DEVELOPMENT AND EVALUATION OF JACKFRUIT BULB SLICER

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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 University

Department of Food and Agricultural Processing Engineering

Kelappaji College of Agricultural Engineering & Technology

Tavanur P.O.-679573 Kerala, India

2017

DECLARATION

We hereby declare that this project entitled "**DEVELOPMENT AND EVALUATION OF JACKFRUIT BULB SLICER**" 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, associate ship, fellowship or other similar title of any other University or society.

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CERTIFICATE

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ACKNOWLEDGEMENT

We wish to express our sincere thanks to our project guide, **Dr. Sudheer K P**, Professor& Project Coordinator, Centre of Excellence in Post-harvest Technology, Department of Agricultural Engineering, College of Horticulture, Vellanikkara, Thrissur, for his constant encouragement, timely advice and continuous guidance. It is with a deep sense of gratitude that we express heartfelt thanks to him.

We are greatly indebted to **Dr. Hajilal M S**, Dean, K.C.A.E.T, Tavanur, **Dr. Prince M V,**Professor and Head, **Dr. Santhi Mary Mathew, Er. George Mathew**, **Dr. Rajesh G K,** and other faculty members of Department of Food and Agricultural Processing Engineering for their valuable advices and constructive suggestions offered during this study.

We are in short of words to acknowledge the selfless services of **Mr. Sreenesh**, **Mr. Lenin**, **Mr.Mohammed**, **Mr. Prasoon**, **Mr. Manoj**, **Mr. Vipin,** and other technicians, without their help this venture would have been impossible for us.

We exploit this opportunity to thank **Library staff, all our batch mates and students of K.C.A.E.T** especially our Ph.D. scholar **Er. Ranasalva N**, for their sharing and caring which always motivated us throughout the venture.

Words do fail to acknowledge **our parents** support, encouragement and help gone a long way in making this attempt a successful one.

Above all, we bow our head before the **ALMIGHTY**, whose grace and blessings have empowered us to complete this toil.

Haritha J

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Dedicated to Women Empowerment

&

To Our Profession of

Agricultural Engineering

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SYMBOLS AND ABBREVIATIONS

%	Percentage
/	Per
@	At the rate of
^{0}C	Degree Celsius
ή	Efficiency
^{0}F	Degree fahrenheit
&	And
^{0}	Degree
AICRP	All India Co-ordinated Research Project
Al	Aluminium
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APEDA	Agricultural and processed food Product export Development Authority
cm	Centimeter
DC	Direct current
Er.	Engineer
et al.	And others
g	Gram
GI	Galvanised Iron
ha	Hectare
hr	Hour
IPGRI	International Plant Genetic Resource Institute
ISA	Indian Standard Angle
K.C.A.E.T.	Kelappaji College of Agricultural Engineering & Technology
kg	Kilogram
kg/hr	Kilogram per hour
kN	Kilo Newton
M	Million
M ha	Million hectare
mg	Milli gram
mm	Millimeter
MS	Mild Steel
MT	Million tones
N	Newton
NHB	National Horticultural Board

pp	Page
Rs.	Rupees
s	Seconds
SS	Stainless steel
t	Tonne
V	Volt
Viz	Namely

INTRODUCTION

Chapter I

INTRODUCTION

India is the second largest producer of fruits and vegetables in the world and is the leader in several horticultural crops, namely mango, banana, papaya, cashew nut, areca nut, potato, and okra (lady's finger). Fruits and vegetables account for nearly 90% of the total horticulture production in the country. India is endowed with a wide spectrum of agro climate zones making it possible to grow almost all varieties of fresh fruits and vegetables. Fruits and vegetable are considered as an important group of protective and nutritious foods as most of them are rich in carbohydrates, protein, vitamins, minerals, dietary fibres.During 2013-14, the production of horticultural crops was about 283.5 million tonnes from an area of 24.2 million hectare. Out of the six categories, that is, fruits, vegetables, flowers, aromatic, spices and plantation crops, the highest annual growth of 9.5% was seen in fruit production (during 2013-14).

Jackfruit (*Artocarpus heterophyllus L.)*is a very large and evergreen tree belonging to the Moraceae family. It is a multi-purpose species providing food, fodder, timber, fuel, medicinal and industrial products and is widely grown in south and south east Asia, parts of central and eastern Africa, Brazil, Suriname and islands of West Indies. In India, it is grown in southern and eastern states *viz*., Kerala, Karnataka, Tamil Nadu, West Bengal, Bihar etc. It is the largest edible fruit in the world and is the national fruit of Bangladesh. Jackfruit is called as *chakka*in Malayalam. It grows well above sea level upto an elevation of 3800 feet at an optimum temperature of 22-35^{0}C. Being grown without any management practices, the fruit has the potential to be identified as the organic fruit of Kerala. People consume it mostly as a fruit when ripe but also as vegetable in the unripe stage. Jackfruit is a rich source of carbohydrates, protein, potassium, calcium, iron, vitamins *viz*., A, B, C and offers numerous health benefits. The flesh of the jackfruit is starchy and fibrous, and is a source of dietary fibre. The fruit's isoflavones, antioxidants and phytonutrients means that it has cancer-fighting properties. It is also known to help ulcers and indigestion. In spite of such a vast and potential usefulness, jackfruit remains an underutilized fruit species and deserves to be given more prominence.

Table 1.1 Nutritional composition of jackfruit

Moisture content (%)	84
Protein (g)	2.6
Fat (g)	0.3
Mineral (g)	0.9
Fibre (g)	2.8
Carbohydrate (g)	9.4
Energy (Cal)	51
Calcium (mg)	30
Phosphorous (mg)	40
Iron (mg)	1.7

Table 1.2 Total cultivated area and production of jackfruit in India

Year	Area (ha)	Production (MT)
2012 – 2013	67	1176
2013 – 2014	158	1573
2014 – 2015	149	2037

Source : National Horticultural Board, 2016

Jackfruit is available mainly during the months of March to August. 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. Jackfruits mature 6 to 8 months from flowering. When mature, there is usually a change of fruit colour from green to yellow-brown. Spines, closely spaced, yield to moderate pressure, and there is a dull, hollow sound when the fruit is tapped. Yield varies from a few fruits during first year of bearing and it may be as high as 250 fruits after 15 years of age (Sharma *et al*., 1997). Unripe jackfruits are cooked as vegetables and ripe jackfruit is eaten raw.

In every year a considerable amount of jackfruit, specially obtained in the glut season (June-July) goes both in quality and quantity due to lack of proper post-harvest technology during harvesting, transporting and storing. Proper post-harvest technology for prolonging shelf life is, therefore, necessary. Jackfruit has a wide potential for value addition. Various products like chips, papad, pakoda, pickle, cutlet etc are prepared from matured jackfruit and products such as halwa, gulabjamun, unniappam, wine, cake, varattyetc are prepared from ripened jackfruit.

Nowadays, demand for jackfruit is increasing day by day owing to its availability, sweetness and nutritional composition. Sensitized growers and entrepreneurs focus more on development of value added products. The increasing demand of jackfruit can be regulated by increasing production and also by varietal improvement in species and method of propagation. In spite of its huge production, the utilization as food material is quite negligible and of about 75% is going as waste. The traditional method of slicing of jackfruit bulb is done by using a knife, which is a time-consuming process and causes drudgery. The tedium in manual processing is a major reason for the underutilisation of the fruit. Thus, effective mechanisation in processing is a need of the hour.

The above scenario urgently demands for the development of a mechanical tool or machine for slicing jackfruit bulbs. This development will reduce the wastage of major quantity of jackfruit and also helps in preparation of primary processed products that can be used for production of other products. The developed tool can be easily operated by women and unskilled labour, so it also increases the commercial utilisation of jackfruit.

With this point of view, a project was undertaken at Kelappaji College of Agricultural Engineering &Technology, Tavanur to develop a jackfruit bulb slicer with the following objectives,

1. To develop a mechanical tool for slicing of jackfruit bulb.

2. To evaluate the performance of the developed jackfruit bulb slicer.

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

This chapter sets out to identify and critically analyse all the previously published literature with regard to the general information of jackfruit, engineering properties of different produces, development and evaluation of slicer machine and the material selection for equipment fabrication.

2.1 Jackfruit (*Artocarpus heterophyllus L.*)

Jackfruit is indigenous and grows wild in the rain forests of the Western Ghats of India. The name originated from Malayalam name *Chakka*, other Indian names of the fruit are: Halasu (Kannada), Panasa (Sanskrit and Telugu), Kathal (Hindi), Phanas (Marathi) and Pala (Tamil) (Pradeepkumar and Kumar, 2008). Jackfruit is popularly known as poor man's fruit in the Eastern and Southern parts of India with significant contribution to the low income families as a good source of vitamins, minerals and calories (Rahman *et al.*, 1995). In Kerala, this fruit is underutilised considering its large scale production, meagre utilization in processing sector and huge post-harvest losses.

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 borne 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 regions *viz*., the lower fleshy edible region, commonly called 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).

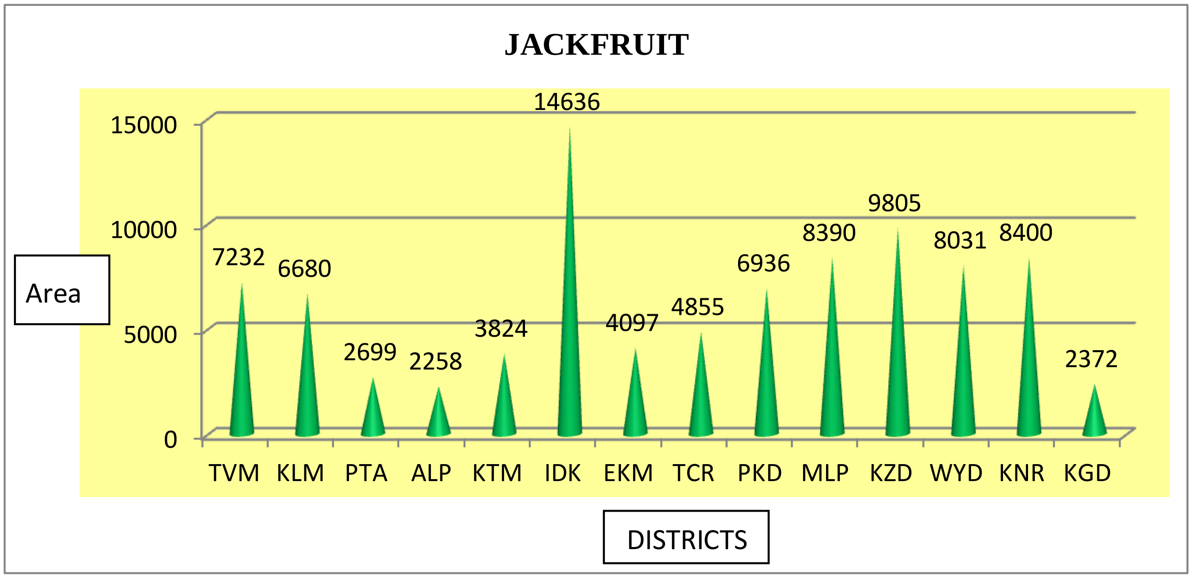

Figure 2.1 District - wise cultivated area of jackfruit in Kerala

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

The jackfruit cultivated in area of 1,02,552 ha, of which an estimated 1,00,000 trees are grown in back yards and as intercrop in other commercial crops. Kerala has the largest area of jackfruit cultivation of about 97,540 ha and production around 348 million fruits (APAARI, 2012).

Fig. 2.1 shows that, the cultivated area of jackfruit in Kerala during (2013-14) was 90,225 ha and jackfruit 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) in India	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
	STATE TOTAL	90224.95	294.234

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

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 is called *Koozha*. But *Varikka* is thick, firm, crisp and has less fragrant pulp. Thamarachakka, Nadavalamvarikka, Vakathanamvarikka, Muttomvarikka, Aathimathuramkoozha, Ceylon varikka and Thengavarikka are the main jackfruit varieties in Kerala. Konkan prolific, Ceylon jack, Hybrid jack, Burliar-1, PLR-1, PPI-1 are few important varieties introduced from the various organizations (Priya *et al*., 2014).

2.1.3 Harvesting

In Asia, depending on the climatic region, fruits ripen mainly from March-June, April-September or June-August and for some offseason crops from September-December (Morton, 1987).

Jackfruits mature 6-8 months from flowering. When mature, there is usually a change of fruit colour from light green to yellow-brown, spines are closely spaced, yield to moderate pressure and there is a dull hollow sound when the fruit is tapped (Sharma *et al*., 1997).

2.1.4 Nutritional composition

Jagadeesh *et al*. (2007) studied the chemical composition of bulbs. The study revealed that, bulbs contain total soluble solid (TSS), acidity, sugars, starch and carotenoid in jackfruit types. 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).

Table 2.2 Nutritional composition of jackfruit – young, ripe and seed (per 100 g)

Composition	Young fruit	Ripe fruit	Seed
Water (g)	76.20 – 85.20	72.00 – 94.00	51.00 – 64.50
Protein (g)	2.00 – 2.60	1.20 – 1.90	6.60 – 7.04
Fat (g)	0.10 – 0.60	0.10 – 0.40	0.40 – 0.43
Carbohydrate (g)	9.40 – 11.50	16.00 – 25.40	25.80 – 38.40
Fibre (g)	2.60 – 3.60	1.00 – 1.50	1.00 – 1.50
Total sugar (g)	-	20.60	-

Table 2.3 Vitamin composition of jackfruit

Vitamin A (IU)	30.00	178.00 – 540.00	10.00 – 17.00
Thiamine (mg)	0.05 – 0.15	0.03 – 0.09	0.25
Riboflavin (mg)	0.05 – 0.20	0.05 – 0.40	0.11 – 0.30
Vitamin C (mg)	12.00 – 14.00	7.00 – 10.00	11.00
Energy (kJ)	50.00 - 210.00	88.00 – 410.00	133.00 – 139.00

Table 2.4 Mineral composition of jackfruit

Source: [Arkroyd *et al*. (1966), Narasimham, (1990), Gunasena *et al*. (1996), Azad, (2000) and Manjeshwar *et al*. (2011)].

Total minerals	0.90	0.87 – 0.90	0.90 – 1.20
Calcium (mg)	30.00 – 73.20	20.00 – 37.00	50.00
Magnesium (mg)	-	27.00	54.00
Phosphorous (mg)	22.00 – 57.20	38.00 – 41.00	38.00 – 97.00
Potassium (mg)	287.00 – 323.00	191.00 – 407.00	246.00
Sodium (mg)	3.00 – 35.00	2.00 – 41.00	63.20
Iron (mg)	0.40 – 1.90	0.50 – 1.10	1.50

2.1.5 Post harvest utility

Jackfruit is generally consumed as raw and refined form and less than 40% of fruit is utilized as a food material and the remaining is going waste because of tedious in manual processing and time consuming process. Moreover, the latex of this fruit is also causing some hindrance during the separation of the fruit bulbs for consumption are the major reason for the underutilized fruit.

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 equipment, especially for peeler and slicer. The determination of physical properties of different fruits followed by various research workers were reviewed for the study.

2.2.1 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 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 the experiment on physical properties of potato viz., length, breadth and thickness to develop a potato peeler. Vernier calipers were used for measuring these properties.

Owolarafe and Shotonde (2004) reported the physical properties required for the designing of an okra slicer, chopper and grater. The average fruit length, width and thickness 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. In order to measure the fruit length, width and thickness digital vernier calipers (least count 2 mm) were used.

Jagadeesh *et al*. (2007) studied the important physico-chemical characters of jackfruits to determine 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 characteristics. Wide variation was observed in fruits characteristics like fruit length values from 20.50 to 60.60 cm and diameter 16.40 to 29.5 cm with the majority of the selections.

Kalita *et al*. (2014) investigated the morphological characteristics of elite genotypes of jackfruit collected from the different districts of Assam. Significant variation was observed in respect of fruit length 23.87-51.27 cm, fruit diameter 14-36 cm, core length 11.67-40.00 cm and core diameter 3.00-16.33 cm among the genotypes.

Kotoky *et al*. (2014) carried out the survey in different districts of Assam to study the qualitative traits of some jackfruit genotypes based on jackfruit descriptor described by the International Plant Genetic Resource Institute (IPGRI). The study revealed that, there was wide range of variability exists with regards to many desirable quantitative characters viz., fruit length (19.50-62.08 cm), fruit diameter (7.00-24.00 cm) and fruit rind thickness (0.30-2.00 cm) among the different jackfruit genotypes.

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.

2.3 Mechanical properties of jackfruit

2.3.1 Cutting force

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.

Ohwovoriole *et al.* (1988) determine the cutting strength to identify the necessary cutting force of unpeeled and peeled cassava tuber. During this test, cutting tool (1.5 mm thick piece of sheet metal with sharpened edge at 300 angle) was placed between the plungers of the universal testing machine. The machine subjects the samples to compression at the speed of 20 mm/min and the resulting data were used to design a cassava peeler.

Visvanathan *et al.* (1996) studied the cutting strength of cassava tuber. The study revealed that, cutting force required to cut the cassava tuber depends on angle and velocity of the knife. The specific cutting energy for cassava tubers was observed to be a minimum (6.5 kJ/m^2) at a knife bevel angle of 30-45˚, knife velocity of about 2.5 m/s and shear angle of 63-75˚.

Emadi (2005) determined the mechanical properties of different varieties of pumpkin and melon fruit to develop a peeler machine. A cutting indentor, cutter device and holder for unpeeled and skin sample were designed and built for testing cutting force of a product in threes states viz., unpeeled, flesh and skin. Sharpened edge (30˚ included angle) of stainless steel with 1.5 mm thick was used for designing and constructing the cutting indentor. Samples were prepared from the different parts of the pumpkin and melon using a cutting device and kept in the holder. The cutting indentor was fixed on the universal testing machine (UTM) which subjects a load at a speed of 20 mm/min. The study reveals that, the cutting strength of unpeeled sample of Jarrahdale, Butternut, Jap, Rockmelon, Honeydew and Watermelon was 5.15, 20.48, 10.99, 12.19, 9.55 and 10.13 N respectively whereas in skin samples, it was found as 2.82, 17.31, 9.41, 12.65, 9.96 and 10.16 N respectively.

Ambrish (2005) determine the maximum required force to cut the anola fruits, which ranged from 15.25 kg for the NA-7 varieties along the stem end side and the least requirement of cutting force was 7.43 kg for Kanchan variety along the axis of fruit.

Shamsudin *et al.* (2009) conducted the experiments on firmness of pineapple fruit at three different locations. The fruit firmness was measured using a cylindrical die of 6 mm in diameter with the Instron Universal Testing Machine (UTM). The result revealed that, force decreased with the stage of maturity from 74.79-42.93 N (top position), 62.56-37.20 N (middle position) and 57.14-36.04 N (bottom position) due to cause of ripening process and storage period.

2.3 Slicing

Slicing is a cutting process for size reduction of fruits and vegetables; it involves pushing or forcing a thin, sharp knife to shear through the material. The result gives minimum deformation and rupture of the cell wall. Chipping or slicing of jackfruit in to thin wafers of about 6.0 – 8.0 mm thick is one of the important unit operations in jackfruit processing. The quality of chips depends up on the size and uniformity of the wafers. Crispness is one of the textural characteristics which determine the consumer acceptance of the product. Crispness can be controlled by maintaining uniformity of chip thickness and proper frying.

2.4Traditional methods

The most widely practiced method of slicingjackfruit in the country is done manually by stainless steel knives to produce thin wafers.

2.5Mechanical method

Nanda (1985) developed a hand operated vertical feed cassava chipping machine consisting of two concentric mild steel drums, the annular space between which is divided into compartments for feeding the tubers. The rotating disc at the bottom of it carries the knife assembly. A pair of bevel gears is provided to operate the machine manually with a crank handle. Later on a pedal operated machine has been developed to increase the output as well as operational convenience.

Balasubramanian *et al.,* (1993) developed and evaluated a motorised cassava chipper. The machine consisting of 18 chipping discs with knives driven by a disc shaft from power source. The tubers can be vertically fed from top and chips are collected at the bottom. The capacity of the chipper is 270kg/hr. The chip recovery was assessed at 92% for 1mm chips at 295rpm.The cost of chipping were estimated at Rs.18/t.

Kachru *et al*., (1996) developed an electrically operated rotary slicer for raw banana. The horizontal type chipping machine consists of a slicer disc attached with blades. An MS shaft is used to drive the slicing disc. A stainless steel semicircular feeding chute is used for feeding the peeled banana and chips are directly discharged into the pan by the centrifugal action. It has an efficiency of 90% and produces chips of uniform thickness.

Liju (1997) developed a vertical feed mechanical chipper. The feeding mechanism has a pressing attachment which consists of a mild steel rod with a wooden end plate at disc and which is lifted up. The raw peeled banana is fed through the slots made in the feeding pipes. The pressing mechanism is then released and the rotating disc with blade cuts the banana into round slices of uniform shape and thickness. The stopper attachment on the pressing mechanism prevents the wooden end plates from damaging the plates.

Chipping efficiency of the machine is 96% and effective capacity of slicing is 223kg peeled raw bananas per hour.

Best and Kennedy (2005) described a food slicing apparatus. It consists of handle, roller and rigid blade; these are made of same/different materials. Roller and blade are rotatably mounted to the handle. Grip portion and yoke are the supporting members of handle and made of plastic and stainless steel materials respectively. One side of blade includes a cutting surface, which is a decline at an angle relative to a plane of the top surface of blade to cut the food and another side of blade was connected with rein forcing rib, which serves the reinforce blade. Therefore blade can easily slice foods of varying hardness.

Dayana Paul *et al*., (2007) develop a potato slicer which consists of feeding unit a slicing mechanism and a driving mechanism. The potatoes, fed manually in to the hopper fall by gravity in to the cylinder at the bottom dead centre of the piston. They are pushed horizontally to the stationary blade as the piston moves towards the top dead centre and thus sliced. The wooden bush on the piston helps in pushing all the slices out of blade assembly. The machine can be used to slice potatoes with minimum percent damage(about 4.02%).The slicing efficiency of the machine is 95.93%. The developed slicer can produce slices at capacity 6 times higher than manual slicing.

Sonawane *et al*., (2011) constructed a power operated rotary banana slicer suitable for small scale processing was developed. This banana slicer mainly consists of feeders for round slicing cutter, power transmission mechanism, base support and frame. The slicer has slicing efficiency of about a 93-94% with effective capacity of about 100 kg per hour.

Athira *et al.,* (2015) developed a modified rotary banana slicer which can be efficiently used in both small and large scale industries for slicing bananaswith minimum loss of material (3.4%) and quality. This banana slicer mainly consists of feed chute, rotary discs with blades, guiding rod, housing and stand, power transmission mechanism. Continuous feeding is possible through stainless steel chutes which has spring loaded curved holding plates to hold the peeled banana straightly. This mechanism ensures the slicing of the last segment of peeled banana, which otherwise will be wasted in other commercial models and manual method. Thus the mechanical damage could reduce from 13.6% in commercial slicers to 3.4% in the present model. An oil coated flexible brush always clean the cutting edge by wiping away the banana sap released through the cut surface. Modified rotary banana slicer had a capacity of 100 kg/hr with a slicing efficiency of 95.86%.

2.7 Material selection

Minimising 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.

Coady *et al*. (2000) investigated the good manufacturing and material selection in the design and fabrication of food processing equipment. The two most common grades of stainless steel used in processing equipment are 1) Type 304: most common and versatile stainless steel with excellent forming and outstanding welding characteristics. It is readily brake/roll formed into a variety of parts for equipment and post weld annealing is not required to restore the excellent performance of this grade. 2) Type 316: better resistance to corrosion and more expensive compared to type 304. Stainless steels are also identified by their surface finishes. Common surface finishes found in food processing equipment are 1) #2B: which is smooth and dull finish. 2) #4, which is general purpose polished finish. Both the finishes are considered smooth. Smoothness is important because crevices provide places for bacterial growth.

Jullien *et al*. (2002) research work was carried to identify the surface characteristics relevant to the hygienic status of stainless steel for the food industry. It was investigated by number of residual adhering Bacillus cereus spores after a complete run of soiling and cleaning in place procedure. The 14 materials tested (304, 316 and 430 grades; pickling (2B), bright annealed (2R) and electropolished finishes) were shown to be highly hygienic with slight differences in adhering spores. However, tested materials were grouped into different classes according to their hygienic status.

Jellesen *et al*. (2006) reported the literature on metal release in the food industry. Stainless steel was the most widely used metallic material in the food industry. Examples of food products with a corrosive effect and cases concerning processes, storing equipment as well as cleaning and sanitising procedures were reviewed.

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.

MATERIALS AND METHOD

Chapter III

MATERIALS AND METHODS

The fabrication procedure of the jackfruit bulb slicer machine, the details of the components and the procedures adopted for evaluation are described.

3.1 Raw material

Mature jackfruits were taken for the performance evaluation of the jackfruit bulb slicer. The jackfruits were collected from KCAET farm. Both the varieties,*ie*., *koozha* and *varikka* were used and was harvested after 6 to 8 months from flowering. The harvest indicators werechange of fruit colour from light green to yellow-brown, and there is a dull hollow sound when the fruit is tapped. The fruits which were within the reach was harvested using a sickle and that from tall trees, a sack is placed on the fruit with a rope tied on the peduncle and it is then lowered down to the ground.

3.2 Study of the existing methods for development of slicer

Prior to the development of jackfruit bulb slicer, the existing methods used for slicing of fruits and vegetables were analysed.

3.3 Development of model

A detailed drawing of the proposed Model I was made and the machine was fabricated usingthe engineering drawing. The machine consists of a feed conveyor belt through which the jackfruit bulbs were fed to the rotating cylindrical blades.However it resulted in improper cutting of the bulbs due to lack of contact time between the jackfruit bulbs and blade. Therefore, to make it more effective, a second model was fabricated (Model II) for uniform slicing of jackfruit bulbs. To develop the Model II, detailed engineering drawings were made. The drawings are shown below.

Plate 3.1 - Model I- Jackfruit bulb slicer

3.4 General layout of the developed mechanical slicer

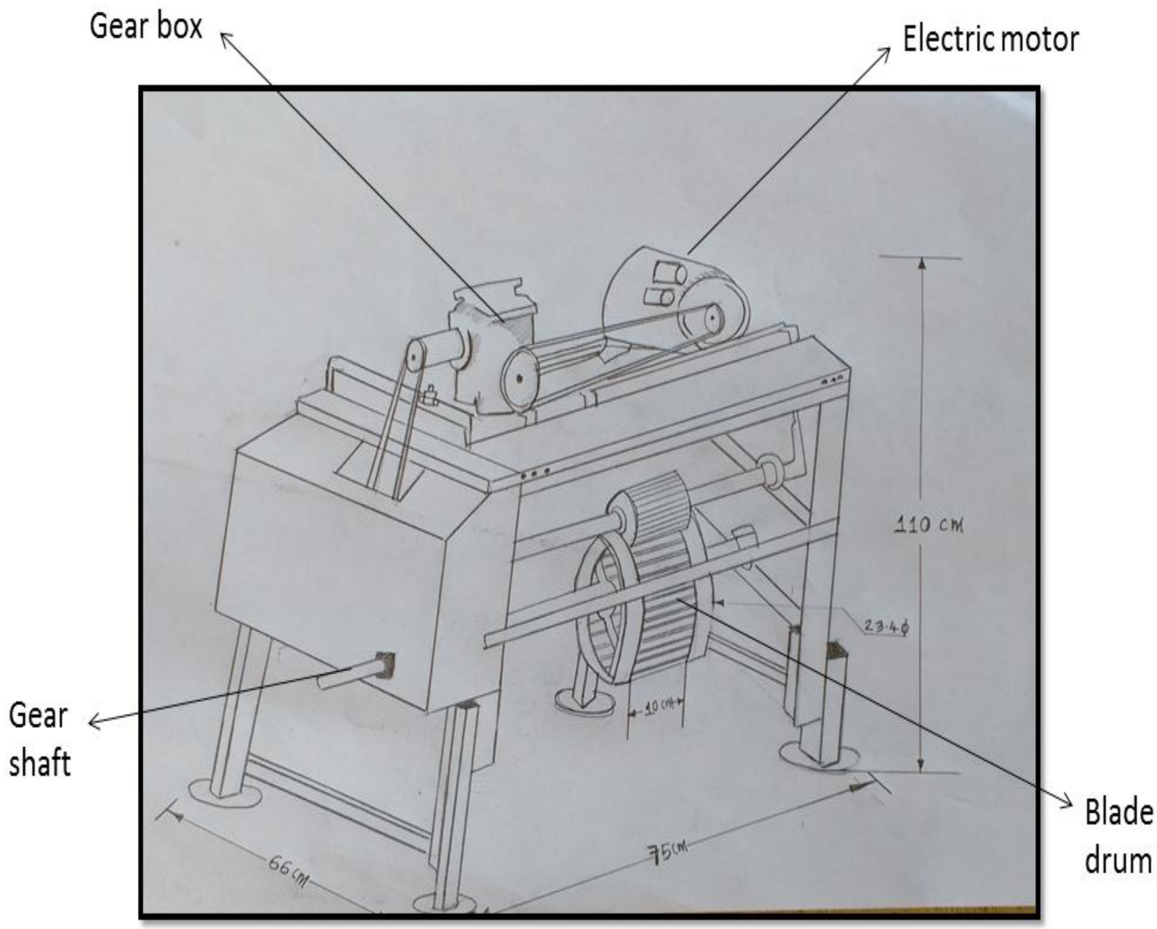

Fig 3.1 Front view of jackfruit bulb slicer

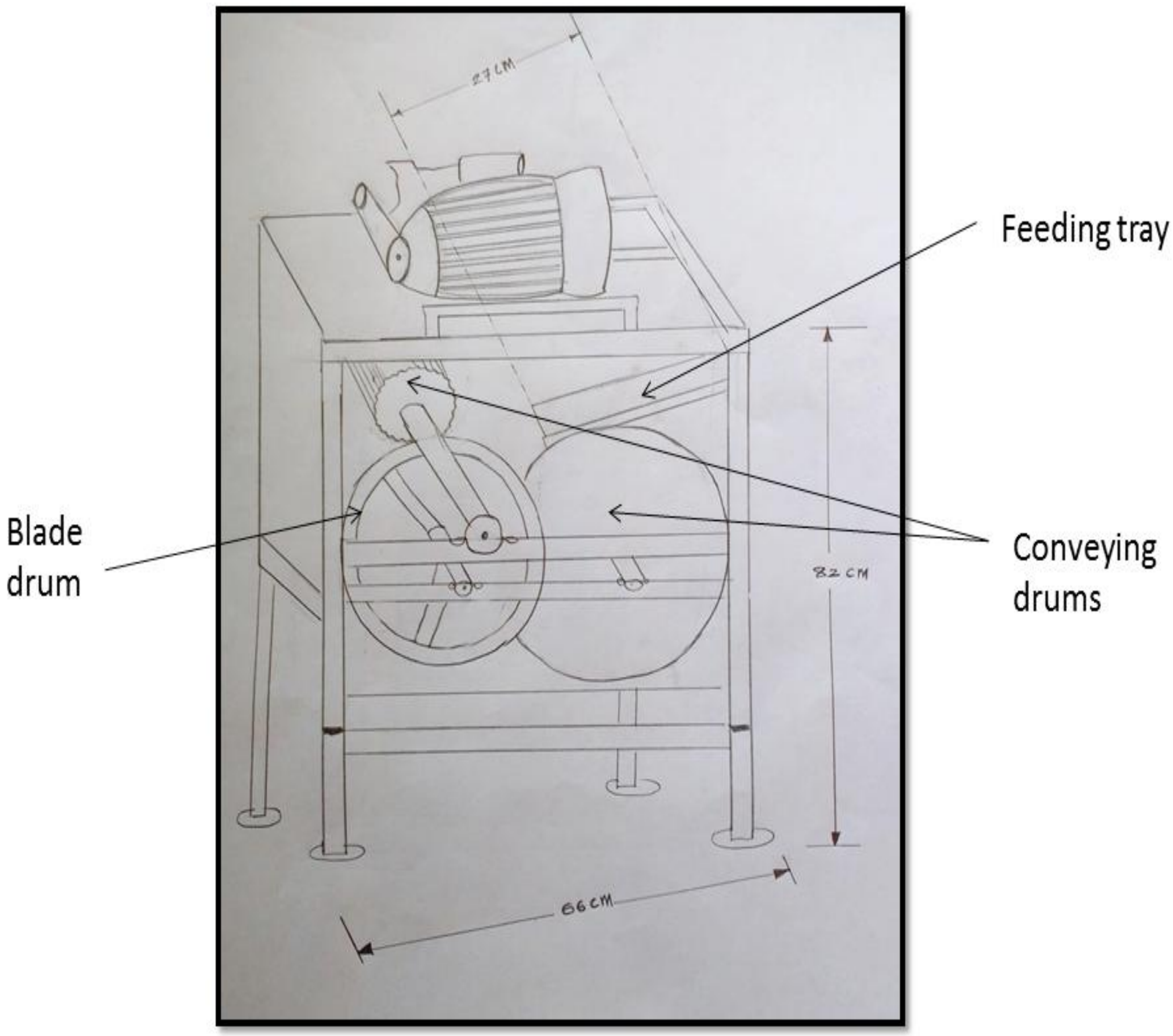

Figure 3.2 Side view of Jackfruit bulb slicer

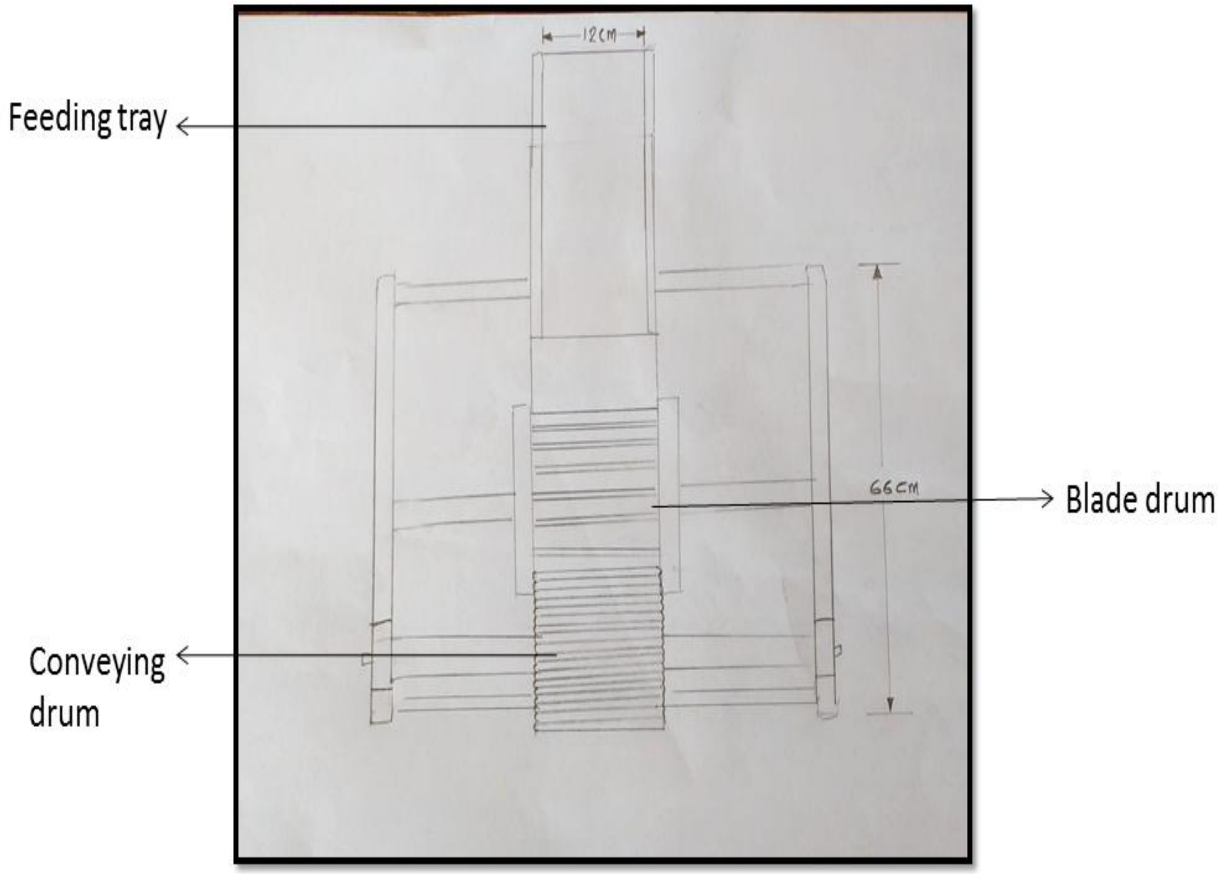

Fig. 3.3 Top view of Jackfruit bulb slicer

Plate 3.2 - Model II- Jackfruit bulb Slicer

3.5 Main parts

Frame assembly

The frame supports the entire machine component to perform its operation satisfactorily. It was fabricated using mild steel. On to this frame assembly, units like feeding tray, transmission system, blade drum and conveying drums were mounted. The overall dimension of the frame assembly was 730 x 660 x 1100 mm where the values corresponds to overall length (mm), overall width (mm) and overall height (mm) of the machine respectively.

1. Electric motor

The primary function of motor is to convert electrical energy to mechanical energy. A 1 hp motor was used to supply power to the transmission box and it gives a speed output of 1500 rpm to the gears. The electric motor was mounted above the frame assembly.

2.Blade drum

A hollow cylindrical blade drum of 23.4 cm diameter was used which consist of 88 SS blades. The length of each blade was 10 cm. The blade was made of stainless steel. The bulbs that were fed comes in contact with the uniformly spaced blades and thereby results in uniform slices due to the cutting action.

3. Conveying drums

Two types of solid cylindrical conveyor drums were used. The drums were of varying diameter with larger drum having diameter of 24 cm and length 12 cm and smaller drum having diameter of 7 cm and length 10 cm. The drums were made out of nylon material. Conveying drums along with the blade drums resulted in uniform jackfruit slices. The drums helped the jackfruit bulbs to be intact with the blade drum for the proper slicing and the drum provided required shearing force.

4. Feeding tray

A feeding tray was provided for feeding bulbs in between conveying and blade drums. The length of the tray was 29 cm and the width was 12 cm. The tray used was slightly inclined towards the blades so that the bulbs that were fed would slide in between the conveying and blade drums. It was made out of stainless steel grade SS304.

3.6 MACHINE CALIBRATION

3.6.1Tachometer

Tachometer is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. A tachometer (Model-DT-2235) of was used for measuring the rotational speed of the developed machine. Reading was rotated in rpm in a calibrated analogue dial. Tachometer readings for the blade drums was 20 rpm and for the conveying drums 20 rpm and 40 rpm respectively.

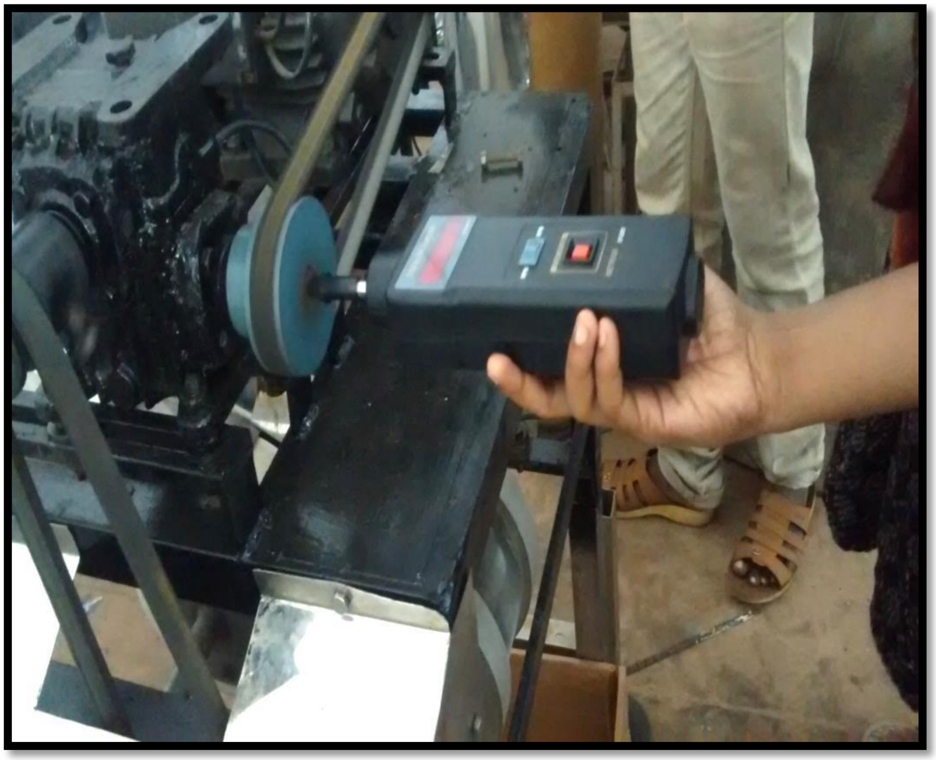

Plate 3.3 - Tachometer

3.6.2Energy meter

An energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device. The jackfruit bulb slicer was connected to the energy meter (Model-SPEM 01) to measure the energy requirement and the readings were measured in kWh. The energy requirement was calculated by operating the jackfruit bulb slicer machine for 5 minutes and it was 0.03kWh. This value was then converted for a 1 hour reading and it was 0.36 kWh.

Plate 3.4 – Energy meter

3.6.3 Digital calliper

A digital calliper is a precision instrument that used to measure internal and external distances extremally accurately. The sliced jackfruit bulbs were randomly selected to measure the thickness. The entire sliced bulbs were divided into 100 g samples and from each 100 g sample 10 number of slices were selected and measured using the digital calliper (Model-KM-DSK150). The end portion thickness and middle portion thickness were calculated. The readings were measured in mm. The average thickness of sliced bulbs were 7$\pm$ 0.62 mm.

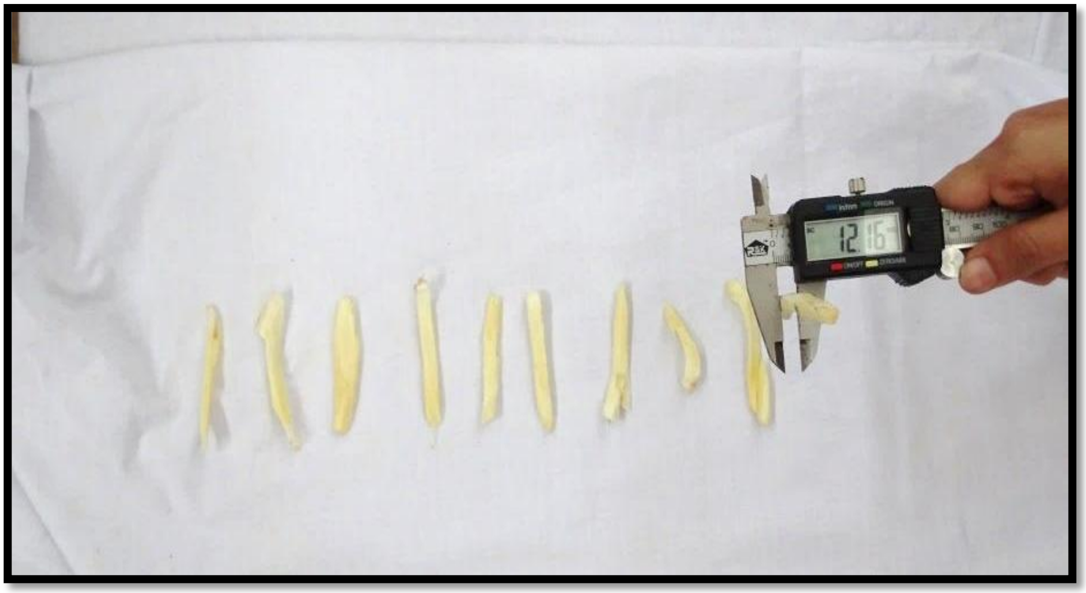

Plate 3.5 – Digital Calliper

3.7 Working method

The bulbs were fed continuously through the feed tray. The electric motor supplies power for the working of gears which in turn rotates the conveyor drums and blade drum. The principle of working was cutting and shearing action. The bulbs that gets entrapped in between the conveyor and blade drums gets sliced. The blades were arranged in such a way to get uniform thickness for the slices. The sliced bulbs were then collected beneath the blade drum.

3.8 Comparison between traditional and mechanical method

3.8.1Traditional method:

Plate 3.6 Traditional method of jackfruit bulb slicing

Jackfruit is a common tropical fruit. Jackfruit and its product are thought to have used by the people from ancient times. Peeling and slicing of the fruit were done manually. The common tools used were knife and sickles. It was a time consuming and labour intensive work. The process of cutting and slicing was drudgerous. Thus, this method cannot be used for any industrial purposes. It requires no or less capital investment.

3.8.2 Mechanical method:

Plate 3.7 Mechanical method of jackfruit bulb slicing

Mechanical method helps in making the work much easier than manual method. By the principle of cutting and shearing action the bulbs were easily sliced due to the action of blades incorporated. It is a time and labour saving operation. It helps in reducing drudgery to a great extent. So, the machine can be widely used for industrial purposes. It requires capital investment.

3.9 Performance evaluation

Jackfruits of proper maturity bought from the KCAET farm was used for conducting experiment. The jackfruits were peeled and cored mechanically using a peeler cum corer machine. The slicer machine was then turned ON, as the blade drum attained a set speed of 48 rpm, raw jackfruit bulbs (deseeded bulbs) were fed into the gap between blade drum and the conveying drum. The time taken for slicing these known amount of jackfruit bulbs was noted and operating capacity, slicing efficiency, percentage damage and sample thickness variance of middle and end portion of sliced bulbs were then evaluated.

3.9.1 Overall capacity (OC)

The operating capacity of the fabricated slicer was calculated by weighing the sliced jackfruit per unit time.

3.9.2Slicing efficiency (η)

Efficiency of jackfruit bulb slicer was evaluated by weighing the damaged and round slices separately and using the following expression,

$$\text{Slicing efficiency, } \eta = \frac{\text{Weight of all slices} - \text{Weight of damaged slices}}{\text{Weight of all slices}} \text{ X } 100$$

3.9.3 Percentage damage (%D)

The percentage damage of the slicer was evaluated using the expression,

$$\text{Percentage damage, } \%D = \frac{\text{Weight of damaged slices}}{\text{Weight of all slices}} \text{ X } 100$$

3.9.4 Effective capacity (EC)

After having noted the efficiency and overall capacity of machine, the effective capacity was found out by the expression.

$$EC = \frac{OC \times \eta}{100}$$

3.9.5 Sample variance (S^2)

The variance of the middle and end portion thickness of sliced jackfruit bulbs was evaluated by the expression,

$$S^2 = \frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}$$

3.10 Comparative evaluation of the jackfruit bulb slicer and commercial slicer

Performance of the developed jackfruit bulb slicer was compared with that of commercial slicer (Model- Balakrishna slicer, Coimbatore).

Plate 3.8-Jackfruit bulb slicer

RESULTS AND DISCUSSIONS

Chapter IV

RESULTS AND DISCUSSIONS

This chapter deals with the result of experiments conducted to evaluate the performance of the developed jackfruit bulb slicer compared to other commercially available slicers.

4.1 Performance and Evaluation of Jackfruit bulb slicer

The fabricated machine was evaluated for its overall capacity, slicing efficiency, percentage damage, effective capacity and thickness variance (middle and end portions).

4.1.1 Overall capacity

For the determination of overall capacity of jackfruit bulb slicer, trials were conducted with *varikka* and *koozha* varieties of jackfruit. When the trials were conducted using *varikka* variety weighing 3.257 kg and 5.500 kg, the overall capacities were found to be 50.11 kg/hr and 51.48 kg/hr respectively, while *koozha* variety weighing 5.000 kg gives an overall capacity of 51.48 kg/hr. The average of the overall capacity was found to be 50 kg/hr. The results are shown in the table 4.1.

The fruits of *varikka* has a firm texture and exudes an aroma whereas the fruits of *koozha* were more fibrous, soft in texture and highly perishable. From the trials conducted, *varikka* variety shows higher capacity compared to the *koozha* variety. This result was in accordance with the findings of Priya *et al. (2014).*

Table 4.1: Overall capacity of the jackfruit bulb slicer

SL.NO.	Weight of jackfruit bulbs (kg)	Time taken for slicing (min)	Overall capacity (kg/hr)
1	3.257 (*varikka)*	3.900	50.11
2	5.000 (*koozha*)	6.190	48.46
3	5.500 (*varikka*)	6.413	51.48
Average			50.0

Table 4.2 – Characteristics of sliced bulbs per 100g

Sample	Number		
	Good	Damage	Small
1	26	11	23
2	24	8	10
3	30	10	15
4	27	5	10
5	22	8	9

4.1.2 Slicing efficiency

For the determination of slicing efficiency, 5 samples each of 100 g sliced bulbs were taken. Observations were made on weight (g) basis and number basis with criteria good, damage and small. The slicing efficiency of the machine was calculated using the formula given in 3.9.2. The slicing efficiency was found to be 90%. Among the two varieties of jackfruit, *varikka* shows more slicing efficiency compared to *koozha*, because the fibre arrangement was more firmer in *varikka*. The results were similar to those of Kachru*et al*. (1996) on electrically operated rotary slicer for raw banana. The results are shown in table 4.3.

Table 4.3 Slicing efficiency of the jackfruit bulb slicer

Weight of all slices (g)	Weight of damaged slices (g)	Slicing efficiency (%)
100	12 (*koozha)*	88
100	10 (*koozha*)	90
100	7 (*varikka*)	93
100	13*(koozha*)	87
100	8*(varikka*)	92
Average		90

4.1.3 Percentage damage

The percentage damage was obtained based on observations collected from 5 samples of 100 g each. This value was calculated on weight basis. The damage of the machine was calculated using the formula 3.9.3. The average percentage damage was found to be 10%. Dayana Paul *et al.* (2007) reported a potato slicer shows minimum percentage damage of 4.02%. The results are shown in table 4.4.

Table 4.4 Percentage damage of the jackfruit bulb slicer

Weight of all slices (g)	Weight of damaged slices (g)	Percentage damage (%)
100	12	12
100	10	10
100	7	7
100	13	13
100	8	8
Average		10

4.1.4 Effective capacity

The effective capacity of the machine was calculated from overall capacity (kg/hr) and slicing efficiency (%) using the formula 3.6.4.The effective capacity was found to be 45 kg/hr. The results are shown in table 4.3.

Table 4.5: Effective capacity of the jackfruit bulb slicer

SL.NO.	Overall capacity (kg/hr)	Slicing efficiency (%)	Effective capacity (kg/hr)
1	50	90	45

4.1.5 Sample variance

For the determination of sample variance of sliced jackfruit bulbs, 10 randomly selected samples were taken. The thickness of the slices at end and middle portions were measured using a digital caliper. The average thickness of slices was found to be 7.62 mm. The variance of the end and middle portion thickness of sliced jackfruit bulb slices was evaluated using the formula 3.9.5.and are found to be 0.8331 and 3.3968 respectively. The thickness of sliced jackfruit bulbs at end and middle portions results are shown in table 4.4.

Table 4.6 - Thickness of slices

Sample	End (mm)	Middle (mm)
1	7.19	7.21
2	7.89	7.83
3	9.57	12.99
4	7.02	6.65
5	6.38	7.31
6	6.84	6.83
7	7.22	6.22
8	8.58	7.86
9	7.62	7.27
10	7.54	6.55

4.2 Performance of commercially available slicer

A commercially available motorized vegetable slicer was chosen for slicing jackfruit bulbs. The machine consists of 18 chipping discs with knives driven by a disc shaft from power source. Vegetables could be vertically fed from top and the chips were collected at the bottom.

The jackfruit bulbs were fed to this slicer. But the slicing efficiency was very poor since the produce obtained was in powdery form. Hence this slicer cannot be used for the jackfruit chips industry.

Plate 4.1- Sliced jackfruit bulbs in commercially available vegetable slicer

4.3 Commercial potentiality of the developed jackfruit bulb slicer

This was the first slicer model developed for the slicing of jackfruit bulbs which holds a key role in jackfruit based entrepreneurship especially for women entrepreneurs. The developed slicer can also be used for the slicing of various vegetables such as carrot, cassava, potato, raw banana etc.

Plate 4.2- Sliced vegetables in jackfruit bulb slicer

SUMMARY AND CONCLUSONS

Chapter V

SUMMARY AND CONCLUSIONS

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

At present, demand for jackfruit is increasing day by day owing to its availability, medicinal value and nutritional composition. Sensitised growers, entrepreneurs and volunteers may focus more on jackfruit value added products. But traditional manual peeling, coring, cutting and slicing is time consuming and labour intensive process. Moreover, the latex of this fruit also causing hindrance during separation of fruit bulb for consumption. The tedium in manual processing is the major reason for the underutilisation of this fruit. Considering these aspects, a study was undertaken to develop a jackfruit bulb slicer.Thus, effective mechanisation for this process is a need of the hour.

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.A preliminary survey in the areas of intensive chips making revealed that commercial scale slicing of jackfruit was done manually by stainless steel scouring knives. This conventional method poses danger to operator's finger by inflecting injury. Also, the frying quality of the chips depends greatly on the uniformity of the wafers. The existing method does not produce chips of uniform size.

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 over the blade drum. The developed slicer could produce slices at capacity two to three times higher than manual slicing. This machine produced uniform sized slices. The machine requires one person to operate. It is simple in construction and operation and therefore technically feasible and economically viable. The capacity of this machine was 50 kg/hr. The fabrication cost of the machine was about Rs 30,000/- and the total operating cost of the machine for 1 hour was calculated using fixed cost and variable cost method as Rs 65.981/ hr. This can also be used as a multipurpose slicer. Modifications of the machine can further improve the performance. Some suggestions that may help future research work are given below:

1. The machine could be equipped with a continuously feeding unit.
2. Blade set could be made adjustable so that slices of required size can be obtained.
3. By incorporating different type of blade assembly the machine could be used for different types of vegetables in various shapes.
4. The capacity of the slicer may be improved by increasing the width of the feeding and cutting/slicing drum.

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APPENDICES

APPENDIX I

CALCULATION OF OPERATING COST

Initial cost (C)

Fabrication cost of mango jackfruit bulb slicer machine including cost of material

= Rs 30,000/-

Average life of machine	=	8 years
Working hours per year	=	2400
Salvage value	=	10% of initial cost

A) Fixed cost

1. Depreciation	=	C- S/L x H
	=	30000-3000/ 8 x 2400
	=	1.406/ hour
2. Interest on investment at 12%	=	(C +S) x 12 /(2x H)
	=	(30 000+ 3000) x 12/(2x 2400 x 100)
	=	0.825/ hour
Total fixed cost	=	depreciation+ interest on investment at 12%
	=	0. 825+ 1.406
	=	2.231/ hour

B) Variable cost

1. Labour wages		
Wages of a labour	=	Rs 500 / 8 hour
	=	Rs 62.5/hour
2. Repair and maintenance cost		
@ 10% of initial cost per annum	=	(30000 x 10)/ (2400 x 100)
	=	1.25/ hour
Total variable cost	=	63.75/ hour
Total operating cost	=	Total fixed cost + total variable cost
	=	63.75 + 2.231
	=	65.981/ hour

ABSTRACT

DEVELOPMENT AND EVALUATION OF JACKFRUIT BULB SLICER

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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

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2017

ABSTRACT

Traditional methods of jackfruit chips making involves four major units operations namely peeling of fruits, cutting of fruits into slices, frying and packaging. Each of these unit operations are done manually especially due to the lack of appropriate mechanical system. At present the chips are made by cutting and slicing raw jackfruit by knife and then deep frying in edible oil. The method is unhygienic and does not produce chips of uniform thickness and may cause injury to the person while slicing. But still the manual method of slicing is widely used due to the lack of efficient mechanical slicers. Hence there is a need to develop a new model of jackfruit slicer which can compete with manual slicing both in speed and quality. The new slicer can be efficiently used in both small and large scale industries for slicing jackfruits with minimum loss of material (10.0 %) and quality. It is a user-friendly machine capable of slicing jackfruit at uniform thickness. Continuous feeding is possible through stainless steel feeding tray which hold the peeled jackfruit bulb, which is then fed in between the blade drum and the conveying drum. The new slicer could be efficiently used in both small and large scale industries for slicing jackfruits with enhanced capacity of 50 kg/hr. T The fabrication cost of the machine was about Rs 30,000/- and the total operating cost of the machine for 1 hour was calculated using fixed cost and variable cost method as Rs 65.981/ hr. This can also be used as a multipurpose slicer.