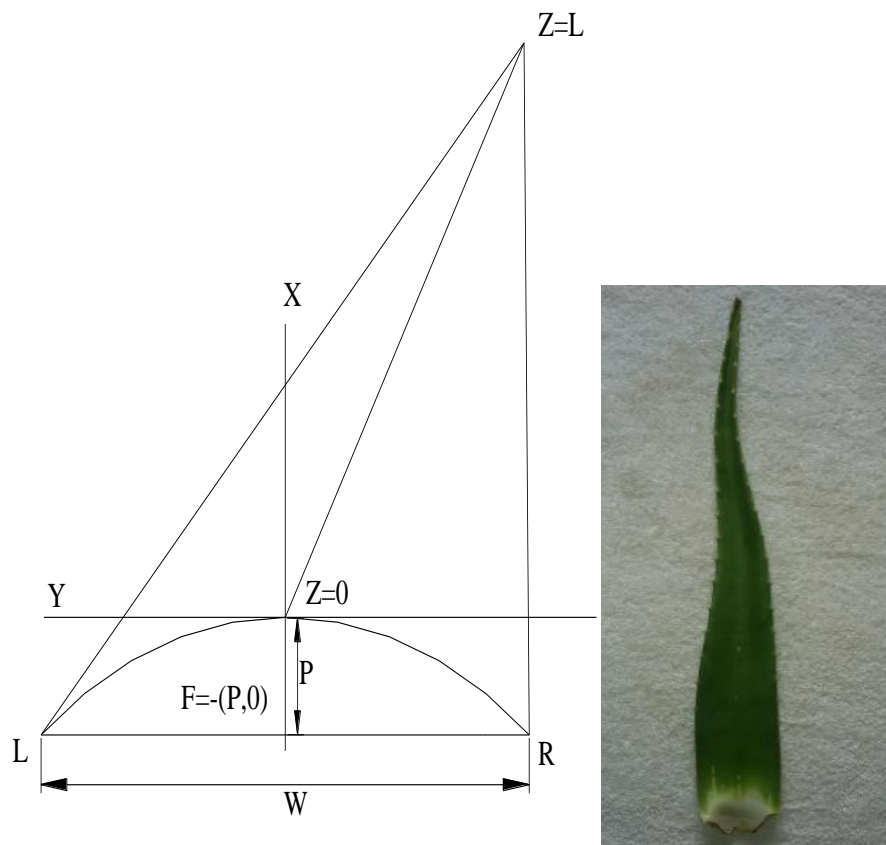
The equipment used for carrying out the performance evaluation of extraction machine were Aloe vera washing machine, Aloe vera gel extraction machine, Variable Frequency Drive (VFD) for varying the roller speed of Aloe vera gel extraction machine, weighing balance for weighing the chemicals, samples, *etc.*, hot air oven for determination of moisture content of Aloe vera gel, Kjeldhal unit to determine the protein content of Aloe vera gel, Soxhlet apparatus to determine the fat content of Aloe vera gel, double beam spectrophotometer for determination of carbohydrates content of Aloe vera gel, muffle furnace to determine ash content of Aloe vera gel, water activity meter to determine water activity of Aloe vera gel, pH meter to determine pH of Aloe vera gel, Hunter lab colourimeter for measurement of colour values of Aloe vera gel and Anton Paar Rheometer to determine viscosity of Aloe vera gel. The specifications of different equipment and instruments used in the experiments are presented in Appendix-I.

#### **3.3 Determination of physical properties of Aloe vera leaf**

In recent years, scientists have directed great efforts in evaluating the basic physical properties of agricultural materials. The design and performance evaluation oriented engineering properties of Aloe vera leaf such as size and shape, volume, weight, density, surface area, apparent volume and textural property (firmness) were determined by the following methods.

##### **3.3.1 Leaf size and shape**

Size is the measure of physical dimension of the object. The size of the Aloe vera leaf was determined by considering the maximum tri-axial dimensions as shown in Fig. 6.



**Fig. 6: a) Approximate geometry of Aloe vera leaf b) Typical Aloe vera leaf**

The length, width and thickness of Aloe vera leaves were measured from 20 No. of randomly selected leaves using standard measuring scale. The average of readings was considered as its length, width and thickness. The size of the leaf was determined by using the formula given by Hernandez *et al.* (2002). In identification of shape of Aloe vera leaf, the longitudinal and lateral cross sections of leaf were traced and compared with the shapes listed in the standard chart. Using standard charts, the shape of the product can be defined either by a number on the chart or by descriptive terms prepared for fruits and vegetables by Mohsenin (1986).

$$S = \pi/12 (Z \times W \times P) \quad \dots (3.1)$$

Where,

S = Size of leaf (mm<sup>3</sup>)

Z = Length of leaf (mm)

W = Width of leaf at base (mm)

P = Thickness of leaf at base (mm)

### 3.3.2 Leaf weight

For determination of leaf weight, 20 No. of randomly selected leaves were weighed in a precision balance and their weights were recorded. The measurements of weights were replicated thrice and the average of the readings was recorded as leaf weight in grams. (Hernandez *et al.*, 2002).

### 3.3.3 Volume and density

The volume of Aloe vera leaf was calculated by water displacement method. In this method, the Aloe vera leaf was first weighed on the scale in air then put into water and the weight of displaced water was noted (Mohsenin, 1986). The volume and density were calculated using the following equations.

$$\text{Volume (m}^3\text{)} = \frac{\text{Weight of displaced water (kg)}}{\text{Weight of density of water (kg.m}^{-3}\text{)}} \times 100 \quad \dots (3.2)$$

$$\text{Density (kg.m}^{-3}\text{)} = \frac{\text{Weight of Aloe vera leaf in air (kg)}}{\text{Volume of Aloe vera leaf (m}^3\text{)}} \times 100 \quad \dots (3.3)$$

### 3.3.4 Surface area

The surface area is one of the important physical properties of biological materials. For determining surface area, Aloe vera leaf was placed on the drawing paper and the outline was traced using pencil. Initial point was marked on the outline of the drawing paper and the

planimeter was traced along the outline in clockwise direction till it reached the initial point. The surface area of the Aloe vera leaf was displayed by the planimeter and it was recorded (Mohsenin, 1986).

### **3.3.5 Firmness**

The firmness of Aloe vera leaf was determined using texture analyzer. The texture analyzer was a microprocessor controlled system, which was interfaced to a personnel computer. The texture analyzer measures force, distance and time, thus providing a three dimensional product analysis (Antonio, 2011).

The following settings of the apparatus were used.

Type of probe used - 2 mm diameter cylinder probe

Test module - Measure force in compression

Test option - Return to start

### **Parameters**

Pre test speed –  $1.5 \text{ mm.s}^{-1}$

Test speed -  $1 \text{ mm.s}^{-1}$

Post test speed -  $10 \text{ mm.s}^{-1}$

Distance - 15 mm

Trigger force - 25 g

Load cell - 5 kg

After running the test, the maximum force applied to puncture the Aloe vera tissue was directly obtained from the data recorder (computer) connected to the Texture Analyzer. The Aloe vera leaves selected were tested for the force required to puncture in different positions namely through the stem end, apex end and at the middle of the leaves. Texture analyzer for measuring the firmness of Aloe vera leaf is depicted in Plate 1.

### **3.4 Leaf trimming process**

The leaf trimming process means that the side, tip and base of the leaf were cut away by using stainless steel knife (manually). The leaf trimming process was carried out by removing lower one inch of the leaf base, the tapering point (2-4 inches) of the leaf top and the short sharp thorns located along the leaf margins as shown in Plate 2.

### **3.5 Manual Aloe vera gel extraction process**

Freshly harvested Aloe vera leaves were selected based on its size and weight later leaves were dipped into tap water and washed thoroughly.



**Plate 1. Texture analyser used for measuring the firmness of Aloe vera leaf**



**Plate 2. Leaf trimming procedure resulting in A, removal of sides, B, removal of base and C, removal of tip of leaf**

Afterwards trimming process of Aloe vera leaves were depicted in section 3.4., then trimmed leaves were cut vertically into two half and gel was separated using stainless steel knife and Aloe vera gel was collected in a box. Manually extracted Aloe vera gel used as a control sample as depicted in Table 4.4., 4.10 and 4.17.

### **3.6 Aloe vera gel extraction machine**

The Aloe vera gel extraction machine developed by M/s. Sanjivani Phytopharma, Pvt. Ltd., Mumbai was procured under NAIP Sub-Project on “A value chain on Aloe vera processing”. The gel extraction machine consisted of belt conveyor, knurling rollers, chain pulley, gel collecting unit, mesh siever for collection of rind and frame for holding all components. Aloe vera gel extractor was powered by 1hp motor. 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 speed of roller speed of Aloe vera gel extraction machine is shown in Plate 3. All contact parts were made up of stainless steel (SS304) with the exception of the frame which was made from mild steel.

#### **3.6.1 Components of Aloe vera gel processing machine**

Aloe vera leaf washing machine combined with Aloe vera gel extraction machine is shown in Plate 4, Aloe vera leaf washing machine is shown in Plate 5 and also Aloe vera gel extraction machine is shown in Plate 6.

##### **3.6.1.1 Components of Aloe vera leaf washing machine**

The Aloe vera leaf washing machine was comprised of

- A frame for supporting all components of the machine
- A feeding channel for feeding the trimmed Aloe vera leaf through chain conveyor into washing unit.
- A washing unit consisted of inlet and outlet water pipe, sprinklers and washing process was carried out through the rotation of chain conveyor and also forcible water spraying process was carried out.
- An outlet water pipe for removal of dust and surface contaminants of trimmed Aloe vera leaves. Trimmed Aloe vera leaves were moved through chain conveyor to Aloe vera gel extraction machine.

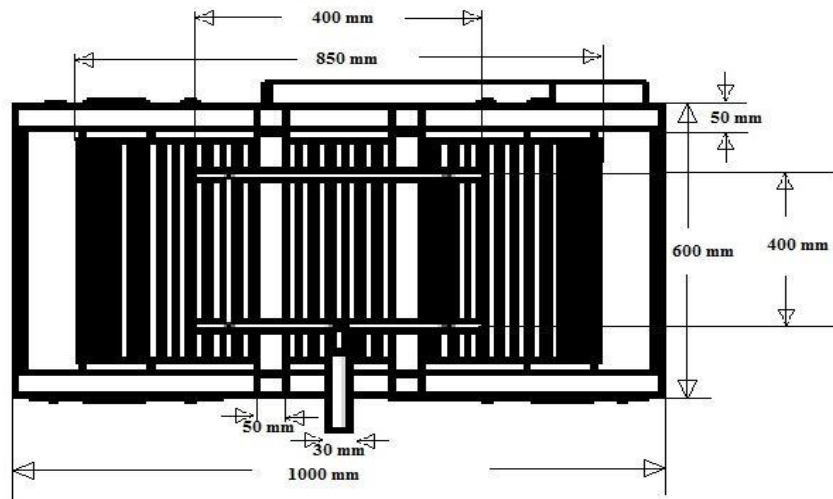
The Aloe vera leaf washing machine (top view and front view) consisting of the following components is shown in Figs. 7 to 9.



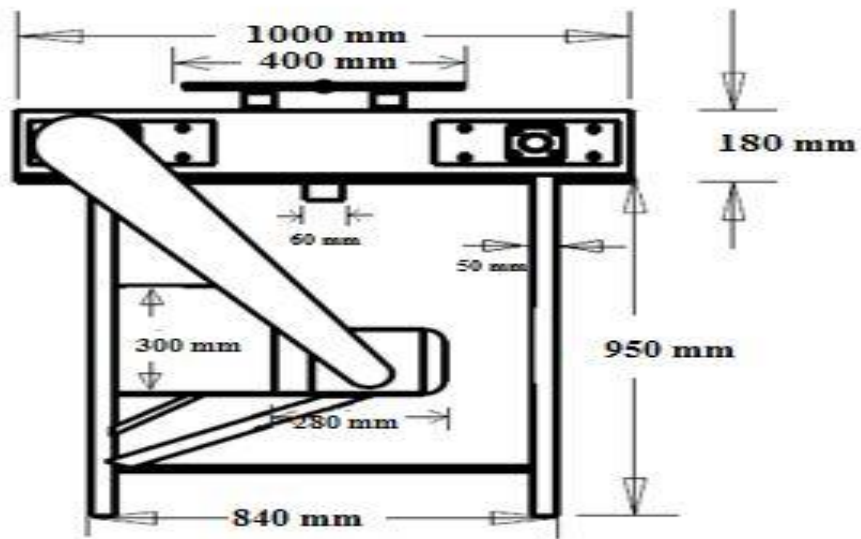
**Plate 3. Variable Frequency Drive used for varying the roller speed of Aloe vera gel extraction machine**



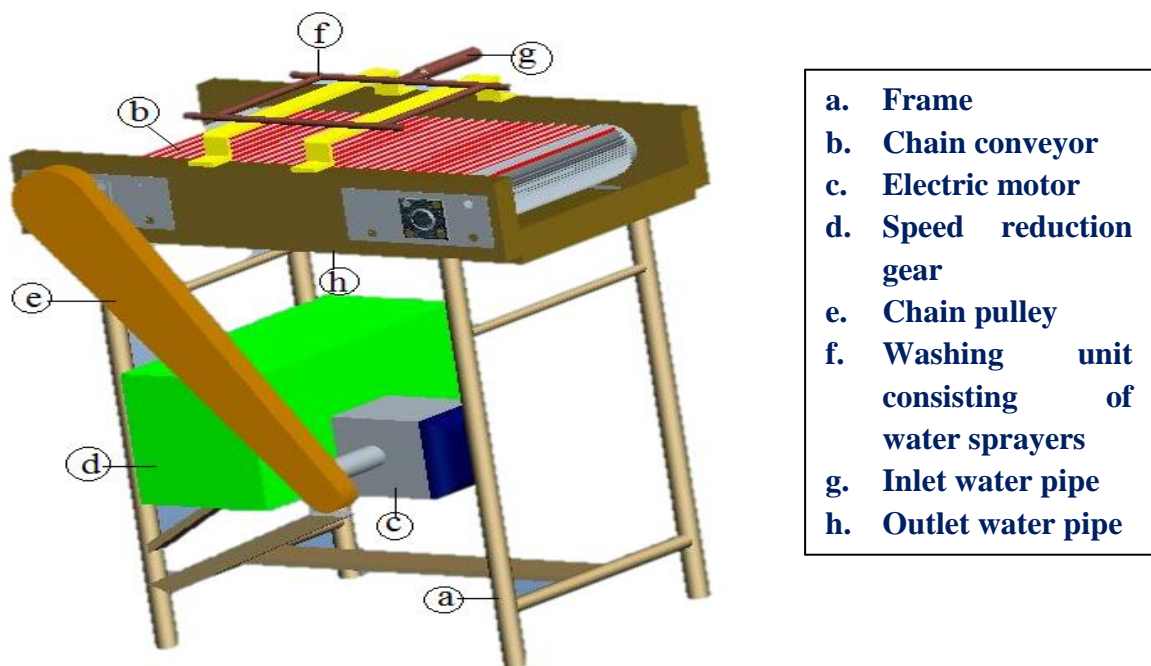
**Plate 4. Aloe vera gel extraction machine combined with Aloe vera leaf washing machine**



**Fig. 7 Top view of Aloe vera leaf washing machine**



**Fig. 8 Front view of Aloe vera leaf washing machine**



**Fig. 9 Components of Aloe vera leaf washing machine**



**Plate 5. Aloe vera leaf washing machine**

### **3.6.1.2 The components of Aloe vera gel extraction machine**

The Aloe vera gel extraction machine comprised of

- A frame for supporting all components of the machine
- A feeding channel for feeding the washed and trimmed Aloe vera leaf through belt conveyor into extraction chamber.
- A extraction chamber consisting of knurling rollers and sprockets and the extraction process was carried out through pressing of leaves by knurling rollers.
- A sieve was used for separating the gel and rind. The residual waste was collected in sieve outlet and the Aloe vera gel was collected in gel outlet.

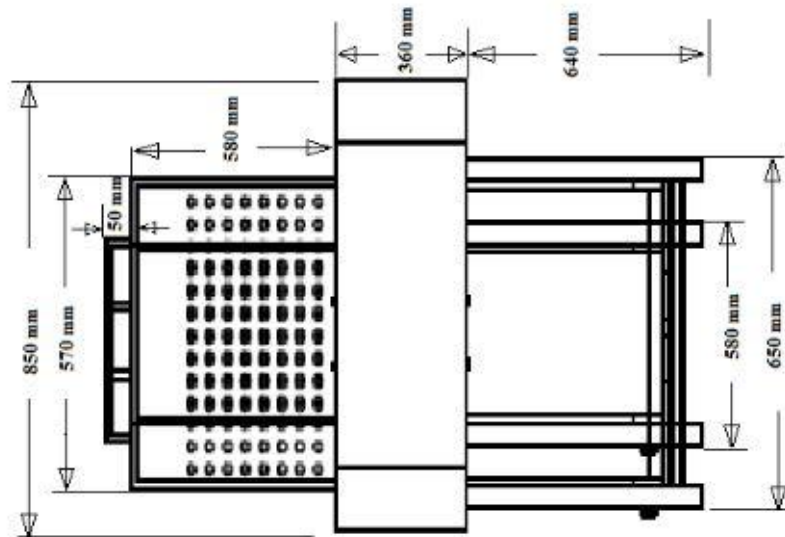
The Aloe vera gel extraction machine (top view and front view) consisting of following components is shown in Figs. 10 to 12.

### **3.6.2 Operation of Aloe vera gel extraction machine**

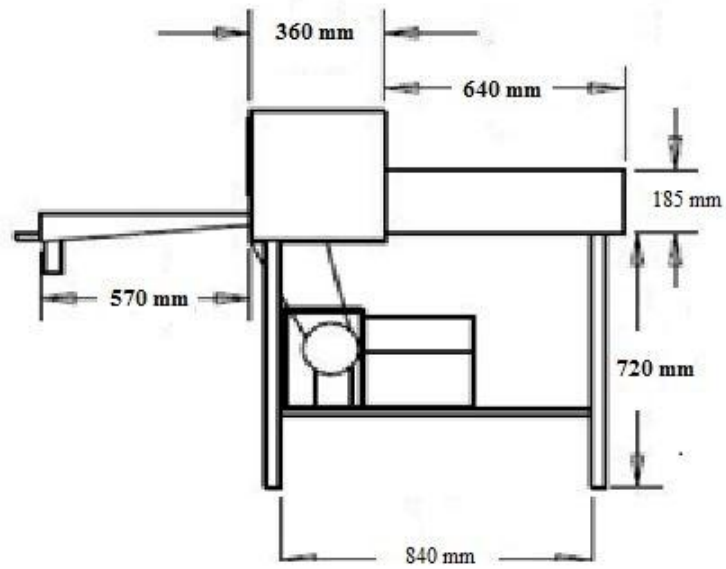
The trimmed Aloe vera leaves were fed through the knurling mesh conveyor of Aloe vera leaf washing machine. After washing, the Aloe vera leaves were moved through the belt conveyor to the Aloe vera gel extraction machine, here Variable Frequency Drive (VFD) used for varying the speed of rollers (30, 40 and 50 rpm) but operational roller speed of Aloe vera gel extractor (roller speed: 11.40, 15.10 and 18.80 rpm) 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). The process flow chart for Aloe vera gel extraction process is shown in Fig. 13.

### **3.7 Proximate composition of Aloe vera gel**

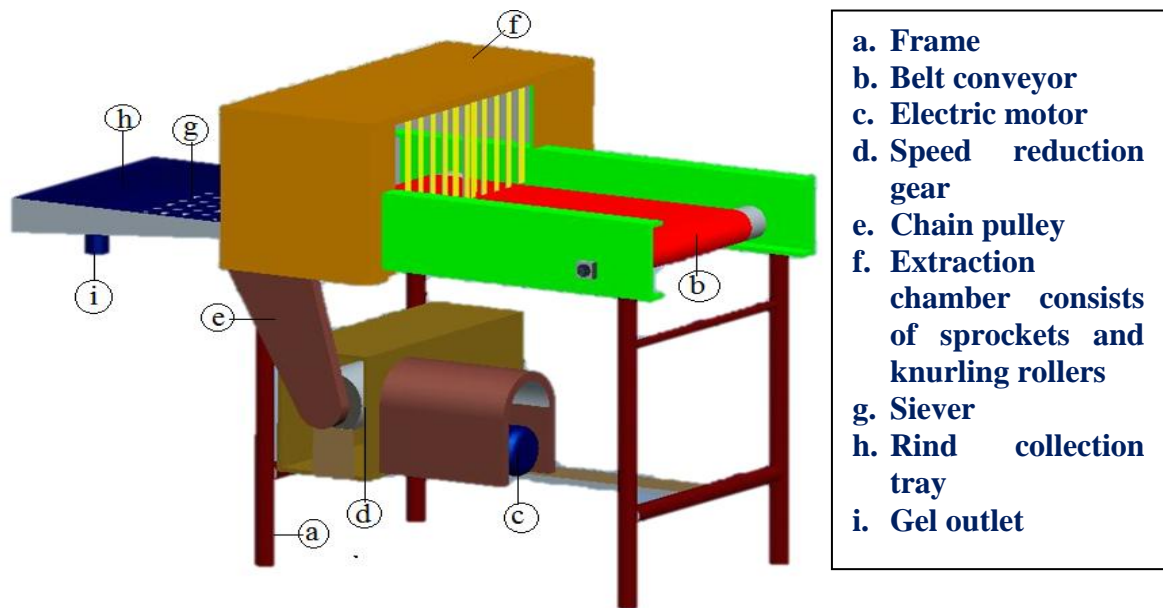
Proximate composition of Aloe vera gel, obtained through gel extraction machine namely, moisture content was determined by hot air oven method. The carbohydrate content was determined by phenol-sulphuric acid method. The crude protein content was determined using the Kjeldhal method with a conversion factor of 6.25. The crude fat content was analysed gravimetrically following Soxhlet extraction. The ash content was estimated by incineration in a muffle furnace at 550 °C. All methodologies were followed according to the recommendations of Official Methods of Analysis (AOAC, 2005).



**Fig. 10 Top view of Aloe vera gel extraction machine**



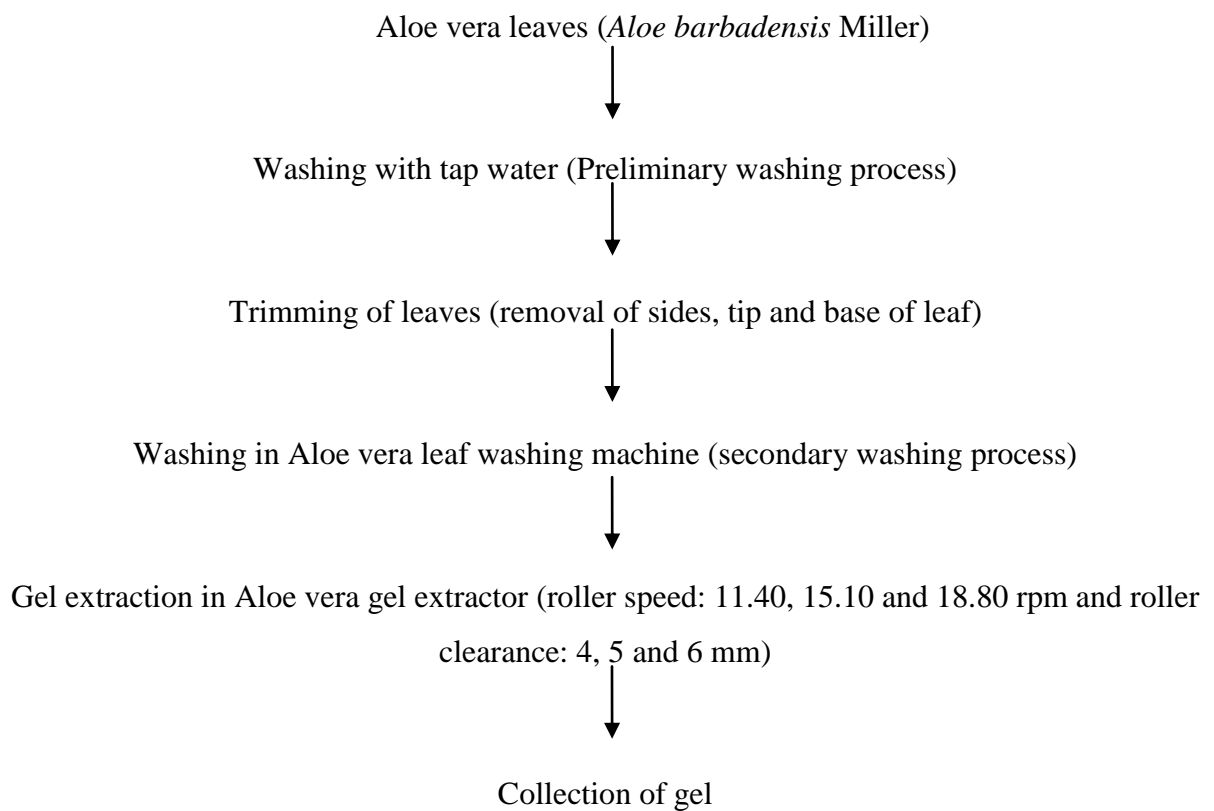
**Fig. 11 Front view of Aloe vera gel extraction machine**



**Fig. 12 Components of Aloe vera gel extraction machine**



**Plate 6. Aloe vera gel extraction machine**



**Fig. 13 Process flow chart for Aloe vera gel extraction**

### 3.7.1 Moisture content

The moisture content of the fresh Aloe vera gel and gel obtained through gel extraction machine samples were determined by following AOAC method (AOAC, 2005, method No. 934.06). A brief description of the method is as follows. Twenty gram of Aloe vera gel was kept in a pre-dried moisture box. Initial weight of sample was recorded as  $W_1$ . The box was placed in the hot air oven maintained at 70 °C for 18 h. After, the box was kept in the desiccator and then weighed. Final weight of sample was recorded as  $W_2$ . All measurements were replicated thrice and the average moisture content for fresh gel and gel obtained through gel extraction machine samples were determined by using the following equation.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad \dots (3.5)$$

Where,

$W_1$  = Initial weight of sample (g)

$W_2$  = Final weight of sample (g)

### 3.7.2 Carbohydrates

Carbohydrates content of Aloe vera gel was determined by using phenol sulphuric acid method (Dubois *et al.*, 1956). The reagents were 4% phenol and 96% sulphuric acid. One gram of Aloe vera gel was hydrolysed in water bath at 60 °C for 3 h with 2.5N 5 ml hydrochloric acid and then cooled to room temperature. The sample was neutralised with sodium carbonate until effervescence ceased, volume make up of sample was done upto 100 ml. The sample was centrifuged at 9000 rpm for 10 min to collect the supernatant.

A portion of supernatant to be analysed was transferred into 10 ml test tube and 1 ml of phenol was added followed by 5 ml of sulphuric acid then the test tube was placed in waterbath at 25 to 30 °C for 20 min for cooling. When the sample was cooled, it was transferred into the cuvette and absorbance was measured at 490 nm in spectrophotometer (Systronics, PC based double beam spectrophotometer 2202). To calculate the concentration of carbohydrate present in the sample, a graph of absorbance versus concentration of carbohydrate was plotted along with a standard curve generated from the analysis of D-glucose.

$$\text{Total carbohydrates (\%)} = \frac{X}{0.1} \times 100$$

X= concentration of D-glucose of standard graph, ppm

### 3.7.3 Crude protein

The crude protein of Aloe vera gel was determined using micro Kjeldahl method (AOAC, 2005, method No. 960.52). One gram of Aloe vera gel powder was transferred to a digestion tube. To this 0.2 g of digestion mixture and 12 ml of concentrated sulphuric acid were added. The sample was digested in a digestion unit until it became colourless. Then the tubes were cooled and transferred to the distillation unit. Twenty five ml of 40% sodium hydroxide was allowed into the tube for 20 min and the liberated ammonium was absorbed by 15 ml of 2% boric acid solution containing mixed indicator. The pink colour of the boric acid solution was turned to green and this was titrated against 0.01 N sulphuric acid until the pink colour was obtained. The per cent of protein was obtained by using the following formula.

$$\text{Crude protein (\%)} = \frac{\text{TV} \times 0.014 \times 100 \text{ (ml)} \times 0.01 \times 100 \times 6.25}{\text{Weight of sample (g)} \times \text{Aliquot used for distillation (ml)}} \quad \dots (3.6)$$

Where,

TV = Titre value

### 3.7.4 Crude fat

Crude fat content of Aloe vera gel samples were estimated by following soxhlet extraction method (AOAC, 2005, method No. 960.39). Five grams of Aloe vera gel powder sample was placed in an extraction thimble. The extraction thimble was placed in an extractor and connected to weighed flask containing 100 ml petroleum ether at the bottom. A reflux condenser was connected at the top of the extractor. The sample was extracted under reflux for 5 to 6 hours. The ether was then removed by evaporation and the flask with the residue was dried in an oven at 100 °C for 10 to 15 min, cooled in desiccator and weighed.

$$\text{Crude fat (\%)} = \frac{W_1 - W_2}{W_3} \times 100 \quad \dots (3.7)$$

Where,

$W_1$  = Initial weight of thimble + sample (g)

$W_2$  = Final weight of thimble + sample (g)

$W_3$  = Weight of sample (g)

### 3.7.5 Ash content

The ash content of Aloe vera gel samples was determined as per AOAC (AOAC, 2005, method No. 923.03) procedure using muffle furnace (MAC: MSW-251). Accurately 5 g of the sample was weighed into a crucible (which was previously heated to about 600 °C and

then cooled). The crucible was placed on a clay pipe triangle and heated first over a low flame till all the material was completely charred, followed by heating in a muffle furnace for about 4-5 h at 600 °C. It was then cooled in a desiccator and weighed. The percentage of ash was calculated by using the following expression.

$$\text{Total ash (\%)} = \frac{W_1}{W_2} \times 100 \quad \dots (3.8)$$

Where,

$W_1$  = Weight of ash (g)

$W_2$  = Weight of sample (g)

### **3.7.5 TSS (% Brix)**

Total Soluble Solids (TSS) were determined according to the method described by Martinez-Romero *et al.* (2006), using Atago digital handheld refractometer. Before use, the instrument was calibrated by using distilled water. Two ml of Aloe vera gel was placed on the prism of the refractometer with the help of a glass rod and the start button was pressed to get the readings. For each sample, the instrument was calibrated by using distilled water. The reading appeared on the screen was directly recorded as total soluble solids (% Brix).

## **3.8 Quality parameters of Aloe vera gel**

The optimization of process parameters for production of Aloe vera gel by different roller speeds and roller clearances from Aloe vera gel extraction machine was mainly based on quality parameters such as pH, water activity, colour and viscosity. The optimization was based on pH and water activity to determine the acidic, basic level and moisture content of Aloe vera gel, respectively and colour values; maximum  $L^*$  and minimum  $a^*$  and  $b^*$ .

### **3.8.1 pH**

The pH of Aloe vera gel was measured by using digital pH meter. Accurately 30 ml of Aloe vera gel sample was taken, then the electrode of the pH meter was dipped in the sample under test. The enter key was pressed to show the pH and temperature of sample simultaneously. For next sample measurement, electrode was removed and washed properly with distilled water, then the above procedure was followed for subsequent samples. All the readings were taken in triplicate (Gautam and Awasthi, 2007).

### **3.8.2 Water activity**

The water activity is a key parameter in quality control of any moisture sensitive product or material. Water activity is defined as the active part of product's moisture content

of free water. It influences the microbial, chemical and enzymatic stability of perishable products such as food, grains and seeds. The water activity of Aloe vera gel was measured by using water activity meter (Plate 7). Before measuring the water activity of Aloe vera gel, the instrument was tested for its accuracy by measuring the water activity of the distilled water, if the water activity for distilled water recorded one, then the instrument was said to be calibrated.

Two grams of Aloe vera gel sample was taken in sample cup which was provided with water activity meter. The sensor was placed on the sample cup and firmly closed. The reading was directly read from the LCD screen on the water activity meter and was taken as water activity of the Aloe vera gel (Margarita *et al.*, 2009).

### **3.8.3 Colour**

Colour is an important attribute because it is usually the first property the consumer observes. It is one of the most important quality acceptances for products, which reflects sensation to the human eye. The 3-dimensional scale  $L^*$ ,  $a^*$  and  $b^*$  values of the Aloe vera gel were determined with colour flex colorimeter in the present investigation and the instrument is shown in Plate 8. The colours of the Aloe vera gel using CIE scale at 10° observer and at D65 illuminant were used. The instrument was initially calibrated with a black glass placed at the sample port, during standardization and then again with white calibrated tile was placed at the sample port during standardization. The  $L^*$  is the lightness coefficient, ranging from (0 for black and 100 for white),  $a^*$  represents greenness and redness (+100 for red and -80 for green), and  $b^*$  represents yellowness and blueness (+70 for yellow and -80 for blue) (Chang *et al.*, 2006).

### **3.8.4 Viscosity**

The rheological test on oscillatory motion was performed on the Rheometer (Anton Paar GmbH, Physica MCR-301, Graz, Austria). The parallel plate geometry of 25 mm diameter with a gap setting of 4 mm was used for testing viscosity of the Aloe vera gel. Standard concentric cylinders (coaxial) geometry was used for the analysis of juice. The temperature was controlled by the Peltier heating element. Liquid nitrogen was used to maintain low temperature. The settings of the instrument were checked during the starting of all analytical tests. Care was taken to avoid the effects of sample loading by performing the gap setting very slowly to avoid high shear rates during sample loading. The samples were scrupulously placed on the test geometry using a spatula and then rotor was slowly lowered using a motorized system until the sample was in intimate contact with the sensor.



**Plate 7. Water activity meter used for measuring the water activity of Aloe vera gel**



**Plate 8. Hunter lab Colourimeter used for measuring the colour values of Aloe vera gel**

To avoid the effects of ageing, fresh samples were used for each experimental run for rheological measurements. The samples were allowed to reach thermal equilibrium by providing rest time of two minutes at the test temperatures prior to the start of each test which also ensured the stress relaxation of the sample observed during loading. The same protocol was followed for each experimental run. The data of rheological measurements were analysed using the RheoPlus/32 V3.21 software. The viscosity test on oscillatory motion was performed on the Rheometer as shown in Plate 9 (Lad and Murthy, 2013).

### 3.9 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 (11.40, 15.10 and 18.80 rpm) and three levels of roller thickness (4 mm, 5 mm and 6 mm) in terms of gel extraction efficiency (%), gel extraction loss (%), gel recovery (%) and gel extraction capacity ( $\text{kg}\cdot\text{h}^{-1}$ ). 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 in decimal 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. This each experiment was replicated three times for trimmed leaves (Ndubisi *et al.*, 2013).

#### 3.9.1 Gel Extraction Efficiency (%)

Gel extraction efficiency was calculated from the ratio of weight of gel extracted to the sum of gel constant value and weight of feed sample.

$$\text{Gel Extraction Efficiency: } E_E = \frac{100 \times W_{ge}}{X \times W_{fs}} \% \quad \dots (3.9)$$

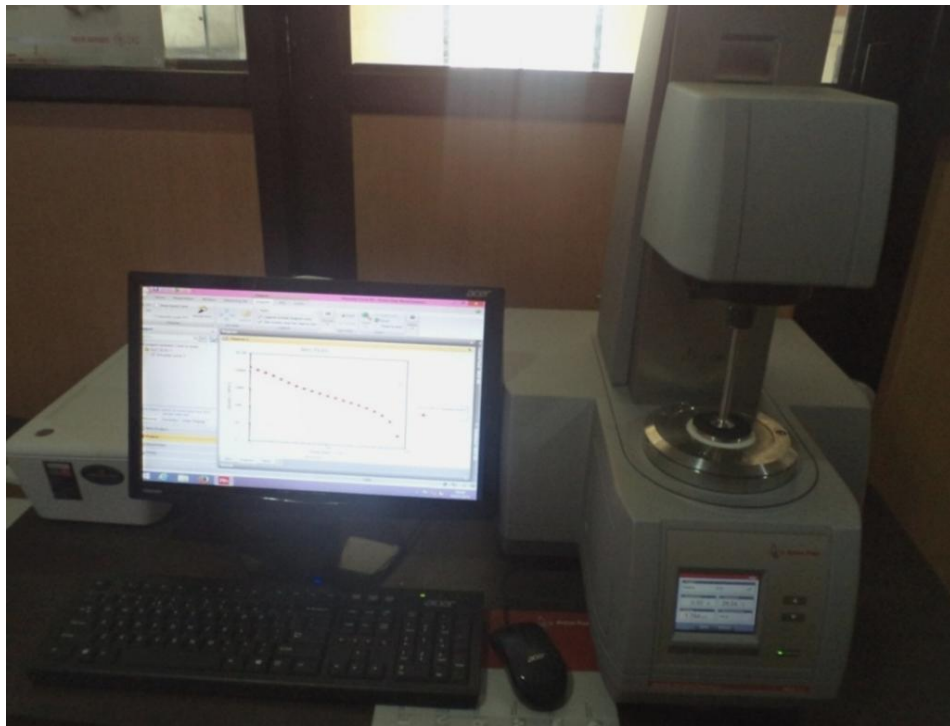
Where,

$W_{ge}$  = Weight of gel extracted in g,

$W_{fs}$  = Weight of feed sample in g

$X$  = Gel constant

$X$  is calculated as the ratio of sum of masses of gel extracted and gel in rind to the mass of trimmed Aloe vera leaves fed in.



**Plate 9. Rheometer used for measuring the viscosity of Aloe vera gel**

### 3.9.2 Gel Extraction Loss (%)

The gel extraction loss was calculated from the ratio of difference between weight of feed sample to the sum of weight of gel extracted and weight of rind waste to the weight of feed sample.

$$\text{Gel Extraction Loss: } E_L = \left[ \frac{100(W_{fs} - (W_{ge} + W_{rw}))}{W_{fs}} \right] \% \quad \dots (3.10)$$

Where,

$W_{ge}$  = Weight of gel extracted in g,

$W_{rw}$  = Weight of residual waste in g,

$W_{fs}$  = Weight of feed sample in g

### 3.9.3 Gel Recovery (%)

The gel recovery was calculated from the ratio of weight of gel extracted to the sum of weight of gel extracted and weight of rind weight.

$$\text{Gel Recovery: } G_R = \frac{100 \times W_{ge}}{W_{ge} + W_{rw}} \% \quad \dots (3.11)$$

Where,

$W_{ge}$  = Weight of gel extracted in g,

$W_{rw}$  = Weight of residual waste in g,

### 3.9.4 Extraction Capacity (kg.h<sup>-1</sup>)

The extraction capacity as calculated from the ratio of weight of feed sample to the time in seconds.

$$\text{Extraction Capacity: } E_C = \frac{W_{fs}}{T} \text{ kg.h}^{-1} \quad \dots (3.12)$$

Where,

$W_{fs}$  = Weight of feed sample in g

T = Time in seconds

## 3.10 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).

$$\text{Fixed cost of the equipment/year} = \text{Fixed cost} \times \text{Capital recovery factor}$$

Where,

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

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

Where,

$R_i$  = 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.

### 3.11 Statistical Analysis

All the experiments in the study were conducted in triplicate and mean values were reported. Factorial completely randomised design (FCRD) was used to analyse the data. After proper analysis, data were accommodated in the tables as per the needs of objectives for interpretation of results. Statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA) for each response. The p-values were used as a tool to check the significance of each of the coefficient, which, in turn were necessary to understand the pattern of the mutual interactions between the test variables. The smaller the magnitude of the p, the more significant is the corresponding coefficient. Values of p less than 0.05 indicate the model terms to be significant. The adequacy of regression model was checked by  $R^2$  and Fisher's F-test (Montgomery, 2001).

The significance of all terms in the polynomial was judged statistically by computing the F-values at a probability (P) of 0.01 or 0.05. A complete second order quadratic model was employed to fit the data and adequacy of the model was tested considering  $R^2$  (The coefficient of multiple determination, a measure of the amount of variation around the mean explained by the model). The mathematical model is reliable with an  $R^2$  value closer to 1 (The closer the  $R^2$

value to 1, the better is the model fit to the experimental data). Coefficient of determination,  $R^2$  is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit (Haber and Runyon, 1977).

The experimental design was done with the aid of the Design-Expert software version 7.7.0 (Statease Inc., Minneapolis, USA) to identify optimum levels of two independent variables. Roller speed (rpm) and roller clearance (mm) for performance evaluation of roller type of Aloe vera gel extraction machine were chosen as independent variables. Fourteen responses were selected as dependent variables viz., gel extraction efficiency, gel extraction loss and gel recovery, extraction capacity, moisture content, carbohydrates, ash, crude protein, crude fat, total soluble solids (TSS), pH, water activity, colour ( $L^*$ ,  $a^*$  and  $b^*$ ) and viscosity. The experiments were designed according to the general factorial design and the order of experiments was fully randomised. The experimental details of FCRD design observation treatment combinations for Aloe vera gel extraction machine and observation table for Aloe vera gel extraction machine are shown in Table 1 and 2.

### **Independent Variables**

1. Roller speed (rpm): 11.40, 15.10 and 18.80
2. Roller clearance (mm): 4, 5 and 6

### **Dependent variables**

1. Gel Extraction Efficiency (%)
2. Gel Extraction Loss (%)
3. Gel Recovery (%)
4. Extraction Capacity ( $\text{kg}\cdot\text{h}^{-1}$ )

### **Experimental details:**

Raw material: Aloe vera leaves

Sample size: 30 trimmed leaves per treatment

Statistical design: Factorial design

Number of treatments: 9

Number of replications: 3

Total number of treatments: 27

Degrees of freedom: 16

**Table 1. Treatment combinations for Aloe vera gel extraction machine**

Sl. No.	Roller Speed (rpm)		Roller Clearance (mm)	Observations		
	Set speed (rpm)	Crushing roller speed (rpm)		R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>
1			4			
2	30	11.40	5			
3			6			
4			4			
5	40	15.10	5			
6			6			
7			4			
8	50	18.80	5			
9			6			

**Table 2. Observation table for Aloe vera gel extraction machine**

Sl. No.	Treatment combinations	Roller Speed (rpm)		Roller Clearance (mm)	Observations taken from machine extraction process					
		Set speed (rpm)	Operating roller speed (rpm)		Wt. of trimmed leaf (g)	Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant Value (X)	Time in seconds(s)
1	T <sub>1</sub>			4						
2	T <sub>2</sub>	30	11.40	5						
3	T <sub>3</sub>			6						
4	T <sub>4</sub>			4						
5	T <sub>5</sub>	40	15.10	5						
6	T <sub>6</sub>			6						
7	T <sub>7</sub>			4						
8	T <sub>8</sub>	50	18.80	5						
9	T <sub>9</sub>			6						

## *Experimental Results*

## IV. EXPERIMENTAL RESULTS

This chapter deals with the results obtained on determination of physical properties of Aloe vera leaf, performance evaluation of roller type Aloe vera gel extraction machine, proximate composition and quality of Aloe vera gel obtained through Aloe vera gel extraction machine *viz.*, moisture content, carbohydrates, ash content, crude protein, crude fat, total soluble solids, pH, water activity, colour and viscosity of Aloe vera gel.

### 4.1 Physical properties of Aloe vera leaf

#### 4.1.1 Size and shape

The size of the Aloe vera leaf was determined by considering the maximum tri-axial dimensions. The length, width and thickness of Aloe vera leaves measured from 20 randomly selected leaves using standard measuring scale. The values obtained are recorded in Table 3. The length, width and thickness ranged from 400.00 to 640.00 mm, 70.00 to 108.00 mm and 10.48-16.95 mm, respectively, with a mean value of 523.50, 80.60 and 13.67 mm, respectively, with a standard deviations of 66.67, 11.43 and 1.52, respectively and coefficient of variations of 12.74, 14.18 and 11.08%, respectively. The size of Aloe vera leaf was calculated using equation 3.1 as explained in Chapter III. The mean size of Aloe vera leaf was 151092.95 mm<sup>3</sup>, the standard deviation for the size of Aloe vera leaf was 32882.38 and coefficient of variation for the size of Aloe vera leaf was 21.76%. The shape of Aloe vera leaf was classified as conic-tapered towards apex.

#### 4.1.2 Leaf weight

The data obtained on weight of Aloe vera leaves are presented in Table 3. The results indicated that the minimum and maximum weights of Aloe vera leaf were recorded to be 118.00 and 224.00 g, respectively with mean weight of 178.60 g, with standard deviation of 26.57 and with coefficient of variation of 14.87%, respectively.

#### 4.1.3 Leaf volume and density

The volume of Aloe vera leaf was determined by water displacement method as explained in Chapter III and Section 3.3.5. The results obtained on the volume of Aloe vera leaf are presented in Table 3. The average volume of an Aloe vera leaf was 149.30 mm<sup>3</sup>. The maximum volume was recorded as 172.14 mm<sup>3</sup>, whereas, the minimum volume of leaf was 97.81mm<sup>3</sup>, the standard deviation was 19.90 and the coefficient of variance was 13.33%. The average density of Aloe vera leaf was found to be 1.20 g.mm<sup>-3</sup>. The maximum density was recorded as 1.43 g.mm<sup>-3</sup>, whereas, the minimum density of the leaf was 1.07 g.mm<sup>-3</sup>, the standard deviation was 0.09 and the coefficient of variance was 7.29%.

#### **4.1.4 Surface area**

The data obtained on the surface area of Aloe vera leaf are presented in Table 3. The average surface area of the Aloe vera leaf was determined to be 224.81 cm<sup>2</sup>. The maximum surface area of Aloe vera leaf was recorded as 341.50 cm<sup>2</sup>, whereas, the minimum volume of the leaf was 132.30 cm<sup>2</sup>. The standard deviation was 51.44 and the coefficient of variance was 22.88%.

#### **4.1.5 Firmness**

Textural property, the firmness of Aloe vera leaf was measured using Texture analyser. The data obtained on the firmness of Aloe vera leaf are recorded in Table 3. The average value of firmness was recorded as 8.39 N. The maximum firmness was recorded as 11.01 N; whereas, the minimum firmness of the leaf was 6.03 N, the standard deviation was 1.46 and the coefficient of variance was 17.40%. TPA curves for Aloe vera leaf is shown in Fig 14.

### **4.2 Performance evaluation of Aloe vera gel extraction machine with different roller speeds and roller clearance combinations**

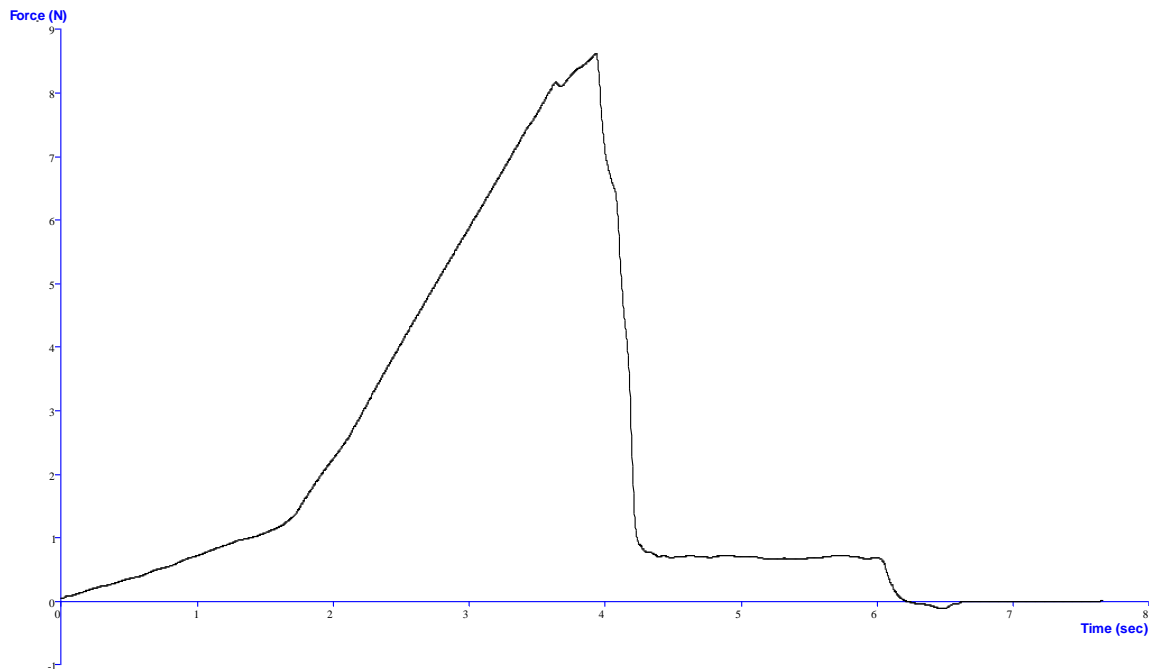
The performance evaluation of Aloe vera gel extraction process was studied in terms of gel extraction efficiency, gel extraction loss, gel recovery and extraction capacity which were calculated by using the equations as explained in Chapter III, Section 3.8. Input factors for optimization of machine parameters for Aloe vera gel extraction machine are shown in Appendix III. The mean values of gel extraction efficiency (%), gel extraction loss (%), gel recovery (%) and extraction capacity (kg.h<sup>-1</sup>) are shown in Table 4.

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

The gel extraction efficiency of Aloe vera gel obtained from Aloe vera gel extraction machine at different roller speed and roller clearance combinations are presented in Table 4. From Table 4, it is seen that at 11.40 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction efficiency ranged from 88.61 to 94.45%. Among the constant roller speed and different roller clearance combinations, the gel extraction efficiency (94.45%) was the highest at 11.40 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest gel extraction efficiency (88.61%) was recorded at 11.40 rpm roller speed and roller clearance of 4 mm. From Table 4, it is observed that at 15.10 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the gel extraction efficiency ranged from 92.25 to 94.85%.

**Table 3. Physical properties of Aloe vera leaves**

Sl. No.	Particulars	Range	Average	SD	C.V. (%)
1	Length (mm)	400.00-640.00	523.50	66.67	12.74
2	Width (mm)	70.00-108.00	80.60	11.43	14.18
3	Thickness (mm)	10.48-16.95	13.67	1.52	11.08
4	Size of leaf (mm <sup>3</sup> )	102300.00- 204897.52	151022.95	32882.38	21.76
5	Weight (g)	118.00-224.00	178.60	26.57	14.87
6	Volume (mm <sup>3</sup> )	97.81-172.14	149.30	19.90	13.33
7	Density (g.mm <sup>-3</sup> )	1.07-1.43	1.20	0.09	7.29
8	Surface area (cm <sup>2</sup> )	132.30-341.50	224.81	51.44	22.88
9	Firmness (N)	6.03-11.01	8.39	1.46	17.40



**Fig. 14 TPA curve for firmness of Aloe vera leaf**

**Table 4. Mean values of gel extraction efficiency (%), gel extraction loss (%), gel recovery (%) and extraction capacity (kg.h<sup>-1</sup>) obtained from different roller speed and clearance combinations**

<b>Treatments</b>	<b>Roller Speed (rpm)</b>	<b>Roller Clearance (mm)</b>	<b>Gel Extraction Efficiency (%)</b>	<b>Gel Extraction Loss (%)</b>	<b>Gel Recovery (%)</b>	<b>Extraction Capacity (kg.h<sup>-1</sup>)</b>
<b>Manual extraction (control)</b>			<b>100</b>	<b>0</b>	<b>57.78</b>	<b>3.15</b>
T <sub>1</sub>	11.40	4	88.61	4.50	37.93	104.32
T <sub>2</sub>	11.40	5	94.45	2.35	41.08	115.02
T <sub>3</sub>	11.40	6	93.79	2.46	38.06	106.09
T <sub>4</sub>	15.10	4	92.25	3.25	40.02	114.20
T <sub>5</sub>	15.10	5	94.85	2.24	42.28	128.11
T <sub>6</sub>	15.10	6	94.42	2.37	41.08	117.19
T <sub>7</sub>	18.80	4	92.80	3.10	40.18	141.44
T <sub>8</sub>	18.80	5	96.08	1.58	43.57	158.06
T <sub>9</sub>	18.80	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

Among the constant roller speed and different roller clearance combinations, the gel extraction efficiency (94.85%) was the highest at 15.10 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest gel extraction efficiency (92.25%) was recorded at 15.10 rpm roller speed and roller clearance of 4 mm. At 18.80 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the gel extraction efficiency ranged from 92.80 to 96.08%. Among the constant roller speed and different roller clearance combinations, the gel extraction efficiency (96.08%) was the highest at 18.80 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest gel extraction efficiency (92.80%) was recorded at 18.80 rpm roller speed and roller clearance of 4 mm. The mean gel extraction efficiency was 93.66%, the standard deviation of treatment combinations of gel extraction efficiency was 2.25 and the coefficient of variance of gel extraction efficiency was 2.40%. The interaction effect of 18.80 rpm roller speed and 5 mm roller clearance on gel extraction efficiency was significant ( $p < 0.05$ ) at five per cent level.

The gel extraction efficiency obtained from manual extraction (control) of Aloe vera gel was found to be 100%. The gel extraction efficiency was higher compared to machine extracted Aloe vera gel are presented in Table 4.

The analysis of variance (ANOVA) and estimated coefficient values of gel extraction efficiency of Aloe vera gel are presented in Table 5. The model (2FI) F-value of 43.91 implies that the model was significant ( $p < 0.05$ ). In this case, A and B were significant model factors. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that proposed models fitted the experimental data with  $R^2$  value of 0.9565, whereas the optimized predictive model had an  $R^2$  value of 0.9022 and was in reasonable agreement with the “Adj R-Squared” of 0.9372. The optimized predictive model (in terms of actual factors) for gel extraction efficiency of Aloe vera gel was presented in equation 4.3. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 23.3982 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for gel extraction efficiency of Aloe vera gel is presented in the following equation.

$$\text{Gel extraction efficiency (\%)} = 93.66 - 1.37 * A - 2.44 * B - 1.24 * (A \times B) \quad \dots (4.3)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

**Table 5. Analysis of variance for gel extraction efficiency (%) of Aloe vera gel extraction machine**

Source	Sum of Squares	Degrees of Freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence interval Low	
Model	121.23	8	15.15	49.51	< 0.0001 (S)	Intercept	93.66	0.11	93.43	93.88
A-Roller speed (rpm)	27.83	2	13.91	45.47	< 0.0001	A	-1.37	0.15	-1.69	-1.06
B-Roller clearance (mm)	82.95	2	41.47	135.52	< 0.0001	B	-2.44	0.15	-2.75	-2.12
A×B	10.45	4	2.61	8.54	0.0005	A×B	-1.24	0.21	-1.69	-0.79
Pure Error	5.51	18	0.31							
Corr. Total	126.74	26								
Mean	93.66	R-Squared		0.9565	SD – Standard deviation					
SD	0.55	Adj R-Squared		0.9372	C.V. % – Coefficient of variance					
C.V. %	0.59	Pred R-Squared		0.9022						
PRESS	12.39	Adeq Precision ratio		23.3982						

S = Significant at (<0.0001%) one percent level significant

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

The extraction loss of Aloe vera gel obtained from Aloe vera gel extraction machine at different roller speed and roller clearance combinations are presented in Table 4. From Table 4, it is seen that at 11.40 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction loss ranged from 2.35 to 4.50%. Among the constant roller speed and different roller clearance combinations, the gel extraction loss (4.50%) was the highest at 11.40 rpm roller speed and roller clearance of 4 mm. Whereas, the lowest gel extraction loss (2.35%) was recorded at 11.40 rpm roller speed and roller clearance of 5 mm. From Table 4, it is observed that at 15.10 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction loss ranged from 2.24 to 3.25%. Among the constant roller speed and different roller clearance combinations, the extraction loss (3.25%) was the highest at 15.10 rpm roller speed and roller clearance of 4 mm. Whereas, the lowest extraction loss (2.24%) was recorded at 15.10 rpm roller speed and roller clearance of 5 mm. At 18.80 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction loss ranged from 1.58 to 3.10%. Among the constant roller speed and different roller clearance combinations, the extraction loss (3.10%) was the highest at 18.80 rpm roller speed and roller clearance of 4 mm. Whereas, the lowest extraction loss (1.58%) was recorded at 18.80 rpm roller speed and roller clearance of 5 mm. The mean gel extraction loss was 2.64%, the standard deviation of treatment combinations of gel extraction loss was 0.87 and the coefficient of variance of gel extraction loss was 32.85%. The interaction effect of 18.80 rpm roller speed and 5 mm of roller clearance on gel extraction loss was significant ( $p < 0.05$ ) at five per cent level are shown in Table 4.

There was no gel extraction loss from manual extraction (control) compared to machine extracted Aloe vera gel are presented in Table 4.

The analysis of variance (ANOVA) and estimated coefficient values of gel extraction loss of Aloe vera gel are presented in Table 6. The model (2FI) F-value of 29.79 implies that the model was significant ( $p < 0.05$ ). In this case, A and B were significant model factors. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that proposed models fitted the experimental data with  $R^2$  value of 0.9298, whereas the optimized predictive model had an  $R^2$  value of 0.8420 and was in reasonable agreement with the “Adj R-Squared” of 0.8986. The optimized predictive model (in terms of actual

factors) for extraction loss of Aloe vera gel is presented in equation 4.4. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 18.3651 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for gel extraction loss of Aloe vera gel is presented in the following equation.

$$\text{Gel extraction loss (\%)} = 2.64 + 0.46 * A + 0.98 * B + 0.42 * (A \times B) \quad \dots (4.4)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

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

The gel recovery of Aloe vera gel from Aloe vera gel extraction machine at different roller speed and roller clearance combinations are presented in Table 4. From Table 4, it is seen that at 11.40 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the gel recovery ranged from 37.93 to 41.08%. Among the constant roller speed and different roller clearance combinations, the gel recovery (41.08%) was the highest at 11.40 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest gel recovery (37.93%) was recorded at 11.40 rpm roller speed and roller clearance of 4 mm. From Table 4, it is observed that at 15.10 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the gel recovery ranged from 40.02 to 42.28%. Among the constant roller speed and different roller clearance combinations, the gel recovery (42.28%) was the highest at 15.10 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest gel recovery (40.02%) was recorded at 15.10 rpm roller speed and roller clearance of 4 mm. From Table 4, At 18.80 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the gel recovery ranged from 40.18 to 43.57%. Among the constant roller speed and different roller clearance combinations, the gel recovery (43.57%) was the highest at 18.80 rpm roller speed and roller clearance of 5 mm. whereas, the lowest gel recovery (40.18%) was recorded at 18.80 rpm roller speed and roller clearance of 4 mm. The mean treatment combination of gel recovery was 40.60%, the standard deviation of treatment combinations of gel recovery was 1.90 and the coefficient of variance of gel recovery was 4.68%. The interaction effect of 18.80 rpm 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 4.

**Table 6. Analysis of variance for gel extraction loss (%) of Aloe vera gel extraction machine**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	18.08	8	2.26	29.79	< 0.0001(S)	Intercept	2.64	0.05	2.53	2.75
A-Roller speed (rpm)	3.42	2	1.71	22.54	< 0.0001	A	0.46	0.07	0.31	0.62
B-Roller clearance (mm)	13.28	2	6.64	87.55	< 0.0001	B	0.98	0.07	0.82	1.13
A×B	1.38	4	0.34	4.54	0.0104	A×B	0.42	0.11	0.20	0.64
Pure Error	1.37	18	0.08							
Corr. Total	19.44	26								
SD	2.64	R-Squared		0.9298	SD – Standard deviation					
Mean	0.28	Adj R-Squared		0.8986	C.V. (%) – Coefficient of variance					
C.V. %	10.42	Pred R-Squared		0.8420						
PRESS	3.07	Adeq Precision ratio		18.3651						

Significant at (<0.0001%) one percent level significant

The gel recovery from manual extraction (control) of Aloe vera gel was found to be 57.88%. This gel recovery was higher compared to machine extracted Aloe vera gel and is presented in Table 4.

The analysis of variance (ANOVA) and estimated coefficient values of gel recovery of Aloe vera gel are presented in Table 7. The model (2FI) F-value of 7.98 implies that the model was significant ( $p < 0.05$ ). In this case, A, B were significant model factors. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.7800, whereas the optimized predictive model had an  $R^2$  value of 0.5050 and was in reasonable agreement with the “Adj R-Squared” of 0.6822. The optimized predictive model (in terms of actual factors) for gel recovery of Aloe vera gel is presented in equation 4.5. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 8.3998 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for gel recovery of Aloe vera gel is presented in the following equation.

$$\text{Gel recovery (\%)} = 40.60 - 1.83A^* - 1.22B^* + 0.38(A \times B) \quad \dots (4.5)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.2.4 Effect of roller speed and roller clearance on extraction capacity ( $\text{kg.h}^{-1}$ ) of extraction machine**

The extraction capacity of Aloe vera gel from Aloe vera gel extraction machine at different roller speed and roller clearance combinations are presented in Table 4. From Table 4, it is seen that at 11.40 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction capacity ranged from 104.32 to 115.02  $\text{kg.h}^{-1}$ . Among the constant roller speed and different roller clearance combinations, the extraction capacity (115.02  $\text{kg.h}^{-1}$ ) was the highest at 11.40 rpm roller speed and roller clearance of 5 mm. whereas, the lowest extraction capacity (104.32  $\text{kg.h}^{-1}$ ) was recorded at 11.40 rpm roller speed and roller clearance of 4 mm. From Table 4, it is observed that at 15.10 rpm roller clearance (4, 5 and 6 mm) combinations, the extraction capacity ranged from 114.20 to 128.11  $\text{kg.h}^{-1}$ .

**Table 7. Analysis of variance for gel recovery (%) of Aloe vera gel extraction machine**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	86.53	8	10.82	7.98	0.0001 (S)	Intercept	40.60	0.22	40.13	41.07
A-Roller speed (rpm)	45.99	2	22.99	16.96	< 0.0001	A	-1.83	0.32	-2.50	-1.17
B-Roller clearance (mm)	39.18	2	19.59	14.45	0.0002	B	-1.22	0.32	-1.89	-0.56
A×B	1.36	4	0.34	0.25	0.9051	A×B	0.38	0.45	-0.56	1.32
Pure Error	24.40	18	1.36							
Corr.Total	110.93	26								
SD	40.60	R-Squared		0.7800	SD – Standard deviation					
Mean	1.16	Adj R-Squared		0.6822	C.V.(%) – Coefficient of variance					
C.V. %	2.87	Pred R-Squared		0.5050						
PRESS	54.91	Adeq Precision ratio		8.3998						

S = Significant at (p<0.0001%) one per cent level

Among the constant roller speed and different roller clearance combinations, the extraction capacity ( $128.11 \text{ kg.h}^{-1}$ ) was the highest at 15.10 rpm roller speed and roller clearance of 6 mm, whereas, the lowest extraction capacity ( $114.20 \text{ kg.h}^{-1}$ ) was recorded at 15.10 rpm roller speed and roller clearance of 4 mm. At 18.80 rpm roller speed and different roller clearance (4, 5 and 6 mm) combinations, the extraction capacity ranged from 140.98 to  $158.06 \text{ kg.h}^{-1}$ . Among the constant roller speed and different roller clearance combinations, the extraction capacity ( $158.06 \text{ kg.h}^{-1}$ ) was the highest at 18.80 rpm roller speed and roller clearance of 5 mm. Whereas, the lowest extraction capacity ( $140.98 \text{ kg.h}^{-1}$ ) was recorded at 18.80 rpm roller speed and roller clearance of 6 mm. The mean treatment combination of extraction capacity was  $125.64 \text{ kg.h}^{-1}$ , the standard deviation of treatment combinations of extraction capacity was 18.99 and the coefficient of variance of extraction capacity was 15.12%. The interaction effect of 18.80 rpm roller speed and 5 mm of roller clearance on extraction capacity was significant ( $p < 0.05$ ) at five per cent level.

The extraction capacity from manual extraction (control) of Aloe vera gel was found to be  $3.15 \text{ kg.h}^{-1}$ . This extraction capacity was less compared to machine extraction process are presented in Table 4.

The analysis of variance (ANOVA) and estimated coefficient values of extraction capacity of Aloe vera gel are presented in Table 8. The model (2FI) F-value of 6.25 implies that the model was significant ( $p < 0.0001$ ). In this case, A was significant model factor. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that proposed models fitted the experimental data with  $R^2$  value of 0.7354, whereas the optimized predictive model had an  $R^2$  value of 0.4046 and was in reasonable agreement with the “Adj R-Squared” of 0.6178. The optimized predictive model (in terms of actual factors) for extraction capacity of Aloe vera gel is presented in equation 4.6. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 7.0751 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for extraction capacity of Aloe vera gel is presented in the following equation.

$$\text{Extraction capacity (kg.h}^{-1}\text{)} = 125.64* -17.16A* -5.65*B + 1.49*(A \times B) \quad \dots (4.6)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

**Table 8. Analysis of variance for extraction capacity (kg.h<sup>-1</sup>) of Aloe vera gel extraction machine**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	8657.32	8	1082.16	6.25	0.0006	Intercept	125.64	2.53	120.32	130.96
A-Roller speed (rpm)	7700.74	2	3850.37	22.25	< 0.0001	A	-17.16	3.58	-24.68	-9.64
B-Roller clearance (mm)	929.93	2	464.97	2.69	0.0953	B	-5.65	3.58	-13.17	1.87
A×B	26.64	4	6.66	0.0385	0.9969	A×B	1.49	5.06	-9.14	12.13
Pure Error	3115.05	18	173.06							
Corr.Total	11772.37	26								
SD	13.16	R-Squared		0.7354	SD – Standard deviation					
Mean	125.64	Adj R-Squared		0.6178	C.V. (%) – Coefficient of variance					
C.V. %	10.47	Pred R-Squared		0.4046						
PRESS	7008.87	Adeq Precision ratio		7.0751						

S=Significant at (p<0.05) five per cent level

### **4.3 Bio-chemical properties of Aloe vera gel**

The bio-chemical properties of Aloe vera gel *viz.*, moisture content, carbohydrate, ash content, crude protein, crude fat, TSS (Total Soluble Solids), pH, water activity ( $a_w$ ), colour and viscosity (mPa.s) were determined using different standard analytical methods as explained in Chapter III. The data obtained are presented in Table 9.

#### **4.3.1 Moisture content (%)**

The results obtained for moisture content of the fresh Aloe vera gel is presented in Table 9. The data shows that the average moisture content of fresh Aloe vera gel was recorded as 98.34% (w.b.).

#### **4.3.2 Carbohydrate content (%)**

The average carbohydrate content of fresh Aloe vera gel was found to be 1.20%. The data on carbohydrate content of fresh Aloe vera gel is presented in Table 9.

#### **4.3.3 Ash content (%)**

The ash content of the fresh Aloe vera gel is presented in Table 9. The data shows that the ash content of fresh Aloe vera gel was recorded as 0.24%.

#### **4.3.4 Crude protein (%)**

The result on the protein content of fresh Aloe vera gel sample is presented in Table 9. From the data, it was observed that the protein content of fresh Aloe vera gel was 0.16%.

#### **4.3.5 Crude fat (%)**

The average fat content of fresh Aloe vera gel was found to be 0.06%. The data on fat content of fresh Aloe vera gel is presented in Table 9.

#### **4.3.6 TSS (Total Soluble Solids)**

The TSS content of the fresh Aloe vera gel is presented in Table 9. The data shows that the TSS content of fresh Aloe vera gel was recorded as 1.66%.

#### **4.3.7 pH**

From the data, it was observed that the pH of fresh Aloe vera gel was 6.13 (Table 9).

#### **4.3.8 Water activity ( $a_w$ )**

From the data, it was observed that the water activity of fresh gel was 0.910 (Table 9).

#### **4.3.9 Colour**

The colour values of fresh Aloe vera gel samples are presented in Table 9. The results indicated that the average colour values *viz.*,  $L^*$ ,  $a^*$  and  $b^*$  values of fresh Aloe vera gel were 29.37, -3.52 and 4.65, respectively.

**Table 9. Bio-chemical properties of Aloe vera gel**

<b>Sl. No.</b>	<b>Parameters</b>	<b>Mean value</b>	
1	Moisture content (% w.b.)	98.34	
2	Carbohydrate (%)	1.20	
3	Ash content (%)	0.24	
4	Crude protein (%)	0.16	
5	Crude fat (%)	0.06	
6	TSS (% Brix)	1.66	
7	pH	6.13	
8	Water activity ( $a_w$ )	0.910	
	$L^*$	29.37	
9	Colour	$a^*$	-3.52
		$b^*$	4.65
10	Viscosity (mPa. s)	1.61	

#### 4.3.10 Viscosity

From the data, it was observed that the viscosity of fresh Aloe vera gel was 1.61mPa. s (Table 9).

#### 4.4 Proximate composition of Aloe vera gel obtained from Aloe vera gel extraction machine

##### 4.4.1 Effect of roller speed and roller clearance combinations on moisture content of Aloe vera gel

The moisture content of Aloe vera gel extracted at different roller speed and roller clearance combinations are determined, analyzed statistically and presented in Table 10. From the data, it was observed that the moisture content was in the range of 98.38 to 98.70% (w.b.). Among the different treatment combinations, the moisture content of 98.70% (w.b.) was the highest at roller speed of 11.40 rpm and roller clearance of 5 mm in treatment T<sub>2</sub>, whereas the lowest of 98.38% was recorded at roller speed of 18.80 rpm and roller clearance of 5 mm at treatment T<sub>8</sub>. The mean treatment combination of moisture content was 98.60% (w.b.), the standard deviation of treatment combinations of moisture content was 0.109 and the coefficient of variance of moisture content was 0.11%. The interaction effect of treatment combinations were not significant ( $p < 0.05$ ) at five per cent level. The moisture content of Aloe vera gel extracted was nearly same when compared to fresh gel (98.34%).

The analysis of variance (ANOVA) and estimated coefficient values of moisture content of Aloe vera gel are presented in Table 11. The model (2FI) F-value of 2.21 implies that the model was not significant ( $p < 0.0001$ ). The values greater than 0.1 indicate that the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with R<sup>2</sup> value of 0.4954, whereas the optimized predictive model had an R<sup>2</sup> value of -0.1353 and was in reasonable agreement with the “Adj R-Squared” of 0.2711. The optimized predictive model (in terms of actual factors) for moisture content of Aloe vera gel is presented in equation 4.7. (Adeq Precision ratio more than 4 was desirable). The Adeq Precision ratio of 4.3782 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for moisture content of Aloe vera gel is presented in the following equation.

$$\text{Moisture content (\%)} = 98.5952 + 0.0726 * A + 0.0337 * B - 0.0248 * (A \times B) \quad \dots (4.7)$$

Where, A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

**Table 10. Proximate composition of Aloe vera gel obtained from Aloe vera gel extraction machine**

<b>Sl. No.</b>	<b>Treatment Combination</b>	<b>Roller Speed (rpm)</b>	<b>Roller clearance (mm)</b>	<b>Moisture content (% w.b.)</b>	<b>Carbohydrates (%)</b>	<b>Ash (%)</b>	<b>Crude fat (%)</b>	<b>Crude protein (%)</b>	<b>TSS % Brix</b>
	<b>Control</b>			98.34	1.20	0.24	0.06	0.16	1.66
1	T <sub>1</sub>	11.40	4	98.68	0.98	0.16	0.03	0.15	1.39
2	T <sub>2</sub>	11.40	5	98.70	0.90	0.20	0.03	0.17	1.34
3	T <sub>3</sub>	11.40	6	98.63	0.99	0.21	0.03	0.14	1.37
4	T <sub>4</sub>	15.10	4	98.68	0.98	0.18	0.02	0.14	1.32
5	T <sub>5</sub>	15.10	5	98.63	1.01	0.18	0.03	0.15	1.39
6	T <sub>6</sub>	15.10	6	98.66	0.98	0.19	0.03	0.15	1.34
7	T <sub>7</sub>	18.80	4	98.53	1.08	0.19	0.03	0.17	1.47
8	T <sub>8</sub>	18.80	5	98.38	1.23	0.19	0.03	0.16	1.65
9	T <sub>9</sub>	18.80	6	98.48	1.13	0.21	0.03	0.15	1.52
		Mean		98.60	1.03	0.19	0.03	0.15	1.42
		SD		0.109	0.100	0.016	0.004	0.012	0.106
		C.V.%		0.11	9.74	8.32	11.86	7.78	7.48

**Table 11. Analysis of variance for moisture content (% w.b.) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.28	8	0.0354	2.21	0.0775 (NS)	Intercept	98.5952	0.0244	98.5440	98.6464
A-Roller speed (rpm)	0.24	2	0.1177	7.35	0.0046	A	0.0726	0.0345	0.0002	0.1450
B-Roller clearance (mm)	0.02	2	0.0085	0.53	0.5983	B	0.0337	0.0345	-0.0387	0.1061
A×B	0.03	4	0.0077	0.48	0.7501	A×B	-0.0248	0.0487	-0.1272	0.0776
Pure Error	0.29	18	0.0160							
Corr. Total	0.57	26								
SD	0.13	R-Squared		0.4954	SD – Standard deviation					
Mean	98.60	Adj R-Squared		0.2711	C.V.% – Coefficient of variance					
C.V. %	0.13	Pred R-Squared		-0.1353						
PRESS	0.65	Adeq Precision ratio		4.3782						

NS –Non Significant at (p<0.05) five per cent level

#### **4.4.2 Effect of roller speed and roller clearance combinations on carbohydrate content of Aloe vera gel**

The carbohydrate content of Aloe vera gel extracted at different roller speed and roller clearance combinations were determined, analyzed statistically and are presented in Table 10. From the data, it was observed that, the carbohydrate content was in the range of 0.90 to 1.23%. Among the different treatment combinations, the carbohydrate content of 1.23% was the highest at roller speed of 18.80 rpm and roller clearance of 5 mm, whereas the lowest of 0.90% was recorded at roller speed of 11.40 rpm and roller clearance of 5 mm. The mean treatment combination of carbohydrate content was 1.03%, the standard deviation of treatment combinations of carbohydrate content was 0.10 and the coefficient of variance of carbohydrate was 9.74%. The interaction effect of treatment combinations were not significant ( $p < 0.05$ ) at one per cent level. The carbohydrate content of Aloe vera gel extracted was nearly same compared to fresh Aloe vera gel (1.20%).

The analysis of variance (ANOVA) and estimated coefficient values of carbohydrate content of Aloe vera gel are presented in Table 12. The model (2FI) F-value of 1.81 implies that the model was not significant ( $p < 0.0001$ ). The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.4461, whereas the optimized predictive model had an  $R^2$  value of -0.2463 and was in reasonable agreement with the “Adj R-Squared” of 0.1999. The optimized predictive model (in terms of actual factors) for carbohydrate content of Aloe vera gel is presented in equation 4.8. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 4.4215 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for carbohydrate of Aloe vera gel is presented in the following equation.

$$\text{Carbohydrate content (\%)} = 1.0311 - 0.0756 * A - 0.0178 * B + 0.0422 * (A \times B) \quad \dots (4.8)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.4.3 Effect of roller speed and roller clearance combinations on Ash content of Aloe vera gel**

The ash content of Aloe vera gel extracted at different roller speed and roller clearance combinations were determined, analyzed statistically and are presented in Table 10.

**Table 12. Analysis of variance for carbohydrate content (%) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.24	8	0.0303	1.81	0.1404 (NS)	Intercept	1.0311	0.0249	0.9788	1.0834
A-Roller speed (rpm)	0.19	2	0.0961	5.75	0.0117	A	-0.0756	0.0352	-0.1495	-0.0016
B-Roller clearance (mm)	0.01	2	0.0027	0.16	0.8531	B	-0.0178	0.0352	-0.0917	0.0561
A×B	0.04	4	0.0112	0.67	0.6226	A×B	0.0422	0.0498	-0.0623	0.1468
Pure Error	0.30	18	0.0167							
Cor Total	0.54	26								
SD	0.13	R-Squared		0.4461	SD – Standard deviation					
Mean	1.03	Adj R-Squared		0.1999	C.V.% – Coefficient of variance					
C.V. %	12.54	Pred R-Squared		-0.2463						
PRESS	0.68	Adeq Precision ratio		4.4215						

NS – Non Significant at (p<0.05) five per cent level

From the data, it was observed that, the ash content was in the range of 0.16 to 0.21% in case of Aloe vera gel obtained through gel extraction machine. Among the different treatment combinations, the ash content of 0.21% was the highest at both roller speed of 11.40 and 18.80 rpm and roller clearance of 6 mm, whereas the lowest of 0.16% was recorded at roller speed of 11.40 rpm and roller clearance of 4 mm. The mean treatment combination of ash content was 0.19%, the standard deviation of treatment combinations of ash content was 0.016 and the coefficient of variance of ash was 8.32%. The interaction effect of treatment combinations are not significant ( $p < 0.05$ ) at five per cent level. The ash content of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (0.24%).

The analysis of variance (ANOVA) and estimated coefficient values of ash content of Aloe vera gel are presented in Table 13. The model (2FI) F-value of 0.85 implies that the model was not significant ( $p > 0.0001$ ). In this case, model factors were not significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that proposed models fitted the experimental data with  $R^2$  value of 0.2752, whereas the optimized predictive model had an  $R^2$  value of -0.6307 and was in reasonable agreement with the “Adj R-Squared” of 0.0469. The optimized predictive model (in terms of actual factors) for ash content of Aloe vera gel is presented in equation 4.9. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 3.1179 indicates an not adequate signal.

The optimized predictive model (in terms of actual factors) for ash content of Aloe vera gel is presented in the following equation.

$$\text{Ash content (\%)} = 0.1900 + 0.0011 * A - 0.0144 * B - 0.0167 * (A \times B) \quad \dots (4.9)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.4.4 Effect of roller speed and roller clearance combinations on crude fat content of Aloe vera gel**

The crude fat content of Aloe vera gel extracted at different roller speed and roller clearance combinations were determined, analyzed statistically and presented in Table 10. From the data, it is observed that, the crude fat content was in the range of 0.02 to 0.03% in case of Aloe vera gel obtained through gel extraction machine.

**Table 13. Analysis of variance for ash content (%) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.0060	8	0.0008	0.85	0.5698 (NS)	Intercept	0.1900	0.0057	0.1780	0.2020
A-Roller speed (rpm)	0.0007	2	0.0003	0.39	0.6811	A	0.0011	0.0081	-0.0158	0.0181
B-Roller clearance (mm)	0.0033	2	0.0016	1.86	0.1843	B	-0.0144	0.0081	-0.0314	0.0025
A×B	0.0020	4	0.0005	0.58	0.6794	A×B	-0.0167	0.0114	-0.0406	0.0073
Pure Error	0.0158	18	0.0009							
Corr. Total	0.0218	26								
SD	0.03	R-Squared	0.2752	SD – Standard deviation						
Mean	0.19	Adj R-Squared	-0.0469	C.V.% – Coefficient of variance						
C.V. %	15.59	Pred R-Squared	-0.6307							
PRESS	0.04	Adeq ratio	Precision	3.1179						

NS –Non Significant at (p<0.05) five per cent level

Among the different treatment combinations, the crude fat content of 0.03% was the highest at roller speeds of 11.40, 15.10 and 18.80 rpm and roller clearances of 4, 5 and 6 mm, whereas the lowest of 0.02% was recorded at roller speed of 15.10 rpm and roller clearance of 4 mm. The mean treatment combination of crude fat content was 0.03, the standard deviation of treatment combinations of crude fat content was 0.004 and the coefficient of variance of crude fat was 11.86%. The interaction effect of treatment combinations are not significant ( $p < 0.05$ ) at five per cent level. The crude fat content of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (0.06%).

The analysis of variance (ANOVA) and estimated coefficient values of crude fat content of Aloe vera gel are presented in Table 14. The model (2FI) F-value of 0.28 implies that the model was not significant ( $p < 0.0001$ ). In this case, model factor were not significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that proposed models fitted the experimental data with  $R^2$  value of 0.1099, whereas the optimized predictive model had an  $R^2$  value of -0.0027 and was in reasonable agreement with the “Adj R-Squared” of -0.2857. The optimized predictive model (in terms of actual factors) for crude fat content of Aloe vera gel is presented in equation 4.10. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 1.5000 indicates an inadequate signal.

The optimized predictive model (in terms of actual factors) for crude fat content of Aloe vera gel is presented in the following equation.

$$\text{Crude fat content (\%)} = 0.0296 + 0.0015 * A - 0.0019 * B + 0.0041 * (A \times B) \quad \dots (4.10)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.4.5 Effect of roller speed and roller clearance combinations on crude protein content of Aloe vera gel**

The crude protein content of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 10. From the data, it was observed that the crude protein content was in the range of 0.14 to 0.17%.

**Table 14. Analysis of variance for crude fat content (%)**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.0003	8	3.7E-05	0.28	0.9650 (NS)	Intercept	0.0296	0.0022	0.0250	0.0343
A-Roller speed (rpm)	0.0001	2	5.93E-05	0.44	0.6480	A	0.0015	0.0031	-0.0051	0.0081
B-Roller clearance (mm)	0.0001	2	2.59E-05	0.19	0.8250	B	-0.0019	0.0031	-0.0085	0.0048
A×B	0.0001	4	3.15E-05	0.24	0.9143	A×B	0.0041	0.0044	-0.0053	0.0134
Pure Error	0.0024	18	0.000133							
Corr. Total	0.0027	26								
SD	0.01	R-Squared	0.1099	SD – Standard deviation						
Mean	0.03	Adj R-Squared	-0.2857	C.V.% – Coefficient of variance						
C.V. %	38.97	Pred R-Squared	-1.0027							
PRESS	0.01	Adeq Precision ratio	1.5000							

NS –Non Significant at (p<0.05) five per cent level

Among the different treatment combinations, the crude protein content of 0.17% was the highest at T<sub>2</sub> and T<sub>7</sub> roller speeds of 15.10 and 18.80 rpm and roller clearances of 4 and 5 mm, whereas the lowest of 0.14% was recorded at T<sub>3</sub> and T<sub>4</sub> roller speeds of 11.40 and 15.10 rpm and roller clearances of 4 and 6 mm. The mean treatment combination of crude protein content was 0.15%, the standard deviation of treatment combinations of crude protein content was 0.012 and the coefficient of variance of crude protein was 7.78%. The interaction effect of treatment combinations are not significant ( $p < 0.05$ ) at five per cent level. The crude protein content of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (0.16%).

The analysis of variance (ANOVA) and estimated coefficient values of crude protein content of Aloe vera gel are presented in Table 15. The model (2FI) F-value of 0.97 implies that the model was not significant ( $p < 0.05$ ). The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with R<sup>2</sup> value of 0.3014, whereas the optimized predictive model had an R<sup>2</sup> value of -0.5718 and was in reasonable agreement with the “Adj R-Squared” of -0.0091. The optimized predictive model (in terms of actual factors) for crude protein content of Aloe vera gel is presented in equation 4.11. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 2.7386 indicates an inadequate signal.

The optimized predictive model (in terms of actual factors) for Crude protein of Aloe vera gel is presented in the following equation.

$$\text{Crude protein (\%)} = 0.1541 + 0.0004A + 0.0004B - 0.0048A \times B \quad \dots (4.11)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.4.6 Effect of roller speed and roller clearance combinations on TSS (% Brix) content of Aloe vera gel**

The TSS content of Aloe vera gel extracted at different roller speed and roller clearance combinations were determined, analyzed statistically and are presented in Table 10. From the data, it was observed that, the TSS content was in the range of 1.32 to 1.65%. Among the different treatment combinations, the TSS content of 1.65% was the highest at roller speed of 18.80 rpm and roller clearance of 5 mm, whereas the lowest TSS content of 1.32% was recorded at roller speed of 15.10 rpm and roller clearance of 4 mm.

**Table 15. Analysis of variance for crude protein content (%) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.0035	8	0.0004	0.97	0.4881 (NS)	Intercept	0.1541	0.0041	0.1456	0.1626
A-Roller speed (rpm)	0.0009	2	0.0005	1.06	0.3677	A	0.0004	0.0057	-0.0117	0.0124
B-Roller clearance (mm)	0.0007	2	0.0003	0.76	0.4828	B	0.0004	0.0057	-0.0117	0.0124
A×B	0.0018	4	0.0005	1.03	0.4171	A×B	-0.0048	0.0081	-0.0219	0.0122
Pure Error	0.0080	18	0.0004							
Corr. Total	0.0115	26								
SD	0.02	R-Squared	0.3014	SD – Standard deviation						
Mean	0.15	Adj R-Squared	-0.0091	C.V.% – Coefficient of variance						
C.V. %	13.68	Pred R-Squared	-0.5718							
PRESS	0.02	Adeq Precision	2.7386							

NS –Non Significant at (p<0.05) five per cent level

The mean treatment combination of TSS content was 1.42%, the standard deviation of treatment combinations of TSS content was 0.106 and the coefficient of variance of TSS content was 7.48%. The interaction effect of treatment combinations were not significant ( $p < 0.05$ ) at five per cent level. The TSS content of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (1.66%).

The analysis of variance (ANOVA) and estimated coefficient values of TSS content of Aloe vera gel are presented in Table 16. The model (2FI) F-value of 1.91 implies that the model was not significant ( $p < 0.05$ ). The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.4596, whereas the optimized predictive model had an  $R^2$  value of -0.2158 and was in reasonable agreement with the “Adj R-Squared” of 0.2195. The optimized predictive model (in terms of actual factors) for TSS content of Aloe vera gel is presented in equation 4.12. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 4.2497 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for TSS content of Aloe vera gel is presented in the following equation.

$$\text{TSS content (\%)} = 1.4211 - 0.0533 * A - 0.0267 * B + 0.0522 * (A \times B) \quad \dots (4.12)$$

Where, A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5 Quality parameters of Aloe vera gel obtained from Aloe vera gel extraction machine**

##### **4.5.1 Effect of roller speed and roller clearance combinations on pH of Aloe vera gel**

The pH of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 17. From the data, it was observed that, the pH was in the range of 6.10 to 6.17. Among the different treatment combinations, the pH of 6.17 was the highest at roller speed of 18.80 rpm and roller clearance of 4 mm, whereas the lowest pH of 6.10 was recorded at roller speed of 11.40 rpm and both roller clearance of 6 mm. The mean treatment combination of pH was 6.13, the standard deviation of treatment combinations of pH was 0.03 and the coefficient of variance of pH was 0.42%. The interaction effect of treatment combinations were significant ( $p < 0.05$ ) at five per cent level.

**Table 16. Analysis of variance for TSS (% Brix) content of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence interval	
									Low	High
Model	0.2714	8	0.0339	1.91	0.1205 (NS)	Intercept	1.4211	0.0256	1.3673	1.4749
A-Roller speed (rpm)	0.2105	2	0.1052	5.94	0.0105	A	-0.0533	0.0362	-0.1295	0.0228
B-Roller clearance (mm)	0.0194	2	0.0097	0.55	0.5879	B	-0.0267	0.0362	-0.1028	0.0495
A×B	0.0415	4	0.0104	0.59	0.6772	A×B	0.0522	0.0512	-0.0554	0.1599
Pure Error	0.3191	18	0.0177							
Corr. Total	0.5905	26								
SD	0.13	R-Squared		0.4596	SD – Standard deviation					
Mean	1.42	Adj R-Squared		0.2195	C.V.% – Coefficient of variance					
C.V. %	9.37	Pred R-Squared		-0.2158						
PRESS	0.72	Adeq Precision ratio		4.2497						

NS –Non Significant at (p<0.05) five per cent level

**Table 17. Quality parameters of Aloe vera gel from Aloe vera gel extraction machine**

Sl. No.	Treatment combination	Roller Speed (rpm)	Roller Clearance (mm)	pH Value	Water activity (a <sub>w</sub> )	Colour value			Viscosity (mPa. s)
						L*	a*	b*	
	Control			<b>6.13</b>	<b>0.910</b>	<b>29.37</b>	<b>-3.52</b>	<b>4.65</b>	<b>1.61</b>
1	T <sub>1</sub>	11.40	4	6.13	0.910	29.00	-4.17	15.30	1.23
2	T <sub>2</sub>	11.40	5	6.11	0.910	24.68	-3.63	12.42	1.36
3	T <sub>3</sub>	11.40	6	6.10	0.907	24.46	-3.72	11.86	1.45
4	T <sub>4</sub>	15.10	4	6.15	0.910	28.31	-4.17	13.81	1.26
5	T <sub>5</sub>	15.10	5	6.15	0.910	27.02	-3.51	12.54	1.45
6	T <sub>6</sub>	15.10	6	6.11	0.910	24.38	-3.67	7.26	1.50
7	T <sub>7</sub>	18.80	4	6.17	0.910	29.66	-3.89	17.44	1.36
8	T <sub>8</sub>	18.80	5	6.15	0.910	29.07	-3.53	11.25	1.64
9	T <sub>9</sub>	18.80	6	6.11	0.900	22.75	-3.68	7.29	1.59
		Mean		6.13	0.909	26.59	-3.77	12.13	1.43
		SD		0.03	0.03	2.56	0.25	3.34	0.14
		C.V.%		0.42	0.37	9.61	-6.67	27.55	9.71

The pH of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (6.13).

The analysis of variance (ANOVA) and estimated coefficient values of pH of Aloe vera gel are presented in Table 18. The model (2FI) F-value of 7.49 implies that the model was significant ( $p < 0.05$ ). The values of "Prob > F" are less than 0.05 indicating that the model term A and B were significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.7691, whereas the optimized predictive model had an  $R^2$  value of 0.4804 and was in reasonable agreement with the "Adj R-Squared" of 0.6664. The optimized predictive model (in terms of actual factors) for pH of Aloe vera gel is presented in equation 4.13. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 7.8328 indicates an adequate signal. The optimized predictive model (in terms of actual factors) for pH of Aloe vera gel is presented in the following equation.

$$\text{pH} = 6.1304 - 0.0170 * A + 0.0185 * B - 0.0052 * (A \times B) \quad \dots (4.13)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5.2 Effect of roller speed and roller clearance combinations on water activity ( $a_w$ ) value of Aloe vera gel**

The water activity ( $a_w$ ) of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 17. From the data, it is observed that, the water activity ( $a_w$ ) value was in the range of 0.900 to 0.910. Among the different treatment combinations, the water activity ( $a_w$ ) of 0.910 was the highest at roller speed of 11.40, 15.10 and 18.80 rpm and roller clearance of 4, 5 and 6 mm, whereas the lowest water activity of 0.900 was recorded at roller speed of 18.80 and roller clearance of 6 mm. The mean treatment combination of water activity was 0.909, the standard deviation of treatment combinations of water activity value was 0.03 and the coefficient of variance of water activity was 0.37%. The interaction effect of treatment combinations are significant ( $p < 0.05$ ) at five per cent level. The water activity of Aloe vera gel extracted was different from fresh Aloe vera gel (0.910).

The analysis of variance (ANOVA) and estimated coefficient values of water activity ( $a_w$ ) value of Aloe vera gel are presented in Table 19.

**Table 18. Analysis of variance for pH value of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.0158	8	0.0020	7.49	0.0002 (S)	Intercept	6.1304	0.0031	6.1238	6.1369
A-Roller speed (rpm)	0.0045	2	0.0022	8.51	0.0025	A	-0.0170	0.0044	-0.0263	-0.0078
B-Roller clearance (mm)	0.0096	2	0.0048	18.31	<0.0001	B	0.0185	0.0044	0.0092	0.0278
A×B	0.0017	4	0.0004	1.58	0.2232	A×B	-0.0052	0.0062	-0.0183	0.0079
Pure Error	0.0047	18	0.0003							
Corr. Total	0.0205	26								
SD	0.0162	R-Squared		0.7651	SD. – Standard deviation					
Mean	6.1304	Adj R-Squared		0.6664	C.V. % – Coefficient of variance					
C.V. %	0.2645	Pred R-Squared		0.4804						
PRESS	0.0107	Adeq Precision ratio		7.8328						

Significant at (p<0.05) five per cent level

**Table 19. Analysis of variance for water activity ( $a_w$ ) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.0003	8	3.46E-05	9.25	< 0.0001 (S)	Intercept	0.9085	0.0004	0.9077	0.9093
A-Roller speed (rpm)	0.0001	2	2.59E-05	7	< 0.0001	A	0.0004	0.0005	-0.0007	0.0015
B-Roller clearance (mm)	0.0001	2	5.93E-05	16	0.0001	B	0.0015	0.0005	0.0004	0.0026
A×B	0.0001	4	2.59E-05	7	0.0014	A×B	-0.0004	0.0007	-0.0019	0.0012
Pure Error	0.0001	18	3.7E-06							
Corr. Total	0.0003	26								
SD	0.0019	R-Squared		0.8043	SD – Standard deviation					
Mean	0.9085	Adj R-Squared		0.7174	C.V.% – Coefficient of variance					
C.V. %	0.2118	Pred R-Squared		0.5598						
PRESS	0.0002	Adeq Precision ratio		9.0000						

Significant at (p<0.0001%) one percent level

The model (2FI) F-value of 9.25 implies that the model was significant ( $p < 0.0001$ ). The values of "Prob < F" are less than 0.0001 indicating the model term A was significant. The values of "Prob < F" are less than 0.0005 indicating the model terms A and B were significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.8043, whereas the optimized predictive model had an  $R^2$  value of 0.5598 and was in reasonable agreement with the "Adj R-Squared" of 0.7174. The optimized predictive model (in terms of actual factors) for water activity of Aloe vera gel was presented in equation 4.14. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 9.0000 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for  $a_w$  value of Aloe vera gel is presented in the following equation.

$$\text{Water activity (} a_w \text{) value} = 0.9085 + 0.0004 * A + 0.0015 * B + 0.0004 * (A \times B) \quad \dots (4.14)$$

Where, A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5.3 Effect of roller speed and roller clearance combinations on colour ( $L^*$ ) value of Aloe vera gel**

Colour is the important physical characteristic of Aloe vera gel and is directly related to the acceptability of food product. The maximum value for lightness is 100 indicating whiteness. Therefore, decrease in  $L^*$  value indicates a decrease in whiteness.

The colour ( $L^*$ ) values of Aloe vera gel extracted at different roller speed and roller clearance combinations were determined, analyzed statistically and are presented in Table 17. From the data, it was observed that, the colour ( $L^*$ ) value was in the range of 22.75 to 29.66 in case of obtained Aloe vera gel through gel extraction machine. Among the different treatment combinations, the colour ( $L^*$ ) value of 29.66 was the highest at roller speed of 18.80 rpm and roller clearance of 4 mm, whereas the lowest colour ( $L^*$ ) value of 22.75 was recorded at roller speed of 18.80 rpm and roller clearance of 6 mm. The mean treatment combination of colour ( $L^*$ ) value was 26.59, the standard deviation of treatment combinations of colour ( $L^*$ ) value was 2.56 and the coefficient of variance of colour ( $L^*$ ) value was 9.61%. The colour ( $L^*$ ) value of Aloe vera gel extracted was different from fresh Aloe vera gel (29.37). The analysis of variance (ANOVA) and estimated coefficient values of colour ( $L^*$ ) value of Aloe vera gel are presented in Table 20.

**Table 20. Analysis of variance for colour ( $L^*$ ) value of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	156.90	8	19.61	7.44	0.0002 (S)	Intercept	26.5930	0.3126	25.9363	27.2496
A-Roller speed (rpm)	5.58	2	2.79	1.06	0.3675	A	-0.5452	0.4420	-1.4738	0.3835
B-Roller clearance (mm)	119.70	2	59.85	22.69	< 0.0001	B	2.3970	0.4420	1.4684	3.3257
A×B	31.61	4	7.90	3.00	0.0466	A×B	0.5552	0.6251	-0.7581	1.8685
Pure Error	47.48	18	2.64							
Corr. Total	204.37	26								
SD	1.62	R-Squared		0.7677	SD – Standard deviation					
Mean	26.59	Adj R-Squared		0.6644	C.V. % – Coefficient of variance					
C.V. %	6.11	Pred R-Squared		0.4773						
PRESS	106.82	Adeq Precision ratio		7.3694						

Significant at (p<0.05) five per cent level

The analysis of variance (ANOVA) and estimated coefficient values of colour ( $L^*$ ) value of Aloe vera gel are presented in Table 20. The model (2FI) F-value of 7.44 implies that the model was significant ( $p < 0.0001\%$ ). The values of "Prob > F" are less than 0.0001 indicating the model term B was significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.7677, whereas the optimized predictive model had an  $R^2$  value of 0.4773 and was in reasonable agreement with the "Adj R-Squared" of 0.6644. The optimized predictive model (in terms of actual factors) for colour ( $L^*$ ) value of Aloe vera gel is presented in equation 4.15. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 7.3694 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for colour ( $L^*$ ) value of Aloe vera gel is presented in the following equation.

$$\text{Colour } (L^*) \text{ value} = 26.5930 - 0.5452 * A + 2.3970 * B + 0.5552 * (A \times B) \quad \dots (4.15)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5.4 Effect of roller speed and roller clearance combinations on colour ( $a^*$ ) value of Aloe vera gel**

The positive values for  $a^*$  indicate redness, while negative values stand for green colour of product. Therefore, increase in  $a^*$  value indicates decrease in green colour.

The colour ( $a^*$ ) value of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 17. From the data, it was observed that, the colour ( $a^*$ ) value was in the range of -4.17 to -3.51. Among the different treatment combinations, the colour ( $a^*$ ) value of -3.51 was the highest at roller speed of 15.10 rpm and roller clearance of 5 mm, whereas the lowest colour ( $a^*$ ) value of -4.17 was recorded at roller speeds of 11.40 and 15.10 rpm and roller clearance of 4 mm. The mean treatment combination of colour ( $a^*$ ) value was -3.77, the standard deviation of treatment combinations of colour ( $a^*$ ) value was 0.25 and the coefficient of variance of colour ( $a^*$ ) value was -6.67%. The interaction effect of treatment combinations are significant ( $p < 0.05$ ) at five per cent level. The colour ( $a^*$ ) value of Aloe vera gel extracted was different when compared to fresh Aloe vera gel (3.52).

The analysis of variance (ANOVA) and estimated coefficient values of colour ( $a^*$ ) value of Aloe vera gel are presented in Table 21.

**Table 21. Analysis of variance for colour ( $a^*$ ) value of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	1.52	8	0.19	2.97	0.0261(S)	Intercept	-3.7737	0.0486	-3.8759	-3.6715
A-Roller speed (rpm)	0.09	2	0.04	0.70	0.5095	A	-0.0652	0.0688	-0.2097	0.0793
B-Roller clearance (mm)	1.33	2	0.67	10.45	0.0010	B	-0.3052	0.0688	-0.4497	0.1607
A×B	0.10	4	0.02	0.37	0.08254	A×B	-0.0259	0.0973	-0.2303	0.1784
Pure Error	1.15	18	0.06							
Cor Total	2.67	26								
SD	0.25	R-Squared		0.5692	SD – Standard deviation					
Mean	-3.77	Adj R-Squared		0.3778	C.V.% – Coefficient of variance					
C.V. %	6.70	Pred R-Squared		-0.0308						
PRESS	2.59	Adeq Precision ratio		4.5463						

Significant at (p<0.05) five per cent level

The model (2FI) F-value of 2.97 implies that the model was significant ( $p < 0.005$ ). In this case factor A was significant. The values of "Prob>F" are more than 0.005 indicating the model terms were not significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.5692, whereas the optimized predictive model had an  $R^2$  value of 0.0308 and was in reasonable agreement with the "Adj R-Squared" of 4.5463. The optimized predictive model (in terms of actual factors) for colour ( $a^*$ ) value of Aloe vera gel is presented in equation 4.16. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 4.5463 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for colour ( $a^*$ ) value of Aloe vera gel is presented in the following equation.

$$\text{Colour } (a^*) \text{ value} = -3.7737 - 0.0652 * A - 0.3052 * B - 0.0259 * (A \times B) \quad \dots (4.16)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5.5 Effect of roller speed and roller clearance combinations on colour ( $b^*$ ) value of Aloe vera gel**

The positive values for  $b^*$  indicate yellowness while negative values stand for green colour of product. Therefore, increase in  $b^*$  value indicates increase in yellow colour. The colour ( $b^*$ ) value of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 17. From the data, it was observed that, the colour ( $b^*$ ) value was in the range of 7.26 to 17.44. Among the different treatment combinations, the lowest colour ( $b^*$ ) value of 7.26 at roller speed of 15.10 rpm and roller clearance of 6 mm, whereas the highest colour ( $b^*$ ) value of 17.44 was recorded at roller speed of 18.80 rpm and roller clearance of 4 mm. The mean treatment combination of colour ( $b^*$ ) value was 12.13, the standard deviation of treatment combinations of colour ( $b^*$ ) value was 3.34 and the coefficient of variance of colour value ( $b^*$ ) was 27.55%. The roller clearance effect of treatment was significant ( $p < 0.001$ ). The interaction effect of treatment combinations was significant ( $p < 0.05$ ) at five percent level. The colour ( $b^*$ ) value of Aloe vera gel extracted was different from fresh Aloe vera gel (4.65).

The analysis of variance (ANOVA) and estimated coefficient values of colour ( $b^*$ ) value of Aloe vera gel are presented in Table 22.

**Table 22. Analysis of variance for colour ( $b^*$ ) value of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	267.96	8	33.49	8.40	< 0.0001 (S)	Intercept	12.1293	0.3842	11.3220	12.9365
A-Roller speed (rpm)	18.06	2	9.03	2.27	0.1325	A	1.0641	0.5434	-0.0775	2.2056
A-Roller clearance (mm)	202.92	2	101.46	25.46	< 0.0001	B	3.3863	0.5434	2.2447	4.5279
A×B	46.97	4	11.74	2.95	0.0490	A×B	-1.2796	0.7684	-2.8941	0.3348
Pure Error	71.75	18	3.99							
Corr. Total	339.70	26								
SD	2.00	R-Squared		0.7888	SD. – Standard deviation					
Mean	12.13	Adj R-Squared		0.6949	C.V.% – Coefficient of variance					
C.V. %	16.46	Pred R-Squared		0.5248						
PRESS	161.43	Adeq Precision ratio		8.8289						

Significant at (p<0.0001%) one percent level

The model (2FI) F-value of 8.40 implies that the model was significant ( $p < 0.0001$ ). The values of "Prob>F" are more than 0.0001 indicating the model term A was significant. The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with  $R^2$  value of 0.7888, whereas the optimized predictive model had an  $R^2$  value of 0.5248 and was in reasonable agreement with the "Adj R-Squared" of 0.6949. The optimized predictive model (in terms of actual factors) for colour ( $b^*$ ) value of Aloe vera gel is presented in equation 4.17. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 8.8289 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for colour ( $b^*$ ) value of Aloe vera gel is presented in the following equation.

$$\text{Colour } (b^*) \text{ value} = 12.1293 + 1.0641 * A + 3.3863 * B - 1.2796 * (A \times B) \quad \dots (4.17)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.5.6 Effect of roller speed and roller clearance combinations on viscosity (mPa.s) of Aloe vera gel**

The viscosity of Aloe vera gel extracted at different roller speed and roller clearance combinations was determined, analyzed statistically and are presented in Table 17. From the data, it was observed that, the viscosity was in the range of 1.23 to 1.64 mPa.s. Among the different treatment combinations, the viscosity of 1.64 mPa.s was the highest at roller speed of 18.80 rpm and roller clearance of 5 mm, whereas the lowest viscosity of 1.23 mPa.s was recorded at roller speed of 11.40 and roller clearance of 4 mm. The mean treatment combination of viscosity was 1.43 mPa.s, the standard deviation of treatment combinations of viscosity was 0.14 and the coefficient of variance of viscosity was 9.71%. The interaction effect of treatment combinations are significant ( $p < 0.05$ ) at five per cent level. The viscosity of Aloe vera gel extracted was different when compared to fresh Aloe vera gel (1.61 mPa.s).

The analysis of variance (ANOVA) and estimated coefficient values of water activity ( $a_w$ ) of Aloe vera gel are presented in Table 23. The model (2FI) F-value of 20.84 implies that the model was significant ( $p < 0.0001$ ). The values of "Prob < F" are less than 0.0001 indicating the model term A, B and AB were significant.

**Table 23. Analysis of variance for viscosity (mPa.s) of Aloe vera gel**

Source	Sum of Squares	Degrees of freedom	Mean Sum of Squares	F Value	p-value Prob > F	Factor	Coefficient Estimate	Standard Error	95% Confidence Interval	
									Low	High
Model	0.46	8	0.06	20.84	< 0.0001 (S)	Factor	1.43	0.01	1.41	1.45
A-Roller speed (rpm)	0.16	2	0.08	28.06	< 0.0001	A	-0.08	0.01	-0.11	-0.05
B-Roller clearance (mm)	0.28	2	0.14	50.69	< 0.0001	B	-0.14	0.01	-0.17	-0.11
A×B	0.03	4	0.01	2.31	0.0974	A×B	0.03	0.02	-0.01	0.07
Pure Error	0.05	18	0.00							
Corr. Total	0.51	26								
SD	0.05	R-Squared		0.9026	SD – Standard deviation					
Mean	1.43	Adj R-Squared		0.8593	C.V.% – Coefficient of variance					
C.V. %	3.68	Pred R-Squared		0.7808						
PRESS	0.11	Adeq Precision ratio		13.4030						

Significant at (p<0.0001%) one percent level

The values greater than 0.1 indicate the model factors are not significant. The statistical analysis indicated that the proposed models fitted the experimental data with R<sup>2</sup> value of 0.9026; whereas the optimized predictive model had an R<sup>2</sup> value of 0.7808 and was in reasonable agreement with the “Adj R-Squared” of 0.8593. The optimized predictive model (in terms of actual factors) for viscosity of Aloe vera gel is presented in equation 4.18. Adeq Precision ratio more than 4 was desirable. The Adeq Precision ratio of 13.4030 indicates an adequate signal.

The optimized predictive model (in terms of actual factors) for viscosity of Aloe vera gel is presented in the following equation.

$$\text{Viscosity (mPa.s)} = 1.43 - 0.08 * A - 0.14 * B + 0.03 * (A \times B) \quad \dots (4.18)$$

Where,

A - Roller speed (rpm)

B - Roller clearance (mm)

A×B - Combination of roller speed and roller clearance

#### **4.6 Optimization of process parameters for performance evaluation of Aloe vera gel extraction machine**

Optimization of the two process variables namely; roller speed (11.40, 15.10 and 18.80 rpm) and roller clearance (4, 5 and 6 mm) are performed in Design Expert Software version 7.7.0. The objective of the optimization was to obtain the combinations of the two process parameters, which produced the Aloe vera gel. The optimum conditions for the Aloe vera gel were decided by evaluating all the responses simultaneously. In the present investigation, the independent variables were kept within the range and dependent variables were chosen as maximized or minimized. The interaction effect of 18.80 rpm roller speed and 5 mm of roller clearance on extraction efficiency, extraction loss, gel recovery and extraction capacity was significant (p < 0.05) at five per cent level. Numerical optimization was performed using statistical models to find the optimal process parameters. The desirability value obtained was Table 24 shows the process parameters and responses achieved from General Factorial design.

#### **4.7 Economics of Aloe vera gel extraction process**

The cost estimation for the extraction of Aloe vera gel was calculated as per the standard procedure as explained in Chapter III, Section 3.10. The detailed calculation of Aloe vera gel is presented in Appendix-II. The total extraction cost of 1 kg of Aloe vera gel was found to be ` 13.36/- and 20.67/-. The benefit (b): cost (c) ratios were worked out to be 3.74:1 and 2.42:1 for machine extracted and manual extracted process, respectively.

**Table 24. Process parameters and responses achieved from general factorial design in Design Expert Software version 7.7.0**

Sl. No.	Name	Goal	Lower limit	Upper Limit	
1	Roller speed (rpm)	is in range	11.40	18.80	
2	Roller clearance (mm)	is in range	4.00	6.00	
3	Extraction efficiency (%)	Maximize	88.04	96.73	
4	Extraction loss (%)	Minimize	1.44	4.96	
5	Gel recovery (%)	Maximize	36.56	44.23	
6	Extraction capacity (kg.h <sup>-1</sup> )	Maximize	92.40	187.86	
7	Moisture (% w.b.)	Minimize	98.28	98.86	
8	Carbohydrates (%)	Maximize	0.74	1.33	
9	Ash (%)	Maximize	0.14	0.28	
10	Crude fat (%)	Minimize	0.01	0.05	
11	Crude protein (%)	Maximize	0.12	0.18	
12	TSS (% Brix)	Maximize	1.14	1.74	
13	pH	Maximize	6.08	6.18	
14	Water activity (a <sub>w</sub> )	Minimize	0.90	0.91	
15	Colour	<i>L</i> <sup>*</sup>	Maximize	21.98	32.46
16		<i>a</i> <sup>*</sup>	Maximize	-4.25	-3.12
17		<i>b</i> <sup>*</sup>	Minimize	6.26	18.07
18	Viscosity (mPa.s)	Maximize	1.21	1.69	

*Discussion*

## V. DISCUSSION

This chapter deals with the discussion of the results of determination of physical properties of Aloe vera leaf, performance evaluation of Aloe vera gel extraction machine and also quality of Aloe vera gel obtained through Aloe vera gel extraction machine.

### 5.1 Determination of physical properties of Aloe vera leaf

#### 5.1.1 Leaf size and shape

The mean value of length, width, thickness and size of the Aloe vera leaf were found to be 523.50 mm, 80.60 mm, 13.67 mm and 151022.95 mm<sup>3</sup>, respectively. The results of physical properties of Aloe vera leaves were lower than earlier reports (Wang and Strong, 1993) which reported that the mean values of length, width, thickness and size were 559 mm, 93 mm, 26 mm and 371070.00 mm<sup>3</sup>, respectively. The variation in physical properties of leaf might be due to the maturity of the plant, spacing between plants, species, location (Reynolds, 2004). It is to be said that, the more thickness, better would be the gel recovery. Therefore the leaf thickness could be taken as one of the selection criteria for the extraction of Aloe vera gel. The shape of Aloe vera leaf was classified as conic-tapered towards apex (Mohsenin, 1986).

#### 5.1.2 Leaf weight

It was observed that the weight of the Aloe vera leaves depended on the thickness, width and length of the leaves. An increase in length, thickness and width results in increased weight of the leaf. The mean weight of the leaf recorded was 178.60 g, whereas, the range was found to be 118.00 to 224.00 g. The results obtained for weights of leaves were not similar to the earlier reports (Wang and Strong, 1993) according to which the mean leaf weight was 459.0 g. It was also observed during the experiments that the Aloe vera leaves having higher weight, had recorded better gel recovery. The variation in weight might be due to the difference in plant ages and cultural practices among locations and growers (Reynolds, 2004).

#### 5.1.3 Leaf volume and density

The average volume of Aloe vera leaf was 149.30 mm<sup>3</sup>. The maximum volume was recorded as 172.14 mm<sup>3</sup>, where as the minimum volume was 97.81 mm<sup>3</sup>. The average density of Aloe vera leaf was found to be 1.20 g.mm<sup>-3</sup>. The maximum density was recorded as 1.43 g.mm<sup>-3</sup>, whereas, the minimum density was 1.07 g.mm<sup>-3</sup>, It was observed that the volume of the leaves depended on the thickness, width and length of the leaves (Wang and Strong, 1993).

#### **5.1.4 Surface area**

The average surface area of the Aloe vera leaf was determined to be 224.81 cm<sup>2</sup>. The results obtained for average area of the Aloe vera leaf depended on the length and width of the leaves. Similar results were reported by Wang and Strong (1993) for *Aloe barbadensis* Miller leaves.

#### **5.1.5 Firmness**

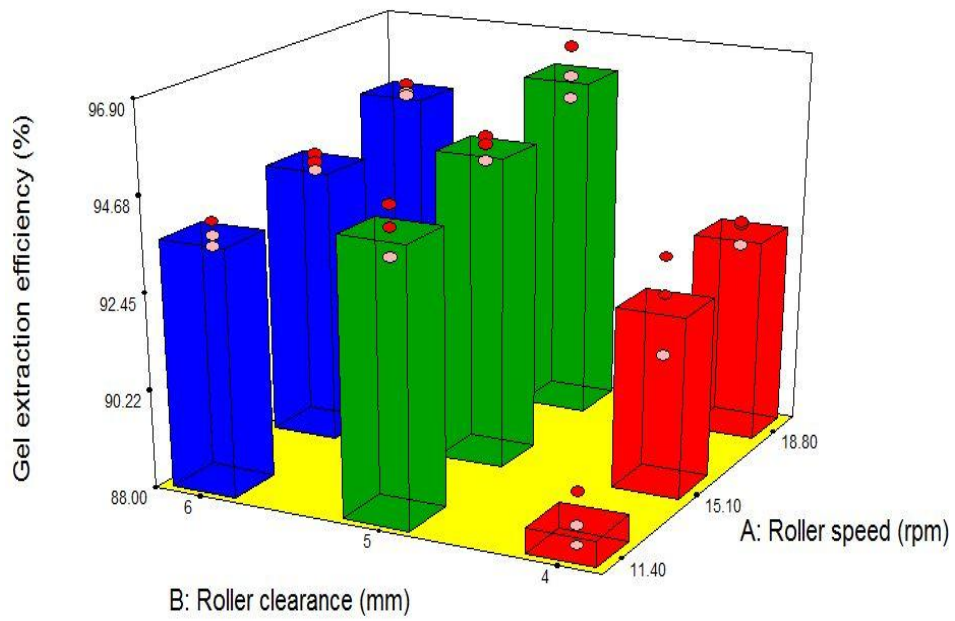
Firmness of fresh Aloe vera leaf sample was found to be 8.39 N. The results of firmness of Aloe vera leaves were higher than earlier reports (Antonio *et al.*, 2011) which reported that the firmness of fresh Aloe vera was 0.34±0.003 N. This might be due the development of a compressed structure in the parenchyma tissue mainly formed by a structural polysaccharides (pectin, cellulose and hemicelluloses) located within the cell wall. Moreover, calcium pectate three dimensional networks might have been formed with the pectins providing firmness to the parenchymal tissue (Margarita *et al.*, 2009). These results are comparable with those corresponding to microwave pre-treated apples (Funebo *et al.*, 2000).

### **5.2 Performance evaluation of Aloe vera gel extraction machine**

The performance evaluation of Aloe vera gel extraction machine was studied in terms of gel extraction efficiency, gel extraction loss, gel recovery and extraction capacity which were calculated by using the equations explained in Chapter III, Section 3.9. The performance evaluation of Aloe vera gel extraction machine from different roller speed and roller clearance combinations are discussed hereunder.

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

From Fig. 15, 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 18.80 rpm roller speed. Khambalkar *et al.* (2007) reported that the extraction efficiency of Aloe vera gel was found to be 91.20% of Aloe vera gel (Fillet) extractor.



**Fig. 15 Effect of roller speed and roller clearance on gel extraction efficiency (%) of Aloe vera gel extraction machine**

Olaoye (2011) reported that the extraction efficiency of the sugarcane juice extraction machine was between 40 and 61% at operating speeds of 0.25 and 0.36 m.s<sup>-1</sup>. The machine efficiency increased with an increase in peripheral speed. Chandegara and Varshney (2014a) 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 18.80 rpm roller speed with 5 mm of roller clearance for obtaining maximum 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) in the case of manual extraction.

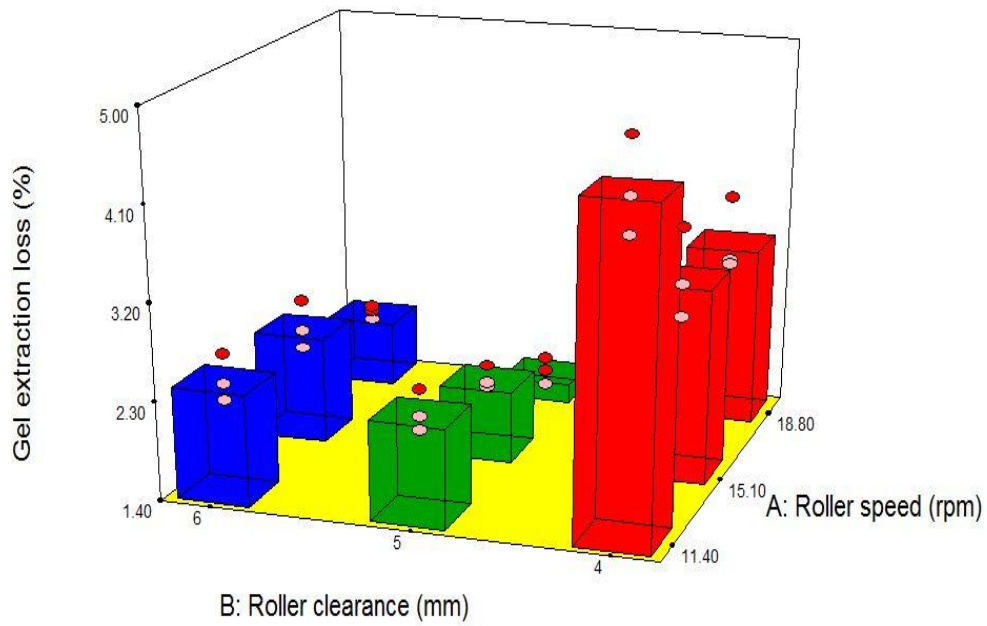
### **5.2.2 Effect of roller speed and roller clearance on gel extraction loss (%)**

From Fig. 16, 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 18.80 rpm 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 (2014a) 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 18.80 rpm roller speed with 5 mm of roller clearance for obtaining minimum gel extraction loss (%).

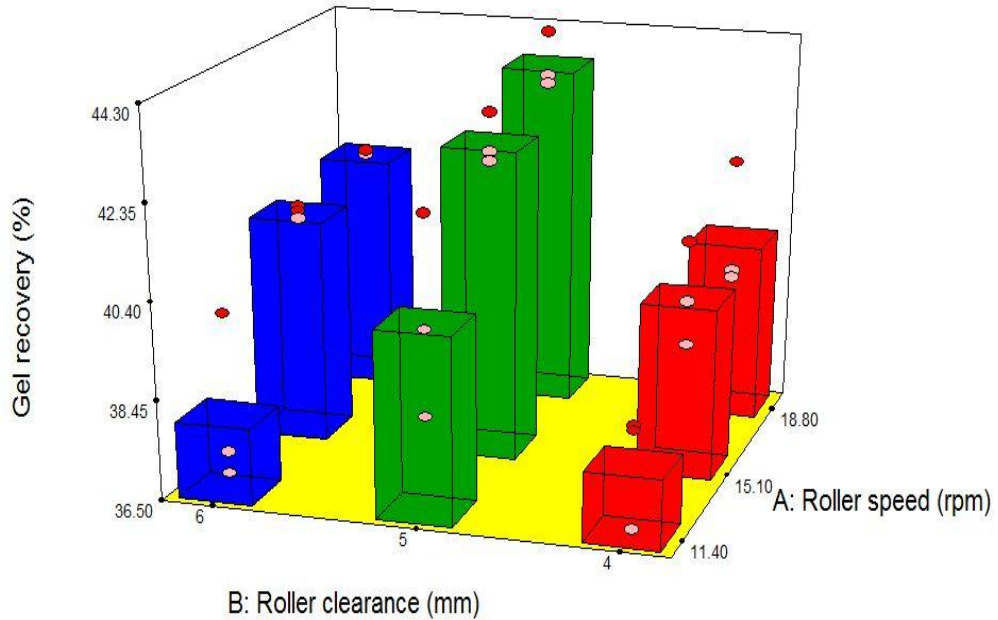
There was no gel extraction loss in manually extracted (control) Aloe vera gel compared to the Aloe vera gel extracted by the machine (1.58%). This might be due to maximum extractability (Khambalkar, 2007) in the case of manual method.

### **5.2.3. Effect of roller speed and roller clearance on gel recovery (%)**

From Fig. 17, it is clear that the gel recovery (%) increased with increase in roller speed. It is observed from Table 5, that the gel recovery (%) was maximum (43.57%) at roller speed of 18.80 rpm and 5 mm of roller clearance. It was observed that as the roller speed increased the gel recovery (%) increased at constant roller clearance.



**Fig. 16 Effect of roller speed and roller clearance on gel extraction loss (%) of Aloe vera gel extraction machine**



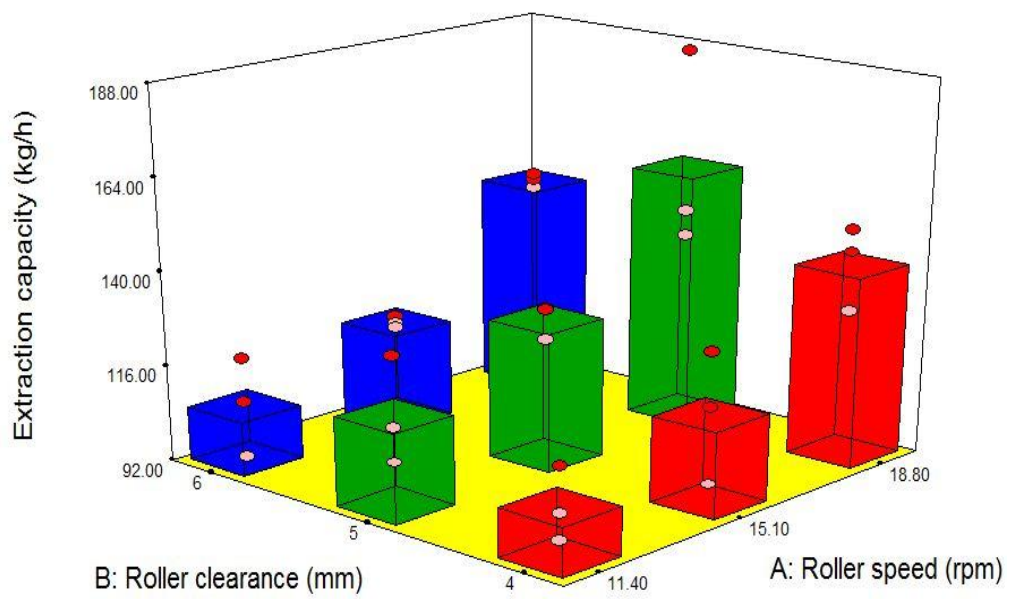
**Fig. 16 Effect of roller speed and roller clearance on gel recovery (%) of Aloe vera gel extraction machine**

Khambalkar *et al.*, 2007, reported that the recovery of gel was found to be 52% for manually operated Aloe vera gel (Fillet) extractor. Boghani *et al.* (2012) 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 Aloe vera leaves. 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) 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 Varshney (2014a) 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 18.80 rpm roller speed with 5 mm roller clearance to obtained maximum gel recovery.

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) reported that the gel recovery obtained from manually extracted Aloe vera gel was 57%. This might be due to maximum extractability and no losses.

### **5.2.3. Effect of roller speed and roller clearance on extraction capacity ( $\text{kg.h}^{-1}$ )**

The effect of roller speed and roller clearance on extraction capacity ( $\text{kg.h}^{-1}$ ) at three levels namely 11.40, 15.10 and 18.80 rpm and 4, 5 and 6 mm are presented in Fig. 18. The interaction effect of 18.80 rpm of roller speed and 5 mm of roller clearance on extraction capacity was significant ( $p < 0.05$ ) at five per cent level. From Table 5, it is clear that the extraction capacity ( $\text{kg.h}^{-1}$ ) increased with increase in roller speed. It is observed that the extraction capacity was maximum ( $158.06 \text{ kg.h}^{-1}$ ) at roller speed of 18.80 rpm 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. The manual extracted (control) Aloe vera gel was found to be of less extraction capacity ( $3.15 \text{ kg.h}^{-1}$ ) compared to Aloe vera gel extracted from machine ( $158.06 \text{ kg.h}^{-1}$ ). It was observed that the rate of work was fifty times higher than the manual method. This might be due to more time consumption and no gel extraction loss found in manual method.



**Fig. 18** Effect of roller speed and roller clearance on extraction capacity ( $\text{kg}\cdot\text{h}^{-1}$ ) of Aloe vera gel extraction machine

Khambalkar *et al.* (2007) reported that the extraction capacity of manually operated Aloe vera gel (Fillet) extractor was found to be 3.923 kg.h<sup>-1</sup> of leaves, whereas the manual extraction method gave very less capacity of 0.654 kg.h<sup>-1</sup>. It was observed that the rate of work was six times higher than the manual method. Anonymous (2007) reported an 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<sup>-1</sup> 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 18.80 rpm roller speed with 5 mm of roller clearance for obtaining maximum extraction capacity.

### **5.3 Bio-chemical properties of Aloe vera gel**

The bio-chemical properties of Aloe vera gel *viz.*, moisture content, carbohydrate, ash, crude fat, crude protein, TSS (Total Soluble Solids), pH, water activity ( $a_w$ ), colour ( $L^*$ ,  $a^*$  and  $b^*$ ) and viscosity (mPa.s) were determined using different standard analytical methods and are discussed hereunder.

#### **5.3.1 Moisture content (%)**

The average moisture content of fresh Aloe vera gel was found to be 98.34% (w.b.). Similar results were observed by Usha (2012) and Karina *et al.* (2013) analysed moisture content of Aloe vera gel were 98.50% (w.b.) and 98.93±0.06% (w.b.), respectively. Gautam and Awasthi (2007) reported initial moisture content of Aloe vera gel as 97.50% (w.b.). Paul (2003) also reported the same value (97.50%) for moisture content. The Aloe vera gel presented a higher value for moisture content compared to that reported by Femenia *et al.* (1999). The reason might be that 98% of leaf constituent is stored water in gel indicated that the Aloe vera gel was highly perishable in nature (Antonio, 2008).

#### **5.3.2 Carbohydrate content (%)**

The average carbohydrate content of fresh Aloe vera gel was found to be 1.20%. Elsa (2008) reported that the polysaccharide composition for Aloe vera gel was 1.080±0.008 g/100 g wet matter. Hu *et al.* (2003) reported that, the three year of old Aloe vera plant possessed higher polysaccharide content.

#### **5.3.3 Ash content (%)**

In the present investigation, the results on ash content of the fresh Aloe vera gel were found to be 0.24%. Similar value was reported by Antonio *et al.* (2014). Karina *et al.* (2013) reported a similar value of Ash content of Aloe vera gel was 0.16±0.02%. Gautam and Awasthi (2007) reported that the ash content of whole leaf Aloe vera gel powder was

14.0±0.00%. Gautam and Awasthi (2007) reported that the variation ash content might be due to changes in chemical constituents of gel with respect to species, maturity index and method of processing of gel.

#### **5.3.4 Crude protein (%)**

In the present investigation, the results on crude protein content of the fresh Aloe vera gel was found to be 0.16%. Similar results were observed by Karina *et al.*, 2013 who analysed crude protein of 0.12±0.01%. Gautham and Awasthi (2007) reported the protein content of fresh Aloe vera as 0.60±0.09. Boghani *et al.* (2012) reported the protein content of Aloe vera juice as 0.03%. Femenia *et al.* (1999) reported that the proteins and lipids accounted for about 6 to 8% and 2 to 5% of the dry matter, respectively with larger quantities being observed in the gel than in the exudates of the plant. The variation might be due to changes in chemical constituents of gel with respect to species, maturity index and method of processing of gel.

#### **5.3.5 Crude fat (%)**

The average crude fat content of fresh Aloe vera gel was found to be 0.06%. The results of present investigation were similar to those reported by Miranda *et al.* (2009). Similar results were observed by Karina *et al.*, 2013 who analysed crude fat content of 0.01±0.02. Gautam and Awasthi (2007) reported the fat content of Aloe vera leaf as 0.70±0.10% and whole leaf Aloe vera gel powder as 2.2±0.19%. The variation might be due to changes in chemical constituents of gel with respect to species, maturity index and method of extraction process.

#### **5.3.6 TSS**

In the present investigation, the result on TSS content of fresh Aloe vera gel was found to be 1.66% Brix. Which is an good agreement with the literature values of Chandegara and Varshney (2014) who reported TSS of Aloe vera gel as 1.17%Brix. Boghani *et al.* (2012) reported the TSS content of Aloe vera juice as 2.1% Brix.

#### **5.3.7 pH**

In the present investigation, the results on pH of fresh Aloe vera gel was found to be 6.13%. Chandegara and Varshney (2014) reported the pH of Aloe vera gel as 6.30. Boghani *et al.* (2012) reported the pH of Aloe vera juice as 4.3. Margarita *et al.* (2009) reported the pH of 4.74±0.01 for whole leaf Aloe vera. Paul (2003) recorded average pH of 4.50 with water content between 97.0 and 99.5% (w.b.) in Aloe vera gel. Eshun and He (2004) also reported

the pH ranging from 4 to 5 for Aloe vera gel. The per cent acidity ranged from 0.037 to 0.065 malic acid/ 100 g dry matter, similar results were obtained for Aloe (pH  $4.57 \pm 0.07$  and acidity  $0.08 \pm 0.01\%$  malic acid for fresh gel) by Hernandez *et al.* (2006). Gautam and Awasthi (2007) reported average pH of whole leaf powder as 4.8. The changes in pH might be due to the difference in maturity of plant, harvesting condition and method of extraction.

### **5.3.8 Water activity ( $a_w$ )**

In the present investigation, the result on water activity of fresh Aloe vera gel was found to be 0.910. Suresh (2008) reported water activity of fresh gel as 0.980. Gritty (2012) reported the water activity of fresh Aloe vera leaf samples as 0.9095. These results were in good agreement with the literature values of Margarita *et al.* (2009), who reported the water activity of fresh whole leaf Aloe vera as 0.985. This might be due to the result of high moisture content of the gel.

### **5.3.9 Colour**

In the present investigation, the results on average colour values *viz.*,  $L^*$ ,  $a^*$  and  $b^*$  values of fresh Aloe vera gel were 29.37, -3.52 and 4.65, respectively. Gritty (2012) reported the colour values of fresh Aloe vera leaf samples *viz.*,  $L^*$ ,  $a^*$  and  $b^*$  values as 39.892, -5.307 and 21.74, respectively. Gautam and Awasthi (2007) who reported the colour of whole leaf Aloe vera powder was olive green. Chang *et al.* (2006) reported that the colour of Aloe vera gel changed from whitish to slightly yellowish to brownish during thermal processing.

### **5.3.10 Viscosity**

In the present investigation, the result on average viscosity of the fresh Aloe vera gel was 1.61 mPa.s. Chandegara and Varshney (2014) reported the average values of dynamic viscosity for manual gel expulsion was  $35.33 \pm 0.21$  cP, These results indicated that the viscosity of gel was affected by temperature and holding time and also extraction process. This might be due to the degradation of biological constituents from Aloe vera gel at higher temperature and long-time extraction process. It was concluded that, higher value of viscosity of the Aloe vera gel had better quality product.

## **5.4 Proximate composition of Aloe vera gel obtained from Aloe vera gel extraction machine**

The proximate composition of Aloe vera gel obtained from Aloe vera gel extraction machine such as moisture content, carbohydrates, crude fat, crude protein and ash were determined by using standard methods which are explained in Chapter III. The statistical

analysis was carried out using Factorial Completely Randomized block Design (FCRD) using Design Expert 7.0.0. The detailed results presented in Chapter IV are discussed here under.

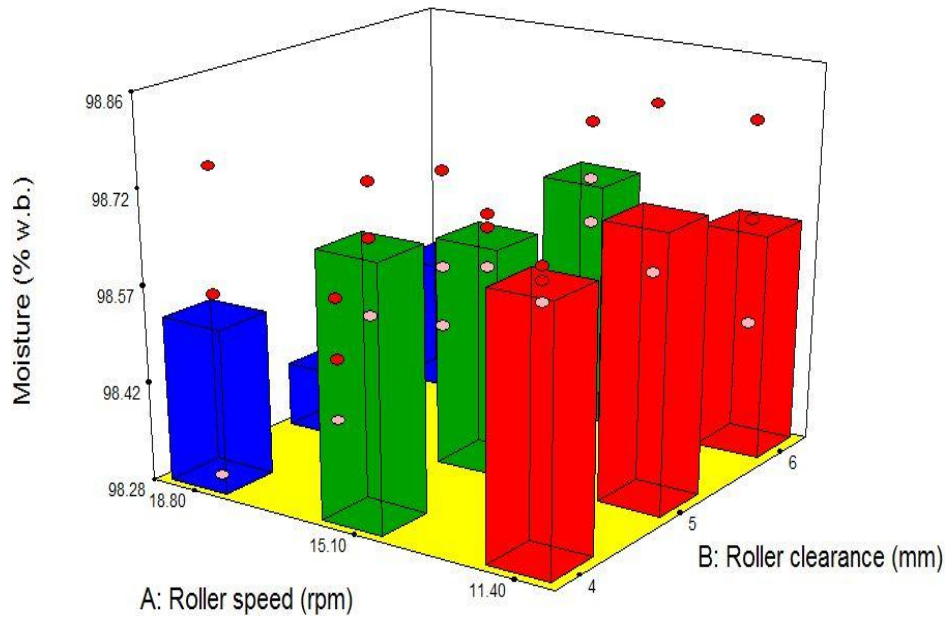
#### **5.4.1 Moisture content**

The moisture content represents the water composition in a food system. It plays a key role in all food materials and is one of the most commonly measured properties of food materials. The information on moisture content is necessary because it tells us whether the product is suitable for storage or for any other processing job.

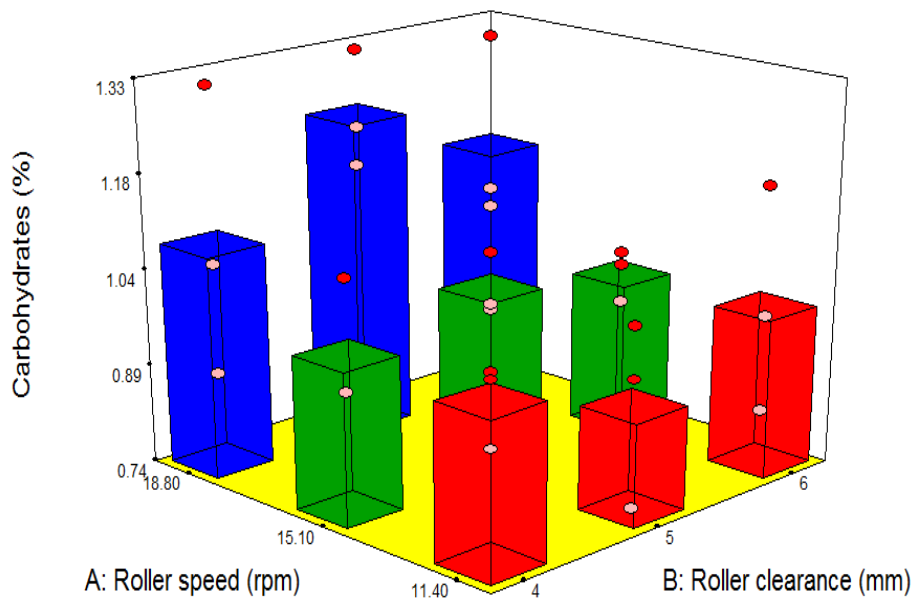
The effect of roller speed and roller clearance combinations on moisture content of Aloe vera gel is shown in Fig. 19. It is depicted in the present investigation that the moisture content of Aloe vera gel slightly decreased but not affected by roller speed and roller clearance combinations of Aloe vera gel extraction machine. Comparison of manually extracted (98.34%) and machine extracted Aloe vera gel moisture content showed similar results. Boghani *et al.* (2012) reported the moisture content of Aloe vera juice as 97.34% (w.b.). Similar results were observed by Usha (2012) who analysed moisture content of 98.5% (w.b.). Similar results were also observed by Karina *et al.*, 2013, analysed moisture content of Aloe vera gel was  $98.93 \pm 0.06\%$  (w.b.) which was in good agreement with the literature values of Gautam and Awasthi (2007) (97.50% w.b.). Paul (2003) also reported the same value for moisture content. The Aloe vera gel analysis presented a higher value for moisture content compared to that reported by Femenia *et al.* (1999). The reason might be that 98% of leaf constituent was stored water in gel indicated that the Aloe vera gel was highly perishable in nature (Antonio, 2008). The interaction effects of treatment combinations are not significant. The moisture content of Aloe vera gel extracted was nearly same when compared to fresh gel. However, the difference was very small and might be attributed to variation of moisture content in different samples.

#### **5.4.2 Carbohydrates content**

The effect of roller speed and roller clearance combinations on carbohydrate content of Aloe vera gel is shown in Fig. 20.



**Fig. 19** Effect of roller speed and roller clearance on moisture content (%) of Aloe vera gel



**Fig. 20** Effect of roller speed and roller clearance on carbohydrates content (%) of Aloe vera gel

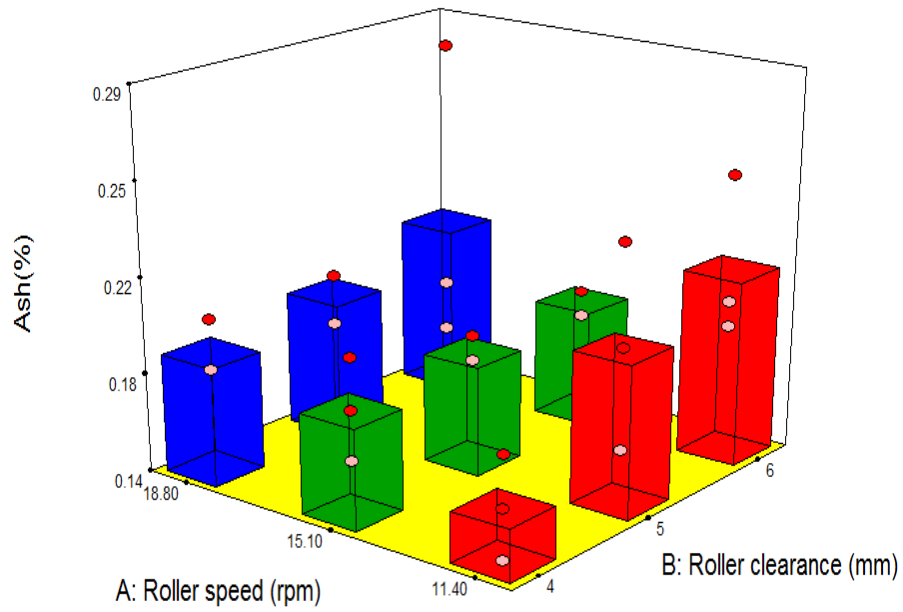
The average carbohydrates content of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be maximum in treatment T<sub>8</sub> at 18.80 rpm roller speed and 5 mm roller clearance (1.23%), whereas the minimum average carbohydrates content was recorded in treatment T<sub>2</sub> at 11.40 rpm roller speed and 5 mm of roller clearance (0.90%). The interaction effects of treatment combinations were not significant. Karina *et al.* (2013) reported that carbohydrates content of Aloe vera gel was 0.66%. Boghani *et al.* (2012) reported the carbohydrates content of Aloe vera juice as 0.92%. Carbohydrates content of machine extracted Aloe vera gel were ranged from 0.90 to 1.23%. Antonio *et al.* (2014) reported that the carbohydrate content of Aloe vera gel was 0.83%. The average carbohydrates content of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be maximum (1.03%). The average carbohydrate content of manually extracted fresh Aloe vera gel was found to be 1.20%. Elsa (2008) reported that the polysaccharide composition for Aloe vera gel was  $1.080 \pm 0.0008$  g/100 g wet matter. Hu *et al.* (2003) reported that, the three year of old Aloe vera plant possessed higher polysaccharide content. The carbohydrate content of machine extracted Aloe vera gel was nearly same compared to manually extracted of fresh Aloe vera gel. However, the difference was very small and might be attributed to variation of carbohydrates content in different samples.

### **5.4.3 Ash content**

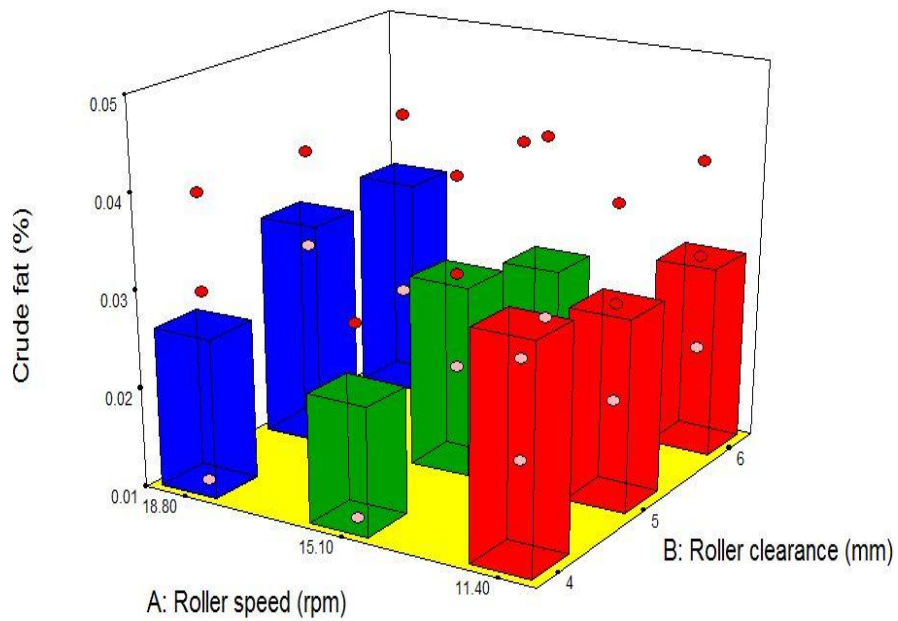
The effect of roller speed and roller clearance combinations on ash content of Aloe vera gel is shown in Fig. 21. The average ash content of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be maximum 11.40 and 18.80 rpm roller speed and 6 mm of roller clearance (0.21%), whereas the minimum average ash content was recorded in 11.40 rpm roller speed and 4 mm of roller clearance (0.16%). From the present investigation it was found that the ash content was not affected by roller speed and roller clearance combinations of Aloe vera gel extraction machine. The interaction effect of treatment combinations are not significant. The ash content of Aloe vera gel extracted was nearly same when compared to fresh Aloe vera gel (0.24%). Antonio *et al.* (2014) reported that ash content of Aloe vera gel was 0.20%. Karina *et al.* (2013) reported that the ash content of Aloe vera gel was  $0.16 \pm 0.02\%$ . Gautam and Awasthi (2007) reported that ash content of fresh Aloe vera leaves was  $0.45 \pm 0.00\%$ . However, the difference was very small and might be attributed to variation of ash content in different samples.

### **5.4.4 Crude fat content**

The effect of roller speed and roller clearance combinations on crude fat content of Aloe vera gel is shown in Fig. 22.



**Fig. 21** Effect of roller speed and roller clearance on ash content (%) of Aloe vera gel



**Fig. 22** Effect of roller speed and roller clearance on crude fat content (%) of Aloe vera gel

The crude fat content of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum (0.03%) in all treatment combinations except 15.10 rpm roller speed and 4 mm of roller clearance (T<sub>4</sub>) (0.02%). Antonio *et al.* (2014) reported that the fat content was the smallest fraction in all the samples and did not show significant difference ( $p>0.05$ ). Karina *et al.* (2013) reported that crude fat content of Aloe vera gel was  $0.01\pm 0.02$ . The interaction effect of treatment combinations was not significant. The variation might be due to changes in chemical constituents of gel with respect to species, maturity index and method of extraction of gel.

The average crude fat content of manually extracted fresh Aloe vera gel was found to be 0.06%. The average crude fat content of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be 0.03%. The crude fat content of machine extracted Aloe vera gel was nearly same when compared to manually extracted Aloe vera gel. However, the difference is very small and might be attributed to variation of crude fat content in maturity index of leaves

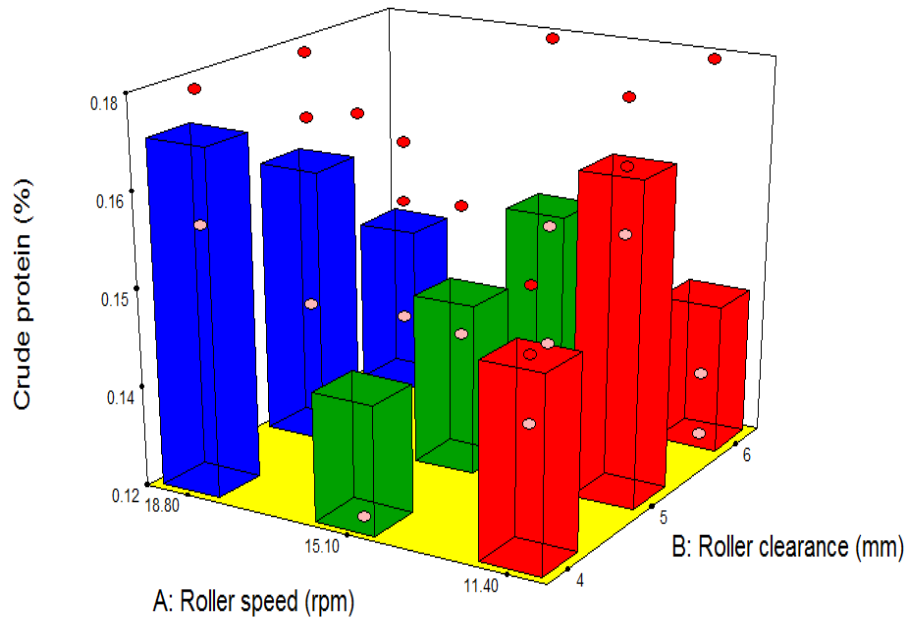
#### **5.4.5 Crude protein content**

The average protein content of Aloe vera gel was found to be maximum in treatments T<sub>2</sub> and T<sub>7</sub> (11.40 and 18.80 rpm roller speed and 5 and 4 mm of roller clearance) was 0.17%, whereas the minimum average protein content was recorded in treatment T<sub>3</sub> and T<sub>4</sub> (11.40 and 15.10 rpm roller speed and 6 and 4 mm of roller clearance) was 0.14%. The effect of roller speed and roller clearance combinations on crude protein content of Aloe vera gel is shown in Fig. 23. Karina *et al.* (2013) reported that crude protein content of Aloe vera gel was  $0.12\pm 0.01\%$ . Boghani *et al.* (2012) reported that the protein content of Aloe vera juice was 0.03%. The interaction effect of treatment combinations was not significant. The variation might be due to changes in chemical constituents of gel with respect to maturity index of leaves and method of extraction.

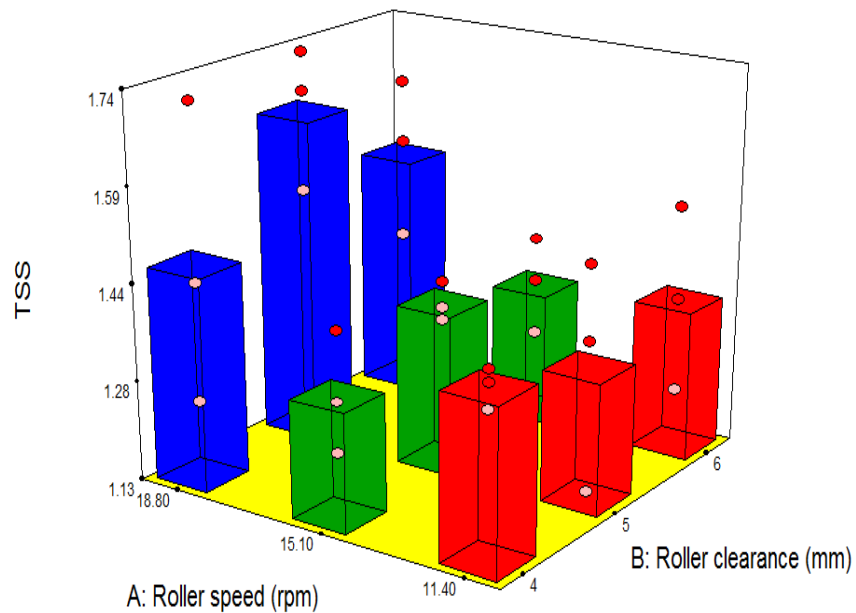
The average crude protein content of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be slightly more (0.17%) compared to the average crude protein content of manually extracted fresh Aloe vera gel (0.16%). However, the difference was very small and might be attributed to variation in maturity index of leaves.

#### **5.4.3 TSS**

The effect of roller speed and roller clearance combinations on TSS (% Brix) of Aloe vera gel is shown in Fig. 24.



**Fig. 23** Effect of roller speed and roller clearance on crude protein content (%) of Aloe vera gel



**Fig. 24.**Effect of roller speed and roller clearance on TSS (% Brix) of Aloe vera gel

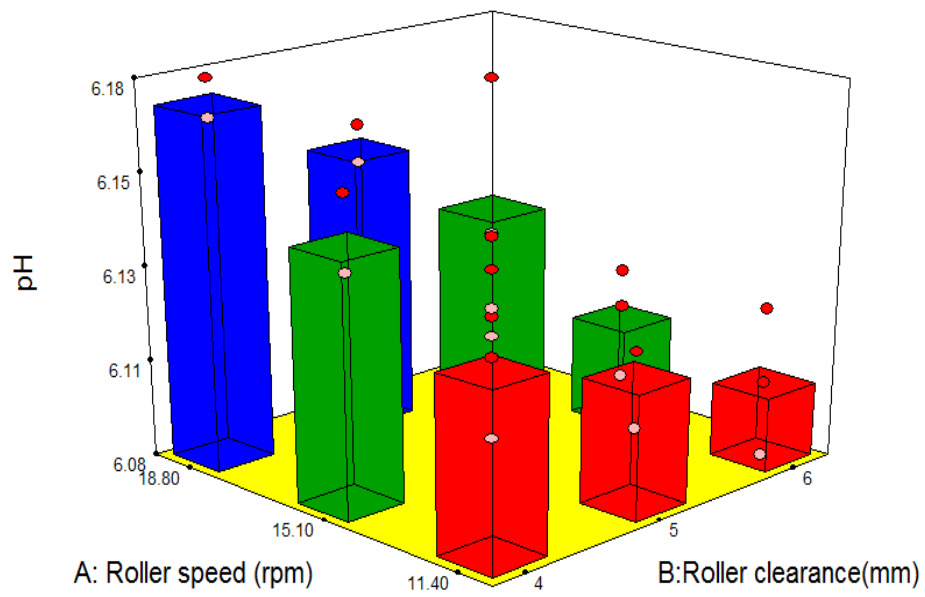
The average TSS (% Brix) content of Aloe vera gel obtained from Aloe vera gel extraction machine was ranged from 1.32 to 1.65%. The TSS (% Brix) of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in 18.80 rpm roller speed and 5 mm of roller clearance (1.65%), whereas the minimum TSS (% Brix) was recorded in 15.10 rpm roller speed and 4 mm of roller clearance (1.32%). The average TSS (% Brix) of manually extracted fresh Aloe vera gel was found to be 1.66%. The TSS (% Brix) of Aloe vera gel extracted by machine was nearly same when compared to manually extracted Aloe vera gel. Which is in good agreement with the literature values of Chandegera and Varshney (2012) reported that TSS of Aloe vera gel was 1.17% Brix. Boghani *et al.* (2012) reported that TSS content of Aloe vera juice was 2.1% Brix. The interaction effect of treatment combinations was not significant. However, the difference was very small and might be attributed to variation of maturity indices of Aloe vera leaves and extraction process.

## **5.5 Quality parameters of Aloe vera gel obtained from Aloe vera gel extraction machine**

The quality parameters of Aloe vera gel obtained from Aloe vera gel extraction machine such as pH, water activity ( $a_w$ ), colour ( $L^*$ ,  $a^*$  and  $b^*$ ) and viscosity (mPa.s) were determined by using standard methods which are explained in Chapter III. Statistical analysis was carried out using Factorial Completely Randomized block Design (FCRD) using Design Expert 7.0.0. The detailed results presented in Chapter IV are discussed here under.

### **5.5.1 pH**

The pH of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in (18.80 rpm roller speed and 4 mm of roller clearance) T<sub>8</sub> treatment (6.17) whereas, the minimum pH was recorded in (11.40 rpm roller speed and 6 mm of roller clearance) treatment T<sub>3</sub> (6.10). The effect of roller speed and roller clearance combinations on pH of Aloe vera gel is shown in Fig. 25. Chandegera and Varshney (2012) reported pH of Aloe vera gel was 6.30. Boghani *et al.* (2012) reported that pH of Aloe vera juice was 4.3. The results indicated that the pH for fresh Aloe vera leaf was 4.41. Paul (2003) recorded average pH of 4.50 with water content between 97.0 and 99.5% (w.b.) in Aloe vera. Gautam and Awasthi (2007) who reported average the pH of whole leaf powder as 4.8. Hernandez *et al.* (2006) reported that Aloe vera (pH  $4.57 \pm 0.07$  and acidity  $0.08 \pm 0.01\%$  malic acid for fresh gel).



**Fig. 25 Effect of roller speed and roller clearance on pH of Aloe vera gel**

The interaction effect of treatment combinations are significant ( $p < 0.05$ ) at five per cent level. The changes in pH might be due to the difference in maturity of plant, harvesting condition and also gel extraction process.

The average pH of Aloe vera gel obtained from Aloe vera gel extraction machine was from 6.10 to 6.17. The average pH of manually extracted fresh Aloe vera gel was found to be 6.13. The average pH value of machine extracted Aloe vera gel was nearly same compared to manually extracted pH of Aloe vera gel.

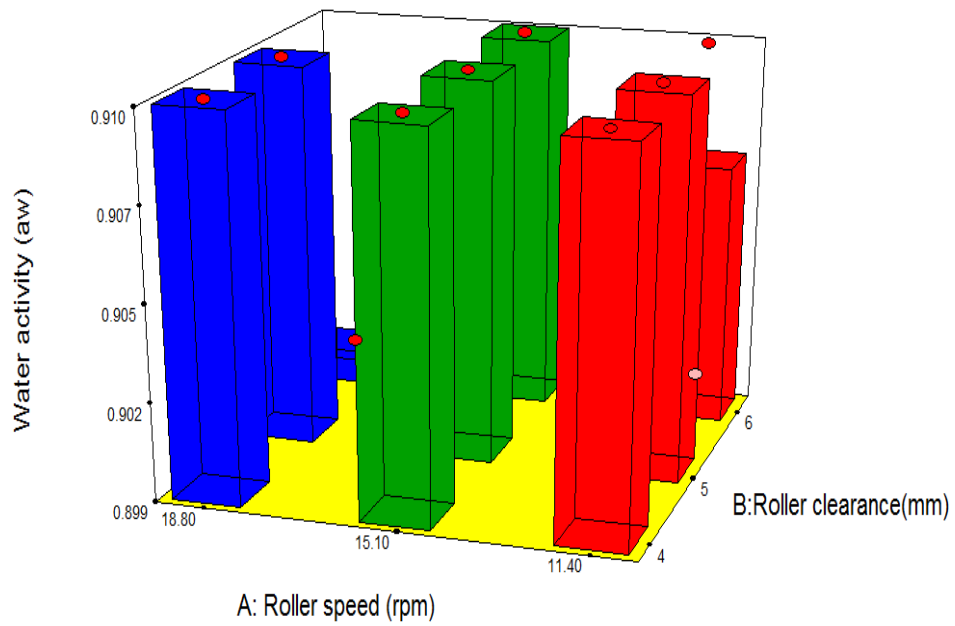
### **5.5.2 Water activity ( $a_w$ )**

The water activity ( $a_w$ ) value of Aloe vera gel obtained from different roller speed and roller clearance combinations (treatments) of Aloe vera gel extraction machine was found to be maximum water activity ( $a_w$ ) value was recorded in all treatment combinations, whereas the minimum water activity ( $a_w$ ) value was recorded (18.80 rpm roller speed and 6 mm of roller clearance) in treatment T<sub>9</sub> (0.900). Margarita *et al.* (2009) reported the water activity of fresh whole leaf Aloe vera as 0.985. Suresh (2008) also reported water activity of fresh gel as 0.980.

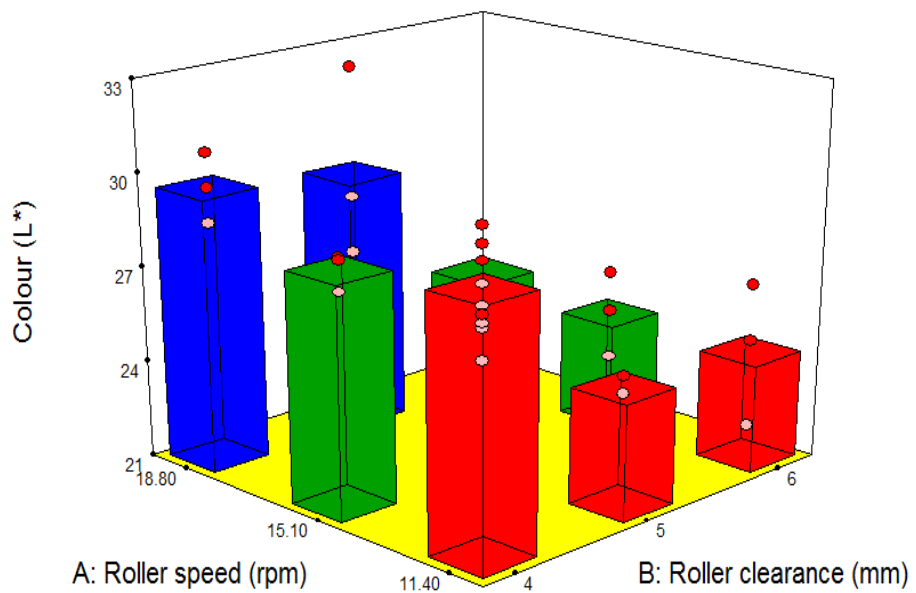
The water activity ( $a_w$ ) of Aloe vera gel obtained from Aloe vera gel extraction machine was ranged from 0.900 to 0.910. The water activity ( $a_w$ ) of manually extracted fresh Aloe vera gel was found to be 0.910. Water activity ( $a_w$ ) of Aloe vera gel extracted by machine was nearly same compared to manually extracted Aloe vera gel. This might be due to the high moisture content of the gel. The interaction effect of treatment combinations was significant ( $p < 0.05$ ) at five per cent level. The changes in water activity might be due to the difference in maturity of plant, harvesting condition, machine extraction process and freshness of gel. The effect of roller speed and roller clearance combinations on water activity of Aloe vera gel is shown in Fig. 26.

### **5.5.3 Colour ( $L^*$ ) value**

Colour is the important physical characteristic of Aloe vera gel and is directly related to the acceptability of food product. The maximum value for lightness is 100 indicating whiteness. Therefore, decrease in  $L^*$  value indicates a decrease in whiteness. The effect of roller speed and roller clearance combinations on colour ( $L^*$ ) values of Aloe vera gel is shown in Fig. 27. The colour ( $L^*$ ) value of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in (18.80 rpm roller speed and 4 mm of roller clearance) T<sub>7</sub> treatment (29.66) whereas the minimum colour ( $L^*$ ) value was recorded in (18.80 rpm roller speed and 6 mm of roller clearance) treatment T<sub>9</sub> (22.75).



**Fig. 26** Effect of roller speed and roller clearance on water activity ( $a_w$ ) of Aloe vera gel



**Fig. 27** Effect of roller speed and roller clearance on colour ( $L^*$ ) value of Aloe vera gel

The colour ( $L^*$ ) value of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be in the range of 22.75 to 29.66. The colour ( $L^*$ ) value of manually extracted fresh Aloe vera gel was 29.37.

Colour ( $L^*$ ) value of Aloe vera gel extracted by machine was different compared to manually extracted Aloe vera gel. The average colour ( $L^*$ ) value Aloe vera gel was recorded as 26.37. This might be due to the high moisture content of the gel. According to Karina *et al.* (2013) the changes in the initial colorimetric parameters  $L^*$ ,  $a^*$  and  $b^*$  of fresh Aloe vera gel were respectively  $52.00 \pm 0.06$ ,  $3.75 \pm 0.02$  and  $18.72 \pm 0.05$  and changed respectively to  $56.66 \pm 0.41$ ,  $0.84 \pm 0.03$  and  $10.70 \pm 0.13$  after 60 days of storage at 4 °C. The colour ( $L^*$ ) value of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be ranging from 22.75 to 29.66.

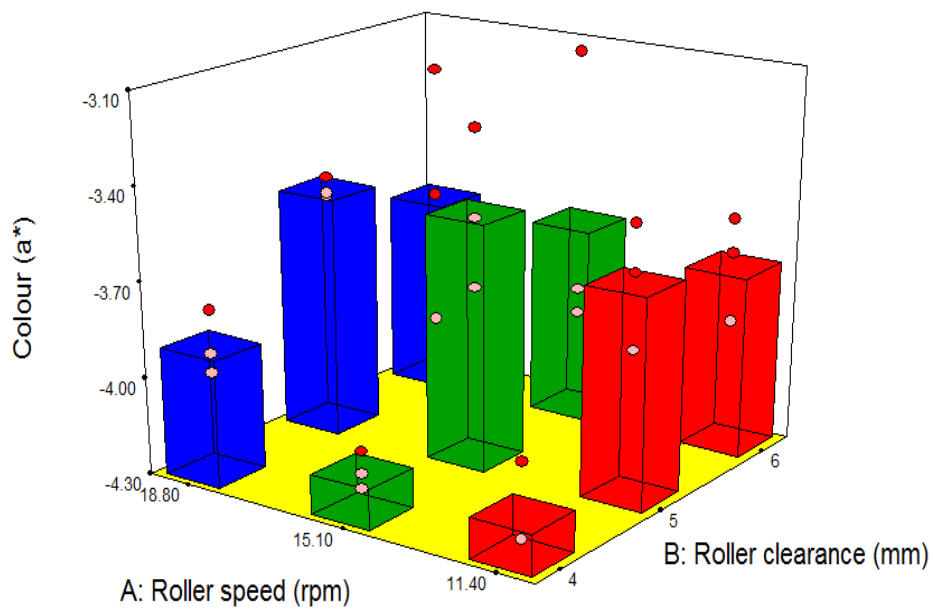
The interaction effect of treatment combinations was significant ( $p < 0.05$ ) at five per cent level. The changes in colour ( $L^*$ ) values might be due to the difference in maturity of plant, harvesting condition, machine extraction process and freshness of gel.

#### **5.5.4 Colour ( $a^*$ ) value**

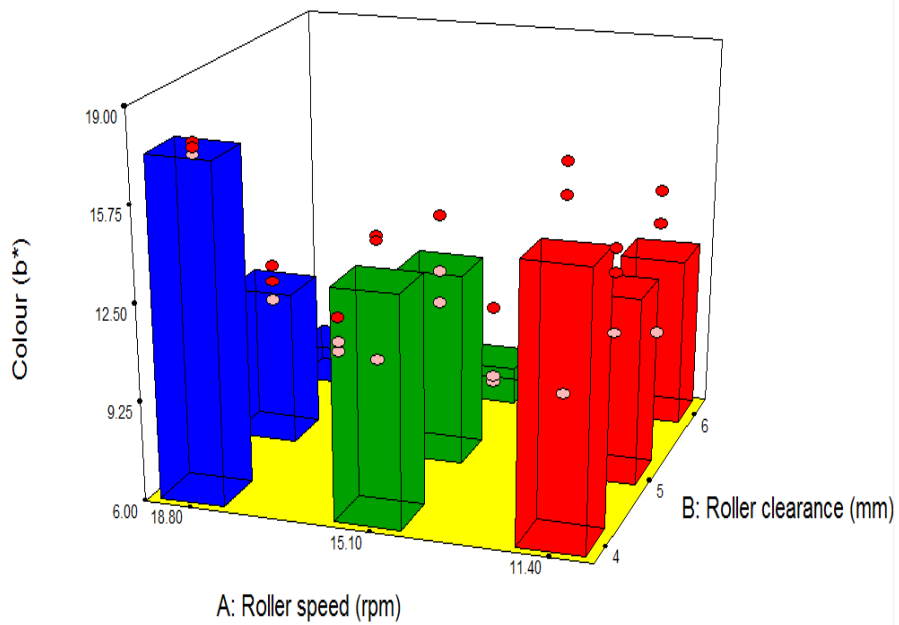
The effect of roller speed and roller clearance combinations on colour ( $a^*$ ) values of Aloe vera gel is shown in Fig. 28. The positive values for  $a^*$  indicate redness, while negative values stand for green colour of product. Therefore, increase in  $a^*$  value indicates decrease in green colour. The colour ( $a^*$ ) value of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in (15.10 rpm roller speed and 4 mm of roller clearance) T<sub>5</sub> treatment (-3.51) whereas the minimum colour ( $a^*$ ) value was recorded in (11.40 and 15.10 rpm roller speeds and 4 mm of roller clearance, respectively) treatment T<sub>1</sub> and T<sub>4</sub> (-4.17). According to Karina *et al.* (2013) the changes in the initial colorimetric parameters  $L^*$ ,  $a^*$  and  $b^*$  of fresh Aloe vera gel were respectively  $52.00 \pm 0.06$ ,  $3.75 \pm 0.02$  and  $18.72 \pm 0.05$  changed respectively to  $56.66 \pm 0.41$ ,  $0.84 \pm 0.03$  and  $10.70 \pm 0.13$  after 60 days of storage at 4 °C. The colour ( $a^*$ ) value of Aloe vera gel obtained from Aloe vera gel extraction machine was ranged from -4.17 to -3.51. The colour ( $a^*$ ) value of manually extracted fresh Aloe vera gel was found to be -3.52. Colour ( $a^*$ ) value of Aloe vera gel extracted with machine was different when compared to manually extracted Aloe vera gel. Values were different due to the difference in maturity of plant and machine extraction process.

#### **5.5.5 Colour ( $b^*$ ) value**

The effect of roller speed and roller clearance combinations on colour ( $b^*$ ) values of Aloe vera gel is shown in Fig. 29.



**Fig. 28** Effect of roller speed and roller clearance on colour ( $a^*$ ) value of Aloe vera gel



**Fig. 29** Effect of roller speed and roller clearance on colour ( $b^*$ ) value of Aloe vera gel

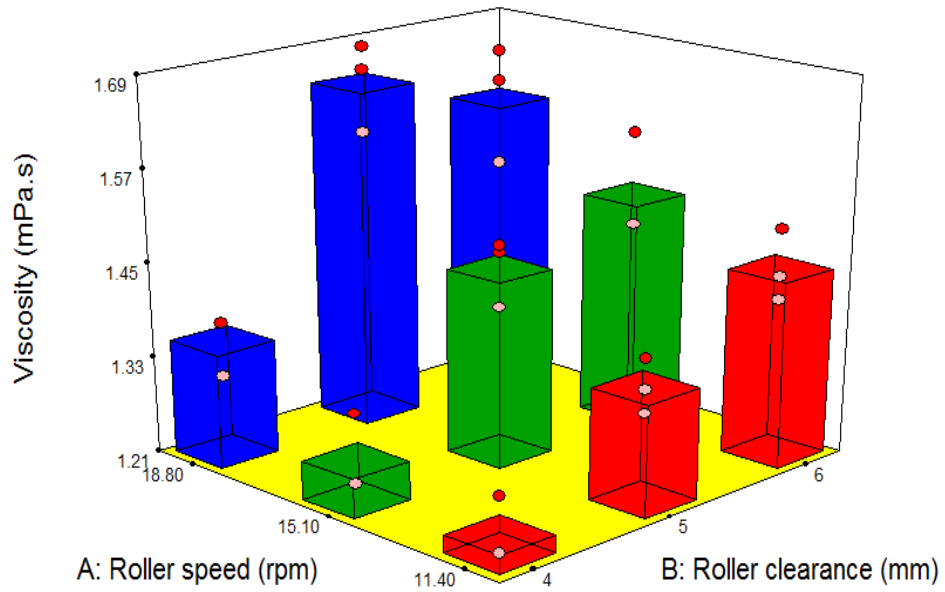
Therefore, increase in  $b^*$  value indicates increase in yellow colour. The colour ( $b^*$ ) value of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in (18.80 rpm roller speed and 4 mm of roller clearance) T<sub>7</sub> treatment (17.44) whereas the minimum colour ( $b^*$ ) value was recorded in (15.10 rpm roller speed and 6 mm of roller clearance) treatment T<sub>6</sub> (7.26). Changes in colour were measured by colorimetric evaluation using three parameters: lightness ( $L^*$ ), green-red ( $a^*$ ) and blue-yellow ( $b^*$ ). The colour coordinates were CIE  $L^*$ ,  $a^*$  and  $b^*$ . Gautam and Awasthi (2007) reported the colour of whole leaf Aloe vera powder as olive green. Chang *et al.* (2006) reported that the colour of Aloe vera gel changed from whitish to slightly yellowish to brownish during thermal processing.

The colour ( $b^*$ ) value of Aloe vera gel obtained from Aloe vera gel extraction machine was found to be range from 17.44 to 7.26. Colour ( $b^*$ ) value of manually extracted fresh Aloe vera gel was found to be 4.65. Colour ( $b^*$ ) value of Aloe vera gel extracted was different when compared to manually extracted Aloe vera gel. Values are different due to the difference in maturity of leaves.

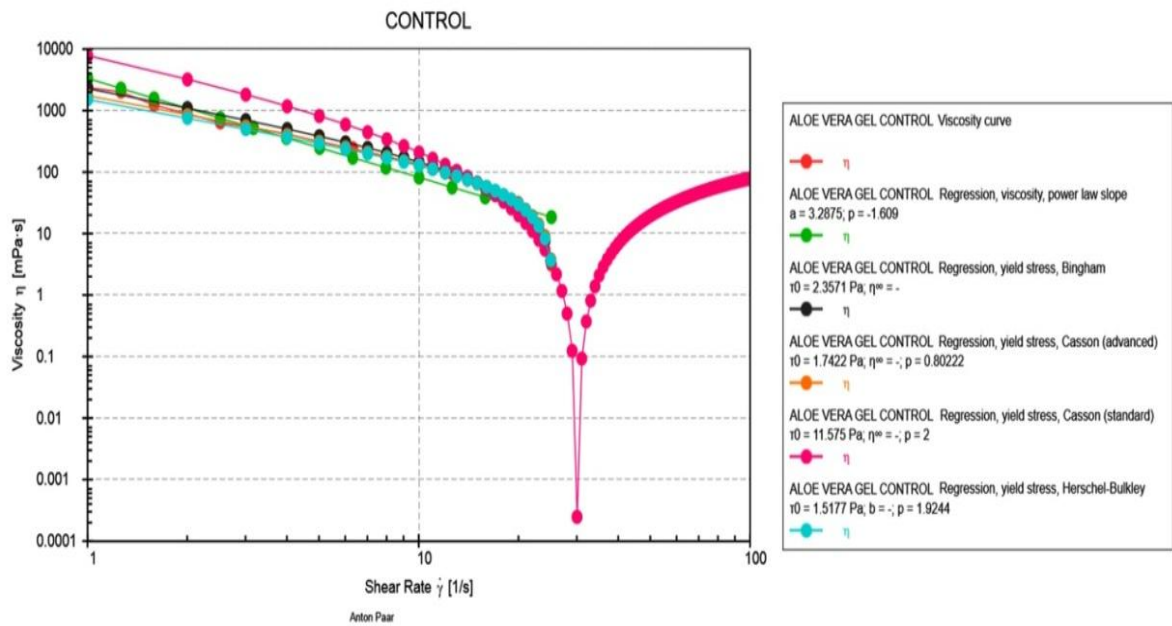
#### **5.5.5 Viscosity (mPa.s)**

The viscosity (mPa.s) of Aloe vera gel obtained from different roller speed and roller clearance combinations of Aloe vera gel extraction machine was found to be maximum in treatment T<sub>8</sub> (1.64) whereas the minimum viscosity (mPa.s) was recorded in treatment T<sub>1</sub> (1.23). The effect of roller speed and roller clearance combinations on viscosity (mPa.s) values of Aloe vera gel is shown in Fig. 30. The average viscosity of Aloe vera gel obtained from Aloe vera gel extraction machine was ranged from 1.23 to 1.64 mPa.s. Viscosity of manually extracted by machine fresh Aloe vera gel was found to be 1.61 mPa.s. Viscosity of Aloe vera gel extracted was different when compared to manually extracted Aloe vera gel. The viscosity of manually and machine extracted Aloe vera gel fitted with the Power law model is shown in Fig. 31 and Fig. 32, respectively.

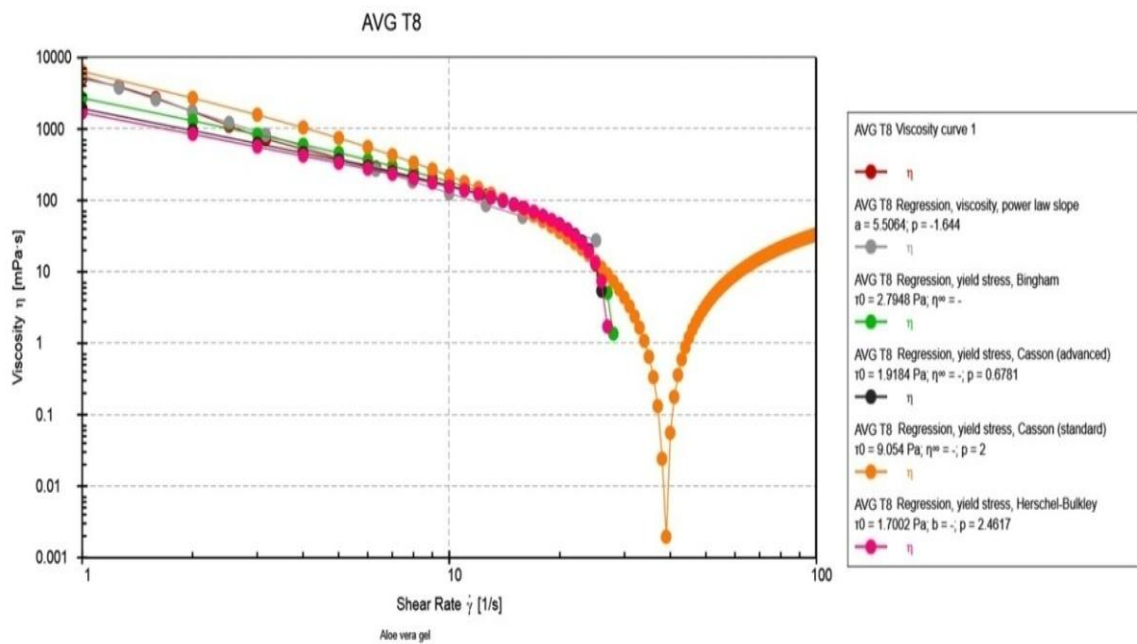
Lad (2013) reported that the viscosities of both Aloe vera gel and juice became independent of shear rate and exhibited comparatively higher shear rates. In the shear thinning region, the relationship between shear viscosity and the shear rate was given by the power-law (Ostwald-de Waele) model. Gowda *et al.* (1979) reported that after harvest of Aloe vera leaf, the viscous pseudoplastic nature of Aloe vera gel was mainly due to the presence of polysaccharides composed of a mixture of acetylated glucomannans and was lost shortly after extraction, apparently due to enzymatic degradation.



**Fig. 30 Effect of roller speed and roller clearance on viscosity (mPa.s) of Aloe vera gel**



**Fig. 31 Viscosity graph of manually extracted Aloe vera gel obtained from Rheometer**



**Fig. 32 Viscosity graph of machine extracted Aloe vera gel obtained from Rheometer**

Chandegara and Varshney (2014a) reported that viscosity decreases as temperature increases and loses its biological activity. Gel quality is based on biological activity for medicinal and cosmetics products. Aloe vera gel possesses bioactive properties that may be lost when subjected to processing procedures that involve heat or shearing action (Nindo *et al.*, 2010). The average values of dynamic viscosity for manual gel expulsion and mechanical gel expulsion were found  $35.33 \pm 0.21$  and  $36.45 \pm 0.34$  cP, respectively. This might be due to existence of biological constituents get lost at higher temperature and long-time extraction process. It was said that, the higher was the viscosity of Aloe vera gel better would be the quality of gel and at the same time the gel was considered to be biologically active.

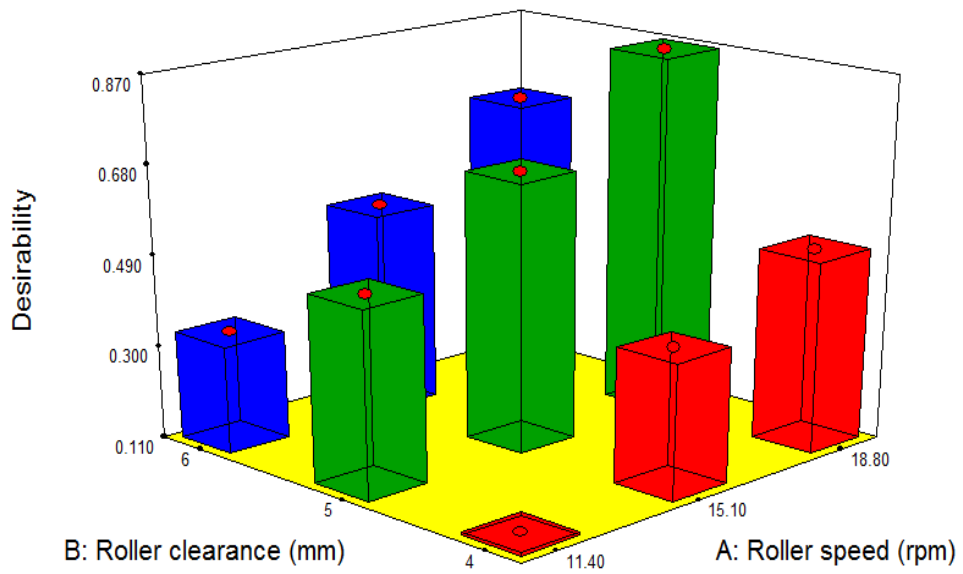
### **5.6 Optimization of process parameters for Aloe vera gel**

The experimental run and optimization work were designed using factorial design method in Design-Expert version 7.7.0 software. The values of all the responses at operating conditions were converted to a desirability function. The desirability function of optimum operating parameters of Aloe vera gel at different treatments is depicted in Fig. 33. The maximum desirability function was 0.864 obtained from optimum operating condition. The desirability values of the minimum and maximum were configured as 0 and 1, respectively. Optimization of the two process variables; Roller speed and roller clearance was performed using the general factorial method in Design Expert Software 7.7.0. 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 18.80 rpm roller speed with 5 mm of roller clearance for obtaining maximum gel extraction efficiency, gel recovery, extraction capacity and minimum gel extraction loss.

### **5.7 Economics of Aloe vera gel extraction process**

The cost estimation for the extraction of Aloe vera gel was carried out as explained in Chapter III. The machines used for extraction of Aloe vera gel were Aloe vera gel extraction machine and Aloe vera washing machine and the energy requirement of process machines were calculated as 38.40 and 24.00 kWh/day, respectively.

The total extraction cost for 1 kg of Aloe vera gel was estimated to be ` 13.36/-. The Aloe vera gel can be sold at a cost of ` 50/- per kg. The B:C ratio of Aloe vera gel was determined as 3.74:1. The B:C ratio shows that the developed process technology for extraction of Aloe vera gel is economically feasible. The detailed calculation is presented in Appendix II.



**Fig. 33 Desirability of optimum operating parameters for machine extracted Aloe vera gel**

## *Summary and Conclusions*

## VI. SUMMARY AND CONCLUSIONS

The present investigation entitled “Performance evaluation of roller type Aloe vera gel extraction machine” was undertaken in the Department of Processing and Food Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka during 2014-15. Determination of physical properties of Aloe vera leaf, design and specifications of Aloe vera leaf washing machine and Aloe vera gel extraction machine, performance evaluation of roller type Aloe vera gel extraction machine, the proximate composition and quality of Aloe vera gel obtained through Aloe vera gel extraction machine *viz.*, moisture content, crude protein, carbohydrates, crude fat, total soluble solids, pH, water activity, colour, viscosity and ash content of Aloe vera gel and economics of Aloe vera gel obtained from the Aloe vera gel extraction processing unit were studied. The results are summarized and the conclusions drawn are presented hereunder.

Hand filleting and whole leaf processing, two types of Aloe vera gel extraction methods are prevalent. Gel is extracted using roller type Aloe vera gel extraction machine. Only recently the processing methods using the entire whole leaf have been perfected so the undesirable elements can be selectively removed, while maximizing the desired constituents. Among the desirable constituents are the polysaccharides (glucomannans), glycoproteins and associated growth factors. However, over 95% of the Aloes on the market today still use only the inner gel.

The bulk quantity of Aloe vera gel is not available in the market round the year. So it is essential to extract Aloe vera gel using Aloe vera gel extraction machine. Compared to manual extraction, machine extracted of Aloe vera gel was less time consuming and labour-saving. The different roller speeds of 11.40, 15.10 and 18.80 rpm and roller clearances of 4, 5 and 6 mm were chosen as independent variables to extract Aloe vera gel. The proximate composition of machine extracted Aloe vera gel *viz.*, moisture, carbohydrates, ash, crude protein, crude fat and TSS (% Brix) were found to be nearly same as compared to manually extracted Aloe vera gel. Quality parameters *viz.*, pH, water activity, colour and viscosity of machine extracted Aloe vera gel was found to be superior to manually extracted Aloe vera gel.

Optimization of the two process variables namely; roller speeds (11.40, 15.10 and 18.80 rpm) and roller clearances (4, 5 and 6 mm) was done in Design Expert Software 7.7.0. Numerical optimization was performed using statistical models to find the optimal process parameters. In the present investigation, the independent variables were kept within the range and dependent variables were chosen as maximized or minimized. The optimized machine

extracted Aloe vera gel was found 18.80 rpm of roller speed and 5 mm of roller clearance was selected for economic analysis.

The performance evaluated of Aloe vera gel extraction machine had eliminated the manual contact in processing of Aloe vera gel and prevented contamination during gel extraction process. The problem of mixing of gel with chemical compound from aloe leaf skin in crushing method was reduced. 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 from Aloe vera gel extraction machine should be operated at 18.80 rpm of roller speed for 5 mm of roller clearance. The results showed that the quality parameters of Aloe vera gel were not affected by roller speed and roller clearance of machine extraction process. The conclusions drawn from the present investigation are listed hereunder.

## Conclusions

- The mean values of determination of physical properties of fresh Aloe vera leaves *viz.*, size, weight, volume, density and firmness were 151022.95 mm<sup>3</sup>, 178.60 g, 149.30 mm<sup>3</sup>, 1.20 g.mm<sup>3</sup> and 8.39 N, respectively.
- The mean values of proximate composition such as moisture content 98.34% (w.b.), carbohydrates content 1.20%, crude protein 0.16%, crude fat 0.06%, ash content 0.24% and TSS 1.66% Brix were found in manually extracted Aloe vera gel.
- The mean values of quality parameters *viz.*, pH, water activity, colour ( $L^*$ ,  $a^*$  and  $b^*$ ) and viscosity (mPa.s) were 6.31, 0.910, 29.37, -3.52, 4.65 and 1.61 (mPa.s), respectively in manually extracted of Aloe vera gel.
- The mean values of extraction efficiency (%), extraction loss (%), gel recovery (%) and extraction capacity (kg.h<sup>-1</sup>) were 93.66%, 2.64%, 40.60% and 125.64 kg.h<sup>-1</sup>, respectively were found in machine extraction of Aloe vera gel.
- The mean values of proximate composition such as moisture content, carbohydrates, crude protein, crude fat, ash content and TSS were 98.60% (w.b.), 1.03%, 0.15%, 0.03%, 0.19% and 1.42% Brix, respectively were found in machine extracted Aloe vera gel.
- The mean values of quality parameters *viz.*, pH, water activity, colour ( $L^*$ ,  $a^*$  and  $b^*$ ) and viscosity were 6.13, 0.90, 26.59, -3.77, 12.13 and 1.43 (mPa.s), respectively in machine extracted Aloe vera gel.

- The optimization of process parameters was carried out using the general factorial method in Design Expert 7.7.0 software on the basis of goal of response. The optimized condition was obtained at 18.80 rpm roller speed and 5 mm of roller clearance.
- The total cost of extraction of Aloe vera gel was estimated as `13.36/- per kg and B:C ratio as 3.74:1.
- The total cost of manual extraction of Aloe vera gel was estimated as ` 20.67/- per kg and B:C ratio as 2.42:1.

## **FUTURE LINE OF WORK**

On the basis of the investigation, the following suggestions were made for further study:

- To predict the Aloe vera gel extraction process and product indices using computing techniques like Artificial Neural Network (ANN) and Genetic Algorithm (GA) modelling for Aloe vera gel extraction machine.
- To study the shelf-life of Aloe vera gel obtained through Aloe vera gel extraction machine.

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## *Appendices*

## APPENDIX – I

### General specifications of various instruments/equipments/machines used in the present investigation

#### 1. Specifications of the Aloe vera gel extraction machine

- Length: 1620 mm
- Width: 850 mm
- Height: 1020 mm

Sl. No.	Machine parts	Description	Measurement (mm)
1	Knurling roller	Diameter	320
2	Roller belt	Width	580
3	Inlet hopper	Length	640
		Width	650
4	Outlet hopper	Length	580
		Width	570
		Depth	80 and 150
5	Electric motor	Rpm	1440
		Hp	1.0

#### 2. Specifications of the Aloe vera leaf washing machine

- Length: 1000 mm
- Width: 600 mm
- Height: 1200 mm

Sl. No.	Machine parts	Description	Measurement (mm)
1	Knurling chain roller	Diameter	320
2	Chain conveyor	Width	460
3	Sprinkler pipe	Length	400
		Width	400
4	Inlet water pipe	Diameter	30
5	Outlet water pipe	Diameter	60
6	Electric motor	Hp	1.0

### 3. Technical specifications of CV100 Series Mini Variable Frequency Drive

Sl. No.	Item	Description
1	Input	Rated voltage and frequency 4T:3-phase,380V ~ 440V AC; 50Hz/60Hz; 2S:Single-phase, 200V~240V;50Hz/60Hz Allowable voltage range 4T:320V~460V AC; 2S:180V~260V;Voltage tolerance <3%; Frequency: ±5%
2	Output	Rated voltage 0~Rated input voltage Frequency 0Hz~400Hz (Customed 0Hz~1000Hz) Overload capacity G type : 150% rated current for 1 minute, 180% rated current for 10 seconds; L type :110% rated current for 1 minute, 150% rated current for 1 second
3	Control Characteristics	Control mode Vector control without PG, V/F control Modulation mode Space vector PWM modulation Starting torque 0.5Hz 150% rated torque vector control without PG) Frequency accuracy Digital setting: Max frequency ×±0.01%; Analog setting: Max. frequency×±0.2% Frequency resolution Digital setting: 0.01Hz ; Analog setting: Max frequency×0.05% Torque boost Manual torque boost :0% ~30.0% V/F pattern 4 patterns: 1 V/F curve mode set by user and 3 kinds of torque-derating modes (2.0 order, 1.7 order and 1.2 order) Acc/Dec curve Linear acceleration/deceleration, Four kinds of acceleration/deceleration time Auto current limit Limit current during the operation automatically to prevent frequent over current trip
4	Operation panel	LED Display Display setting frequency, output frequency , output voltage, output current and so on, about 20 parameters Parameters copy Copy parameters by operation panel Keys lock and function selection Lock part of keys or all the keys. Define the function of part of keys
5	Efficiency	≥90%

#### 4. Technical specifications of Stable Microsystem Texture Analyser

Sl. No.	Particulars	Specification
1	Force capacity	750 kg.f (7.5 kN)
2	Force resolution	0.1g
3	Load cells	5, 30, 50, 100, 250, 500, 750 kg.f
4	Speed range	0.01 – 20 mm.s <sup>-1</sup> (13 mm.s <sup>-1</sup> @ 500-750 kg.f)
5	Range setting	1-524 mm
6	Data sampling rate	8 kHz
7	Power supply	Universal mains input voltage
8	Net weight	37.0Kg

#### 5. Technical specifications of spectrophotometer

Sl. No.	Parameter	Specifications
1	Measurement modes	% REL and % TRN
2	Measurement principle	DUAL BEAM
3	Sphere dimension	152 mm diameter
4	Light source	Pulsed xenon
5	Wavelength range	360 nm to 740 nm
6	Wavelength interval	10 nm
7	Photometric range	0-200%
8	Optical configuration	D/8 or D/0 viewing geometry
9	Wavelength accuracy	0.1 nm (Average)
10	Repeatability	Less than 0.1 DE CIELAB (white tile)
11	Inter instrument agreement (LAV)	0.15DE (Maximum)
12	Measurement time	2 s
13	Large area view (LAV)	25.4 mm diameter
14	Medium area view (MAV)	5.0 mm×10.0 mm
15	Small area view (SAV)	12.0 mm diameter
16	Very small area view (VSAV)	3 mm diameter
17	UV filter	IN/OUT
18	Visible cut-off filter	420 nm/465 nm/560 nm
19	Specular component	Included/excluded

20	Operating temperature	150-320 °C
21	Relative humidity	<90% non-condensing
22	Electrical requirements	110-120V AC/50-60 Hz 230-240V AC/50-60 Hz
23	Weight	21 kg approx.
24	Size	65m×29 cm×23 cm

## 6. Technical specifications of digital hand-held refractometer

Sl. No.	Particulars	Specifications
1	Model	3840 (PAL-Maple)
2	Brix scale (range minimum)	0
3	Brix scale (range maximum)	85
4	Resolution	0/1 % Brix
5	Temperature compensation	50 to 212 °F (10-100 °C)
6	Temperature range	10-100 °C
7	Temperature accuracy	±1 °C
8	Temperature resolution	0.1 °C
9	Sample volume	0.3 ml
10	Response time	3 seconds
11	Product type	Refractometer (Digital)
12	Display	3 digit LCD
13	Dimensions	2" W×4-1/4"H×1-1/4" D
14	Power	2AA batteries

## 7. Technical specifications of Rotronic water activity meter

Sl. No.	Parameters	Operating range
1	Temperature measurement	5 to 50 °C
2	Humidity measurement	0 to 100% RH
	<b>Reproducibility</b>	
3	Humidity measurement	<0.5% RH
4	Temperature measurement	<0.2 °C
5	Long term stability	<1% RH/ year
6	Supply voltage	6 to 15 DC

7	Current consumption	12 mA
<b>Output signals</b>		
8	Digital	DIO
9	Analogue	ROV: 0....1V=0..100% RH, 5...50 °C
10	Load per analogue output	>1000 Ohm
<b>Adjustment points</b>		
11	Humidity	35%, 80%, 10%, 5%, or 0% RH
12	Temperature	T <sub>min</sub> , T <sub>max</sub>

## 8. Technical specifications of Hunterlab Colourimeter

Sl. No.	Particulars	Specifications
1	Port size	31.8 mm (45°/0°) and 14.3 mm (diffuse/8°)
2	Reproducibility	0.15 (Avg. DE* on BCRA II tile set)
3	Spectral range	400–700 nm
4	Spectral resolution	10 nm
5	Spectral band pass	< 12 nm
6	Photometric	0–150%
7	Lamp life	> 500,000 flashes
8	Display (cm)	6.4×6.4 LCD
9	Colour spaces	CIE XYZ CIE $L^* a^* b^*$ , CIE $L^*, c^*, h^*$ Hunter $L, a, b$
10	Indices	$\Delta E^*$ , $\Delta E$ , $\Delta E_{cmc}$ , Whiteness, Yellowness, Meta merism, Tint, Brightness, ISO Greyscale, Gray Stain
11	Illuminants	A, C, D65, TL84, F2 and 10 Degree observer
12	Approximate size	36 cm (depth)×13 cm (width)×16 cm (height)
13	Weight	4.5 Kg

## 9. Technical specifications of Anton Paar Rheometer

Sl. No.	Particulars	Specifications
1	Product	MCR modular compact Rheometer
2	Software	Anton Paar, Rheocompass and Rheoplus
3.	Rheological test	Both Oscillatory and Rotational mode
4	Temperature range	15-35 °C
5	Relative Humidity	20-60%
6	Torque resolution	100 Nm
7	Min. torque rotation	250 µNm
8	Maximum torque rotation/ oscillation	125 mNm
9	Minimum angular frequency	628 rad/s
11	Measuring plate pp 25	Diameter-25 mm
12	Air pressure	2.10 bar
13	Machine provision	Machinery directive, electromagnetic compatibility directive and low voltage directive
15	Manufacturer	Anton Paar GmbH, Anton Paar-str 20, A-8054 Graz, Austria-Europe
14	Weight	43 kg
15	Dimension	440×600×620 mm

## APPENDIX - II

### A. Economics of machine extracted Aloe vera gel extraction process

#### 1. Estimation of cost of extraction of Aloe vera gel

Cost of gel extraction machine	= ` 4,00,000/-
Cost of the leaf washing machine	= ` 1,00,000 /-
Cost of the variable frequency drive (VFD)	= ` 10,500/-
Cost of the other accessories	= ` 15000/-
Cost of the electronic balance	= ` 15,000/-
Life span of the unit (n)	= 10 years
Annual usage	= 275 days
Interest rate (i)	= 4.5% per annum
Housing, insurance and taxes	= 4% per annum
Repair and maintenance charges of equipment	= 5% per annum

**Total cost of the equipment, E** = 4, 00,000+1,00,000+15000+10,500+15,000  
= ` 5, 40,500 /-

#### I. Fixed cost per year

- i. Fixed cost of the equipments, E (Gel extraction machine, leaf washing machine, variable frequency drive and electronic balance unit)

$$\begin{aligned} &= \frac{i(i+1)^n}{(i+1)^n - 1} \times E \\ &= \frac{0.045(0.045+1)^{10}}{(0.045+1)^{10} - 1} \times 5,40,500 \\ &= ` 68,320 /- \end{aligned}$$

- ii. Housing, insurance and taxes of equipments = 16000 + 4000 + 420 + 600 + 600  
= ` 21620/- per year

**Total fixed cost/year = i + ii**

$$= 68320+21620$$

$$= 89620 \text{ ₹/per year}$$

## II Variable cost per year

### A) Repair and maintenance charges of equipment

Repair and maintenance charges of equipments (Gel extraction machine, leaf washing machine and variable frequency drive =  $20000+5000+525+750$

$$= ₹ 26275 \text{ per year}$$

### B) Cost of energy

a. Energy requirement of gel extraction machine = 38.4 kWh/day

b. Energy requirement of leaf washing machine = 24 kWh/day

### Total energy requirement

$$= a+b$$

$$= 38.4+24$$

$$= 62.4 \text{ kWh/day}$$

Electricity charges = 4 ₹/ kWh

Electricity consumption charges = No. of days  $\times$  Total energy requirement  $\times$  4

$$= 275 \times 62.4 \times 4$$

$$= ₹ 68640/- \text{ per year}$$

### C) Labour charges

No. of labourers = 2

Labour charges per day = ₹ 175/-

Cost of labour per year =  $350 \times 275$

$$= ₹ 96250/-$$

### D) Cost of raw material

**Cost of Aloe vera leaf:** Cost of 1 kg of leaves = ₹ 5/-

Optimized parameters of roller speed (18.80 rpm) and roller clearance (5 mm) were obtained for gel recovery (68.72 kg) and extraction capacity ( $158.06 \text{ kg.h}^{-1}$ ) for trimmed Aloe vera leaves.

Trimmed Aloe vera leaves are required for the extraction of 1day = 158.06×8  
= ` 1264.48 kg/day

**Total cost of material for trimmed Aloe vera leaves** = 1264.48×275×5  
= ` 1738660/- per year

**Total variable cost per year** = A+B+C+D  
= 26,275+68640+96250+1738660/-  
= ` 1929825/-

**Total cost of extraction of Aloe vera gel**  
= Total fixed cost + Total variable cost  
= 89620+1929825  
= ` 2019445/-

**Total extraction of Aloe vera gel per year for trimmed leaves** = 68.72×8×275  
= 151184 kg/year

**Cost of extraction of one kg of Aloe vera gel**  
=  $\frac{\text{Total cost of extraction}}{\text{Total quantity of Aloe vera gel extracted}}$   
=  $\frac{2019445}{151184}$   
= ` 13.36/- per kg

Assuming the market selling price of Aloe vera gel = ` 50/- per kg

### **B:C ratio**

Therefore the total cost extraction of 1 kg of Aloe vera gel was found to be ` 13.36/-.

The benefit cost ratio was found to be 3.74:1.

## **B. Economics of manual Aloe vera gel extraction process**

For manual extraction was obtained gel recovery (1.82 kg) and extraction capacity (3.15 kg.h<sup>-1</sup>) for trimmed Aloe vera leaves.

### **A) Labour charges**

No. of labourers = 2

Labour charges per day = ` 175/-

Cost of labour per year = 350×275  
= ` 96250/-

### **B) Cost of Aloe vera leaf: Cost of 1 kg of leaves = ` 5 /-**

**Annual working days = 275 days**

**Trimmed Aloe vera leaves are required for the extraction of 1day = 3.15×8×2**  
**= 50.4 kg/day**

**Total cost of material for trimmed Aloe vera leaves = 50.4×275×5**  
**= `69300/- per year**

**Total Cost of extraction = A + B**  
**= 96250+69300**  
**= 165550**

**Total extraction of Aloe vera gel per year for trimmed leaves = 1.82×2×8×275**  
**= 8008 kg/year**

**Cost of extraction of one kg of Aloe vera gel**

$$= \frac{\text{Total cost of extraction}}{\text{Total quantity of Aloe vera gel extracted}}$$

$$=165550/8008$$

$$= ` 20.67 \text{ per kg}$$

Assuming the market selling price of Aloe vera gel = `50/- per kg

**B:C ratio**

Therefore the total cost extraction of 1 kg of Aloe vera gel was found to be ` 20.67/-.

The benefit cost ratio was found to be 2.42:1.

**Appendix – III**  
**Input factors for optimization of machine parameters for Aloe vera gel extraction machine**

Aloe vera gel extraction process Treatment 1 (11.40 rpm and 4 mm)																							
Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf (mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf (mm)	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC (kg.h <sup>-1</sup> )	
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip										
1	169	286	74	63	17	125	268	58	44	28	14.62	10.27	6.55										
2	189	354	86	71	28	117	239	69	61.5	38.5	14.78	10.49	8.14										
3	164	435	81	61	19	131	261	67	53	29	13.67	10.98	7.96										
4	195	390	84	67	26	132	236	69	62	39	17.53	13.3	9.1										
5	217	380	96	75	30	173	295	82	59	31.5	15.38	9.67	6.5										
6	210	340	89	71	31	145	249	76.5	67	37	16.87	10.51	8.19										
7	129	365	76	61	22	126	251	70	58	36	14.44	11.15	6.27										
8	230	411	91	71	23	110	275	78	67	41	16.91	12.46	7.77										
9	187	410	82	68	15	131	267	73	64	34	14.79	10.9	7.5										
10	219	430	95	77	15	165	285	78	60	28	15.89	10.48	7.01										
11	201	446	86	63	23	160	279	74	63	39	16.07	13.17	9.16										
12	245	390	101	77	20	189	261	77	68	40	17.04	11.7	10.41										
13	171	360	82	70	28.5	116	223.5	75	58	40	15.36	9.79	7.22										
14	219	380	75	63	20	134	262	68	57	35	17.34	13.41	8.23										
15	200	410	99	80	16	160	280.5	85	69	37	14.8	10.21	8.57										
16	218	395	87	74	27	155	272	81	66	28	15.02	11.59	8.28										
17	165	446	86	63	14	136	290	77	58	30	15.04	11.3	5.95										
18	167	425	75	66	19	132	314	66	57	34	13.65	11.45	7.89										
19	187	442	76	63	12	125	255	64	55	36	14.74	10.78	6.14										
20	204	405	81	64	21	140	314	66	55	32	15.9	13.45	5.59										
21	264	446	79	63	12	118	265	64	56	33	14.18	10.82	7.47										
22	215	431	78	68	12	146	295	66	54	33	15.65	9.9	6.29										
23	190	365	91	74	26	145	287	85	67	35	16.32	11.36	6.91										
24	192	390	79	64	21	139	335.5	70	53	33	14.56	11.78	8.03										
25	164	341	85	80	29	145	264	78	68	38	14.81	12.68	8.01										
26	239	350	96	83	39	191	295	87	69	42	16.86	11.72	7.65										
27	208	350	98	83	28	154	245	91	71	41	17.83	12.47	8.69										
28	220	396	74	77	18	175	305	76	61	32	16.33	13.11	8.42										
29	203	491	98	74	15	156	268	87	67	33	16	11.58	8.85										
30	276	430	102	80	13	176	312	92	66	46	13.73	13.81	11.85										
<b>Tot al</b>	<b>6057</b>	<b>11890</b>	<b>2582</b>	<b>2114</b>	<b>639.5</b>	<b>4346</b>	<b>8249</b>	<b>2250</b>	<b>1834</b>	<b>1059</b>	<b>448.6</b>	<b>346</b>	<b>234.53</b>	<b>1570</b>	<b>2582</b>	<b>195</b>	<b>0.41</b>	<b>3.0</b>	<b>88.61</b>	<b>4.50</b>	<b>37.93</b>	<b>104.32</b>	

**Aloe vera gel extraction process Treatment 2 (11.40 rpm and 5 mm)**

Leaf No	Wt. of fresh leaf (g)	Length of fresh leaf(mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf(mm)	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC (kg.h <sup>-1</sup> )
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	255	456	82	70	18.5	215	233	68	60	33.5	13.47	12.95	6.19									
2	272	345	86	66	18	217	260	72	61	30	14.41	10.27	7.98									
3	161	346	82	65	21	122	274	69	56	28	14.42	10.80	6.82									
4	205	400	90	75	21	143	256	78.5	52	34.5	16.06	12.44	8.34									
5	273	355	83	67	21	223	248	74.5	56.5	31.5	16.26	11.74	8.97									
6	166	305	94	70	28	111	280	72	62	35	15.16	11.20	7.92									
7	212	336	89	77	23	156	232.5	77	65	41	16.81	13.88	8.36									
8	282	380	80	70	18	133	231	67	60	37	17.50	13.15	9.31									
9	282	361	83	65	15	217	227	68	56	35	15.43	10.21	7.64									
10	176	395	72	64	30	118	263	66.5	55	28	15.07	12.28	6.91									
11	267	351	75	65	18	215	247	63	51	29	16.33	11.63	8.26									
12	196	412	79	66	15	144	254	61	57	33	16.14	12.87	8.02									
13	283	445	84	63	25	131	229.5	70	61	44	16.12	12.32	9.13									
14	227	415	89	70	21.5	161	256	73	62	30	17.03	12.17	7.07									
15	178	340	86	72	27	129	266	71	53	29	14.76	10.98	7.46									
16	197	391	83	69	23	144	251	70	61	34	14.79	13.15	8.16									
17	260	341	73	56	24	215	260	56	49	32	14.04	12.35	7.49									
18	202	465	87	61	22	127	235	73	63	35	15.28	10.71	6.36									
19	195	336	80	69	26	134	329	67	58	32	16.52	12.12	7.00									
20	185	388	77	65	20	124	242	66	54	33	13.88	11.80	8.07									
21	175	376	76	57	20	127	256	67	53	24	14.77	12.95	8.27									
22	204	386	81	69	31	142	236	60.5	52	30	15.61	11.05	7.75									
23	223	471	76	55	23	168	264	74	61	37.5	17.06	13.55	8.89									
24	228	451	82	55	20	175	272	69	54	30	17.34	12.53	6.90									
25	271	401	87	67	26	116	218	68	56	35	15.44	13.42	6.44									
26	206	386	79	60	28	163	267	83	55	34	16.42	11.79	6.82									
27	262	440	77	54	19	217	267	56	40	23	14.29	10.51	6.21									
28	212	431	66	52	17	159	250	81	66	42	16.20	12.81	9.50									
29	202	400	90	66	18	139	267	76	61	34	16.60	12.11	8.01									
30	255	396	74	58	26	208	261	67	52	27	15.59	11.13	5.87									
<b>Total</b>	<b>6712</b>	<b>11701</b>	<b>2442</b>	<b>1938</b>	<b>663</b>	<b>4793</b>	<b>7632</b>	<b>2084</b>	<b>1702</b>	<b>981</b>	<b>468.74</b>	<b>360.8</b>	<b>230</b>	<b>1927</b>	<b>2743</b>	<b>112</b>	<b>0.42</b>	<b>3.0</b>	<b>94.45</b>	<b>2.35</b>	<b>41.03</b>	<b>115.02</b>

**Aloe vera gel extraction process Treatment 3 (11.40 rpm and 6 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf (mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf, mm	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel, g	Gel constant value	Time min	EE (%)	EL (%)	GY (%)	EC kg.h <sup>-1</sup>
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	198	329	87	75	27	144	231	77	64	35	18.36	11.15	8.64									
2	180	362	86	65	31	123	235	56.5	52	47	15.29	10.59	6.77									
3	289	405	106	79	22	197	284	84.5	60	28	16.64	10.13	8.51									
4	243	391	98	82	21	163	246	80	67	39.5	16.05	12.63	6.83									
5	201	351	88	72	30	134	232	72.5	60	33	15.86	9.15	7.62									
6	185	366	81	70	20	116	247	78	60	24	14.65	10.39	7.43									
7	208	371	86	71	13	136	257	69	51	28	14.80	11.77	7.66									
8	188	321	77	68	31	134	217	69.5	60	39	16.59	11.73	7.82									
9	196	332	80	66	23	130	221	70	56	35	18.36	12.15	9.61									
10	179	386	86	70	21	111	217	73	59	31	14.20	8.68	6.19									
11	170	426	72	54	12	113	264	58	48	30	13.32	9.84	6.13									
12	205	461	87	56	13	139	270	79.5	55.5	29.5	12.69	7.99	6.17									
13	243	357	94	74	29	173	269	83	68	37	15.69	10.19	7.98									
14	185	400	82	60	13	127	267	71	51	32	15.27	10.55	8.90									
15	180	401	90	70	18	170	321	78	66	34	14.65	10.96	8.32									
16	194	431	78	57	15	129	249	66	55	32	15.73	11.14	7.82									
17	218	441	86	63	12	151	257	74	60	32	16.34	10.93	8.13									
18	212	476	97	65	12	138	263	75	56	29	13.63	9.79	6.67									
19	250	351	103	84	34	187	260	82	68	38	15.72	13.13	10.69									
20	247	359	98	75	30	167	224	81.5	58	34	18.73	13.82	11.38									
21	285	397	102	81	22	150	259.5	94	73	36	14.75	11.79	8.36									
22	226	436	99	73	17	160	267	78	54	45.5	17.74	12.21	8.62									
23	214	473	90	68	14	134	258	77.5	55	32	15.28	9.91	6.27									
24	250	455	96	71	16	150	290	84	66	34.45	15.82	11.79	10.17									
25	153	370	85	67	16	139	242	78	63	34	15.82	12.47	9.90									
26	192	401	75	53	18	126	271	64	55	28	14.72	10.46	7.10									
27	253	362	99	78	22	183	240	83	66	34	18.67	13.13	7.64									
28	301	397	96	80	25	224	319	92	70	32	18.58	14.14	6.71									
29	215	341	102	77	23	147	150	76	62	36	16.76	12.70	7.29									
30	150	356	85	66	26	127	257	64.5	50	28	13.58	9.87	7.22									
<b>Total</b>	<b>6410</b>	<b>11705</b>	<b>2691</b>	<b>2090</b>	<b>626</b>	<b>4421</b>	<b>7585</b>	<b>2269</b>	<b>1789</b>	<b>1007</b>	<b>474.2</b>	<b>335.1</b>	<b>238.5</b>	<b>1655</b>	<b>2677</b>	<b>108</b>	<b>0.40</b>	<b>3.0</b>	<b>93.79</b>	<b>2.46</b>	<b>38.06</b>	<b>106.09</b>

**Aloe vera gel extraction process Treatment 4 (15.10 rpm and 4 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(m m)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf (mm)	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC kg.h <sup>-1</sup>
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	200	440	90	67	21	137	270	72.5	51	26	14.77	9.39	6.08									
2	252	415	90	71	30	150	260	72	56.5	30.5	14.25	10.83	7.53									
3	248	410	90	76	32	150	265	82.5	75	45	17.17	14.29	7.70									
4	279	385	100	90	35	184	250	74.5	65	46.5	18.97	12.59	7.76									
5	170	425	75.5	61	17	108	275	62.5	55	30	12.43	9.72	7.12									
6	278	410	103	90	32	203	310	80.5	64	30.5	14.16	13.03	6.51									
7	189	495	75	58	18	134	280	55	52.5	26	14.78	9.51	7.19									
8	210	450	81	58	18	151	275	57.5	48.5	25	16.22	13.40	7.19									
9	220	415	92.5	70	22	156	265	80	74.5	35	15.78	12.24	8.28									
10	174	350	83	67	24	114	215	61	53.5	35	13.69	10.16	7.81									
11	241	415	91	74	28	150.5	315	68.5	62.5	30	16.26	11.36	8.42									
12	186	405	75	60	23	131	275	61	52	35	12.77	11.79	8.09									
13	235	430	84	70	24	168	290	65	55	37.5	16.03	12.04	9.05									
14	196	385	79	68	29.5	139.5	260	70	62	34	16.74	11.25	6.42									
15	156	385	86	68	25	113	245	57	49.5	26	16.40	12.34	7.89									
16	293	430	96	79	33	209.5	290	87.5	73.5	43.5	18.90	13.04	8.45									
17	182	400	81	64.5	23	127	310	66	50	30	14.02	9.65	6.40									
18	183	425	84	59	22	123	280	61	52.5	22.5	13.92	9.61	3.53									
19	194	450	77.5	58.5	17.5	138	285	63.5	52	26	13.21	9.34	6.04									
20	226	485	82	63	15	152	275	65	52.5	25.5	18.04	12.60	8.73									
21	230	450	89	66	30	158	305	72	60	25.5	14.72	10.23	4.27									
22	175	475	69.5	53	26	119	265	67	52.5	36	14.36	9.82	6.51									
23	200	485	80	65	20	131	255	66	56	35.5	16.17	12.26	7.98									
24	193	475	92	69	30	175	295	84	66.5	32.5	14.72	11.25	7.04									
25	172	410	70.5	59	39	110	235.2	72	56.5	45.5	14.84	11.39	6.83									
26	186	465	79.1	62	21	122	240	67	56.5	40	15.16	11.32	6.81									
27	178	465	82	60	24	134	260	74	58.5	37	12.37	10.71	7.46									
28	198	420	77	65	33	142	220.2	81.5	61.5	46.5	14.25	12.99	8.10									
29	187	425	78.1	59	23	120	230	71	55.5	36	14.66	12.74	8.65									
30	189	440	79	61	25	134	245	61.5	57	35	14.55	12.03	7.89									
<b>Total</b>	<b>6220</b>	<b>12915</b>	<b>2512</b>	<b>1991</b>	<b>760</b>	<b>4283</b>	<b>8040.4</b>	<b>2079</b>	<b>1738</b>	<b>1009</b>	<b>454.2</b>	<b>342.8</b>	<b>217.7</b>	<b>1663</b>	<b>2482</b>	<b>137</b>	<b>0.42</b>	<b>2.5</b>	<b>92.25</b>	<b>3.25</b>	<b>40.02</b>	<b>111.20</b>

**Aloe vera gel extraction process Treatment 5 (15.10 rpm and 5 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf, mm	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC kg.h <sup>-1</sup>
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	242	380	86	75	25	201	260	77	57	37	15.44	12.37	8.53									
2	227	445	140	70	27	188	260	80	69	44	16.04	11.14	8.00									
3	186	275	80	72.5	50	127	185	75	71	54	15.58	12.23	7.97									
4	195	365	75	56	25	135	257	63	54	34	17.20	14.01	8.50									
5	195	325	86	70	26	133	180	80	72	54	17.76	11.86	7.11									
6	192	420	81	70	21	132	255	75	63	45	13.57	10.01	7.29									
7	172	330	70	56.5	27	117	239	64	52	39	14.08	13.04	7.79									
8	175	442	74	57	22	123	289	63	50	36	13.49	11.25	7.78									
9	200	410	85	66	20	184	210	70	65	50	14.48	11.92	8.36									
10	208	315	85	69	30	141	191	75	70	50	20.67	13.57	9.53									
11	155	335	75	69	29	103	230	67	55	37	14.15	10.99	7.37									
12	172	445	77	57	10	122	280	65	50	28	14.21	11.45	6.70									
13	169	340	65	51	25	97	234	54	45	35	12.11	11.01	7.09									
14	233	380	85	71	25	162	241	74	62	46	17.39	12.93	9.37									
15	221	385	86	67	24	158	271	71	58	33	15.75	12.79	7.12									
16	120	375	82	68.5	25	152	242	79	67	45	15.92	11.14	6.35									
17	237	370	143	66	25	154	199	82	72	50	16.72	13.36	10.33									
18	207	370	80	65	21	119	248	73	55	33	15.75	10.18	6.44									
19	220	395	87	66	25	147	235	75	64	45	17.22	12.65	8.36									
20	200	410	67	56	21	112	267	68	46	26	15.38	10.81	6.06									
21	274	435	80	55	17	128	281	69	55	33	13.16	10.09	7.20									
22	280	360	82	68	30	235	234	78	63	46	14.61	10.63	6.48									
23	200	380	70	62	25	184	240	59	53	37	16.72	12.83	6.89									
24	262	440	85	64	21	214	280	70	60	36	17.29	12.90	7.60									
25	184	395	77	60	22	121	239	66	57	31	13.90	10.41	7.65									
26	163	365	77	61	25	110	235	65	59	37	14.50	8.65	6.38									
27	195	405	83	65	30	150	260	70.5	60	34	13.16	9.89	7.63									
28	241	395	88	68	31	172	252	75	65	48	16.98	13.58	9.15									
29	265	370	144	70	30	217	220	66.5	59	45	15.69	11.76	7.30									
30	194	340	80	66	39	133	260	77	67	45	15.73	12.27	8.73									
<b>Total</b>	<b>6184</b>	<b>11397</b>	<b>2575</b>	<b>1938</b>	<b>773</b>	<b>4471</b>	<b>7274</b>	<b>2126</b>	<b>1795</b>	<b>1213</b>	<b>464.6</b>	<b>351.7</b>	<b>231</b>	<b>1848</b>	<b>2523</b>	<b>100</b>	<b>0.44</b>	<b>2.5</b>	<b>94.85</b>	<b>2.24</b>	<b>42.28</b>	<b>128.11</b>

**Aloe vera gel extraction process Treatment 6 (15.10 rpm and 6 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf (mm)	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC (kg.h <sup>-1</sup> )
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	250	459	110	81	30	127	301	103	78	41	18.45	10.84	7.77									
2	237	409	96	78	24	147	199	75	68	38	16.36	10.74	6.78									
3	207	437	92	66	20	133	266	81	59	38	14.91	11.68	6.02									
4	245	466	96	79	18	116	284	83	60	42	16.12	11.72	9.03									
5	276	371	100	77	15	152	261	90	79	46	15.63	10.74	6.67									
6	198	422	92	78	26	128	246	80	61	39	12.82	10.70	6.23									
7	278	387	91	70	18	120	254	78	69	43	17.59	14.07	7.02									
8	236	347	87	63	22	162	266	84	65	40	16.41	10.66	6.99									
9	203	413	74	53	19	127	264	70	48	32	12.48	11.36	7.68									
10	281	430	87	58	18	153	266	78	66	41	15.48	11.13	7.02									
11	312	394	89	67	23	115	254	86	70	51	15.22	11.66	7.58									
12	336	345	109	75	27	333	264	87	75	45	18.56	15.92	6.97									
13	257	394	114	75	21	111	227	98	75	56	17.08	13.93	9.12									
14	263	348	99	64	18	103	256	87	68	48	15.89	12.23	8.67									
15	230	377	104	71	20	171	296	73	62	36	17.76	14.33	6.99									
16	243	366	100	68	21	175	273	90	70	42	14.98	10.76	8.09									
17	229	399	90	64	14	177	300	77	65	31	18.23	11.27	7.13									
18	287	389	88	79	30	211	263	92	75	47	19.11	13.60	7.69									
19	261	421	90	74	18	154	256	79	62	41	18.18	13.28	7.77									
20	231	444	83	62	23	134	292	73	55	37	18.57	11.40	8.59									
21	190	386	87	66	20	166	227	66	63	41	17.78	12.90	8.33									
22	130	406	80	56	18	112	237	71	57	35	17.47	13.88	10.36									
23	175	426	83	62	14	115	231	87	66	49	16.46	9.12	7.14									
24	159	376	80	56	20	131	276	70	55	34	16.98	10.78	6.19									
25	181	367	88	60	20	137	257	61	56	32	21.87	14.86	11.53									
26	129	402	113	69	25	119	263	101	71	39	19.58	13.03	6.55									
27	155	506	79	64	16	111	237	88	71	43.5	18.02	11.65	7.88									
28	139.5	434	83	70	31	119	259	78	66	35	18.06	12.02	8.04									
29	121.5	457	87	68	24	109	274	82	67	40	19.49	12.64	8.77									
30	242	421	107	82	31	223	297	96	72	41.5	19.43	12.56	7.89									
<b>Total</b>	<b>6682</b>	<b>12199</b>	<b>2778</b>	<b>2055</b>	<b>644</b>	<b>4391</b>	<b>7846</b>	<b>2464</b>	<b>1974</b>	<b>1224</b>	<b>514.9</b>	<b>365.5</b>	<b>232.4</b>	<b>1761</b>	<b>2526</b>	<b>104</b>	<b>0.42</b>	<b>2.5</b>	<b>94.42</b>	<b>2.37</b>	<b>41.08</b>	<b>117.19</b>



**Aloe vera gel extraction process Treatment 7 (18.80 rpm and 4 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(m m)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf(mm)	Width of trimmed leaf (mm)			Thickness of trimmed leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC (kg.h <sup>-1</sup> )
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	163	431.7	91	70	17	152	298	78.5	65	29	18.51	11.53	6.39									
2	207	388	90	77	35	126.5	268	80	66	42	13.74	9.23	5.42									
3	207	386	88	73	19	152	254	78	64	39	16.59	11.40	6.79									
4	218	422	88	73	17	152	283	79	65	34	16.93	11.11	5.98									
5	265	442	94	75	18	180	257	93	78	43	18.76	13.03	8.64									
6	166	498	73	56	16	138	285	78	55	30	14.52	11.33	6.74									
7	265	442	96	83	23	203	305	93	75	38	16.48	12.19	6.40									
8	183	406	83	65	23	137	297	80	63	30	14.22	10.46	5.55									
9	241	376	97.5	73	25	126	276	84	63	32	15.54	9.39	6.46									
10	351	441	119	89	20	249	248.5	104.5	87	44	20.81	16.27	13.00									
11	213	487	91	58	15	151	328	80	57	24	12.04	10.78	5.35									
12	188	506	83	66	13	134	318	67	57	21	14.97	11.35	4.14									
13	246	479	84	65	16	179	333	124	61	28	16.51	12.71	5.60									
14	187	441	87	71	16	130	273	82	69	29	16.47	7.72	6.04									
15	221	464	90	68	26	158	300	83	60	33	15.18	11.09	6.79									
16	198	451	90	67	17	139	299	78	58	28	15.48	10.64	5.16									
17	290	495	105	76	18	107	304	88	62	29	17.86	11.63	5.95									
18	269	412	78	57	15	124	286	73	58	25	15.27	9.58	5.50									
19	224	426	97	75	24	199	301	88	71	34	15.66	11.06	5.23									
20	215	443	92	66	18	155	283	81	61	31	16.98	11.31	6.95									
21	214	383	108	68	21	143	192	90	73	33	18.42	10.06	6.02									
22	271	446	86	65	20	132	282	75	59	32	14.87	10.90	4.66									
23	217	402	92	57	20	164.5	300	86	61	34	15.96	10.09	5.17									
24	290	446	87	74	14	144	276	80	64	32	16.25	11.25	7.16									
25	224	523	86	72	9.5	155	298	74	63	30	16.50	11.16	6.45									
26	309	387	106	83	16.7	221	282	98	73	40	19.03	15.18	7.44									
27	238	368	93	79	17.6	170	290	78	66	35	18.36	10.07	7.34									
28	292	442	79	63	16	150	282	65	55	28	25.40	14.28	5.69									
29	223	388	92	74	25	174	276	81	68	37	15.55	13.13	6.63									
30	238	445	90	72	23	166	307	80	73	47	16.05	12.01	6.75									
<b>Total</b>	<b>6870</b>	<b>13067</b>	<b>2736</b>	<b>2110</b>	<b>574</b>	<b>4711</b>	<b>8582</b>	<b>2499</b>	<b>1950</b>	<b>991</b>	<b>498.9</b>	<b>341.8</b>	<b>191.3</b>	<b>1833</b>	<b>2737</b>	<b>142</b>	<b>0.42</b>	<b>2.0</b>	<b>92.80</b>	<b>3.10</b>	<b>40.18</b>	<b>141.44</b>



**Aloe vera gel extraction process Treatment 8 (18.80 rpm and 5 mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf,mm	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time min	EE (%)	EL (%)	GY (%)	EC kg.h <sup>-1</sup>
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	178	432	81	58	12	126	252	75	65	36	14.05	11.63	6.74									
2	173	372	81	57	27	121	172	66	52	36	17.86	13.01	9.58									
3	144	321	72	64	24	119	209	68	58	38	18.46	12.28	5.99									
4	212	426	84	62	21	185	270	73	58	37	16.19	12.87	7.15									
5	350	439	91	70	19	281	259	80	68	44	19.09	15.73	8.25									
6	210	339	107	71	33	163	220	91	71	43	20.02	14.81	8.79									
7	197	317	85	68	21	141	216	77	66	43	19.56	11.87	8.89									
8	192	381	82	66	31	144	257	66	60	36	15.85	15.07	7.73									
9	216	417	99	67	23	137	254	84	71	39	18.55	14.27	7.10									
10	215	393	86	63	26	163	292	83	61	35	16.02	12.96	7.97									
11	276	352	103	88	35	221	268	93	79	44	20.60	14.91	11.06									
12	239	337.5	89	69	26	182	248	82	65	25	19.94	13.69	9.45									
13	213	377	91	73	29	157	251	85	68	43	14.94	11.31	5.04									
14	242	382	102	71	29	183	258	91	66	41	17.77	12.89	8.28									
15	175	368	81	66	22	135	279	71	59	38	17.75	13.38	7.14									
16	218	352	85	66	16.8	216	335	75	63	39	19.94	14.07	7.60									
17	163	270	100	83	32	123	287	92	75	48	19.39	13.54	6.60									
18	248	398	97.1	82	41	219	181	87	83	58	18.78	16.06	9.29									
19	173	387	41.01	60	29	130	243	65	58	31	15.21	11.12	6.30									
20	238	382	60.6	77	34	202	235	84	72	47	19.29	14.90	8.18									
21	220	347	50.8	65	32	161	258	73	60	41	18.73	14.03	6.94									
22	278	362	113	82	31.5	226	282	100	79	43	20.34	13.14	7.07									
23	200	378	87	84	33	131	223	79	68	48	17.71	12.77	6.09									
24	237	398	83	71	38	212	265	76	61	39	15.78	13.96	6.95									
25	206	391	85	72	32	149	261	72	59	37	14.76	13.09	9.62									
26	330	432	92	75	20	295	283	78	67	37	18.90	17.06	8.04									
27	286	347	86	81	35	212	238	81	70	40	18.30	13.51	7.70									
28	205	372	82	70	26	152	276	65	57	35	16.80	14.14	7.76									
29	280	358	96	81	44	214	288	84	72	45	19.18	15.60	6.67									
30	223	443	103	80	23	169	287	78	66	27	17.03	10.73	5.89									
<b>Total</b>	<b>6737</b>	<b>11270.5</b>	<b>2595.5</b>	<b>2142</b>	<b>845.3</b>	<b>5269</b>	<b>7647</b>	<b>2374</b>	<b>1977</b>	<b>1193</b>	<b>536.70</b>	<b>407.80</b>	<b>229.80</b>	<b>2250</b>	<b>2928</b>	<b>91</b>	<b>0.44</b>	<b>2</b>	<b>96.08</b>	<b>1.58</b>	<b>43.57</b>	<b>158.06</b>

**Aloe vera gel extraction process Treatment 9 (18.80 rpm and 6mm)**

Leaf No.	Wt. of fresh leaf (g)	Length of fresh leaf(mm)	Width of fresh leaf (mm)			Wt. of trimmed leaf (g)	Length of trimmed leaf ,mm	Width of trimmed leaf (mm)			Thickness of trimmed Leaf (mm)			Wt. of gel (g)	Wt. of rind (g)	Wt. of rind with gel (g)	Gel constant value	Time (min)	EE (%)	EL (%)	GY (%)	EC (kg.h <sup>-1</sup> )
			Base	Middle	Tip			Base	Middle	Tip	Base	Middle	Tip									
1	203	341	94	67	24	144	257	79	53	30	15.85	11.29	6.73									
2	236	382	89	73	29	155	261	74	62	35	17.15	12.23	7.04									
3	217	486	90	63	20	160	304	79	58	30	14.14	11.71	7.90									
4	172	376	78	64	31	157	298	70	57	28	16.16	10.75	4.97									
5	203	396	83	70	35	155	326	70	63	35	15.33	10.93	5.32									
6	282	371	98	80	25	220	269	94	73	36	16.72	15.43	9.09									
7	171	448	78	61	20	114	275	67	53	28	14.16	10.27	5.71									
8	182	466	86	60	21	129	295	71	53	28	14.09	8.49	6.37									
9	182	401	79	58	24	138	315	66	54	23	16.31	12.51	6.34									
10	192	309	101	84	33	132	214	84	71	37	16.47	12.82	8.72									
11	188	340	93	68	30	143	243	79	62	30	16.66	9.18	8.62									
12	176	406	77	64	31	130	277	69	57	34	15.26	12.21	9.42									
13	175	406	81	64	29	130	286	71	58	30	12.50	9.65	5.52									
14	230	347	100	76	34	175	257	92	71	36	15.98	13.32	7.63									
15	213	446	86	66	31	164	306	78	60	31	14.58	12.49	5.31									
16	224	445	87	59	28	189	319	73	59	34	15.74	13.60	5.88									
17	262	436	97	86	33	198	276	80	71	39	20.02	13.65	5.51									
18	175	346	82	63	35	120	210	71	55	41	14.47	10.77	8.21									
19	231	345	93	79	40	198	265	86	76	40	14.90	12.99	7.26									
20	243	395	98	81	30	174	248	92	82	32	18.81	11.76	6.03									
21	206	331	88	75	31	151	229	78	68	34	16.82	12.76	6.59									
22	235	396	91	70	32	177	326	81	66	31	13.81	10.14	6.04									
23	205	381	77	61	34	164	277	73	61	33	19.32	13.05	8.20									
24	230	420	78	60	27	177	300	70	64	41	19.18	13.41	6.08									
25	206	330	85	72	37	155	245	74	65	46	16.19	13.97	5.54									
26	179	371	94	70	30	142	309	82	60	25	14.37	8.75	4.82									
27	206	261	87	80	56	190	220	77	70	51	20.11	12.93	5.92									
28	150	389	75	59	29	138	314	65	45	27.5	15.40	10.17	6.20									
29	185	351	83	68	31	153	363	69	71	36	14.65	12.54	6.49									
30	186	427	54	51	19	127	266	71	59	32	14.03	10.39	5.97									
<b>Total</b>	<b>6145</b>	<b>11545</b>	<b>2582</b>	<b>2052</b>	<b>909</b>	<b>4699</b>	<b>8350</b>	<b>2285</b>	<b>1877</b>	<b>1014</b>	<b>479.1</b>	<b>354.1</b>	<b>199.4</b>	<b>1965</b>	<b>2699</b>	<b>95</b>	<b>0.43</b>	<b>2</b>	<b>95.23</b>	<b>2.03</b>	<b>41.39</b>	<b>146.32</b>

# PERFORMANCE EVALUATION OF ROLLER TYPE OF ALOE VERA GEL EXTRACTION MACHINE

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**2015**

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**ABSTRACT**

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The present work was aimed to study the performance evaluation of roller type Aloe vera gel extraction machine. 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. Sanjivani 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 11.40, 15.10 and 18.80 rpm 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 18.80 rpm of roller speed and 5 mm of roller clearance. 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<sup>-1</sup> were obtained at roller speed of 18.80 rpm with 5 mm of roller clearance. The proximate composition of machine extracted Aloe vera gel *viz.*, moisture, carbohydrates, ash, crude protein, crude fat and TSS (% Brix) were found to be nearly same as compared to manually extracted Aloe vera gel. Quality parameters *viz.*, pH, water activity, colour and viscosity of machine extracted Aloe vera gel was found to be superior compared to manually extracted Aloe vera gel. The extraction cost of Aloe vera gel from manually was estimated as `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 `13.36/- per kg with benefit cost ratio of 3.74:1.