DEVELOPMENT AND PERFORMANCE EVALUATION OF POWER OPERATED JACKFRUIT SEED SEPARATOR

By

ANNZIA M ELIAS

DHANYA SASEENDRAN

KADHEEJA P M

NIKHITHA MOHAN A

PROJECT REPORT

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Faculty of Agricultural Engineering and Technology
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Department of Processing and Food Engineering
Kelappaji College of Agricultural Engineering & Technology
Tavanur P.O.-679573 Kerala, India

DECLARATION

We hereby declare that this project entitled "**DEVELOPMENT AND PERFORMANCE EVALUATION OF POWER OPERATED JACKFRUIT SEED SEPARATOR**" is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Annzia M Elias
2015-06-004

Dhanya Saseendran
2015-06-008

Khadeeja P M
2015-06-010

Nikhitha Mohan A
2015-06-016

Place : Tavanur

Date : 28/01/2019

CERTIFICATE

Certified that this project entitled “**DEVELOPMENT AND PERFORMANCE EVALUATION OF POWER OPERATED JACKFRUIT SEED SEPARATOR**” is a bonafide record of project work jointly done by **Annzia M Elias , Dhanya Saseendran, Khadeeja P M, & Nikhitha Mohan A** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Dr. Rajesh G K
Assistant Professor
Dept. of Processing and Food Engineering
Kelappaji College of Agricultural Engineering And Technology
Tavanur, Malappuram-679573

Place : Tavanur
Date : 28/01/2019

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Annzia M Elias

DhanyaSaseendran

Khadeeja P M

Nikhitha Mohan A

Dedicated to Women Empowerment

&

To Our Profession of

Food Engineering

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Introduction

CHAPTER 1

INTRODUCTION

India is the second largest producer of fruits and vegetables in the world after china. Major horticultural crops grown in our country are mango, banana, jackfruit, papaya, cashew nut, areca nut, potato, okra (lady's finger) etc. India is endowed with a wide spectrum of agro climatic zones making it possible to grow almost all varieties of fruits and vegetables. Fruits and vegetables are considered as an important group of protective and nutritious foods as most of them are rich in carbohydrates, protein, vitamins, minerals and dietary fibers. Due to insufficient handling & processing methods and lack of efficient processing equipments, nearly 25-30% of produce is wasted every year (Rais and Sheoran, 2015). To avoid these problems, we need technological development and diversification of these valuable fruits which is most important in filling the ever increasing demand-supply gap. Among the horticultural crops, jack fruit is one of the most underutilized fruits having more wastage.

Jack fruit (*Artocarpus heterophyllus)* is a tropical fruit species found in tropical, high rainfall, coastal and humid areas of the world. It belongs to family Moraceae. It is the favorite fruit of many, owing to its sweetness. It is a large, evergreen tree, 10-15m in height, indigenous to the evergreen forests at altitude of 450-1,200m MSL an optimum temperature of 22-35^{0}C and cultivated throughout the tropical parts of India. It grows well above sea level upto an elevation of 5000 feet. Stem of this plant is straight rough whereas bark is green or black, 1.25cm thick, exuding milky latex, leaves broad obovate, elliptic, decurrent, glabrous, entire inflorescence solitary axillaries, cauliforous and ramflours on short leafy shoots. Seeds are separated horny endocarpus enclosed by sub-gelatinous exocarpus (1mm thick) oblong ellipsoid in nature. The sweet yellow sheaths around the seeds are about 3–5 mm thick. The jackfruit tree is widely cultivated in tropical regions of India, Bangladesh, Nepal, Sri Lanka, Vietnam, Thailand, Malaysia, Indonesia and Philippines. Jackfruit is also found across Africa, e.g., in Cameroon, Uganda, Tanzania, and Mauritius, as well as throughout Brazil and Caribbean nations such as

Jamaica. However, India is considered to be the native of jack fruit. The area and production of jackfruit in India during the year 2015 – 2016 is 1.51Lakh ha and 1.7 MT, respectively whereas during 2016-2017 it is increased to 1.56 Lakh ha and 1.8 MT, respectively.

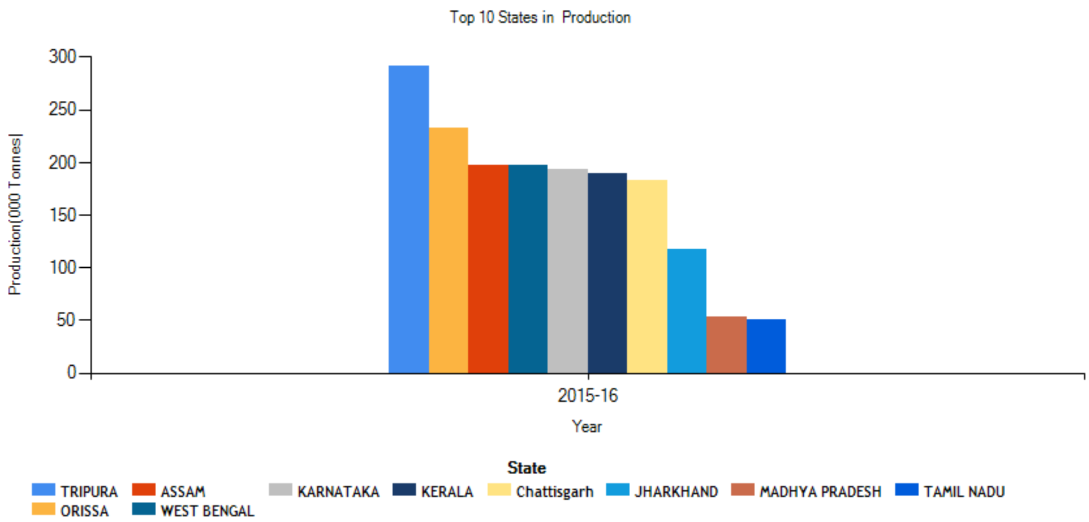

Fig no. 1.1 Top ten states in jackfruit production

Source: National Horticulture Board (NHB), 2015-2016

In our country, the jackfruit is mainly grown in southern states like Kerala, Tamil Nadu, Karnataka, coastal Maharashtra and other states *viz.*, Assam, Orissa, Tripura, West bengal and foothills of Himalayas. Kerala had a production of 1.9 Lakh tonnes in 2015-2016 (National Horticultural Board, 2017).

Jackfruit is called as *Chakka* in Malayalam, *kathhal* (hindi and urdu), *pala* (tamil), *halasina hannu* (kannada) *panasa pandu* (telugu) and *phanos* (marathi and Konkani). The fleshy carpel which is botanically the perianth is the edible portion. The main fruiting season falls between March to August with the minor season from November to January (Medagoda and Tennakoon, 2001). The fruit is composed of carbohydrate content and hence it is also called “Rice tree” or “Poor man’s food”. The jackfruit is grouped into four main categories, *viz.*, Soft fleshed type, Firm Fleshed type, Rudrakshi and Singapore or Ceylon Jack. Wide variations in sweetness

(TSS), acidity, aroma/flavor and taste are also reported. There are two main varieties- *Koozhachakka* and *Varikkachakka*. In *Koozhachakka,* the fruits are small, fibrous, soft and mushy, but very sweet carpals. *Varikkachakka* is crisp and almost crunchy though not quite as sweet. This form is more important commercially and is more palatable to western taste.

Apart from its use as a table fruit, jack is a popular fruit for preparation of pickles, chips, jack leather and *papad*. The fruit has good potential for value addition into several products like squash, jam, candy, halwa etc. The ripe bulbs can be preserved for one year in sugar syrup or in the form of sweetened pulp. The unripe mature bulbs can be blanched and dehydrated for further use throughout the year. Jackfruit seed is a rich source of starch and a delicacy during season. The timber of jackfruit tree is highly valued for its strength and sought for construction and furniture. The dried leaves are stitched to make disposable plates.

The traditional method of peeling and coring of jackfruit is done by cutting the fruit into two halves lengthwise using a knife. After the core removal, the individual jackfruits bulbs are separated manually which is a time consuming process and causes drudgery. Moreover, the latex of this fruit causes hindrance during the separation of the jack fruit bulb. To overcome latex problem, hands, knives and work area are smeared with a vegetable oil to enable easy separation of bulbs and clean up at the end. The tedium in manual processing of jackfruit is a major reason for the underutilization of the fruit. Thus, effective mechanization in processing is a need of the hour.

There is no mechanized protocol for converting a whole jackfruit into a finished form used as raw material in processing industries. A tool for peeling and core separation from jackfruit had already been developed in this college. Hence, there is an urgent demand for a jackfruit seed separator to separate seed from jackfruit bulb which helps in the smooth and fast working of jackfruit processing industries. With this point of view, a project was undertaken at Kelappaji College of Agricultural

Engineering &Technology, Tavanur to develop a power operated jackfruit seed separator with the following objectives,

a) Study of existing methods used to separate seeds from jackfruit bulb
b) To develop a power operated jackfruit seed separator
c) To conduct the performance evaluation of the developed machine in terms of capacity, efficiency and damage percentage

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

This chapter sets out to identify and critically analyze all the previously published literature with regard to the general information of jackfruit, engineering properties of fruits, development and evaluation of power operated jackfruit seed separator and the material selection for equipment fabrication.

2.1 Agronomy

Jackfruit is a tropical plant that grows in countries of Southeast Asia, but is particularly abundant in India and Bangladesh. Jackfruit is recognized as the national fruit of Bangladesh. The total production and cultivation area of jackfruit in India during 2017-18 were approximately 1.7 MT and 1.53 Lakh ha respectively (NHB.gov.in statistics 2017-18). This fruit crop is adapted to warm and humid climates, but it can thrive up to 1500 meters. It favors an annual rainfall of 1500 mm or more without pronounced dry season. It grows on various types of soil but prefers deep, well-drained, alluvial, sandy or clay loam soils with pH range of 6.0 to 7.5. The main fruiting season falls between March to June with the minor season from November to January. Jackfruit can be described as a medium-sized, evergreen, monoecious tree up to 20 meters tall and 80 cm in diameter. It produces fruits which are very green or greenish yellow when ripe, hanging on short stalks from the main stem or large older branches. The fruits are botanically a syncarp, up to 90 cm x 50 cm in size. There are numerous seeds in a single fruit. A well developed fruit may contain up to 500 seeds, each weighing 3-6 grams. Jackfruit is ready for harvesting after 7 years of planting. Jackfruit plants through grafting method start bearing fruits from 4th year itself. Tender jackfruits are harvested for use as vegetable during early spring and summer until the seeds harden. The optimum stage of harvest maturity of jackfruit has been reported to be 90-110 days after the appearance of the spike. At full maturity or ripening, the spines on the surface of the fruit become flatten. Harvesting is done by cutting off the footstalks carrying the fruits.

2.1.1 Botanical aspects and distribution

Jackfruit tree is an evergreen tree, around 10-15 m tall with oval shaped dark green leaves. It is a long lived tree having a life span of 60-70 years and contains sticky white latex in all parts of fruit. The flowering twigs are borne primarily on the trunk and main branches. Jackfruit tree is monoecious, male and female flowers are born separately on the same tree. The composite fruit may be large as 20 kg or more. Fruit is the primary economic product of tree and used in both stages when mature and immature (Nachegowda *et al*., 2014).

Jackfruit is made up of three parts *viz*., the lower fleshy edible region, commonly as the bulb; the middle fused region, that forms the rind of the syncarp and the upper free and horny non-edible region commonly known as the spikes. Except for the thorny outer bark, all parts of the fruit are edible (Prakash *et al*., 2009).

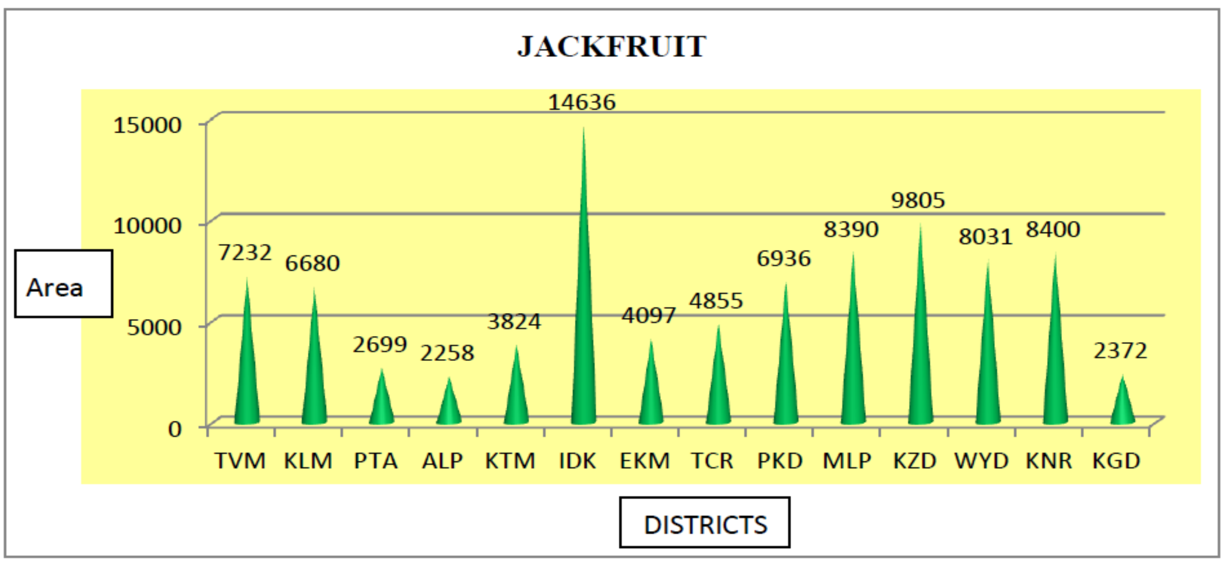

Figure 2.1 District - wise cultivated area of jackfruit in Kerala

Source: Agricultural Statistics (2013-2014) - Department of Economics and Statistics, Govt. of Kerala (2015)

The cultivated area of jackfruit in Kerala during (2013-14) was 90,225 ha. It was widely cultivated in Idukki (14636 ha), Kozhikode (9805 ha) and Kannur (8400 ha) districts and stand 1st, 2nd and 3rd positions with 16%, 11% and 9% of area, respectively. Gross production of jackfruit in Kerala is 294 million fruits with Idukki district holding the top most position (60 million) followed by Kannur district (27 million) (Table 2.1)

Table 2.1 District-wise area and production of jackfruit in Kerala

SL.NO.	Name of districts	Area of cultivation (ha)	Production(Million Number)
1.	Thiruvananthapuram	7232.43	25.84
2.	Kollam	6680.00	23.136
3.	Pathanamthitta	2699.54	8.968
4.	Alappuzha	2258.3	5.627
5.	Kottayam	3824.06	14.728
6.	Idukki	14635.02	60.307
7.	Ernakulam	4097.46	14.35
8.	Thrissur	4864.5	15.636
9.	Palakkad	6936.21	22.697
10.	Malappuram	8390.12	22.278
11.	Kozhikode	9805.43	23.121
12.	Wayanad	8030.6	21.275
13.	Kannur	8399.59	27.081
14.	Kasargod	2371.79	9.209
	Total	**90224.95**	**294.234**

Source: Agricultural Statistics (2013-2014) - Department of Economics and Statistics,Govt. of Kerala (2015)

2.1.2 Post harvest utility

Jackfruit is generally consumed as raw/ processed form. Due to time consuming and hardship during manual processing, less than 40% of total production of jack fruits only utilized as food material and remaining goes as waste. Moreover, the latex of this fruit also causes hindrance during the separation of fruit bulbs for use.

2.1.3 Physical properties of jackfruit

The physical properties of agricultural produce are very important in the design of particular equipment and analysis of the behavior of the product during post-harvest operations (Sahay and Singh, 1994). It can increase the efficiency of newly developed processing machine. The determination of physical properties of different fruits under taken by various research workers are reviewed for the study.

Size, generally refers to characteristics of an object which determines the space requirement within the limit and necessary for satisfactory description of the any solid object. The size of fruits is important in determining their suitability and understands the properties that may affect the design of machines. Researchers have used various techniques to investigate the dimensions of different produce.

Singh and Shukla (1995) conducted an experiment on physical properties of potato *viz.*, length, breadth and thickness. Vernier calipers were used for measuring these properties, and the length, breadth and thickness of potato were 44mm, 55mm and 32mm, respectively

Owolarafe and Shotonde (2004) reported the physical properties required for the design of an okra slicer, chopper and separator. The average length, width and thickness of okra were 54.60, 28.60 and 26.70, mm respectively.

Jha *et al*. (2006) studied the physical and mechanical properties of mango fruit to determine the maturity. The fruit length, width and thickness of mango were measured using digital vernier calipers of least count 2 mm. The average length ,width, and thickness of mango were 130mm,55mm and 40mm respectively.

Jagadeesh *et al*. (2007) studied the important physico-chemical characteristics of jackfruits to study the degree of divergence present among the selections. The dimensions of the jackfruits among the clusters varied from 32.33-45.50 cm in length, 19.50-24.02 cm in diameter and 1.03-1.44 cm in rind thickness.

Haq (2011) investigated the variation in jackfruit physical properties. Wide variations were observed in fruits characteristics like fruit length values from 20.50 to 60.60 cm and diameter 16.40 to 29.5 cm among the selections.

Shyamalamma *et al*. (2014) investigated the physical properties of elite jackfruit genotypes collected from the Bangalore rural and Tumkur district. Study revealed that wide variation was observed in fruits characteristics like fruit length of 20.50-43.00 cm, fruit diameter of 14.50-22.00 cm and rind thickness of 0.60-2.00 cm among the jackfruit genotypes.

2.2 Food Values

Jackfruit is a highly nutritious fruit which contains an ample proportion of nutritive constituents which are easily digested and absorbed, while available at reasonable cost. It is one of the most easily assimilated fruits. It has a rare combination of energy value, tissue building elements, proteins, vitamins and minerals. It is a good source of calorie. The energy value of 100g jackfruit is about 95 kilo calories. It contains a large amount of easily assailable sugar, making it a good source of quick energy. The food value of jackfruit per 100 g edible portion is represented in Table 2.2

Table 2.2 Food value of jackfruits (United state department of agriculture 2014-15)

Food value (per 100 g edible portion)	
Moisture	73g
Protein	1.72g
Fat	0.64g
Minerals	0.524g
Fiber	1.5g
Carbohydrate	19.8g
Potassium	448mg
Calcium	24 mg
Phosphorus	21mg
Iron	0.23mg
Vitamin C	13.8 mg
Energy	95 kcal

2.3 Varieties

Different varieties of jackfruits and its properties, origin and available seasons are described below.

Table 2.3 Jackfruit varieties

Cultivar and origin	Growth habit and rate	Fruit size and weight (pds)	Fruit shape	Yield per tree (pds)	Season and months
Black Gold, Australia	Open, spreading, fast	Medium, 22	Long, tapered	Heavy, 120-200	Late, Sept.-Oct.
Cheena, Australia	Open, low spreading, moderate	Small, 5-10	Long, narrow, uniform	Moderately heavy, 110-154	Mid, July-Aug.
Chompa Gob	Open, spreading, fast	Medium, 12-20	Blocky, uniform	Moderately heavy, 90-120	Mid, July-Aug.
Cochin, Australia	Sparse, upright, slow	Small, 2-5	Round, irregular	Moderately heavy, 80-130	Early, June-July
Dang Rasimi, Thailand	Open, spreading, fast	Medium-large, 18-20	Uniform oblong	Very heavy, 165-275	Mid, July-Aug.
Gold Nugget, Australia	Dense, spreading, fast	Small, 7-12	Round	Heavy, 132-176	Early, May-June
Honey Gold, Australia	Sparse, spreading, slow-moderate	Small to medium-small, 10-12	Blocky	Moderate, 77-110	Mid, July-Aug.
J-30, Malaysia	Vigorous, open, conical, fast	Medium, 17-25	Uniform, oblong	Moderately heavy, 110-132	Mid, July-Aug.
J-31, Malaysia	Open, spreading, fast	Large, 26	Irregular	Moderately heavy, 92-132	Early, May-June
Kun Wi Chan, Thailand	Vigorous, dense, fast	Large, 33-40	Uniform, round	Very heavy, 242	Mid, July-Aug.
Lemon Gold, Australia	Moderately dense, spreading, moderate	Medium-small, 13	Blocky	Moderate, 66-100	Mid, July-Aug.
NS1, Malaysia	Dense, upright, moderate	Small to medium-small, 9-12	Blocky	Heavy, 200	Early, May-June

(National Horticultural Board ,statistics 2015-16)

2.4 Value Addition in Jackfruit

2.4.1 Jack fruit bulb jelly and jam

Well-matured jackfruits were collected and it was washed and bulbs were separated carefully. Then it was cut into small pieces and blended it in the blender and filtrated through the filter cloth. The filtrate containing juice was taken for preparing jelly. Pectin was mixed well with sugar. The saucepan was placed on a burner for cooking. Then pectin and sugar mixture added into it and stirred. When TSS reached 66 to 67 % the mixture was removed from the burner which indicates the end point of jelly preparation. KMS was dissolved in 10 ml warm water and it was added to the mixture. Jackfruit juice and agar was used in case of jam preparation. Sodium benzoate was dissolved in 10 ml warm water and it was added to the mixture. Lemon juice/citric acid were also mixed during its preparation.

2.4.2 Jack fruit chips

Jack fruit chips are delicious product which has international acceptance. This is made by peeling and cutting the unripe fruit into thin wafers and frying in oil. They keep well in closed containers for 2-3 months without deterioration in quality.

2.4.3 Jack fruit seed flour

Remove the jackfruit rind portion and carefully select the jackfruit seeds. It is peeled, cut into thin slices and rinse with water. Get hold of a cheesecloth or similar and lay it on a tray. Put the jackfruit seed slices evenly distributed and put it in a cabinet dryer, food dehydrator or solar dryer. Keep the temperature of dryer 60 to 65 degrees Celsius for around 8 to 10 hours. It is then pulverized using a hammer mill and packed properly either active or passive MAP and store at room temperature for further processing.

2.5 Seed Extraction Methods of Agricultural Produce

2.5.1 Fermentation method:

This method is employed for tomato fruits. The selected ripe fruits are harvested from the plants and allowed to ripe further for a day or two in a heap or in an earthen pot. They are then crushed well in an earthen pot by hand or by any mechanical method to make a paste. No fruit juice should be allowed to drain out. Now the entire mass is kept in the vat for a day or two to ferment. It may be

completed in one or two or more days according to high or low temperature. Profuse foam formation on the top and no adhering of seed to the tomato flesh on stirring the mass vigorously with a wooden stick or hand, indicates that the fermentation is complete. Now the flesh will float on the top, while the seeds will settle down at the bottom of the vat. Remove all the fermented mass on the top and then decant off gently all the liquid. The seeds resting on the bottom of the vat are collected and washed 8-10 times with clear water and then they are spread in the sun to become dry. When they are perfectly dry in the sun fill it in an airtight container and keep it cool dry place.
It is the simplest method and can be adopted by any layman.

2.5.2 Alkali treatment method:

When fruits are big enough but the number of seeds are small, this method is adopted. Cut the selected ripe fruits into halves and then scoop out the slimy mass containing the seeds into an earthen or porcelain vessel with the help of the handle of a stainless steel, tea spoon or wooden stick. The flesh thus separated can be used for eating raw or for any other purpose. Treat the slimy mass with an alkali mixture (150 grams of washing soda is added to 5 liters of boiling water) in equal volumes. When the alkali mixture is cooled, allow it to stand overnight in an earthen or porcelain vessel. By next day, all the seeds will settle down at the bottom of the container. Decant off the clear liquid at the top. Seeds thus obtained are washed thoroughly with clear water and allowed to dry in the sun and are preserved.

2.5.3 Acid treatment method

This method is followed where seed production is done on large scale. It can also be adopted on the home scale. In this method, the fleshes of the fruit can be saved. Slimy seed mass is separated as mentioned above and kept in an earthen or a porcelain or glass vessel. This is done by treating with commercial hydrochloric acid in the proportion of 30 ml of fluid per 12kg of the material. The seeds are separated from the slimy mass within 15 – 30 min., if acid is thoroughly mixed. The acidified liquid at the bottom are immediately washed with water and allowed to dry in sun. They are then preserved. In this method the seeds can be extracted and dried on same day.

2.5.4 Mechanical methods

Todd *et al.* (1983) developed a pilot scale extractor for separating seeds from cucumber fruit (Cucunis sativus L.). The essential elements of the seed extractor were two counter rotating crushing rollers, a rotating drum to separate the seeds from the pulp, an interconnecting gravity transfer chute, a collecting pan and power transmission system. The method of seed extraction includes the crushing of fruit followed by sieving action with the help of rotating drum. The capacity of the developed machine was 100 fruit per minute and recovers 98 % of the seed.

Anagha Balan *et al.*2015 developed a tamarind deseeder. The principle of operation is the combined effect of rubbing and shearing action on tamarind fruit. Model consists of a handle, oscillating sector with pegs, concave sieve, frame and stand. Deshelled tamarind fruits were used for the experiment. The oscillating sector move over the tamarind and due to the rubbing action between tamarind and pegs the seeds get removed. The number of seeds removed will depend on moisture content of fruit, number of oscillations given and feed rate. A comparison test was done by tamarind with fiber and without fiber. From the comparison it is clear that tamarind without fiber is more suitable. Maximum amount of seeds got separated when the feed rate was 6kg and moisture content in the range of 6 to 8% (wet basis). The capacity of the machine was 100g/minute. The efficiency of machine was estimated as 87.17% for tamarind without fiber and 73.79% for tamarind with fiber.

Shayfull *et al.*(2007) developed chilly seed extration machine. It has 2 pairs of rotating cutter and teeth per row. The dried chilies were inserted through hopper and shredded into small pieces. It was then dropped on a vibrating sieve. Unseeded chilly seeds drop through the sieve and accumulated into a bin, where the rest remain on the vibrating sieve to be directed to a specific outlet and collected.

Kalre *et al.*(1983) developed a tomato seed extractor. It consists of a rotatory cylinder with corrugations and a helix fixed on its surface, stationary expanded metal concave, holding frame and the feeding hopper. The cylinder was rotated manually with the help of a handle mounted directly on the shaft of the drum. The tomatoes were fed to the rotating drum through a hopper. The tomatoes were crushed and the screw conveyor mounted on the rotary cylinder passed the pulp and skin forward which was collected in the first tray while the juice and the seeds were collected in the second tray. The seed were then kept for fermentation to remove the gelatinous coat. The capacity of the machine was 60kg/h.

Wehner *et al.*(1983) fabricated a pilot scale extractor for cucumber seeds. The machine was able to extract seeds from matured cucumber fruit at the rate of about 100 fruits per minute. It recovered 98% of the seed that could be extracted by hand. The machine consist of two counter revolving fruit crushing rollers, a rotating drum for separating the seeds from the pulp and flesh, an inter connectivity gravity transfer chute and a seed collecting pan.

Brar and Harisingh (1984) designed the channel method to shorten the time consumed for tomato seed fermentation. The device consists of a thin metal channel 215 cm long, 30cm wide and 15cm deep separated into 8 sections by removable cross plates. 5 kg of fermented pulp poured into the first section and water was supplied at 10 to 12 l/min. The device was inclined and during rinsing the seeds are trapped on the different cross plates. A 5 kg seed sample processed by this method took 8 to 10 min compared with 15 to 18 by the conventional fermentation method.

Nicholas(1971) developed a mechanical vegetable seed extraction machine. It consists of horizontal drum and rotary shaft with beaters. The drum was made of GI sheets. The rotary shaft with beater rotates inside the drum. The beater had a bend MS flat holder welded to the shaft and was arranged spirally on the shaft. To this a replaceable blunt tine was bolted. A screen holding frame was fitted at the bottom section of the frame to allow the fitting of different screens. Two outlets were provided, one at the bottom of the drum, to collect the extracted seeds and juice, coming out of the screen. The second outlet was provided at the rear end to remove the pulp. A pipe for feeding water was also attached at the top of the drum. Dry feeding of brinjal resulted in 75% seed extraction efficiency. The capacity was 10kg of seed per hour and 93% germination was obtained.

Reed (1981) developed a pressure spray system in which the fermentation process was eliminated for cleaning the muskmelon seeds. The holes of 3mm diameter were cut in the edge of fruit. Seeds were flushed out with a stream of water from tap. The fruit was held over a kitchen strainer with bottom end of the fruit suspended inside the strainer. The water filled into the seed cavity. The seeds flushed out of the fruit were collected in the strainer. The fruit was then inverted and the process repeated until all seeds were removed.

More and Kanawade (1994) fabricated a power operated pomegranate seed extractor. The machine consisted of a hopper, shaft with knife, concave outlet chutes for seed and rind and a power transmission system. The machine was tested for its efficiency in separating the seed from a whole pomegranate seed and rind come out from separated outlets. The performance was compared with hand separation of seeds. The seed separation efficiency of the machine was 86% and average purity of the seed was 96%. Rind separation from the seed was very efficient. The capacity of the machine was estimated as 150kg/h.

Rani *et al.* (2000) developed a vegetable seed extractor for brinjal. Three important factors affecting the performance of the machine were concave clearance, cylinder peripheral speed and feed rate. Performance evaluation was conducted at 2, 4 and 6 mm concave clearance 8.5, 6.8 and 5.7 m/s cylinder peripheral speed and 1.76, 1.90 and 2.00 q/h feed rate. The 8.5 m/s speed provided the fastest seed extraction rate of 2.52 kg/h and the highest seed recovery (91.6%). The 2mm clearance provided a 2.98kg/h extraction rate and 97.4% recovery. The treatment combination 2mm clearance with 8.5m\s cylinder speed and 1.76q/h feed rate produced the highest seed extraction(3.327 kg/h) among treatments.

Deepak *et al.* (2004) fabricated an ash gourd seed extractor. The cut fruit is fixed in the frame of the machine and the seed along with pulp is removed using a rotating blade. The blade is connected to the motor with a flexible rotor shaft. The seed extraction of ash gourd was carried out by piercing the blade into the cut section. The capacity of the machine was 81.39Kg/h and seed extraction efficiency was 97.5%.

Kushwaha *et al.*(2005) fabricate an okra seed extractor. Studies were conducted on the effect of different cylinder speeds (5,6 and 7m/s), concave clearance (7, 10 and 3mm), moisture contents (12.3,15.8 and 18.8%d.b) and type of extraction drum at a feed rate of 70kg/h on machine performance and seed quality. Three types of extractor drums namely; square head bolted, rubberised and rasp bar was used. Seed quality was evaluated for vigour index, dead seed, normal and abnormal germination. The performance of seed extractor was evaluated for its extraction effficiency, cleaning efficiency, seed loss and energy consumption at different crop and machine variables. The average energy consumption per quintal (100kg) seed was found as 1.9kWh. The best seed quality machine perfomance was found at 12.3% moisture content (d.b), 7 mm concave clearance and 5 m/s cylinder speed with the square head bolted drum extraction mechanism.

Materials And Methods

Chapter III

MATERIALS AND METHODS

The various engineering properties required to develop a jackfruit seed separator are discussed in this chapter. The fabrication procedure of the jackfruit seed seperator, the details of the components and the procedures adopted for evaluation are also described.

3.1 Study of existing methods used for jackfruit seed separation

Prior to the development of jackfruit seed separator, a survey was conducted in Malappuram and adjacent districts *viz.*, Kozhikode, Thrissur and Palakkad to study the existing methods of jackfruit seed separation.

3.2 Procurement of raw materials

Mature jackfruits procured from the Instructional Farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur were used to conduct the performance evaluation of the developed jackfruit bulb seperator. Koozha and varikka varieties having maturity index 6 to 8 months were selected. Main harvest indicators were change of fruit colour from light green to yellow-brown and produce dull hollow sound when fruit is tapped. The fruits were harvested using a sickle and a sack is placed on the fruit with a rope tied on the peduncle and it is then lowered down to the ground. The jackfruit was then peeled and cored using jackfruit peeler cum corer. The fabrication items for the construction of machine were purchased from coimbatore.

3.3 Engineering properties of procured jackfruit bulb

Prior to the development of jackfruit seed separator, engineering properties of the procured jackfruit bulb were studied. Engineering properties like size, mass, shape, density were determined by standard methods as explained in the following section. Frictional properties, such as coefficient of friction and angle of repose were also determined

3.3.1 Dimensions of jackfruit bulb

The dimensions of bulb such as length(L), width(W) and thickness(T) were measured in mm with the help of a vernier caliper having a least count of 0.01mm. A sample of 5 bulbs were taken and the averge value was calculated.

Plate 3.1 verneir caliper

3.3.2 Determination of mass

The mass of individual bulb was determined by selecting 5 number sample in random using an electronic balance to an accuracy of 0.01g and the mean value was reported.

3.3.3 Determination of shape

Shape is an important property in grading fruits and vegetables and its quality evaluation. The shape of food material is usually expressed in terms of sphericity (Ø). Sphericity is defined as the ratio of the diameter of a sphere having the same volume as that of the particle to the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle (Sahay and Singh, 2010). The sphericity of the jackfruit bulb was determined by the formula given below.

$$\emptyset = \frac{\sqrt[3]{LBT}}{L} \qquad \ldots (1)$$

where,

L – Length of bulb, mm

B – width of bulb, mm

T – thickness of bulb, mm

3.3.4 Bulk density

The bulk density is the ratio of mass of jackfruit bulb to its total (bulk) volume. It was determined by filling the jackfruit bulb in a cylindrical container of known volume. The weight and volume of jackfruit bulb were calculated.The bulk density was calculated by using the expression given below.

$$\rho_b = \frac{M}{V} \qquad \ldots (2)$$

Where,

ρ_b - bulk density,kgm^{-3}

M - mass of the sample, kg

V- volume of the container,m^3

3.3.5 Determination of volume of bulb

Volume of jackfruit bulb was determined by platform scale method (Mohsenin, 1986). The jackfruit bulb was completely submerged in water using the sinker rod without touching the sides or bottom of the beaker by the bulbs. Volume was calculated as the ratio of the weight of water displaced by the solid sample to weight density of water.

$$\text{Volume of bulb}, (m^3) = \frac{\text{Weight of displaced water (kg)}}{\text{Density of water, } (kg\ m^{-3})} \ldots \ldots (3)$$

3.3.6 Coefficient of friction

The coefficient of friction is the tangent of the angle of the inclined surface upon which the friction force tangential to the surface and the component of the weight normal to the surfaces are acting (Sahay and Singh, 2010). It is the ratio of frictional force and normal reaction.

Coefficient of friction can also be defined as the frictional force acting between the surface of contact and sample at rest. It is the ratio of the force required to slide the agricultural produce over a surface to the normal force applied by it against the surface. Coefficients of friction experiments were done for jackfruit bulbs using four surfaces viz., stainless steel and aluminum. The apparatus used for the determination of coefficient of friction of jackfruit bulb consists of a frictionless pulley fitted on a frame or bottomless hollow cylinder, a loading pan and test surface. The jackfruit bulb was tied at one end using a thread and placed on the test surface and weight was added on loading pan until the jackfruit bulb began to slide. The weight of the jackfruit bulb and the weight added on loading pan represents the normal reaction (N) and frictional force (F), respectively (Sahay and Singh, 2010). The coefficient of static friction was calculated as given below

$$\text{Coefficient of Friction} = \frac{\text{Frictional force, (Kg)}}{\text{Normal reaction (Kg)}} \qquad \ldots (4)$$

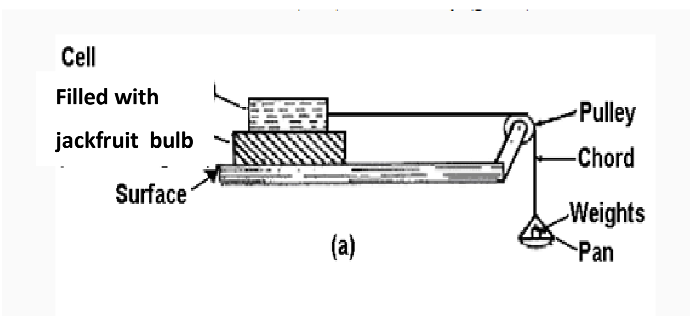

Figure 3.1 Coefficient of friction apparatus

3.3.7 Angle of repose

The angle made by a biological material with horizontal surface when piled from a known height is known as angle of repose. It was measured by using bottomless cylinder placed on a flat surface and filled it with jackfruit bulbs. The cylinder was raised slowly allowing the bulbs to flow and to form a heap on the surface (Mishra and Kulkarni 2009). The angle of repose was calculated using the measured value of diameter and height of cone.

$$\theta = \tan^{-1}\frac{H}{R} \quad \ldots (5)$$

where,

H- Height of cone (cm)

R- Radius of cone (cm)

3.4 Development of power operated jackfruit seed separator

Based on the engineering properties of jackfruit bulbs, a jackfruit seed separation equipment was designed and fabricated in the workshop of KCAET, Tavanur. The developed machine consists of the following parts.

a. Rubber belts
b. Driven rollers
c. Idler rollers
d. Power transmission unit
e. Motor
f. Frame assembly
g. Outlet chute

Rubber belt

It consists of two endless vertical rubber belt rotating laterally with the help of two driven pulleys. One belt is rotating while the other is kept stationary. These belt are tapered towards the outlet. The clearance between the rubber belts is kept smaller than the average thickness of the jackfruit bulb. For effective seed separation , two rubber strips of thickness 20mm are fixed at 150mm distance apart along the width of the movable belt. The width of the belt is kept as 280mm.

Driven roller

The movement of the belt was done by a driven roller. The roller shaft is 280mm cylindrical in shape and placed at the bottom end of the rubber belt. The shaft is connected to the motor through gear box inorder to adjust the speed. The speed of the shaft is fixed at 83rpm.

Idler rollers

Idler rollers maintain or adjust tension in the rubber belt. It also provide correct shaping , support and protection of belt and also enable the movement of jackfruit bulbs. It supports the belt and control the flow of materials. Two idler rollers having diameter 50mm were mounted between the drive and driven roller shafts.

Power transmission unit

An electric motor of 0.5 hp having a speed of 1440 rpm was used as a prime mover for the operation of the machine. A tachometer (Model-DT-2235) was used to measure the rotational speed of the roller shaft. The speed of the roller shaft was reduced with the help of gear box assembly.

Plate 3.2 Tacheometer

Frame assembly

The frame supports the entire machine component to perform its operation satisfactorily. It was fabricated using mild steel. The components *viz.,* rubber belts, roller shafts, idler rollers, motor were mounted on the frame. The overall dimension of the frame assembly *viz.,* length (mm), overall width (mm) and overall height (mm) of the machine was 55mm x 43mm x 35mm, respectively.

Outlet chute

The deseeded jackfruit bulb and jack fruit seed are collected at the collecting tray *via* a stainless steel outlet chute placed at the bottom of the machine.

3.4.1 Line diagram and 3D view of the developed machine

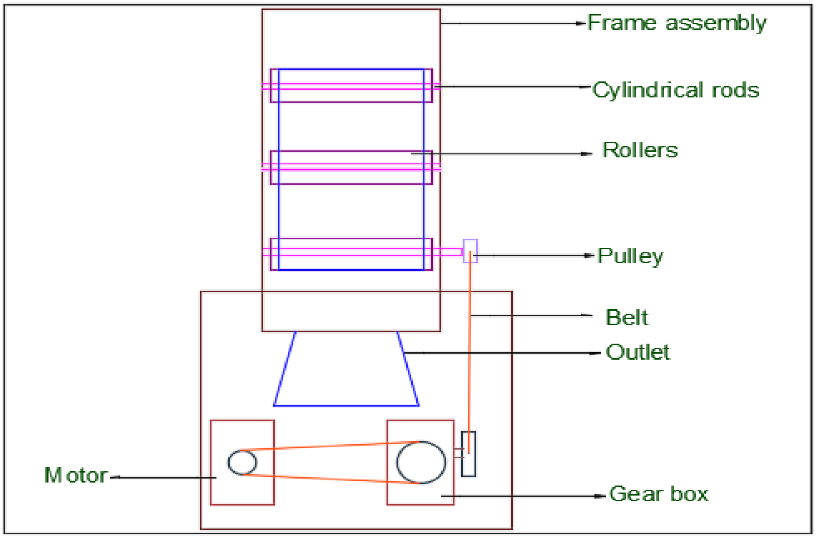

Fig 3.2 Line diagram of jackfruit seed separator

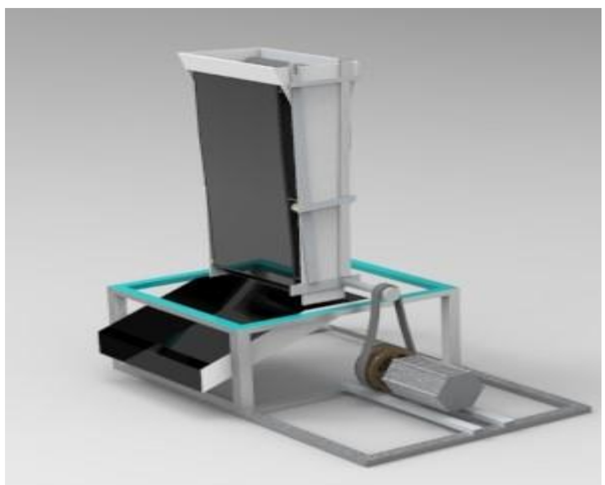

Fig 3.3 Side view of jackfruit seed separator

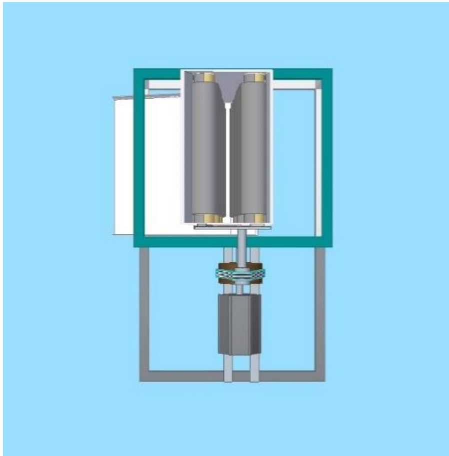

Fig 3.4 Top view of jackfruit seed separator

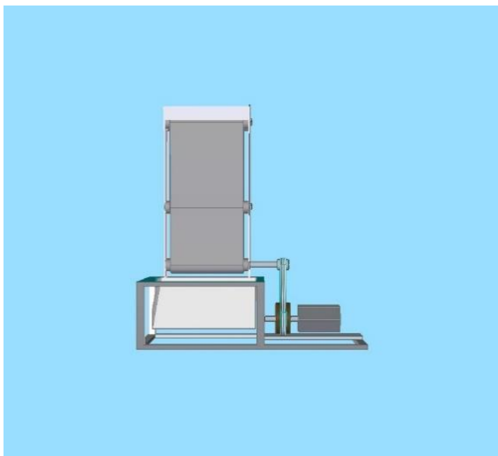

Fig 3.5 front view of jackfruit seed separator

3.4.2 Working of the developed jackfruit seed separator

The different parts of the developed machine as shown in Fig. (3.1and 3.2) are rubber belts, driven rollers, idler rollers, power transmission unit, motor, frame assembly and outlet chute. It consists of two endless vertical rubber belts rotating laterally with the help of two driven pulleys. One belt is rotating and the other is kept stationary. The belts are tapered towards the outlet. The difference in surface speeds of the belts develops a shearing force on the surface of jackfruit resulting in seed separation and breaking of jackfruit bulb. The clearance between the rubber belts is kept smaller than the thickness of the bulb. For effective seed separation, two rubber strips are fixed at certain distance along the width of the movable belt. Jackfruit bulbs were manually fed into the hopper. Bulbs were then passed in between the rubber belts. As it proceeds downwards, shear force is developed due to the difference in surface speeds of the belts result in seed separation and breaking of jackfruit bulb. The seed and the broken bulb are then collected at the outlet chute.

Plate 3.3 Power operated jackfruit seed separator

3.5 Performance evaluation

Matured jackfruit procured from the Instructional Farm, KCAET, Tavanur were used for conducting the experiment. The gap between the belts was adjusted based on the variety of jackfruit. Performance of the machine was evaluated based on overall capacity, separation efficiency and percentage damage.

3.5.1 Overall capacity of the machine

Capacity of the machine is defined as the ratio of total weight of jackfruit fed to the total time required for breaking. It is expressed in kilograms per hour.

$$\text{Capacity, (kg /hr)} = \frac{\text{Total weight of jackfruit bulbs fed to the machine, (kg)}}{\text{Time taken for breaking, (hr)}} \quad ...(7)$$

3.5.2 Separation efficiency (η)

Separation efficiency of the machine is the ratio of total quantity of sample separated to the number of samples fed to the machine which is expressed as percentage.

Separating efficiency,

$$ή = \frac{\text{number of jackfruit bulbs fed} - \text{number of unbroken jackfruit bulbs left}}{\text{number of jackfruit bulbs fed}} \times 100 \quad .(8)$$

3.5.3 Percent damage

The percentage damage of the separator is the ratio of number of damaged jackfruit bulbs to the total jackfruit bulbs fed which is expressed as percentage.

$$\text{Percent damage (\%)} = \frac{\text{Number of damaged jackfruit bulbs}}{\text{Number of total jackfruit bulbs}} \times 100 \quad ...(9)$$

3.5.4 Effective capacity (EC)

Effective capacity was measured as the product of overall capacity and efficiency.

$$EC = \frac{OC \times ή}{100} \quad \ldots (10)$$

3.6 Comparison between traditional and mechanical method

Manual separation of jackfruit bulb is a time consuming process and causes drudgery. Moreover, the latex of this fruit causes hindrance during the separation of the jackfruit bulb. The performance of the developed machine was compared with that of manual operation for which the jackfruit bulbs were broken and deseeded using conventional stainless steel knives.

Results And Discussions

Chapter IV

RESULTS AND DISCUSSIONS

This chapter deals with the result of the experiments conducted to determine the engineering properties of bulbs and performance evaluation of the developed jackfruit seed separator.

4.1 Study of existing methods used for jackfruit seed separation

Survey revealed that no mechanical jackfruit seed separator has been developed so far and the seed extraction from jackfruit bulb is still done traditionally using stainless steel knives.

4.2 Determination of engineering properties

The result of physical properties such as size, shape, mass, density and frictional properties like angle of repose, coefficient of friction etc., are presented and discussed in this section.

4.2.1 Engineering properties of raw jackfruit bulb

The engineering properties of the raw jackfruit bulb are presented in Table 4.1. Jackfruit bulb is yellow in colour. It had an initial moisture content of 73% (wb). The L*, a* and b* values of jackfruit bulb were 63.66±2.01,5.04±2.02and 18.85±0.25 respectively. The average mass of the bulb was 35.8g. The average length, width and thickness of bulb were measured as 55mm, 44mm and 32mm, respectively. The sphericity of the jackfruit bulb was found to be 0.023. The volume of the bulb varied between 0.73 to 0.77m^3 with an average value of 0.75m^3. The coefficient of static friction was calculated using standard equation and was found to be 5 & 3.75 for stainless steel sheet and aluminum sheet, respectively. The average angle of repose of the jackfruit bulb was estimated as 47.2^0.

Table 4.1 Engineering properties of raw jackfruit bulb

SL No.	Properties of jackfruit bulb		Average value
1	Moisture content(%)		73
2	Dimensions	Length(mm)	55
3		Width(mm)	44
4		Thickness(mm)	32
5	Mass(g)		35.8
6	Sphericity		0.023
7	Bulk density(kg/m^3)		120.57
8	Volume(m^3)		0.75
9	Colour values	L*	63.66±2.01
		a*	5.04±2.02
		b*	18.85±0.25
10	Coefficient of friction(stainless steel)		5
11	Coefficient of friction(aluminium)		3.75
12	Angle of repose (^{0})		47.2

4.3 Performance Evaluation of the Developed Jackfruit Seed Separator

Performance evaluation is the basic criteria to evaluate the ability of the developed machine. The fabricated machine was evaluated in terms of overall capacity, separation efficiency, percentage damage and effective capacity.

4.3.1 Overall capacity

The overall capacity of the developed jackfruit seed separator was measured using the formula given in section 3.5.1. The results of the experiments done are presented in Table 4.2. The overall capacity of the machine was found to be 94.1kg/h.

Table 4.2 Overall capacity of jackfruit seed separator

Sl No	Weight of jackfruit bulbs (kg)	Time taken for separation (sec)	Overall capacity (kg\hr)
1.	0.5	18	100
2.	0.5	20	90.9
3.	0.5	20	90.9
4.	0.5	19	94.34
5.	0.5	19	94.34
Average			**94.1**

4.3.2 Separation Efficiency

Separation efficiency of the machine was calculated using the formula given in section 3.5.2 and the results are tabulated in Table 4.3. For the determination of separation efficiency, 5 samples were tested and the average value was noted. The separation efficiency of the machine varied from 86.6% to 93.3% with an average value of 89.3%.

Table 4.3 Separation efficiency of jackfruit seed separator

Sl.No.	Number of bulbs	Number of unseparated bulbs	Separation efficiency (%)
1.	15	2	86.6
2.	15	1	93.3
3.	15	2	86.6
4.	15	2	86.6
5.	15	1	93.3
	Average		89.3

Table 4.4. Characteristics of separated bulbs

Sample	Number	
	Good	Damaged
1	12	1
2	13	1
3	13	0
4	13	0
5	12	1

4.3.3 Percentage damage of jackfruit

The percentage damage was measured as using the formula presented in the section 3.5.3 and is shown in Table 4.5. The percentage damage varied from 0 to 6.66% with an average value of 2.66 %.

Table 4.5 Percentage damage of jackfruit seed separator

Sl.No.	**Number of bulbs**	**Number of damaged pulp**	**Percentage damage (%)**
1.	15	1	6.66
2.	15	0	0
3.	15	0	0
4.	15	1	6.66
5.	15	0	0
	Average		2.66

4.3.4 Effective capacity

The effective capacity of the machine was calculated from overall capacity (kg/hr) and separation efficiency (%) using the formula mentioned in section 3.5.4. The effective capacity of jackfruit seed separator was found to be 83.40. The results are shown in Table 4.6.

Table 4.6. Effective capacity of jackfruit seed separator

Sl. No	**Overall capacity (kg/hr)**	**Separation efficiency (%)**	**Effective capacity (kg/hr)**
1.	93.93	88.8	83.40

Plate 5.1 Working model of power operated jackfruit seed separator

4.4 Comparative evaluation of manual method and mechanical method of jackfruit seed separation

A comparison of manual and mechanical method of jackfruit seed separation is shown in Table 4.7. From the table, it is observed that, a skilled labour can separate seeds from jackfruit bulb of 1 kg in 185 seconds where as the power-operated jackfruit seed separator can separate seeds in 36 seconds only. Hence, the capacity of the developed machine is far better than manual operation. Manual jackfruit bulb separation was a time consuming and labour intensive process. The machine eliminates the drudgery involved in manual separation and saves time. The machine is simple in construction and operation and require only one person to operate it.

Table 4.7. Comparison of manual method and mechanical method of jackfruit seed separation

Sl No.	Time required for separating seeds from 1kg jackfruit bulb	
	Manual method(s)	**Mechanical method(s)**
1.	180	36
2.	190	32
3.	185	40
Average	**185**	**36**

4.5 Suggestions for the future work

An attempt has been done to develop a women friendly machine to separate seed from jackfruit bulb. It holds a key role in jackfruit based entrepreneurship, especially for women entrepreneurs.

Suggestions

- Explore the possibility of separating bulbs from garlic pod by alternating machine parameters.
- Separate chute may be provided to collect deseeded jackfruit bulb and seed.

Summary and conclusions

Chapter V

SUMMARY AND CONCLUSIONS

Jackfruit (*Artocarpus heterophyllus*) belongs to the family Moraceae that is popular and an important underutilized fruit in India. Globally, India is the largest producer of jackfruit, recording a production of 1.573 MT with a total cultivated area of 1,58,000 ha during 2013-14. In Kerala, jackfruit is cultivated in an area of about 90,225 ha with a production of about 294 million fruits per year (science direct). Jackfruit is a nutritional fruit rich in many vitamins, nutrients and having anti-cancer properties.

At present, demand for jackfruit is increasing day by day owing to its availability, medicinal value and nutritional composition. Sensitized growers, entrepreneurs and volunteers now focus on value added products from jackfruit. However, traditional manual peeling, coring, cutting and separation of seed is time consuming and labour intensive process. Moreover, the latex of this fruit also causes hindrance during separation of fruit bulb for consumption. The tedium in manual processing is the major reason for the underutilization of this fruit. Thus, effective mechanization for this process is a need of the hour. Considering these aspects, a study was undertaken to develop a jackfruit seed separator.

Matured, unripe jackfruits (cv. *Varikka* and *Koozha*) harvested from the instructional farm of K.C.A.E.T, Tavanur, were used for the study. Before the fabrication of the machine, the selected physical and mechanical properties of fruit were studied. Based on the engineering properties of jackfruit bulbs, a jackfruit seed separation equipment was designed and fabricated in the workshop of KCAET, Tavanur. The developed machine consists of the following parts -rubber belts, driven rollers, idler rollers, power transmission unit, motor, frame assembly and outlet chute. It consists of two endless vertical rubber belts rotating laterally with the help of two driven pulleys. One belt is rotating and the other is kept stationary. The belts are tapered towards the outlet. The difference in surface speeds of the belts develops a shearing force on the surface of jackfruit resulting in seed separation and breaking of jackfruit bulb. The clearance between the rubber belts is kept smaller than the thickness of the bulb. For effective seed separation, two rubber strips are fixed at certain distance along the width of the movable belt. Jackfruit bulbs were manually fed into the hopper. Bulbs were then passed in between the rubber belts. As it proceeds downwards, shear force is developed due to the difference in surface speeds of the belts result in seed separation and breaking of jackfruit bulb. The seed and the broken bulb are then collected at the outlet chute. Performance of the machine was evaluated based on overall capacity, separation efficiency and percentage damage.

Jackfruit bulb is yellow in colour. It had an initial moisture content of 73% (wb). The L*, a* and b* values of jackfruit bulb were 63.66±2.01,5.04±2.02 and 18.85±0.25, respectively. The average mass of the bulb was 35.8g. The average length, width and thickness of bulb were measured as 55mm, 44mm and 32mm, respectively. The sphericity of the jackfruit bulb was found to be 0.023. The volume of the bulb varied between 0.73 to 0.77m^3 with an average value of 0.75m^3. The coefficient of static friction was calculated using standard equation and was found to be 5 & 3.75 for stainless steel sheet and aluminum sheet, respectively. The average angle of repose of the jackfruit bulb was estimated as 47.2^0. The overall capacity of the machine was found to be 94.1kg/h. The separation efficiency, percent damage of jackfruit bulb and effective capacity of the machine were recorded as 89.3%, 2.66 % and 83.40, respectively.

It was concluded from the study that though no significant variations in the values of capacity and percent loss were observed among the trials conducted, the values of these parameters were influenced by the size, shape, variety of jackfruit and skill of the worker in feeding the raw material uniformly to the separator. The developed separator can separate seeds from jackfruit bulb at capacity three to four times higher than manual method. The machine requires one person to operate. It is simple in construction and operation and hence it is technically feasible and economically viable. The fabrication cost and the cost of operation of the developed machine was estimated as Rs 15220/-.and Rs 65.74/hr, respectively.

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APPENDICES

APPENDIX I

CALCULATION OF OPERATING COST

Initial cost (C)

Fabrication cost of power operated jackfruit

bulb Separator including cost of material = 15,220

Average life of machine = 10 yrs

Working hours /year = 1200hr

Salvage value = 10% of initial cost

A) Fixed cost

1. Depreciation $= \frac{C-S}{L \times H}$

$= \frac{15220-1522}{10 \times 1200}$

= 1.14

2. Interest on investment@ 12% $= \frac{(C+S)x12}{2x\,Hx\,100}$

$= \frac{(15220+1522)\times 12}{2x1200x100}$

= 0.83/hr

Total fixed cost = 1.97/hr

B) Variable cost

1. Labour wages

Wages of labour = Rs 500/day of

2. Repair and Maintenance cost

@ 10% of initial cost p.a. $= \frac{15220 \times 10}{100 \times 1200}$

= 1.27/hr

Total variable cost = 1.27+62.5

= 63.77/hr

Total operating cost = Fixed cost + Variable cost

= 1.97 + 63.77

= 65.74/hr

ABSTRACT

ABSTRACT

Jackfruit is a nutritional fruit rich in many vitamins, nutrients and having anti-cancer properties. At present, demand for jackfruit is increasing day by day owing to its availability, medicinal value and nutritional composition. At present, sensitized growers, entrepreneurs and volunteers focus more on jackfruit value added products. But traditional manual peeling, coring, cutting and separation of seed is time consuming and labour intensive process. At present, it is carried out manually and no means of mechanical device for separation of seed from jackfruit bulb has been commercialized till now. The conventional method of separation is done by using stainless steel knives. This poses operational drudgery to the labours and can cause damages to the bulbs. Prior to the development of mechanical jackfruit seed separator, study on existing methods of jackfruit seed separation was done. Also an investigation of the physical and mechanical properties of jackfruit bulb was under taken. Based on these properties, a power operated jackfruit seed separator was developed. The developed machine consists of the following parts -rubber belts, driven rollers, idler rollers, power transmission unit, motor, frame assembly and outlet chute. Two endless rubber belt rotating with the help of two driven pulleys. .The jackfruit bulbs were manually loaded to the inlet at the top of the frame assembly, which was then passed between the rubber belts. As it proceeds downwards, shear force is developed due to the difference in surface speeds of the belts result in seed separation and breaking of jackfruit bulb. The seed and the broken bulb are then collected at the outlet chute. Performance of the machine was evaluated based on overall capacity, separation efficiency and percentage damage. The overall capacity of the jackfruit seed seperator was found to be 93.93kg/hr. The seperation efficiency and percentage damage of jackfruit bulbs were 88.8% and 2.22%, respectively. The effective capacity of the jackfruit bulb seperator was calculated as 83.40%. The capacity of the developed jackfruit seed separator was four times higher than manual operation. The fabrication cost and the cost of operation of the developed machine was estimated as Rs 15220/-.and Rs 65.74/hr, respectively.