DEVELOPMENT AND PERFORMANCE EVALUATION OF TENDER JACKFRUIT PEELER

By

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KERALA, INDIA

2022

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PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology
in
Agricultural Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural Engineering

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
TAVANUR-679573, MALAPPURAM
KERALA, INDIA

2022

DECLARATION

We, hereby declare that this thesis entitled ***"Development and Performance Evaluation of Tender Jackfruit Peeler"*** is a bonafide record of research work done by us concerning the research work and the thesis 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.

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CERTIFICATE

Certified that this project entitled ***"Development and Performance Evaluation of Tender Jackfruit Peeler"*** is a bonafide record of project work jointly done by **Ankith Anilkumar, Aveen Ragh, Aman, Vaisakh K** 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.

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ACKNOWLEDGEMENT

Any accomplishment requires the efforts of many people, and this work is no different. We find great pleasure in expressing our deep sense of gratitude success.

First of all, with profound and reverence we would like to express our sincere gratitude to our project guide, **Dr Rajesh. G.K,** Assistant Professor, Dept. of Processing and Food Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, for his valuable guidance, profound suggestions, constant backing, encouragement and advice throughout the project work. This project has been a result of the combined efforts of our guide and us. We consider it as our greatest fortune to have him as the guide for our project work and our obligation to him lasts forever.

With great gratitude and due respect, we express our heartfelt thanks to **Dr Sathian K. K,** Dean, KCAET, Tavanur. We engrave our deep sense of gratitude to **Dr Prince M.V,** HOD, Department of Processing and Food Engineering, **Ms Sreeja R.,** Assistant Professor, Department of Processing and Food Engineering, **Er. Anjaly M. G,** Assistant Professor, AICRP on PHET, and **Er. Ann Annie Shaju,** Assistant Professor(**C**)**,** Co-Guide KCAET, Tavanur for their support and encouragement.

We also express our profound sense of gratitude to **Mr. Lenin**, Technician, and **Mr. Vipin,** Technician, KCAET, Tavanur for their immense help and continuous support throughout the project or completing it successfully.

We are greatly indebted to our parents or their love, blessings and support which gave strength to complete our study. We also acknowledge our friends or their support and care throughout the project duration. Last but not the least, we bow our heads before **God Almighty** for the blessings bestowed upon us which made us materialize this endeavour.

Dedicated to

Agricultural Engineering Profession

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SYMBOLS AND ABBREVIATION

Abbreviations/ Notations	Description
=	Equal to
×	Multiplication
/	Per
%	Percentage
MT	Million tonne
m	Metre
ft	Feet
in	Inch
G	Gram
mg	Milligram
mm	Milli metre
viz.	Namely
Cm	Centimetre
Kg	Kilogram
K.C.A.E.T	Kelappaji College of Agricultural Engineering and Technology
min	Minute
kJ	Kilo joule
m^2	metre square
s	Second
N	Newton
kN	Kilo newton
Fig.	Figure
etc.	Etcetera
rpm	Revolution per minute
Pa	Pascal
NaOH	Sodium hydroxide
hr	Hour
Sl.	Serial
No.	Number
SD	Standard deviation
W	Watts
-	Subtraction
+	Addition
±	Plus or Minus

λ	Lambda
hp	Horsepower
MS	Mild steel
SS	Stainless steel
°	Degree
&	And
ID	Inner diameter
OD	Outer diameter
US	United States
CAD	Computer Aided Design
ie.	That is
APEDA	Agricultural and Processed Food Products Export Development Authority

Introduction

CHAPTER I

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus*) belongs to the family Moraceae which is popular and important underutilized fruit in India. Jackfruit is the largest edible fruit in the world. It orginates in the forests of the Western Ghats (India), where it still grows as wild in the evergreen forests of Assam and Myanmar. It is cultivated throughout Bangladesh, Burma, India, Indonesia, Malaysia, Philippines, SriLanka, Thailand, and some extent in Brazil, Queensland and Australia. In recognition of its special status in 2018, the Kerala government designated jackfruit the official state fruit.

India is the largest producer of jackfruit followed by Bangladesh and Thailand (Kittur *et al*., 2015). The trees populate north-eastern states like Assam, Tripura, Bihar, Uttar Pradesh, the foothills of the Himalayas and South Indian states of Kerala, Tamil Nadu and Karnataka. In India, total cultivation of jackfruit as of 2021-2022 has been 18.76 Lakh tones over 1.87 Lakh hectares of land. In Kerala, the annual production of jackfruit is 2.63 Lakh tones, which contributes 14.01% of its share in India (APEDA, 2021).

Tender jackfruit is the immature jackfruit which is less mature compared to the jackfruit as it is harvested at a certain maturity from the jackfruit tree. The tender jackfruit is a nutritional fruit rich in many vitamins, nutrients. 'Fresh Produce Jackfruit Tender' is a nutritious flour made with the goodness of jackfruit, which is a healthier option than maida or rice. It is a good source of fiber and contains less calories, making it a great alternative to make roti, porridge, or pancakes etc. Recent study suggests that tender jackfruit is good for diabetes.

At present, demand for tender jackfruit is increasing day by day. The growers, entrepreneurs and volunteers may focus more on tender jackfruit value added products. But the traditional manual method of peeling is done by using a knife, which is a time consuming process and causes drudgery. The fruit is widely under-utilized due to the large peeling losses and intensive labour when it comes to the peeling operations. Thus, effective mechanization for this process is a need of the hour.

The above scenario urgently demands for the development of a mechanical tool or machine for peeling of tender jackfruit. This development will reduce the wastage of major quantity of tender jackfruit and also helps in the preparation of primary processed products that can be used for production of other value-added products. The developed tool can be easily operated by an unskilled labour, so it will increases the commercial utilization of tender jackfruit. In this context, the present study on “Development and evaluation of a tender jackfruit peeler” was formulated with the following objectives.

1. To study the selected physical and mechanical properties of tender jackfruit.

2. To develop a mechanical tool for peeling of tender jackfruit.

3. To evaluate the performance of the developed mechanical tool.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

This chapter focuses on analyzing all the previously published literature with regard to the general information of jackfruit, engineering properties of different agricultural produces including tender jackfruit and the development and evaluation of a cost effective highly efficient tender jackfruit peeler. This chapter gives an insight about the materials used for the fabrication of tender jackfruit peeler.

2.1 TENDER JACKFRUIT (*Artocarpus Heterophyllus L.*)

Jackfruit is the largest as well as underutilized fruit in India. Jackfruit having a maturity period of 60–70 days after flowering is termed as tender jackfruit. The tender jackfruit may be large as 1.1 kg or more. It is a rich source of carbohydrates, calcium, phosphorous, potassium, vitamins, fibre etc. Several value added products can be prepared using tender jackfruit. The inherent quality attributes of tender jackfruit might have been identified traditionally which implicitly become a reason for its market value especially in developing countries (Rana *et al.*, 2018).

Tender jackfruits are used abundantly in cooking. The malayalam name of tender jackfruit is *'Eddi Chakka'*. The fruit is widely under-utilized due to the large peeling losses and intensive labour when it comes to the peeling operations. It is a less mature produce of jackfruit as it is harvested at a certain maturity from the jackfruit tree. Jackfruit is popularly known as poor man's fruit in eastern and southern part of India. It is a good source of vitamins and calories (Rahman *et al.,*1995)

2.1.1 Botanical aspects and description

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 borne separately on the same tree. The tender jackfruit may be large as 1.1kg or more. Fruit is the primary economic product of tree and used in both stages when mature and immature (Nachegowda *et al.*, 2014).

The fruit comprises an axis (core), perianth and true fruit. The axis possesses immense latex (secerated by laticiferous cells) by which the fruit are held together. The perianth consists a lower fleshy (edible bulb), middle fused (forms the rind) 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).

2.1.2 Varieties

According to Elevitch and Manner (2006) the variation in species is based on tree size and structure, leaf and fruit form, age of fruit bearing, fruit size, shape, color and texture of the edible pulp. Koozha and Varikka are the two main varieties of jackfruits available in Kerala. Jackfruit having thin, fibrous and mushy edible pulp which is very sweet and emitting strong odour called as Koozha. But Varikka is thick, firm, crisp and has less fragrant pulp.

2.1.3 Nutritional composition

Jagadeesh *et al.* (2007) studied the chemical composition of jackfruit bulbs. The study revealed that, bulbs contain total soluble solid (TSS), acidity, sugars, starch and carotenoid. Also, it is a nutritious fruit, rich in vitamin A, vitamin B complex, vitamin C, potassium, calcium, iron, proteins and carbohydrates.

Jackfruits have high nutritional and medicinal values. It can strengthen immune system, protect against cancer, aid in healthy digestion, helps to maintain a healthy eye and skin, help to boost energy, lowering high blood pressure, controls asthma, help to strengthen the bone, prevent anaemia and maintain a healthy thyroid (Priya *et al.*, 2014).

Sandeep *et al.* (2018) studied the nutritional properties of tender jackfruit. They found that, as the fruit maturity in soft variety of tender jackfruit increased from stage 1 to 4, there was a decrease in Vitamin A and C from 44.4 ± 2.6 to

22.5 ± 0.3 IU and 12.12 ± 1.12 to 7.04 ± 1.10 mg, respectively, whereas carbohydrates, calcium, sodium, phosphorus, potassium, energy values shown a significant increase from 19.6±0.5 to 25.8 ± 0.3 g, 43.8± 1.8 to 57.5±1.6 mg, 12.1±0.38 to 43.6 ± 0.93 mg, 2.3 ± 0.6 to 22.8 ± 1.6 mg, 190.6±4.5 to 412.6±4.9 mg, and 312.8 ± 22.4 to 444.8±39.6 kJ, respectively.

2.2 Physical properties

The study of the physical properties of products is 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 processing equipments. The different physical properties are weight, volume, bulk density diameter, perimeter, peel thickness, sphericity etc.

2.2.1 Fruit Size

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 agricultural produce 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 and its experimental results are given below.

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.

Gomez *et al.* (2015) studied the physico-morphological characteristics of jackfruit accessions in Kerala. The dimensions of the jackfruits among the jackfruit accessions varied from 28.66-52.66 cm in length and 18.46-30.50 cm in diameter.

Sandeep *et al*. (2018) studied the average values of the tender jackfruit in term of major dimensions (i.e., length and diameter) and weights at different stages. For hard variety, there was a significant ($P \setminus 0.05$) increases of 121.12, 46.09 and 75.93% in the mean values of weight, length, and diameter, respectively, from stage 1 to 4. Similarly, a significant ($P \setminus 0.05$) increases of 60.80, 57.63 and 119.77% was observed in the mean values of weight, length and diameter, respectively, for soft variety jackfruit.

Vahid *et al.* (2017) conducted a study on physical properties of pineapple. He observed that the diameter and length of pineapple varied from 80mm to 95mm and 180mm to 200mm, respectively.

Mahawar *et al.* (2020) conducted the study on "development of a mechanical peeler cum juice extractor for kinnow and sweet orange". The fruit dimensions *viz.*, length, diameter, height etc were measured using stnandard procedures. Thickness of the peel was measured by a vernier caliper (M/s Mitutoyo, Japan, ± 0.01mm). The length was measured by taking the average of three tender jackfruits by using a ruler and a measuring wire. The diameter was found by taking the average diameter of three jackfruit specimen by taking the largest circumference and smallest circumference of each jackfruit. The average diameter was measured using the following equation,

$$P = \pi D \qquad ..2.1$$

2.2.2 Mass

The mass of the tender jackfruit peeler was obtained by taking the average of three tender jackfruit's by placing each of the jackfruit on the weighing balance.

Jagadeesh *et al*. (2007) studied the important physico-chemical characters of jackfruits to determine the degree of divergence present among the selections. Observed values of total fruit mass, seed mass, rind mass, flake mass and bulb mass of the jackfruits among the clusters varied from 4.68-14.86 kg, 0.71-3.67 kg, 2.06-4.85 kg, 1.61-5.62 kg and 3.11-9.28 kg, respectively.

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 weight of 3.75-10.35 kg, fruit rind weight of 0.30-0.50 kg and weight of flakes per kg of fruit was 0.50-0.71 kg among the jackfruit genotypes.

Gomez *et al.* (2015) studied the physico-morphological characteristics of jackfruit accessions in Kerala. The observed value of fruit weight among the jackfruit accessions ranged from 3.95-20.13 kg.

Shidenur (2016) has studies the physical properties of matured jackfruit. The weight of jackfruit varied from 5.35-16.65kg and mean weight was found as 8.34±2.94kg.

2.1.4 Sphericity

Sphericity is a measure of how closely the shape of an object resembles that of a perfect sphere. The shape of jackfruit can be determined in terms of sphericity, which is directly influences the flow characteristic of the product.

Singh *et al.* (2018) conducted studies on the shape of jackfruit in terms of sphericity, which is directly influences the flow characteristic of the product. The sphericity of the jackfruit was highly influenced by its stage of maturity for both the varieties. For both the varieties the sphericity decreased with increase in stages ($P < 0.05$). The fruit of hard variety was found to be a sphere in its initial stages i.e. 1 and 2 because the sphericity values were 0.91 and 0.89, respectively, whereas it decreases to 0.83 at stage 4. In the case of soft variety, the jackfruit was almost cylindrical in its initial stages and retain oblong in stage 4. The sphericity values for soft variety in stage 1 and 4 were 0.78 and 0.89, respectively.

2.3 Mechanical properties of jackfruit

2.3.1 Cutting force

The cutting force is essential to determine the minimum force required to cut the peel from the fruit without much peeling loss. The cutting strength is one of the most important tests in the mechanical properties. The test used to determine the materials strength and resistance of tissue to loading cutting force during cutting and coring operation. Some researches carried out work on requirement of cutting force to cut the fruits which helps in the particular equipment. The determination of cutting strength of different produce followed by various research workers were reviewed for the study.

Mathew and Pandiselvam (2017) did extensive research on the cutting strength of jackfruit using Universal testing machine. The cutting strength of jackfruits varied from 2.5-3.5 kN and average value was found to be 2.96 ± 0.42 kN. The measured cutting strength is relevant to determining the factor of safety for cutting tool and fruit holder thickness of designed tool. These are important factors that should be taken into consideration during design and development of peeler cum corer machine for jackfruit.

2.3.2 Peeler machines for different agricultural produces

Peeling operations are the important preliminary stage of fruits and vegetables processing. The price and quality of the processed product is highly dependent on these stages. Manual peeling is possible for all products but high losses and consumption of time and labour, have motivated the peeling industry to use mechanical peeler. There is a number of mechanical peelers and slicer/cutting machines are developed to suit the peeling and slicing of either a particular product or a group of products. In general, mechanical peelers are classified into various groups on the basis of type of mechanism that can incorporate during peeling system. The mechanical peelers include abrasive devices, devices with blades, rollers and drums. There is a variety of peeler machines which are developed by various research scientists to peeling and slicing/cutting of different types of fruits and vegetables *viz.*, pumpkin, apple, mango, pineapple, melon, papaya, cucumber etc. Also, there is no published literature article related to tender jackfruit peeler machine. A review of peeler machines for different produces is presented below.

Agrawal *et al*. (1983) developed a abrasive brush type ginger peeling machine. The main parts of the machine are two continuous abrasive vertical brush belts, which are driven in opposite directions with a downward relative velocity by a variable-speed electric motor. When the two belts are driven in opposite direction causes an abrasive action on ginger passing in between while the downward relative velocities provide the downward movement of the ginger. The machine was found to operate satisfactorily with a peeling efficiency of 75- 85 %.

Kim (2006) patented a fruits peeler with cutting part. The simple device consists of a single piece of metal piece with a round peeling part inside of metal and cutting part outside of the same metal to peel and cut fruits. Peeling part removes the peel from round and convex surfaces of fruits and cutting part is used to cut the fruit to eat able size.

Shidenur (2016) fabricated jackfruit peeler cum corer machine in which the major components are fruit holder, peeler assembly, corer assembly along with cutting mechanism, power transmission unit and frame assembly. Performance evaluation of the machine was conducted in the laboratory to optimize the speed of peeling with minimum bulb damages. And the result was found to be the peeling operation at optimized speed (90 rpm) showed minimum bulb wastage for small (7.85%), medium (7.24%) and large (6.20%) sized fruits with high peeling efficiency of 85.27, 83.51 and80.64% with a trend of increasing operational time of 38.24, 44.58 and 50.34 sec, respectively.

Yen *et al.* (2020) done research on the design and analysis of a garlic peeling machine. The streamline of the air flow produced in the model was able to form in the spiral structural, due to which a vortex of air will be performed in the model. The air flows in from the inlet and then leaves the main body through outlet. The design was able to replace the traditional hand peeling method. The simulation of fluid flow proves that the air flow in from the bottom, inlet is able to produce a vortex in the peeling chamber and then the garlic skin goes out through the top, outlet. It was able to separate the peeled garlic and the garlic skin and hence the design was generated.

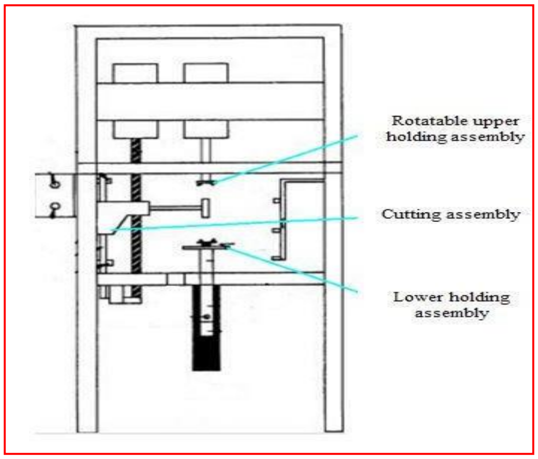

Fig 2.1 Fruit peeler

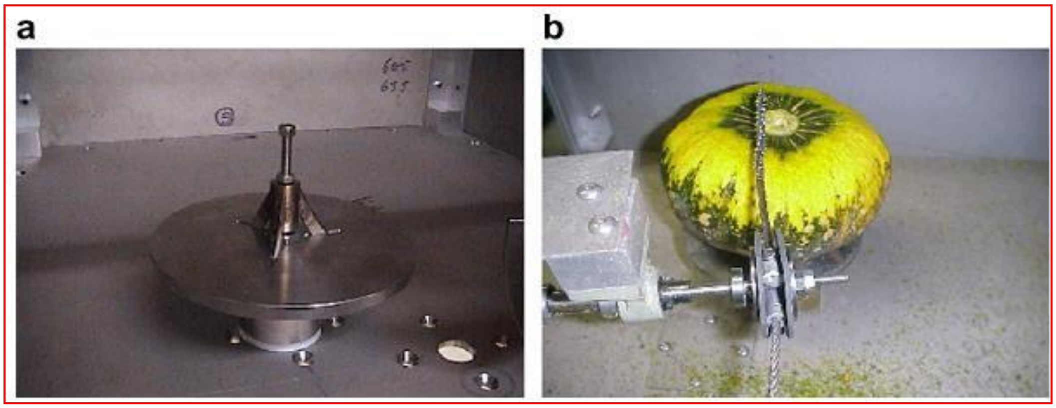

Fig. 2.2 (a) Vegetable holder (b) Peeler head

2.5 Cutting tool for different agricultural produces

Many factors were considered in the design of the cutting machine which includes the physical and mechanical properties of the materials for construction. The blade of the cutting machine is usually expected to be sharp enough to cut easily.

Further the materials needed for construction of the machine must neither contaminates the vegetables nor get corroded when in contact with water. Stainless steel materials were therefore used for fabricating components.

Ajibola *et al*. (2016) *et al.* designed a manual potato peeler cum slicer, using stainless steel material. He observed that the maximum length and diameter of tubers to be fed to the machine were 150 mm and 70 mm, respectively. The average peeling efficiency was found to be 80.1%.

Kabir *et al.* (2021) designed, constructed and evaluated motorized tomato slicing machine for tomato. It consists of gear mechanism, electric motor, synthetic rubber and bearings. The machine was designed to cut tomatoes into slices of 2.45cm thickness. The machine was evaluated in terms of slicing efficiency, output capacity and minimum damage. The percentage damage, slicing efficiency and output capacity for large, medium and small tomatoes were 3.33%, 93.33%, 179.25kg/hr ; 5%, 88.33% , 181kg/hr and 5%, 81.67% and 178kg/hr, respectively.

2.6 Performance evaluation of peeling machine

Agrawal (1987) evaluated the performance of a ginger peeling machine. The peeling efficiency of the machine at full capacity (20 kg/h)were found as 71%. The peeling efficiency were determined by the following formula.

$$Peeling\ efficiency = \frac{(\text{Weight of total skin removed by machine})}{(Weight\ of\ total\ skin\ on\ ginger)} \times 100 \quad ..2.3$$

Rajesh *et al.* (2016) evaluvated the performance of plantain peeler cum slicer. The material loss of machine was determined using the following formula. The average material lose was obtained as 13.69%.

$$\boldsymbol{Material\ loss} = \frac{(\mathbf{Z})}{(\boldsymbol{W}+\boldsymbol{Z})} \times \mathbf{100} \quad \ldots \mathbf{2.4}$$

Where, Z = Weight of flesh obtained from the peel (g)

W = Total weight of plantain after mechanical peeling (g)

2.7 Material selection

Minimizing the chance of food contamination by designing a piece of equipment for ease of cleaning should be the goal of all processing equipment design engineers. If the proper grade of stainless steel is used in food processing, corrosion will not be encountered.

Agrawal *et al*. (2014) reported that AISI 304 stainless steel (SS) was used in applications like automotive, oil, gas and the food industry due to its excellent combination of corrosion resistance and mechanical properties.

2.8 Cost Economics

Cost of peeling of tender jackfruit was estimated by considering the fixed and variable costs. Shidenur (2016) developed a jackfruit peeler , corer cum cutting machine. The cost of the machine was about Rs. 46950 which comprises material and fabrication cost & total hourly operational cost was estimated as Rs. 52.97.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter describes the design and development of tender jackfruit peeling machine. The engineering properties of tender jackfruit, materials used for the fabrication of various components of machine and the performance evaluation of the machine are explained in this chapter.

3.1 PROCUREMENT OF JACKFRUIT

Tender jackfruit (*Artocarpus heterophyllus L, Moraceae* family) of Varikka variety harvested from the Instructional Farm of KCAET, Tavanur were used for study.

3.2 MEASUREMENT OF ENGINEERING PROPERTIES OF TENDER JACKFRUIT

3.2.1 Physical properties of jackfruit

The major physical properties required for the development of the machine are fruit length, fruit diameter, rind thickness and fruit mass.

3.2.1.1 Fruit Length

Fruit length is the maximum height measured from the top(stem) of tender jackfruit to the bottom(calyx). It was measured using ruler (Shidenur, 2016).

3.2.1.2 Fruit diameter

Longest dimension perpendicular to fruit length is to be considered as fruit diameter and it was measured by measuring the circumference of tender jackfruit using measuring tape. The sensitivity of measuring tape was 1mm. The diameter of the tender jackfruit was calculated using the equation

$$d=C/\pi \qquad \ldots 3.1$$

where, d is the tender jackfruit diameter (mm) and C is the tender jackfruit circumference (Shidenur, 2016).

3.2.1.3 Fruit rind thickness

The rind was removed manually from the jackfruit using a sharp knife. Its thickness was measured in centimeter using a digital caliper with accuracy of 0.01mm and the mean values were calculated (Shyamalamma *et al*., 2014).

3.2.1.4 Fruit Mass

Mass of individual fruit was determined with an electronic balance of 0.1 g sensitivity and the mean values were calculated. The values were recorded in kilogram (Shidenur., 2016).

3.2.1.5 Bulk density

The bulk density of tender jackfruit was measured by the methodology portrayed by Pandiselvam (2015). Tender jackfruits were placed into a cylinder of known volume. The weight of the samples was measured using an electronic balance. Experiment was repeated for accuracy and average values were considered. The bulk density was computed using the following equation;

$$Bulk\ density = \frac{\text{(Weight of tender jackfruit)}}{\text{(Volume of the cylinder)}} \quad \ldots 3.2$$

3.2.1.6 Sphericity

The spericity of fruit was determined by using overhead projector. (Singh *et al.* 2018)

3.4 DEVELOPMENT OF TENDER JACKFRUIT PEELER

Based on the preliminary studies, tender jackfruit peeler was developed. The working principle of peeling operation is, as the jackfruit rotates the peeling was done helically due to the linear motion of the blade from bottom to top. The clearance between the blade and peeler arm was fixed on the basis of thickness of the rind. The major fabricated components of the machine are

1. Fruit holder
2. Peeler assembly
3. Power transmission unit
4. Frame assembly

3.4.1 Fruit holder

Fruit holder consists of disc and blade, which are made up of food grade (SS304) stainless steel. It was designed as a rotating disc that can carry the tender jackfruit on a horizontal plane. The dimensions of the disc were 1cm thickness and 7.5 cm diameter. The jackfruit was fixed on the disc by four blades to avoid the slippage between fruit and circular disc, each projection was made with the dimensions (0.9 cm height, 3cm width and 0.5 cm thickness). The shaft made up of MS rod consist of two pulleys (diameter 15 and 4.26 cm) is connected with motor and peeler assembly for power transmission.

Plate.3.1 Fruit holder

3.4.2 Peeler assembly

Peeler assembly consists of screw shaft, peeler arm, blade and spring.

Plate.3.2 Peeler assembly

3.4.2.1 Screw shaft

The screw shaft was made using MS rod with square threads on the outer surface. The dimensions of the screw shaft were 64 cm length, 2.4 cm diameter and 2.3, 1.5 and 1.5 mm screw pitch, thread width and thread height, respectively. It was passed through the internally threaded circular passage of rectangular housing, which in turn attached to the peeler arm. The 26 cm diameter pulley made up of cast iron was fixed on the bottom of the screw shaft to take the drive from fruit holder shaft. The main function of the screw shaft is to provide a linear motion to the peeler arm by rotating on its own axis.

3.4.2.2 Peeler arm

The peeler arm was made using food grade SS 304 stainless steel having 18.5 cm length, 2.6 cm width and 0.5cm thickness. One end of the peeler arm was connected to a rectangular housing, which in turn is attached to an internally threaded circular passage. For effective peeling another end of peeler arm was bent slightly at 35° angle which supports the peeling blade. The peeler was connected with screw shaft which enables the peeling blade to move parallel over the jackfruit profile, so that fruit was completely peeled from bottom to top.

3.4.2.3 Spring

The spring was attached between peeler arm and rectangular housing. The specifications of the spring were 8cm length and 1.5 cm diameter. It provides flexibility to the peeling operation, so that cutting blade easily passes over the surface of jackfruit. A main function of the spring is to press the peeler arm softly over the fruit profile and holds the peeling blade in position against the jackfruit. Apart from this, spring aids the blade against the irregular surface of jackfruit.

3.4.2.4 Peeling blade

The blade was made using food grade SS 304 stainless steel having a 2 mm thickness which is inwardly curved along its longitudinal length to provide a bow shaped construction. Clearance of 1.2 cm between peeler arm and blade was fixed based on the rind thickness of jackfruit. Main function of the blade is to peel the rind out of whole jackfruit and able to traverse an angular displacement of 40° angle during peeling operation, which depends on diameter of the tender jackfruit.

3.4.3 Power transmission unit

Transmission system was developed for proper power transmission from electric motor to peeling operation of the developed machine. The power transmission system consisted of electric motor, gear box and belt and pulley.

3.4.3.1 Electric motor

The speed of tender jackfruit peeler was optimized using a 0.5 hp single phase reversible electric motor of 1425 rpm.

3.4.3.2 Speed reduction gear box

The speed of tender jackfruit peeler machine was optimized using reduction of speed gear box. The speed reduction gear was connected with motor to reduce the speed from 5:1 rpm and convert the horizontal rotational motion to vertical. It consisted of set of rotating gears, engine shaft and propeller shaft, each shaft having a 6 inch pulley.

3.4.4.3 Belt and pulley

The speed of the peeling operation could be changed based on belt and pulley arrangement. Belt and pulley were used to transmit power from one shaft to another by means of pulleys and belts respectively. The diameter of pulley was selected based on optimized speed of the developed machine. Two type belts *viz.* open belt of B41 and A43 made up of rubber material were used for power transmission. The length of belt was selected based on centre to centre distance between sheaves and diameters of driver and driven pulleys. A double pulley was used to transmit power from the electric motor to the peeling mechanism for the effective peeling of the tender jackfruit. The belt was selected in such a way that it could resist the tensile and compressive forces exerted on itself during the power transmission process of the electric motor.

3.4.4 Frame assembly

Main frame was required to support other parts of the developed machine and to withstand against vibration during the operation. The main frame was fabricated from MS iron square channel for mounting fruit holder, peeler assembly and power transmission system. The length, width and height of mainframe were 65, 65 and 98 cm, respectively. The peeler assembly, fruit holder and electric motor were assembled on main frame using nuts and bolts.

Plate 3.3 Tender jackfruit peeler

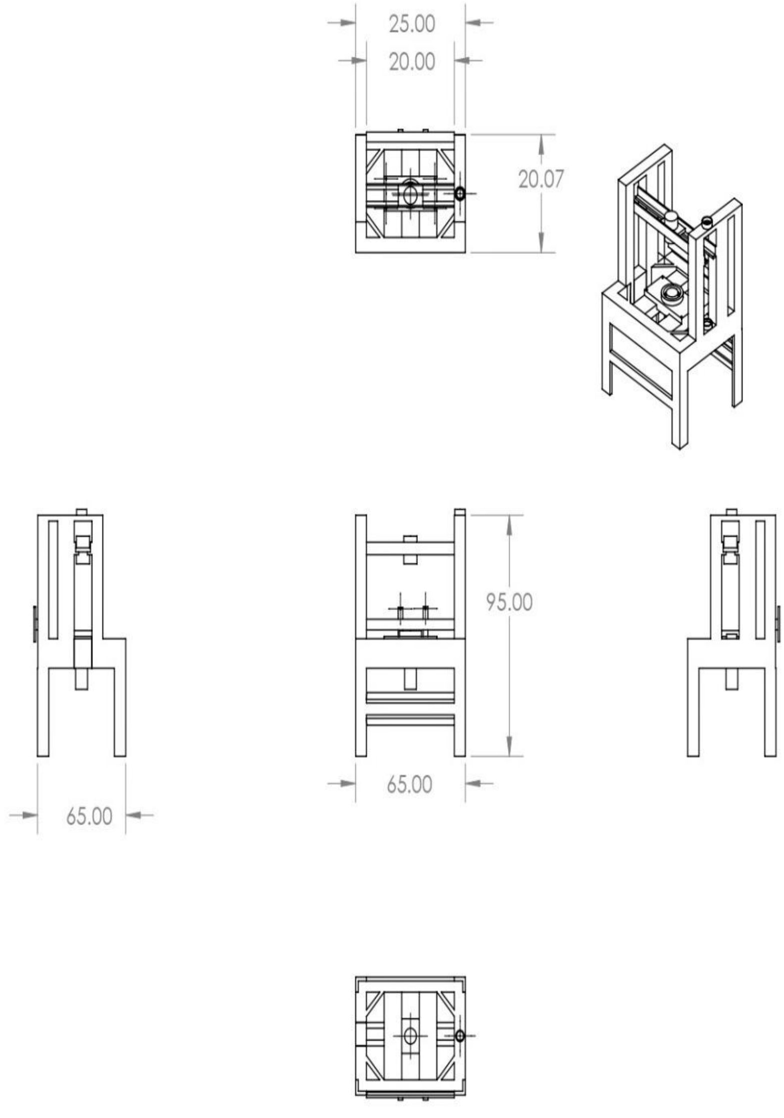

Fig 3.1 Front view and side view of tender jackfruit

Table 3.1. Specifications of the developed tender jackfruit peeler

SI.NO.	Item	Values
A	**Overall dimensions(L×B×H), cm**	65×65×98
B	**Fruit holder**	
i.	Disc Diameter, cm Thickness, cm	 7.5 1
ii.	Projection(B×H),cm	3×0.9
C	**Peeler assembly**	
i.	Screw shaft diameter, cm	2.4
ii.	Screw shaft length, cm	64
iii.	Peeler arm (L×B×T),cm	18.5×2.6×0.5
iv.	Peeling blade thickness, cm	0.2
D	**Power transmission unit**	
i	Motor ,hp	0.5
ii	Gear box, speed reduction ratio	5:1
iii	Number of belts	2
iv	Number of pulleys	2

3.5 OPERATIONAL PROCEDURE FOR TENDER JACKFRUIT PEELER

3.5.1 Pre-preparation

The stem (top) side portion of fruit was removed manually to find out the position of the central core and the calyx (bottom) portion of the fruit was removed to ensure the fruit stand properly over the fruit holder.

The fruit was placed on fruit holder which moves the jackfruit circularly on a horizontal plane. While loading, jackfruit was held vertically to stand on the fruit holder with correct fruit positioning to distribute the fruit load uniformly throughout surface of fruit holder at the time of peeling operation. After loading the jackfruit, fruit was tightly holding in vertical direction.

3.5.2 Peeling operation

Motor was switched on during the peeling operation. Fruit holder was driven in a clockwise direction on a horizontal plane and simultaneously tender jackfruit was also made to rotate in the same direction. As the fruit holder rotated, it enabled peeling blade to move parallel to profile of the jackfruit rotational axis. Spring pressed the peeling blade softly on the fruit profile, so that fruit was completely peeled. By changing the rotational direction of the motor shaft peeler blade was brought to its original position.

Plate 3.4 Tender jackfruit

Plate 3.5 Trimmed Tender jackfruit

Plate 3.6 Loading of tender jackfruit

Plate 3.7 Peeled jackfruit

3.6 Performance evaluation of the developed tender jackfruit

3.6.1 Experimental details

Three sizes of jackfruit were chosen for peeling (small, medium and large).

3.6.2 Time of peeling operation

Time for peeling operation of the developed machine during each combination of jackfruit size and speed was determined using stop watch.

3.6.3 Peeling Efficiency

Peeling efficiency was determined as the ratio of weight of peel removed to total weight of peel remove. The suggested formula by Singh and Shukla (1995) was used for the calculation of the peeling efficiency.

$$Peeling\ efficiency = \frac{(Y-Z)}{(Y)} \times 100 \qquad \text{....3.2}$$

Where, Y = Weight of total peel on jackfruit (g)

Z = Weight of peel removed by hand trimming after mechanical peeling (g)

3.6.4 Material Loss

Material loss was determined as the ratio of weight of flesh obtained from the peel to the total weight after mechanical peeling. Material loss was calculated using the formula suggested by Rajesh *et al*. (2016).

$$Material\ loss = \frac{(Z)}{(W+Z)} \times 100 \ldots\ldots\ldots\ldots 3.3$$

Where, Z = Weight of flesh obtained from the peel (g)

W = Total weight of fruit after mechanical peeling (g)

3.7 COMPARISON ON DEVELOPED TENDER JACKFRUIT MACHINE WITH MANUAL PEELING

The manual peeling was also carried out using different tender jackfruit by employing one skilled labour and the result was compared with mechanical operation. The total processing time for mechanical operation of peeling for each sample was recorded using stop watch. Similarly, the time of manual operation was calculated.

3.8 COST ECONOMICS

Based on the material cost and cost of fabrication, the total cost of developed tender jackfruit peeler cum corer machine was worked out. The operation cost of mechanical and manual operation was worked out, by considering the fixed and variable costs.

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results of the engineering properties of tender jackfruit conducted and the experiments carried out for the evaluation of the developed tender jackfruit peeler.

4.1 PHYSICAL PROPERTIES OF TENDER JACKFRUIT

The values of weight, fruit length, fruit diameter, rind thickness and sphericity, of small, medium, large tender jackfruit were found out using standard methods and tabulated in Table 4.1.

4.1.1 Size

The length of the fruit is important for fixing the height of peeler screw shaft assembly. The length of jackfruit for three different sizes *viz.* small, medium and large was found as 18, 19.5 and 21.5 cm, respectively. The result of fruit length was found to be closer with the findings of Gomez *et al*. (2015). The value of fruit diameter is used to fix the width of the peel removing tool. The values of fruit diameter were found to be 9.23, 11.46 and 12.42 cm for small, medium and large tender jackfruit, respectively. The result of fruit diameter is in line with the findings of Gomez *et al*. (2015). Fruit rind thickness is found out to fix the clearance between blade and peeler arm in order to remove the peel completely from the fruit. The values of rind thickness for small, medium and large tender jackfruit were found to be 1.07, 0.94, and 1.09 cm, respectively. Variability of fruit rind thickness in the present study was found to be closer with the findings of Shyamalamma *et al*. (2014).

4.1.2 Fruit weight

Weight of fruit is important in determining the factor of safety distribution in designed fruit holder disc in order to withstand against maximum load during the peeling operations. The values of the weight of tender jackfruit were found to be 1.10, 1.35 and 0.71 kg for small, medium and large tender jackfruit, respectively. The result was found to be closer with findings of Reddy *et al.* (2004) and Gomez *et al*. (2015).

Table 4.1 Physical properties of jackfruit

Sl.No	Physical properties	Small	Medium	Large	Average value
1.	Fruit Length (cm)	18	19.5	21.5	19.6
2.	Fruit diameter (cm)	9.23	11.46	12.42	11.03
3.	Fruit weight (kg)	0.718	1.108	1.35	1.05
4.	Rind Thickness (cm)	0.95	1.072	1.095	1.039
5.	Sphericity	0.513	0.53	0.442	0.495

4.2 Performance evaluation of tender jackfruit peeler

The performance evaluation of the developed machine was carried out with selected three tender jackfruits having small, medium and large size. The speed of the fruit holder was fixed at 100 rpm. Performance evaluation of the machine was conducted in terms of time of peeling(s), peeling efficiency (%) and the material loss (%).

4.2.1 Time of peeling operation

The time of peeling operation of developed machine for all tender jackfruit size and speed was determined using stop watch and the result is tabulated in the Table 4.2.

The peeling action of small size tender jackfruit took less time (128.4 s) and found to be ideally suitable compared to other two sized fruits. The time of peeling was maximum (138 s) in case of large size tender jackfruit. From the result, it is understood that the peeling time increases with fruit length and circumference. The result was found to be closer with findings of Shidenur (2016).

Table.4.2 Time of peeling

Sl. No.	Treatment	Time of peeling(s)
1	Small	128.4
2	Medium	130.8
3	Large	138

4.2.1.2 Peeling efficiency

The peeling efficiency of developed machine was calculated by using the equation 3.2 and is given in Table 4.3. It was observed that, peeling efficiency was highest (93.1%) in large size fruits whereas, lowest (86.5%) in case of small size fruits. The increased trend in peeling efficiency with an increasing fruit size was due to higher rind thickness. Another reason was that with increasing fruit size, diameter also increased which resulted in variation of angle of contact between peeling blade and fruit surface. The result was found to be closer with findings of Shidenur (2016)

Table.4.3 Peeling efficiency

Sl.No	Size	Peel weight (g)	Weight of the peel remained on the jackfruit(g)	Total weight(g)	Peeling efficiency (%)
1.	Small	534.3	83	617.3	86.5
2.	Medium	615	57.1	672.1	91.5
3.	Large	722.3	53.5	775.8	93.1

4.2.1.3 Material loss during peeling operation

The material loss (%) during the peeling operation was calculated using the equation 3.3 and is given in the Table 4.3.The highest material loss (9.7%) was observed in large size fruits whereas, lowest (9.34%) was for small size fruit.

From this study it is observed that material loss increased with increase in fruit size. The increase in material loss in higher fruit size was due to the angle of contact between blade and fruit surface as well as the clearance between peeling blade and end of the peeler arm because of higher rind thickness. The present study of material loss was found to be closer with the findings of Vahid *et al*. (2017).

Table 4.4 Material loss

Sl. No.	Size of sample	Total flesh weight loss(g)	Total flesh weight (g)	Material loss (%)
1.	Small	87.422	936	9.34
2.	Medium	120.5	1252	9.4
3.	Large	147.779	1523.7	9.7

4.3 COMPARISON STUDY OF TENDER JACKFRUIT PEELER MACHINE WITH TRADITIONAL METHOD OF PEELING

Experiments were conducted to compare the tender jackfruit peeler with the traditional method of manual peeling for different size jackfruits. The average time taken for peeling was maximum (5.20 min/fruit) for manual operation and in case of mechanical operation, it was only 2.30 min/fruit, which was lesser than manual operation.

4.4 COST ECONOMICS

The cost of the developed tender jackfruit peeler was calculated as Rs. 35,000/-. The operational cost of the machine was measured as Rs.150.86 per day. The benefit-cost ratio of the developed machine was 2.306:1.00. The cost economics of the developed machine is shown in Appendix A.

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSION

Jackfruit (*Artocarpus heterophyllus*) belongs to the family Moraceae which is popular and an important underutilized fruit in India. India is the largest producer of jackfruit in the world, with a total cultivated area and production (2020-2021) of 1.58 Lakh ha and 1.876 MT, respectively.

The tender jackfruit is a nutritional fruit rich in many vitamins and other nutrients. The composite flour made from tender jackfruit is a nutritious flour made from tender jackfruit, which is a healthier option than maida or rice. It is a good source of fiber and contains less calories, making it a great alternative to make roti, porridge, or pancakes etc. Recent study suggests that tender jackfruit is good for diabetes. At present, demand for tender jackfruit is increasing day by day. The growers, entrepreneurs and volunteers may focus more on tender jackfruit value added products. But the traditional manual peeling is a time consuming and labour intensive process. Thus effective mechanization for this process is a need of the hour.

Tender jackfruits (*cv*. Varikka), harvested from the Instructional Farm of K.C.A.E.T, Tavanur were used for the study. Fruits of only oblong/round shapes were harvested from the selected trees. Before the fabrication of the machine, the selected engineering properties of tender jackfruit were studied.

The length of fruit is an important parameter for fixing the height of peeler screw shaft assembly. Fruit rind thickness was found out to fix the clearance between blade and peeler arm in order to remove the peel completely from the fruit. Based on the study of fruit linear dimension (diameter and length), tender jackfruit was classified into small, medium and large. Weight of fruit was important in the design and fabrication of fruit holder disc. Shape of the tender jackfruit was determined in terms of sphericity.

Based on the engineering properties, peeler for tender jackfruit was designed and fabricated. The major components of the machine are fruit holder, peeler assembly, power transmission unit and frame assembly. The working principle of peeling operation is, as the jackfruit rotates, peeling was done helically due to the linear motion of the blade from bottom to top.

Performance evaluation of the machine was conducted in terms of time of peeling, peeling efficiency and weight loss. The rotational speed of the tender jackfruit holder was fixed at 100 rpm. The peeling action took less time (128.4 s) in small size jackfruits compared to medium as well as large sized fruits. The time of peeling was maximum (138 s) in case of large size tender jackfruit. The peeling efficiency was highest (93.1%) in large size fruits whereas, lowest (86.5%) in case of small size fruits. The highest material loss (9.7%) was observed in large size fruits whereas, lowest (9.34%) was found in small size fruit.

A comparative study of manual method of peeling with the developed tender jackfruit peeler was carried out. The average time taken for peeling in manual operation and mechanical operation was found to be 5.20min/fruit and 2.30 min/fruit, respectively. This indicated that the developed machine aids in faster peeling of tender jackfruit with least drudgery besides more efficient and also could be used in small and medium scale industry.

The cost of the developed machine was found to be Rs. 35,000/-. The operational cost of machine was estimated as Rs.150.86/day.

Scope for future work

- Providing a more powerful induction motor so that uniform peeling is possible.
- Providing a customizable knife tip to change the knife tip for effective peeling as the shape of the tender jackfruit is very uneven and changing the knife tip will result in more peeling efficiency and less material loss.
- Providing proximity sensors so as to stop the peeling process automatically

once it has completed the entire peeling process and save energy.

- Using colour detection sensors to know the change in colour and transferring this information to a micro controller and based on the feedback a device can be placed near the knife mechanism to adjust the knife and change the depth of cut to improve peeling efficiency and reduce material loss.

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Appendices

APPENDIX A

Cost Economics of developed tender jackfruit peeler

Cost of machineries		
Cost of developed tender jackfruit machine	=	Rs. 26878
Miscellaneous item	=	Rs. 8122
Total cost	=	Rs. 35000

Assumptions

Life span (L)	=	10 years
Annual working hours (H)	=	976 hours per year
Interest on intial cost (i)	=	15% of initial cost
Repair and maintenance	=	8% of initial cost
Insurance and taxes	=	2% of initial cost
Electricity charge	=	Rs. 7 per unit
Labour wages/person	=	Rs. 200 per day

1.Total Fixed cost per day		
i. Depreciation	=	$\frac{C-S}{L \times H} = Rs. 3.227\ /h$
ii. Interest	=	$\frac{C-S}{2} \times \frac{i}{H} = Rs. 2.458\ /h$
iii. Insurance & taxes	=	2% of initial cost= Rs.7.2/h
Total Fixed Cost		Rs.107/day
2. Total variable cost per day		
i. Repair & maintenance	=	8% of initial cost = Rs. 2.8682 /h
ii. Electricity	=	Total cost = Rs.20.86/day
Total variable cost	=	Rs.43.81/day

Total cost	=	Rs.150.89 /day
capacity	=	Rs. 4.605 /day
Total cost of operation	=	Rs.409 /day
Cost of peeling at present day market	=	Rs.95
Benefit to cost ratio	=	2.322:1.00

DEVELOPMENT AND PERFORMANCE EVALUATION OF TENDER JACKFRUIT PEELER

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ABSTRACT

Submitted in partial fulfillment of the requirement for the degree

Bachelor of Technology
in
Agricultural Engineering

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2022

Abstract

ABSTRACT

Tender jackfruit is the immature jackfruit which is harvested before the fruit has reached maturity. At present demand for tender jackfruit is increasing day by day. The growers, entrepreneurs and volunteers may focus more on tender jackfruit value added products. But the traditional manual method of peeling is done by using a knife, which is a time consuming process and causes drudgery. The fruit is widely under-utilized due to the large peeling losses and intensive labour when it comes to the peeling operations. Thus effective mechanization for this process is a need of the hour.

The present study aims at development and evaluation of a tender jackfruit peeling machine. The principle operation of the machine is, as the tender jackfruit rotates peeling is done helically due to the linear motion of the blade from top to bottom. Performance evaluation of the machine was conducted in the college workshop with three sizes of tender jackfruit *viz.* small, medium, large fruit. Rotational speed of the tender jackfruit holder was fixed at 100 rpm. The peeling action took less time (128.4 s) in small size jackfruits compared to medium as well as large sized fruits. The time of peeling was maximum (138 s) in case of large size tender jackfruit. The peeling efficiency was highest (93.1%) in large size fruits whereas, lowest (86.5%) in case of small size fruits. The highest material loss (9.7%) was observed in large size fruits whereas, lowest(9.34%) was found in small size fruit. A comparative study of manual method of peeling with the developed tender jackfruit peeler was carried out. The average time taken for peeling using manual operation and mechanical operation was found to be 5.20min/fruit and 2.30 min/fruit, respectively. The cost of the machine was estimated as Rs. 35,000/-. The operational cost of the machine was measured as Rs.150.86 /day. The benefit-cost ratio of the developed machine was 2.31:1. The developed machine aids in faster peeling of tender jackfruit with least drudgery besides more efficient and hence it could be recommended to use in small and medium scale jackfruit processing industry.