DEVELOPMENT AND PERFORMANCE EVALUATION OF A SEMI-AUTOMATIC PINEAPPLE PEELING MACHINE

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2017

DECLARATION

We hereby declare that this thesis entitled **"DEVELOPMENT AND PERFORMANCE EVALUATION OF A SEMI-AUTOMATIC PINEAPPLE PEELING MACHINE"** is bonafide record of research work done by us during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date: 27/02/2017

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CERTIFICATE

Certified that this project report entitled **"DEVELOPMENT AND PERFORMANCE EVALUATION OF A SEMI-AUTOMATIC PINEAPPLE PEELING MACHINE"** is a record of project work done jointly by Abdul vahid P (2013-06-001), Anjali A V (2013-06-002),Anjitha P K (2013-06-003),Arunkrishnan A (2013-06-004),Neethu K P (2013-06-005) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship ,fellowship to them.

Tavanur
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Abdhul vahid P

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DEDICATED TO OUR

BELOVED

GUIDE AND PARENTS

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LIST OF SYMBOLS AND ABBREVIATIONS

=	Equal to
&	And
/	Divided by
X	Multiplication
%	Percentage
Agric.	Agricultural
CFTRI	Central Food Technological Research Institute
Cm	Centimeter
DAS	Diameter adjusting system
DC	Direct current
Engng	Engineering
et al.	and others
F APE	Food and agricultural process engineering
Fd	Food
g	Gram
GP/GS	Galvanized pipe
Ha	Hector
HCl	Hydrochloric acid
Hp	Horsepower

Hr	Hour
ie.	That is
Ind.	Industry
Int.	International
J.	Journal
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
IU	Inernational Units
M	meter
Mm	Millimeter
MS	Mild steel
MSD	Muscular skeletal disorder
MT	Metric tonne
No.	Number
Nutr.	Nutrition
pp.	Page number
Res.	Research
Rpm	rotations per minute
RTS	Ready to serve
Rs	Rupees
s	Second
Sci.	Science

Sl	Serial
Stud.	Studies
Technol.	Technology
TSS	Total soluble solids
USA	United States of America
V	Volt
W	Watts

CHAPTER 1

INTRODUCTION

Fruit plays an important role in human diet. Fruits are required for balance diet and good health. Nutritionist advises to take 60 to 85 g of fruit per day in addition to cereals and pulses. Fruits are good source of vitamins and minerals without which human body cannot maintain proper health and develop resistant to disease. Fruit also contain pectin, cellulose, fats, protein etc.

The global production of fruits was 37.5MT in 2014. During the past 15 years china had become largest producer of fruit that is about 83.24 MT in the world. It contributes to 16% share in production. India holds second position of fruits about 49 MT and it contributes 10% to global production. Brazil is third largest producer with 36 MT & contributes 7% to global production. The other countries in top 10 are USA (51%), Italy (4%), Spain (3%), and Mexico (3%). India holds first position in Mango, Banana, Litchi, Papaya, Pomegranate and Sapota production, second place in Lime and Lemon and sixth place in pineapple production of world (Anon., 2017 a).

India's divers' climate ensures availability of all varieties of fresh fruits. It ranks second in fruits production in the world, after China. As per national horticultural database published by national horticultural board, during 2014-15 India produce 86.602 million metric tonnes of fruits. The area under cultivation of fruits stood at 6.110 million hectares. Our country accounts 10 % to total global production. India exports about 90 % of fresh fruits to West Asia and East European markets. Pineapple is one of the commercially important fruits crop of india holding 6^{th} position in productivity and contributes 8 % to world production. It is cultivated

about 84000 ha about a production of 1341000 tones. It is abundantly grown in West Bengal, Kerala, Karnataka, Bihar, and Maharashtra with maximum area in Assam (Anon., 2017 b).

Pineapple (*Ananas Cosmosus*) belongs to bromilaceace family is considered as the major fruit grown in kerala. The total area and production of pineapple in kerala is 12579 ha and 314475 tons (vazhakulam pineapple. 2013). The major component of pineapple is water (86 g/100g). It also contains vitamins like vitamin C, vitamin B1, vitamin B6. dietary fibers like pectin, sugar, minerals like copper, potassium etc. The major vitamin present is vitamin C which is the primary water soluble antioxidant of our body. A group of sulfur containing proteolytic enzymes (bromelain) present in pineapple aid digestion. The fresh pineapple rich in bromelain can be used for meat tenderization. It also has some anti inflammatory properties and anti clotting properties. Daily consumption of pineapple helps to fight against arthritis, indigestion, and worm infection. Presence of vitamin A helps in maintaining healthy mucus membrane, skin and vision. The presence of copper and potassium helps in red blood cells synthesis and controlling the blood pressure, respectively (Anon., 2017 c).

The pineapple had become one of the main fruit items that generate profit in the market due its nutritional benefits. In every processing industry peeling process is done manually by the workers. The manual peeling process is done by using bare hands and knifes just like we are doing at home. Peeling is one of the most crucial parts in processing of a pineapple and it needs lot of force and muscle usage due to its thick skin, also there is chance for human drudgery. In case of pineapple peeling the workers forced to take repetitive movements. Which involve mainly the upper body part thus making the body vulnerable to back pain and other MSD symptoms for

workers. The most infected part is known as the carpel. If the processing duration increased the body part might not be able function well according to its usage. Pineapple peeling is time consuming and labour intensive (Mohamed, 2010).

In Kerala there are a lot of small scale pineapple processing industries, but the lack of proper equipments for peeling leads to an inefficient processing. The available literature and visit conducted to various pineapple processing industries in Kerala revealed that there exist no viable equipments for the peeling of pineapple. A Gineca machine and manual pineapple peeling, coring and slicing equipment were reported earlier but their working is much complicated and cause larger material loss in pineapple and also costly. So these machines are not being adopted for the use by the small scale processors of Kerala.

Considering the above constrains an attempt was undertaken at K.C.A.E.T Tavanur, to develop a user friendly pineapple peeler with the following objectives

1. To study about the physical properties of pineapple
2. To develop a user friendly pineapple peeler
3. To evaluate the performance of fabricated machine

CHAPTER 2

REVIEW OF LITERATURE

The literature pertaining to the design, cultivation, scenario, benefits and processing equipments of pineapple is presented in this chapter

2.1 ORIGIN AND AGRONOMICAL ASPECTS

Pineapple (*Ananas Cosmosus*) belongs to Bromilaceace family is one of the choicest fruit of the world owing of its characteristics pleasant flavor, aroma, sweet juicy and seedlessness and it is described as the "queen of fruits". Pineapple is indigenous to Brazil although it is spread to other tropical parts of America. By the time of Columbus, it was took in it to Europe and also brought to India by Portuguese in 1548.

It is a humid tropical plant which can grow well in both plain and elevations not exceeding 900m. It tolerates neither very high temperature nor frost and it grows in almost all type of soil provided it is free draining. It is tolerate to drought because of their water storage cells. In India pineapple is grown in Assam, Kerala, West Bengal, Tripura, Meghalaya, Bihar and Karnataka (Anon., 2017d).

The rainy season is best time for planting. The field is prepared by ploughing, harrowing, etc. before planting. Pineapple is cultivated in level ground, flat beds and ridges or in deep trenches. Trenches ensure moisture conservation but labour intensive operation. It can be grown as pure crop on plantation scale or as intercrop in coconut garden. (CFTRI, 1985)

The pineapple is a perennial herbaceous plant, whose root system remains close to the surface and reproduced vegetatively. The sprouts (or slips) produced by the plant after fruit-bearing are used for replanting. The crowns can also be used for the plant reproduction, but this process is slower and less productive. While in the natural state the pineapple can produce several fruits over successive production cycles. Industrial production requires new plant stock to be planted after each production cycle. Depending on climatic conditions and the varieties, a cycle extends on average over 14 to 20 months with three stages:

- sprouts planted and grown (6 to 7 months)
- flowering until harvest (5 to 6 months)
- sprout production for replanting (3 to 6 months) (Anon., 2016).

The pineapple is technically called a sorosis "a fusing of many fruit together to form one unit". Each "eye" (fruitlet) is a complete fruit. Flowering starts at the bottom of the sorosis and continues up as a spiral to the last eye. When the formation of fruitlets stops, the growing point reverts to a vegetative state and the top (crown) is formed. A good induction will ensure a large number of fruitlets are formed which, with good cultural care, all will fill out to give a well-shaped, high-yielding fruit. Because ripening of the fruitlets follows the same pattern as flowering, the bottom portion of pineapples is riper, sweeter and has better flavour than the top (Anon., 2017e).

2.2 VARIETIES

As many varieties of pineapple are cultivated all over the world. The most important commercial varieties are Kew, Giant Kew, Smooth Cayenne, Sarawah and

Mauritius. But in Indian only the exotic varieties like Kew, Queen and Mauritius are cultivated on commercial basis. There also some indigenous types, the prominent ones and Jaidoop and Lakhat grown in Assam and Simhachalam grown in Vishakhapatnam (Anon., 2017f).

Kew is a late maturing variety and is the leading commercial variety in India, ripening in August and September. It is valuedparticularly for its canning quality. Fruit weighs 2-3 kg, oblong in shape, and it's the biggest among all other varieties under cultivation. It is slightly tapering towards the crown. Eyesare broad and shallow making fruits more suitable for canning. The fruit is yellow whenfully ripe and flesh is light yellow, almost fibreless, and very juicy with 0.6-1.2% acid,and its TSS content varies from 12-160 ^{0}Brix (Anon., 2017f).

The queen isan old cultivar and is grown mainly in Australia, India and South Africa, where it is cultivated fortable and processing purpose. It is also an early fruiting variety ripening in June-July. Fruit weighs 1-1.5 kg. When fully mature, fruit is golden-yellow andinternal flesh is deep golden-yellow. The flesh, although less juicy than Cayenne and is crispy with apleasant aroma. Acidity ranges between 0.6 and 0.8% while the TSS is 15-16^{0}Brix.

Mauritius is grown in some parts of Meghalaya and Kerala in India. Fruits are of medium size and are of 2 types, deep yellow and red skinned. Fruits of yellow variety are oblong, fibrous, and medium sweet comparedto red type. Mauritius is exclusively grown for table purpose; leaves are yellowish green, spinythroughout the margin, crown also is spiny in both the types. It is a mid season cultivar, ripens in July-August (Anon., 2016).

Jaldhup and Lakhat are two local types, both being named after the places of their maximum production. Thevarieties are cultivated for tableas well as processingpurpose. Both fall in Queen Group of fruits,being smaller than 'Queen'. Jaldhup has its sweetness well blended with acidity. Fruits of Jaldhup have a characteristic alcoholic flavor of their own and can be easily distinguished from other fruits of the Queen group (Anon., 2016).

Kew is leading commercial variety grown in India. It is valued particularly for canning quality. Queen is next to Kew in the matter of production followed by the Mauritius both being extensively used for the table. Pineapple usually flowers from February to April and the fruit are ready from July to September. Off season flowers produce frits in September to December. The fruit are being harvested when they just began to turn yellow, the eyes become full and bracts wither. The fruit are harvested between 115-130 days after flowering they better suited for canning as they give maximum yield and minimum wastage. Sharp knives are used for harvesting the fruit retaining 5-7 cm of stalk (Anon., 2016).

The yield depends on the plant population per hectare. A plant population of 35000-40000/ha, yields about 40-50 tonnes whereas the yield varies normally between 50-60 tones with a plant population, up to 63,758 plants/ha. The yield could be increased nearly six times than obtained from conventional methods without adversely affecting size and shape. Grading of pineapple fruit is done on the basis of size, shape, maturity and freedom from disease and pest. The fruit may be packaged individually or wrapped in groups by using paddy straws (pineapple –an industrial profile, CFTRI, 1985)

2.3 GLOBAL SCENARIO

. The demand for pineapple is increasing day by day. The pineapple is globally sold as 50% fresh fruit, 30% as canned fruit and 20% as fruit concentrate. The global trade for pineapple has increased 100% in past one decade. The worldwide production of Pineapple is around 24.8 million tons in 2014. The Costarica is the major producer of pineapple followed by Brazil, Philippines, Thailand, Indonesia, India and China. The major exporters are Costarica, USA, Belgium, France, Italy, and Germany. The worldwide production of Pineapple from 2002 to 2014 is given in Fig.2.1

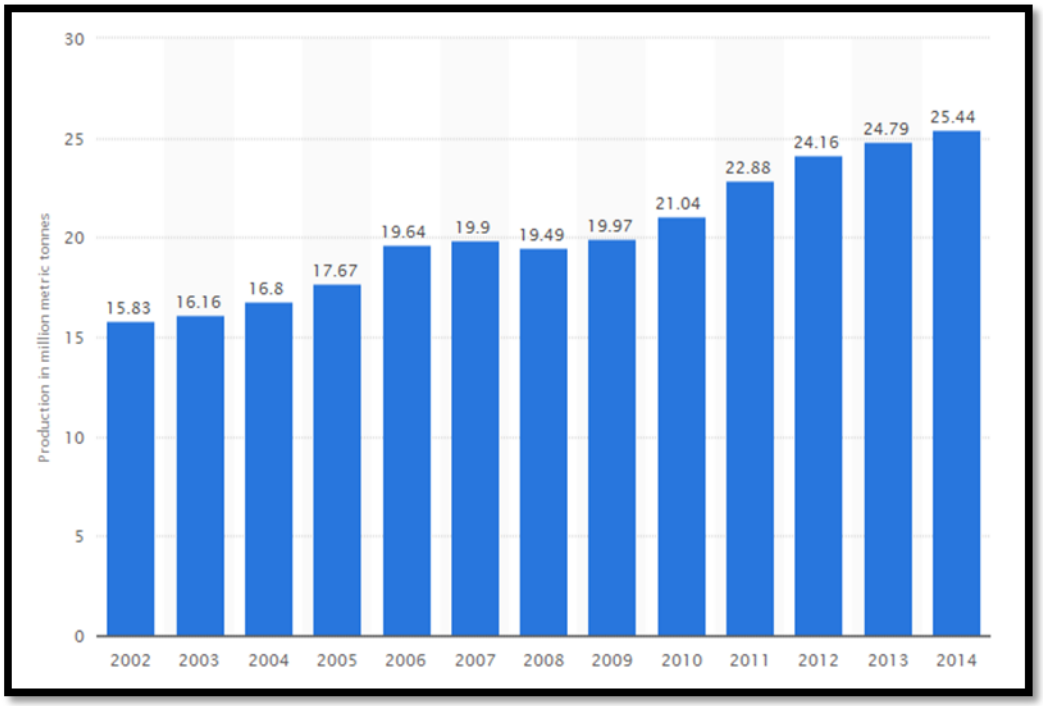

Fig.2.1 World wide pineapple production from 2002-2014 (in million metric tonnes)

(Source:global pineapple production statistics,2014)

Costarica is the biggest producer of pineapple approximately 2,916 thousand metric tons every year. The country have perfect environment for the growth of pineapple. The cultivating are of pineapple is 1112,000 acres. The second largest producer is Brazil. The annual production rate is 2,483,830 tones. Due to the high temperature environment produce sweeter pineapple. Next on the list are the Philippines, with an annual production rate of 2, 45820 tones, in 172,947 acres. The other leading pineapple producer countries are Thailand (2,209,350 tones), Indonesia (1,837,160 tones), India (1,571,000 tones), Nigeria (1,420,000 tones), china (1,386,360 tones), Mexico (771,940 tones), and Colombia (643,040 tones).The leading countries in pineapple production, worldwide in 2014 are given in Fig.2.2.

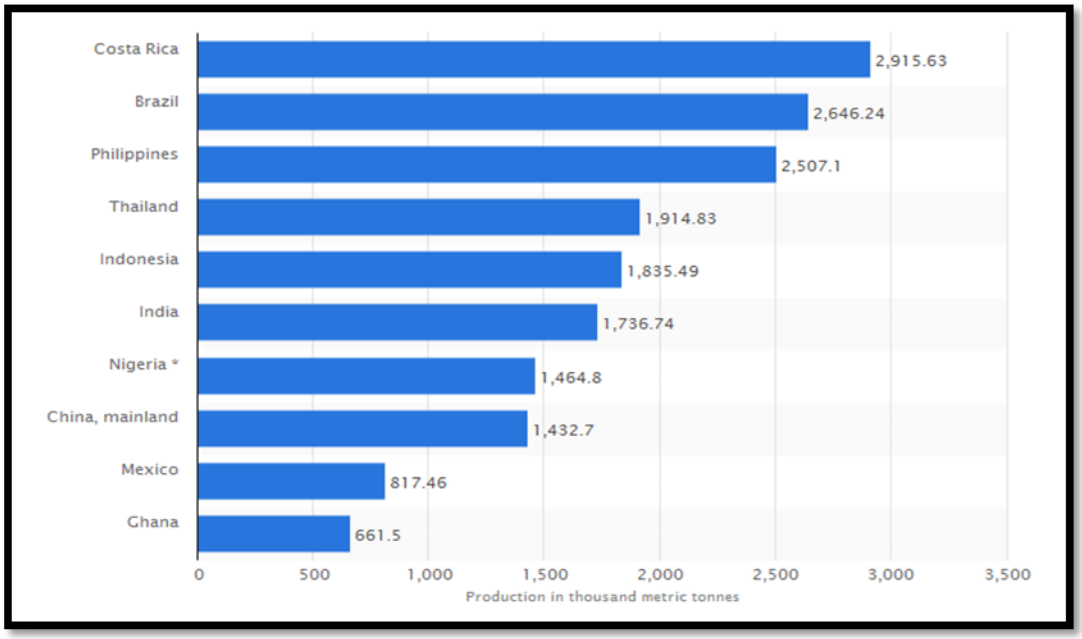

Fig.2.2. Leading countries in pineapple production,worldwide in 2014 (in, 1000 metric tonnes)

Source: (statistics. 2014)

2.4 NATIONAL SCENARIO

India holds 6th position in productivity of pineapple. India contributes 8% to world production. It is cultivated about 84000 ha about a production of 1341000T. India also major position in the export of pineapple they are exported to Nepal, United Arab Emirates, Saudi Arabia, Oman, Bahrain. In Tamil Nadu, Karnataka, Assam, and Meghalaya major cultivation is Kew variety. Mauritious it is largely cultivated in Assam and also cultivated in the region of Karnataka, Meghalaya, West Bengal, Kerala, Manipur, Tripura, Arunachal Pradesh, Mizoram and Nagaland whereas the Giant Kew varieties grown in west Bengal, Goa, Meghalaya. The queen variety will grow in Tripura, Assam Meghalaya. The yearly production of pineapple in India is shown in Fig.2.3, and state wise production of pineapple in India is given in Fig.2.4 (Indian horticulture database, 2013).

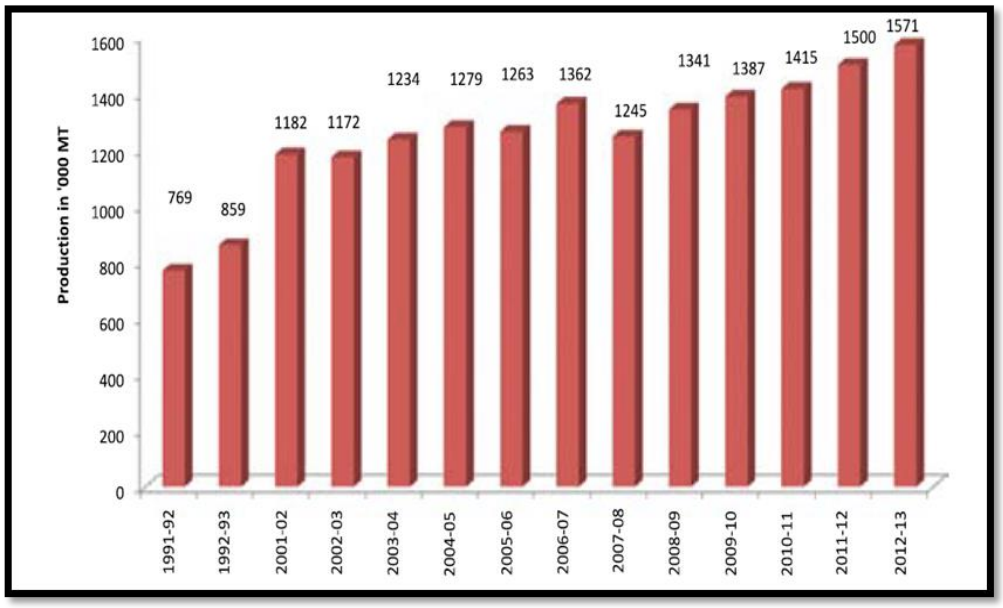

Fig. 2.3.Yearly production of pineapple in India.

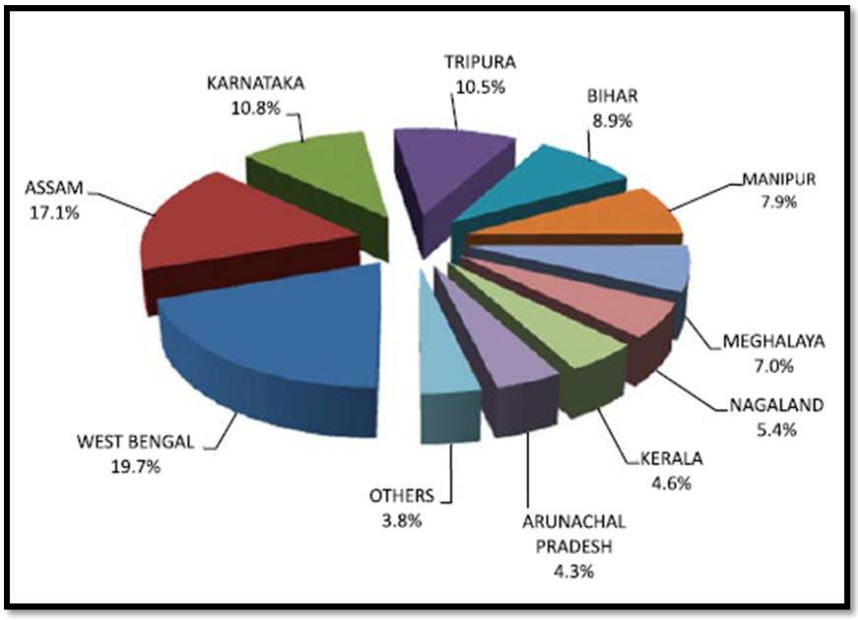

Fig.2. 4 State wise pineapple production in India

2.5 STATE SCENARIO

Kerala produces about 102400 tonnes from 12500 ha of land. Production remains constant for last few years. The congenial humid climate has favored the cultivation of pineapple. Best quality of Mauritius variety is come from Kerala. About 60% of production is from Ernakulum especially in vazhakulam region. It cultivated as on inter crop in rubber and coconut and also cultivated paddy field. (Joy., 2013).

2.6 CULTIVATION OF PINEAPPLE IN KERALA

Kerala has exclusive advantage in producing Mauritius variety, which is highly suitable for export market. The pineapple growers to a large extent are now adopting the modern cultivation practices like high-density planting, hormone application for uniformity in flowering and other management practices. The

pineapple fruits are consumed as fresh fruit or made into products like jam, squash, candy etc., for value addition. The variety proposed for cultivation is Mauritius since huge internal market as well as export potential is available. Its advantages include longer shelf life, sweetness and can be consumed as fresh fruits. Sea shipment protocol for export of pineapple has been developed. Supply chain for pineapple from Kerala is identified to be the most competitive for the domestic market due to the varietal advantage as there is price difference in the range of 1-2 Rs/kg between Mauritius and Kew in favour of Mauritius. Consumer preference for Mauritius is huge due to the fact that it is most suitable for table purpose and Giant Kew and Queen are best suitable for processing. Kerala Agricultural University has released a new hybrid pineapple Amritha. It is a hybrid between Kew and Ripley queen. It has spiny leaves and 13-15 months duration. Fruit is cylindrical, tapering slightly from near base, weighing 1.5-2.0 kg. Crown is small weighing 80-100 g, ratio of fruit weight to plant weight is medium. Fruit is green when unripe and uniformly yellow when ripe; fissure and eyecorking absent, spirals are left oriented. Fruit is firm with mild external aroma, skin 6 mm thick, flesh firm, non-fibrous, crisp and pale yellow in colour with rich aroma. Taste is good with high total soluble solids and low acidity.(Anon., 2017g)

2.7 PRODUCTS OF PINEAPLLE

Pineapples are used for the production of canned pineapple slices and tibits, canned juice, squash, concentrate and RTS beverages. By products of pineapple are alcohol, calcium citrate, citric acid, vinegar, pineapple flavor, gum, bromelain, oxalic acid and cattle feed. There are some other value added products are listed here under

1. Candied pineapple it is from pineapples which has been processed and being preserved by using sugar or sweetening substrate
2. Pineapple juice and pineapple squash is a soft drink based on juice or pulp juice
3. Preserved pineapple and pineapple pickle is the pineapple fruit that has been fermented and preserved using salt
4. Sweet pineapple sauce can be prepared by cooking fruit puree, pineapple, salt, sugar and blend it with water until boiled
5. Dried pineapple fruit is processed using a drier. This pineapple fruit contain a small number of added sugars
6. Chilled pineapple sauce can be prepared by cooking pineapple puree, salt, sugar and concentrate material together with water until boiled
7. Pineapple jam is made from mature pineapple fruit which is boiled with sugar with additional substances
8. Pineapple fiber, meatballs, frozen food products have been in the limelight for some time now
9. Pineapple fiber biscuits are made with a mixture of dried pineapple fiber, flour, sugar, margarine, eggs and a few other ingredients which make the biscuits crunchy and delicious
10. Pineapple ice cream is an ice cream made from milk products with milk fat (Anon., 2017h)

2.8 NUTRITIONAL VALUE

Table 1 shows the composition of pineapple in 100gram (Joy.,2010).

Table 1. Composition of pineapple in 100 g.

Constituents	**Amount**
Calcium	16 mg
Energy	52 calories
Carbohydrates	13.7 gm
Dietary fibers	1.4 gm
Magnesium	12 mg
Protein	0.54 g
Phosphorous	11 mg
Potassium	150 mg
Vitamin A	13 IU
Vitamin B1	0.079 mg
Vitamin B6	0.110 mg
Vitamin C	24 mg

2.9 FUNCTIONAL BENEFITS OF PINEAPPLE

Pineapple (*Ananus comosus*, Bromeliaceae) is a wonderful tropical fruit having exceptional juiciness, vibrant tropical flavor and immense health benefits. Pineapple is rich in vitamins and minerals. Pineapple is a digestive aid and a natural Anti-Inflammatory fruit. A group of sulfur containing proteolytic (protein digesting) enzymes (bromelain) present in pineapple help in digestion. Fresh pineapples are rich in bromelain used for tenderizing meat. Bromelain has demonstrated significant ant-

inflammatory effects, reducing swelling in inflammatory conditions such as acute sinusitis, sore throat, arthritis and gout and speeding recovery from injuries and surgery. Pineapple enzymes have been used with success to treat rheumatoid arthritis and to speed tissue repair as a result of injuries, diabetic ulcers and general surgery. Pineapple reduces blood clotting and helps remove plaque from arterial walls. Studies suggest that pineapple enzymes may improve circulation in those with narrowed arteries, such as angina sufferers. Pineapples are used to help cure bronquitis and throat infections. It is efficient in the treatment of arterioscleroses and anemia. Pineapple is an excellent cerebral toner; it combats loss of memory, sadness and melancholy. Pineapple fruits are primarily used in three segments, namely fresh fruit, canning and juice concentrate with characteristic requirements of size, shape, colour, aroma and flavor (joy, 2010).

2.10 METHODS OF PEELING

Peeling is one of the most important preparatory steps in processing of some of the fruits and vegetables meant for canning freezing and dehydration. In the beginning of the fruit processing industries, only hand peeling was practiced several methods, machinery and equipments have been developed since then. The various methods are discussed below.

2.10.1 **Hand peeling**

Hand peeling using stainless steel knives with curved blade and a special guard to regulate the depth of peeling can be used universally for any fruit or vegetable. The advantages of this method are minimum investment and water requirement and no enzyme simulation as in the case of heat and lye peeling methods.

The peels can be further utilized and wash water is not contaminated with chemicals. Disadvantages are high labour cost and chance of contamination with microorganism. Hand peeling as almost been replaced with modern trends of peeling. (Setty *et al*, 1993)

In the pineapple processing industries of Kerala initial peeling is done using knives. The pineapple is then sliced and final peeling done using punches. Different peeling tools are given in Fig.2.5.

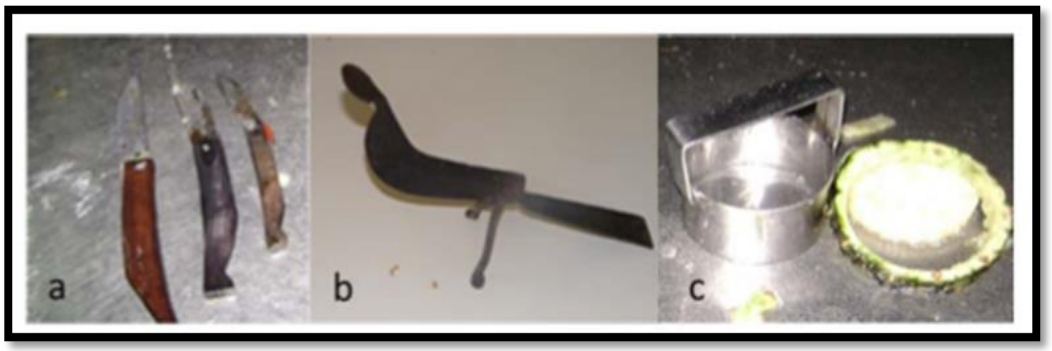

Fig.2.5. Different peeling tools:(a) avariety of knives,(b) baithi,(c) punch cutter

(image sourceTH-1340-09610503)

2.10.2 **Peeling by heat**

Boiling water or steam loosens the peel of certain fruits and vegetables like tomato, peaches etc and then it can be slipped from fruit by hand or with scrubber. In a steam peeler, the fruits are placed on a moving belt, one layer deep and passed through a steam box equipped with a series of spray heads from which the steam is sprayed directly on the material. Then peel is removed by soft brushes after cooling in cold water. Advantages include easier automation and precise temperature control

to minimize peeling losses, absence of chemical contamination of water and reduced pollution problems as compared to chemical peeling. (Setty *et al*, 1993)

2.10.3 **Lye peeling**

The method involves dipping the fruit in to the heated lye for a definite period, followed by thorough washing of the peeled fruit. Lye (sodium hydroxide solution) dissolves the fruit and vegetable peels and the rate of dissolution depends on lye concentration, temperature and period of immersion. The surface tissue of most fruits consist of three layers mainly epidermis, middle lamella and parenchyma. The middle lamella is composed of pectinous substances that are highly soluble in lye but parenchyma cells are more resistance to the lye. Hence epidermis is removed along with middle lamella without affecting parenchyma. Advantages of lye peeling are lover cost, rapid handling, reduced loss of fruit when compared to hand peeling, amenability to large scale operation and suitable to all shapes, sizes and varieties.

Residual lye may be neutralized by further dipping in dilute citric acid solution. The disadvantages include high peeling losses, loss o damaged fruits and pollution of large volume of water.(Setty *et al*,1993)

2.10.4 **Dry cost peeling**

It constitutes the modification of the lye peeling process developed to overcome some of the serious pollution and waste disposal problems inherent in the ordinary lye peeling process. The process uses infrared energy at a very high temperature to condition the surface of fruits and vegetables treated with strong lye, while the rolling of the conveyer turns the material so as to expose all the material to the infrared energy. This accelerates the chemical peeling activity and process makes

use of the lye more completely there by reducing caustic consumption. The advantages include reduced processing cost, lower volume of plant effluent, increased product yield and use of sludge as a cattle feed. (Setty *et al*, 1993)

2.10.5 **Freeze peeling (cryogenic peeling)**

Peaches and tomatoes are frozen quickly in liquid nitrogen, Freon 12, or liquid air, to a depth slightly below the skin and thawed rapidly in tap water. The flesh is not frozen, so the peel is released easily. Peel losses are reduced to half as compared to conventional process and pollution problems are avoided to a certain extent.(Setty *et al*,1993)

2.10.6 **Flame peeling**

It utilizes high temperature.(650-2000 °F) of spend combustion gases. The material is passed through a flame for very short period for blistering the skin and pulling away from the flesh by high pressure of water. This process is specially applicable to tomato, pepper, onion and garlic. (Setty*et al*,1993)

2.10.7 **Vacuum peeling**

A bulgarian vacuum method for peeling tomatoes consist of scalding the vegetables at 96^{o} C and applying vacuum at 600-700mmHg for tearing off the tomato peel. It has high peeling efficiency, retention of high fruit quality, low energy requirements as well as costs. (Setty *et al*, 1993)

Kyuhong *et al*, (1995) developed a vacuum sucking type persimmon peeler. The main components are the vacuum ejector, vacuum switch, and vacuum release valve, peeling knives or air compressor and motor. The prototype is a sequentially

controlled machine, which removes stem of the persimmon fixes it to the machine, peels its skin and discharges it quickly. Peeling performance is 363-398 fruits per hour and 3.9-4.3 times faster than manual peeling.

2.10.8 **Acid peeling**

Peach peel is soluble in hot solution of 0.1% HCl, 0.05% oxalic acid, 0.1% citric acid or 0.1% tartaric acid. It disintegrates the peel rather than loosening it. (Setty *et al*, 1993)

2.10.9 **Calcium chloride peeling**

Dipping tomatoes in boiling calcium chloride solution loosens the skin for the easy removal with its disadvantage is difficulty in controlling the absorption of calcium by the fruit (Setty *et al*, 1993).

2.10.10 **Peeling with ammonium salts**

Fruits and vegetables, when treated with 0.5-15% aqueous solution of mono, di, and tri ammonium orthophosphate at 85-95^{o} C for 3-10 minutes (pH 7.0-9.5) produces astonishing skinning effect without destroying the tissue. The effectiveness can be improved by adding surface active agents preferably at 0.0-0.2% level (Setty *et al*, 1993).

2.10.11 **Mechanical peelers**

Usually the pineapple processing machine involves the processing of peeling, slicing and coring. Each of the process needs for a sophisticated machine to perform the process. Processing pineapple in large quantity usually involves big company for heavy industry which required high capital cost. One of the most popular machines to

process pineapple is GINACA machine. Origin of equipment was at Hawaii. Commercial pineapple production began in Hawaii about 1890. Fruit was hand peeled and sliced to match can sizes for export. James D. Dole (1911) hired Henry G. Ginaca to design a machine to automate the process. As fruit dropped through the Ginaca machine a cylinder was cut to proper diameter, trimmed top and bottom, and cored. The further revolution of Ginaca machine bring to the increasing of production volume to more than triple compared by using manual method that fully depend on the labour, also making pineapple Hawaii's second largest crop. In the faster Ginaca machines now used around the world, the principle remains unchanged. (The American society of mechanical engineers, 1993). A basic model of Ginaca machine is shown in Figure.2.6)

Fig. 2.6 Basic model of Ginaca machine (The American society of mechanical engineers, 1993)

1919 Model Ginaca Machine

After a period of initial success which firmly established the preparation methods used, the Ginaca was redesigned as a production machine in 1919 and this model is still used in one form or another by many canners today. The totally

different are the using of inclined sizing knife and vertical turrent compared between the models before it. The maximum speed of this machine can process 65 pineapples per minute. Shawn in Fig2.7

1925 Model Ginaca Machine

The model has capability to process from 90-100pineapples per minute. 1925 model was developed by aligning the turrent with the sizing knife. The improvement had hardly improves the eradicators, feeds, auxilary drives and construction. (The American society of mechanical engineers,1993). Figure 2.8 shows the 1925 model of Ginaca machine

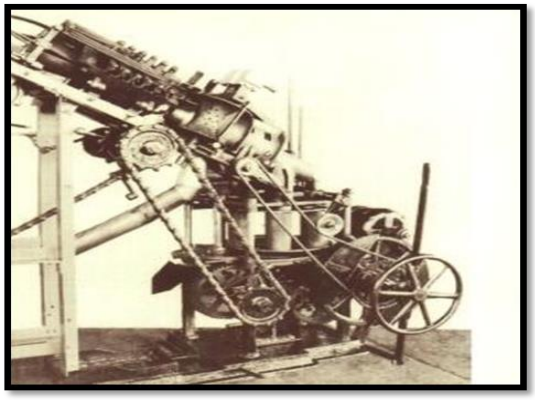

Fig.2.7. 1919 Model Ginaca machine (The American society of mechanical engineers, 1993)

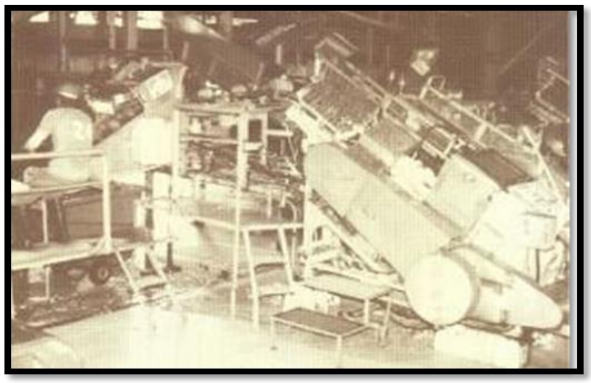

Fig. 2.8. 1925 Model of Ginaca machine. (The American society of mechanical engineers, 1993)

2.11 REVIEWS REGARDING PEELING PROCESS OF FRUITS AND VEGETABLES

Hamlin *et al*. (1917) developed fruits and vegetable peeling machine. This innovation relates to vegetable peelers and mainly for peeling potatoes and similar vegetables by an abrasive action. The machine is adapted for rapid operation and so designed as to treat large quantities of potatoes in a thorough manner and yet with minimum amount of waste of the vegetables. The main parts of machine are rigid frame, horizontal cross bars, suitable cross braces to make the same rigid. Central portion of cross bars are supported by bearings. In the bearings is journaled a hollow shaft one end of which is closed where it is projects through the bearing, while the other end and intermediate portion of the shaft is provided with a series of jet holes. It also comprises a drum which is in cylindrical form supported upon the shaft and coaxial there with. After filling the potatoes water is poured in to the drum just about to cover the potatoes. The drum is then rotated at a moderate rate of speed by any suitable power or hand means applied to the end of shaft opposite to the nozzle. As the result of rotation of the drum the mass of potatoes and water is caused to guide relatively along or over the abrasive lining surface of drum at the same time the potatoes are moved by the protuberances towards the end of drum and owing to these movements and undulation practically all surfaces of the potatoes are presented to the abundant where by the peel or skin there of quickly and effectively removed with a very slight loss of potato.

Murphy *et al*. (1946) developed egg, fruit and vegetable peeler. The invention relates to improved multiple purposed peeler that is a hand grasped and manipulated implement for use in kitchens and the like and adapted to penetrate and peel edibles

like fruits and vegetables and hard boiled eggs. The equipment can be used to cut the outer layer of fruits and vegetables to the depth desired, while employing penetrating and cutting means in a manner to protect the hand of the operator, together with means enabling the operator to easy maintain uniform depth of the cut, whereby to satisfactorily attain the ends desired.

Kafejive *et al*. (1970) developed a method for peeling fruits and vegetables. Here the fruits and vegetables heated superficially from 60 to 100 °C, after which they are replaced in a vacuum having an absolute pressure of about 460 mm mercury column or lower causing thereby an explosive separation of the skin, and are then taken out of the vacuum and processed in known ways. After the separation of the skin, the fruits and vegetables can be held in the vacuum longer than 40 seconds, and during this time the gases contained in their tissue separate.

Fox *et al*. (1955) developed a vegetable peeler having spray disperser. The peeling machine has a cylindrical housing including a chamber having a disk rotably mounted at its bottom. The disk is spaced about the entire periphery from the inner wall of the chamber, and has an abrasive working surface which removes the outer skin of the vegetables or fruits, such as potatoes. The disk is revolved by suitable drive means and in the process of removing the skin it roughens the surface then exposed, leaving fuzz thereon. The inner walls of the chamber above the disk are provided with a ribbed liner, the ribs extending radially inwardly of the chamber for a slight distance, and being relatively closely spaced and arranged substantially vertically with respect to the plane of the disk. The ribbed liner serves to rub or smooth the roughened undersurface, scrapping and removing the fuzz from the

vegetables as they are tumbled against the walls of the chamber, due to the centrifugal force acting on the vegetables from the rotation of the disk.

Asselbergas *et al*. (1956) developed equipment for peeling fruit and vegetables by infrared process. The method employed an insulated infrared tunnel with 30 kw metal sheath radiant panels. Apples were exposed in the tunnel for 8 to 30 seconds, depending up on the apple variety, cooled in water and then the peel removed by hand. Peeling losses were less than 2.7 percent and the apples did not brown when exposed to air. Presumably, during exposure of the apple to radiation some steam was formed in the intercellular spaces immediately below the histological peel with the buildup of steam pressure, the intercellular connections in this region were severed, allowing the removal of the histological peel. Here the length of the cooked outer layer of the fresh was less than 1 mm. The infrared radiation also offered the following possibilities that are; it is a full or semi automatic method of peeling, reduced peeling losses, reduced cost due to the radiation of hand labour required, and a high product quality.

Young *et al*. (1960) fabricated a potato peeler, which facilitate the preparation of various fruits, vegetables and the like for cooking and human consumption, by removing the peels, and other inedible and unpalatable portions there from and by shredding certain fruits or vegetables. Although this invention is equally applicable in preparing innumerable fruits, vegetables and the like for human consumption and for treating innumerable other substances, for simplicity of explanation, the same will be described with respect to a select few of such applications it being under stood that the same is not so limited in its application. According to this invention a blade having edges which may be relatively dull when compared with a conventional

kitchen knife is adapted for rapid vibration to facilitate removal of peels from a potato or other fruit or vegetable when moved over the surface thereof in contact there with. The blade having rebent portions is mounted for rapid vibration in a portable and easily manipulable housing. The blade is adapted to be brought into contact with the surface of the potato or other fruit or vegetable to be peeled and the rapid vibrations of the blade are effective upon slight pressure there against to remove only the peel there from. Upon greater pressure the blade is effective to remove as much of the fruit or vegetable as desired. The equipment makes the peeling process easy and efficient.

Willard *et al.* (1968) invented an apparatus and method for peeling fruits and vegetables, which facilitates the peeling of products such as fruits or vegetables and for removing defective portions by subjecting the product to radiant heat to raise the temperature of exterior portions of the product and to soften those portions. Peels and defective portions are thereafter removed from the product. The apparatus includes peeling and trimming apparatus having a peeler and a conveyer for transporting the product from the peeler to and through a radiant heater. An abrader is provided to remove defective portions of the product after it emerges from the radiant heater.

Hart *et al.* (1971) invented a system for peeling fruits and vegetables. Here the fruits and vegetables are treated (e.g., with lye) to loosen the peel, and the loosened peel is removed by nonabrasive dry wiping with rotating discs of soft flexible rubber.

Lazzarini *et al*. (1971) developed a peeling machine and method for fruits and vegetables includes a rotatable cylinder having its peripheral wall formed of a plurality of parallel horizontally disposed rotatable peeling rolls through which material such as pears, peaches, etc., is conveyed for peeling action. Each roll is

provided with a peeling surface composed of a series of annular resilient peeling elements which are effective on treated fruit and vegetables to remove the skin.

Odigboh (1976) designed a mechanical cassava peeler. The machine comprises of two cylinders which are fixed inclined at an angle of 15° to the horizontal plane and parallel to each other with a clearance of 20 mm. Knives are fixed on the surface of the driver cylinder, which is rotates clockwise at 200 rpm. The driven cylinder which has an abrasive surface also rotates clockwise at 88 rpm. When the cassava pieces are fed to the space between the cylinders products are being peeled off, while the cylinders rotate anticlockwise and move down.

Cambell (1982) described the construction of a peeler for potatoes. It tumbles the potatoes along a rasp like surface on the interior of a rotating, nearly horizontal cylinder.

Agrawal *et al*. (1983) developed an 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.

Ewald (1986) developed an apple corer having four molded plastic components fitted together to form the design. It consists of hollow cutting tube, core remover which is slides along the cutting tube, handle attached at the end of the cutting tube and compression plug. The tip of the cutting tube has serrated teeth for easier boring into the apple. Finally, cutting tube was removed from the bored apple

and the resulting core left in the tube is ejected by sliding the core remover towards the tip of the cutter.

Rose *et al*. (1987) patented an apparatus for removing the peel from pineapple. It consists of tubular knife which having toothed cutting edge to cut through a pineapple and elongated guide telescopically positioned within the tubular knife. The elongated guide adopted to direct the toothed cutting edge towards a pineapple that is interposed between the guide and a cutting pad. The mechanism for moving the tubular knife towards the cutting pad includes leveraged means, which reduces the force required to move tubular knife through the body of fruit. Flexible elongated guide increase the effective diameter of the guide and allows the apparatus to be used with different diameter tubular knives for different size pineapples. The core tube and the tubular knife were coupled together and move simultaneously.

Cohen and Siegel (1994) patented a fruit and vegetable peeler. The peeler included a head portion for engaging a fruit/vegetable, a handle for gripping the tooland flexible portion for permitting the head portion to pivot relative to the handle. The head portion of the tool carries the cutting blade, which is inwardly curved along its longitudinal length to provide a bow shaped construction. The flexible portion permits the cutting blade to follow the natural contour of fruits/vegetables, so that the cutting blade easily passes over the surface of the fruit/vegetable.

Mandher and senthilkumaran (1995) developed a continuous motorized peeler for raw mangoes. The principle is to rotate the fruit in an enclosed cylinder, against the sharp projections on the inner surface.

Anie *et al*. (1996) developed a mechanical abrasive roller type ginger peeling

machine and studied the performance by varying the pretreatment conditions and speed of the roller. The machine consists of an abrasive unit, driving unit, collected unit and frame. Aberration unit does the work of peeling when ginger rhizomes are dressed manually on to the rotating roller.

Sommer (1997) described a device for peeling elongated vegetables, preferably asparagus. The device includes a housing equipped with a passage designed to allow a stick of asparagus to be inserted. Inside of the housing fitted with several peeling blade, which are oriented in different directions of the passage and act on the stick of asparagus. At least one of the blades can move crosswise to the elongated direction of the passage and pushes flexibly towards the stick of asparagus.

Protte (1999) discussed a peeler machine for stalk-like vegetables, comprising a plurality of knife stations that are successively arranged along the vegetable moving inside the machine. The machine also includes a plurality of pairs of feed rollers and each pair is supported between successive knife stations in order to carry and push the stalk-like vegetables through the knife stations.

He and Tardif (2000) discussed a peeler machine equipped with blades to peel vegetables. The vegetable, which is fixed in the hollow base of the machine, can be rotated by screw shaft on the top. As the rod rotates manually by a hand, simultaneously product also started to rotates at same direction. A blade, which is connected to the supporting rod and pressed by a spring, moves against the vegetable to be peeled. When the vegetable starts rotating, the peeling blade removes the peel.

Martin (2000) patented a peeling machine for peeling of various fruits and

vegetables. The peeler machine equipped with a rotatable upper holding assembly and a lower holding assembly connected to a frame for securing and rotating the produces to be peeled (Fig.2.9). The lower assembly was coupled with air cylinder in order to secure the fruits/vegetables between the upper and lower holding assemblies. A movable carriage assembly (linear direction) is coupled to the frame and containing a cutting assembly which is engaged with the end of a second cylinder. As the carriage assembly moves upwards, the extension of the second air cylinder pushes the cutting assembly towards the fruits/vegetables; as a result peeling will take place.

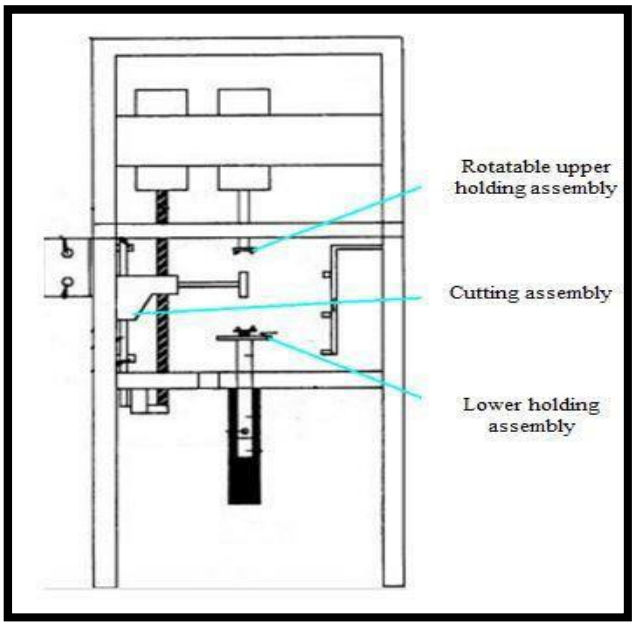

Fig.2.9. Fruit peeler

Gingras (2001) described an apparatus for peeling of vegetables of round/oval shape viz., cucumbers, turnips, carrots or potatoes. The machine has a frame including an adjustable hole to receive and let pass the vegetables to be peeled. The frame also equipped with several knives in such a manner that can slide towards the centre of the hole. The knives are distributed all around the frame in an equal manner

and each carries a blade extended tangentially within the hole. Therefore adjacent part of the vegetable peels introduced into and pushed through the hole. Tension spring is provided between each blade and inner surface of the blade in order to push the knives towards the centre of the hole. This peeler allows peeling vegetables in a single pass or with a minimal number of passes.

Harding (2001) patented a peeler for convex surface of a fruits and vegetables. The machine includes a U-shaped peeling blade and a feeder which grips and contacts the fruits/vegetables at a position opposite the apex of the peeling blade. This apparatus also includes at least one guide for guiding the fruits or vegetables to pass in front of peeling blade.

Ridler (2001) presented a peeling apparatus for fruits and vegetables. The apparatus comprises of traversing blade which continuously and intermittently rotates in the opposite direction to a rotating fruits/vegetables. The apparatus was designed in such a way that it is controlled and powered manually. The operator rotates the fruits/vegetable that is placed on a detachable arbor by one hand and at the same time peeling blade was controlled by another hand.

Ukatu (2005) developed an industrial yam peeler. It consists of yam tuber container, conveyor system, tuber guides and peeling chamber. The yam tubercontainer holds the tubers ready to be peeled. The conveyor system consists of four pair of cylindrical roller for feeding unpeeled tubers to the machine and another two pairs for withdrawing peeled produce. The spring loaded tuber guides ensures the incoming tuber is directed to the peeler blade. The peeling chamber consists of three peeler arms which are spring loaded to provide the pressure needed for peeling and

allow accommodating the varying size of tubers. The peeler blade welded on the peeler arm scrapes the tuber at pre-set depth.

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 eatable size.

Primavera *et al*. (2006) developed a vegetable and fruit peeler to remove the skin, veins and seeds of a fruit or vegetable. The system comprises an inclined board with ridges to hold the fruit or vegetable to be treated and a hand tool with an edge adapted to remove the skin, veins and seeds of a fruit or vegetable that is placed on the ridged board.

Emadi *et al*. (2008) developed a mechanical peeler for pumpkins, using an abrasive-cutter brush. Vegetable holder and peeler head are the two main parts of the machine (Fig.2.10). The vegetable holder made up of disc for carrying the produce circularly on a horizontal plane and it supplied rotational velocities up to 300 rpm by an electric motor. The peeler head was designed to provide the perpendicular access to the produce's surface. A separate electric motor was used with higher speed limit (2000 rpm) to carry the abrasive-cutter brushes on its output shaft. To provide the flexibility during peeling, whole peeler head attachment was mounted on pivoted bracket. The cutting action causes the effective peeling.

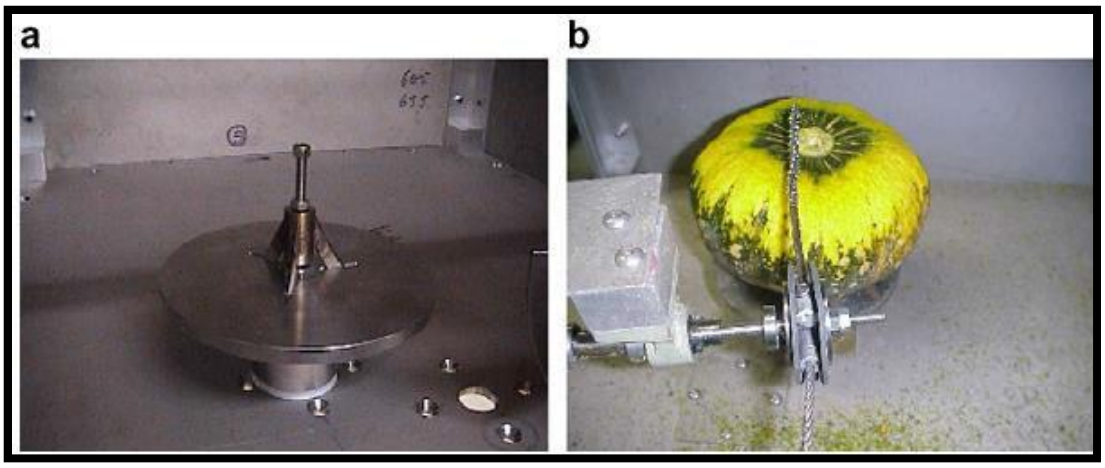

Fig.2.10. (a) vegetable holder (b) peeler head

SitiMazlina *et al*. (2010) designed and developed an apparatus for grating and peeling fruits and vegetables. The machine consisted of grater, pushrod, trident, peeling blade, arm and end-cutting blade. This machine was fabricated from food grade stainless steel. The trident was fixed on the centre of machine body which supports the fruits and vegetables to be grated and peeled by providing circularly motion on a horizontal plane. The adjustable pushrod was placed opposite to the trident and on the same axis. The main function of the pushrod is to hold the fruit upto enable the rotation and to push the fruit against the trident. The grater was situated on a handle which is movable to grate the fruit/vegetables for food decoration purpose. The arm was located on sliding vector which enable to move parallel to the fruit rotational axis and supports the peeling blade, which peels the fruits and vegetables. Elastic system was connected between arm and peeling blade. The function of the elastic system is to presses the arm softly on the fruit profile, holds the peeling blade position against the fruit profile and enables the peeling blade to move on fruit profile, so that machine automatically peels the fruits and vegetables

that are spherical and oval shape (Fig.2.11). Pair of end-cutting blades located on another handle to cut the fruit ends after the completion of peeling and grating operations. This machine is useful to grate the fruits and vegetables with or without scales on the skin. There were some fruits and vegetables viz., cucumber, carrot and papaya that were grated using this operation (Fig.2.12).

Fig .2.11.Peeling products (a) papaya (b) papaya flesh (c) papaya skin

Fig.2.12.Grating cucumber; grating products (a) cucumber (b) carrot(c) papaya

Singh *et al*. (2013) designed a hand operated pineapple peeler-cum-slicer. Slicing plate and core remover shaft are the two main important parts of this design. Stainless steel pipe of 22 cm length and 2.5 cm diameter was used for constructing the core remover shaft. One end of the corer was kept with sharp teeth for easy

penetration during the coring operation. For constructing slicing plate, the stainless steel plate of 7.0 cm diameter was attached to the pipe in helical manner around the corer with a gap of 1.5 cm between grooves for cutting the pineapple rings. Itsimultaneously removes the core and produces pineapple rings of uniform thickness and diameter in a single motion. The designed device works satisfactorily with easy operation, efficient, time saving and economical for the farmers.

Oluwole *et al.* (2013) developed a work focused on the design and construction of a batch cassava peeling machine able to handle one diametric size of cassava tubers. The principle of abrasive peeling using a stationary outer abrasive drum and a rotating inner abrasive drum was used based on a batch capacity of 8.5 kg and cut tuber lengths of 200mm and diameters of 90mm. An average peeling efficiency recorded was 70.45 percent while the average flesh loss was 5.09 percent. Percentage of broken cassava was estimated as 2%.

Tagare *et al.* (2013) developed a work on design and manufacturing of sugar cane peeling machine. It is aimed at providing a base for the commercial production of a sugarcane peeling machine, using locally available raw materials at a relatively low cost. The successful fabrication of a sugarcane peeling machine is one of the major, if not the major, challenge in sugarcane processing. This work is intended to help solve some of the problems hindering a successful design and manufacturing of a sugarcane peeling machine. Machine was tested by abrasive tool and efficiency upto 59.66% was achieved.

Thongsroy and Klajring (2015) designed a fruit peeling machine, using a two way blade. The main parts of the machine are peeling blade set, fruit holder set and

controller set. The peeling blade set comprises of peeling blade with edge diameter of 2.7 cm and pneumatic cylinder which acts as controller of peeling blade set closely connected with fruit surface. The peeling blade set was designed in such a way that could be able to move linear direction (peeling up and down) by turning around the spiral screw shaft. Upper axle of the fruit holder set was connected with electric motor in order to spin fruit whereas, lower axle connected with pneumatic cylinder in order to grab fruit. Two electric motors with 1.0 hp are the power sources provided for fruit holder and peeling blade set. The controller set was fabricated with inverter to adjust the rotational speed of motor. The performance evaluation of designed peeling machine was carried out with Holland variety of papaya and Sun Lady variety of cantaloupe fruits (Fig.2.13).

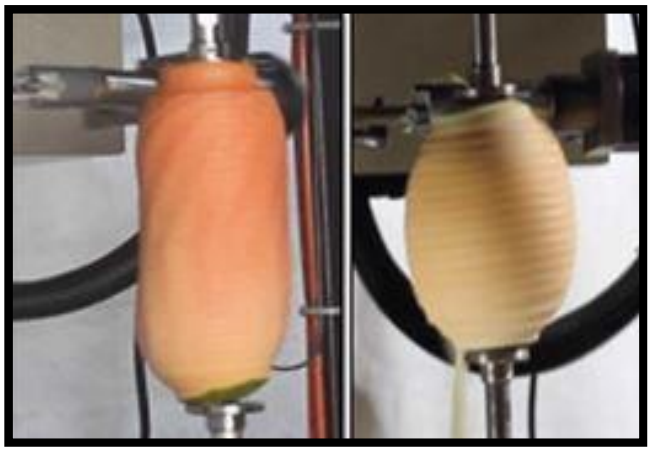

Fig.2.13 .Papaya and Cantaloupe peeled

Vidhu *et al*. (2002) designed a pineapple peeler cum corer cum slicer. This machine is for peeling, coring and slicing of pineapple is recommended for the restaurants and for canning industry. The output capacity is 93kg/hr. Shown in Fig.2.14.

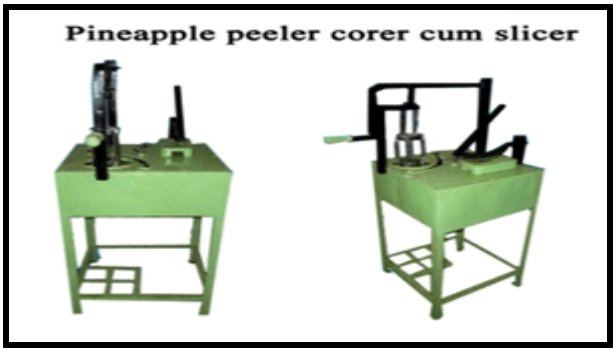

Fig.2.14 pineapple peeler cum corer cum slicer.

2.12. REVIEWS REGARDING THE COMPOSITION OF PINEAPPLE

Hemalatha *et al*. (2013) studied about the physicochemical constituents of pineapple and waste. It is a rich source of ascorbic acid supplement to our diet. Pineapple pulp waste showed maximum amount of reducing sugars (30.5 mg/100 g) and ash (1.8 mg/100 g) respectively. Pineapple waste contains high concentration of biodegradable organic material and suspended particles. Pineapple waste showed higher concentration of crude fibre, non reducing sugar, protein, ascorbic acid and moisture content. Therefore pineapple waste is used as substrate for growth of microbes in fermentation process.

Hajar *et al.* (2012) analysed the psychochemical properties of pineapple extract variety N36 for three different ripening stages: indexes 1, 2 and 3. Physicochemical properties such as total soluble solids (TSS), pH, titratable acidity (TA), absorbance and pulp content of pineapple peel extract were determined. It was found that the physicochemical properties: TSS, pH values, TA, absorbance and pulp content were significantly increased at the 5% level with the increase in ripening

stages. These new data on ripening changes occurring in pineapple (*Ananascomosus)* peel variety N36 can contribute to further development in the agricultural sector

Nadzirah *et al*. (2013) determined the psychochemical properties of pineapple variety N36 harvested and stored at different maturity stages. The aim of this study is to determine colour changes during storage and physicochemical properties of peel, core and crown extracts of pineapple variety N36 for maturity indices of 1, 2 and 3. The *L** (lightness), *a** (redness) and *b** (yellowness) values for peels increased significantly at each maturity stage during seven days storage. pH of pineapple peel, core and crown extracts were in the range of 3.24 to 3.84. The titratable acidity, percentage of pulp and Total Soluble Solid (TSS) of pineapple peel, core and crown extracts were in the range of 0.16 to 0.36%, 1.37 to 2.91% and 1.4 to 5.3˚Brix, respectively. Fructose and glucose contents were significantly highest in pineapple core extract followed by pineapple peel extract and pineapple crown extract for maturity index 2. Significant difference was found in sucrose content between pineapple core and peel extracts with 8.92% and 3.87%, respectively for maturity index 3. However, sucrose was not detected in pineapple crown extract. Pineapple core extract was significantly higher amount of total sugar content compared to pineapple peel and crown extracts for all maturity indices.

Brat *et al*. (2004) determined the physicochemical characterization of new pineapple hybrid (FLHORAN41 cv). That is the physicochemical characteristics (pH, total and soluble solids, and titratable acidity), sugars, organic acids, carotenoids, anthocyanins, volatile compounds, and cell wall polysaccharides of a new pineapple hybrid (FLHORAN41 cultivar) were measured throughout maturation and compared with the Smooth Cayenne cv. At full maturity, the FLHORAN41 cv. has a higher

titratable acidity and soluble solids content than the Smooth Cayenne cv. The golden yellow flesh and red−orange to scarlet shell of ripe FLHORAN41 cv. fruits are due to carotenoid and anthocyanin levels that are, respectively, 2.5 and 1.5 times higher than those of the flesh and shell of the ripe Smooth Cayenne cv., respectively. During maturation of the FLHORAN41 cv., there was an increase in all classes of aroma compounds (mainly terpene hydrocarbons and esters), although their relative proportions were similar in both cultivars at full maturity. Cell wall polysaccharides undergo little change during maturation.

Mithra *et al*. (2013) conducted a study on the deactivation of bromeline in pineapple juice and analysed its psychochemical and organoleptic properties for successful commercialization via fast moving consumer goods industries in Indian subcontinent. The main aim is to study the biochemical and physical attributes of juice extracted from the pulp which has high sugar (glucose and fructose) content and adequate moisture. Pineapple confers health benefit on the host as it contains huge quantities of vitamin C and other antioxidants. Deactivation of bromelain was also performed so that there are no hindrances in the juice manufacturing process. Sodium metabisulphite was also added to increase the shelf life of the product. During the production period, the pH, temperature and acidity were monitored. The pineapple juice was then subsequently characterized for sugar analysis, gas chromatography, UV spectral analysis and FT-IR. The amount of volatile compounds was quantified by HPLC with differential solvent system.

The juice sample was also subjected to sensory evaluation and their colour stability was also checked. This research component would be a key technique to unlock the problems and tap the potential of pineapple juice manufacturing in India.

Hossain *et al*. (2015) studied nutritional value and medicinal benefits of pineapple. They determined the nutritional value and importance of pineapple in the health aspects. Thailand, Philippines, Mexico, Costa Rica, Brazil, China, Nigeria, Kenya, Indonesia, Hawaii, India, Bangladesh are the major pineapple producing countries. The demand of pineapple in the international market is expanding day by day. Generally, the ripen pineapple fruit is consumed fresh and juice as source of essential minerals and vitamins with some medicinal values. Pineapple contains considerable calcium, potassium, fibre and vitamin C. Various food items like jam, jelly, pickles are produced from pineapple. Qualities of pineapple vary due to growing environment and variety. Ripening agents accelerates ripening, but affects the nutritional quality of the pineapple fruits.

2.13. 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. Knowledge of the physical properties like weight, length and diameter of the fruit, length and diameter of fruit core and fruit rind thickness are necessary for development of mechanical tool for pineapple peeling. The determination of physical properties of different fruits followed by various research workers were reviewed for the study.

2.13.1. **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 and its experimental results are given below.

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.

Rafiee *et al*. (2007) studied some of the physical properties of bergamot (Citrus medica) fruit by image processing technique to develop appropriate technologies for its processing. The fruit dimensions and projected areas were determined using a Win Area UT-06 system (Fig.2.15) with sensitivity of 0.05 mm, where T, W and L are the minor, medium and major perpendicular dimensions of the fruit and PT, PL and PW are projected area perpendicular to W, T and L, respectively (Fig.2.16). The length, width and thickness of the fruit varied from 78.70 to 160 mm, 64.2 to 128.5 mm and 64 to 125 mm respectively.

Sharifi *et al*. (2007) reported the length, width and thickness of the orange fruit which were recorded with an accuracy of 0.05 mm using a set of Win Area-UT-06. The basic operating principle of this set is image processing

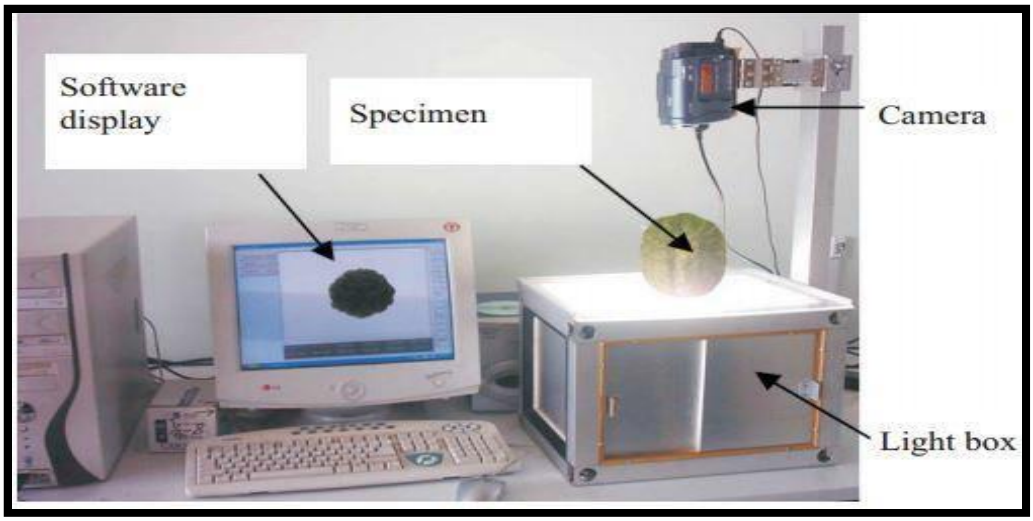

Fig.2.15.Win Area UT-06 system

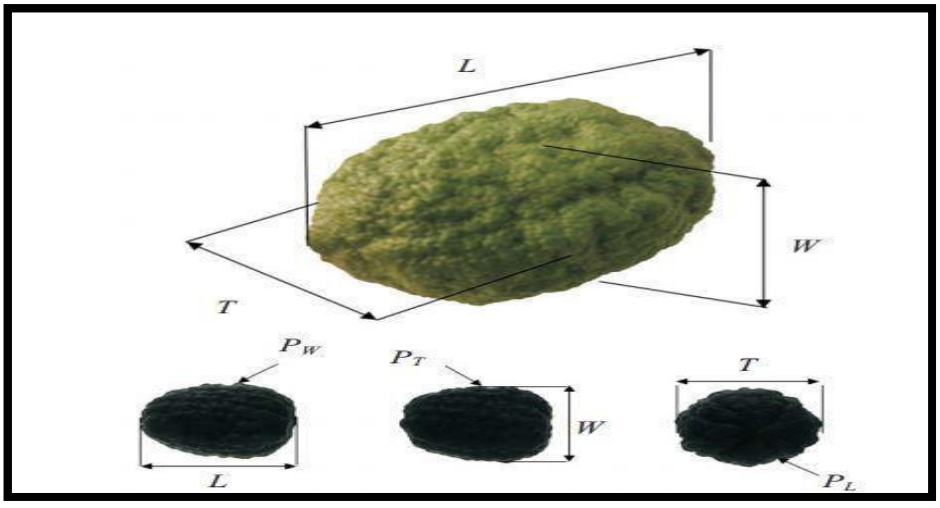

Fig.2.16. Projected areas and dimensions of bergamot fruit

Jahromi *et al*. (2008) reported the selected engineering properties of the date fruit which were determined using an image processing technique to develop appropriate technologies for its processing. In order to obtain the fruit dimensions and projected areas, Win Area UT-06 system was used. This system consists of following 4 components:

a) Sony photograph camera, model CCD-TRV225E

b) Device for preparing media to picture taking

c) Capture card named Winfast, model DV2000

d) Computer software programmed with visual basic 6.0.

In this system, fruits images were acquired by camera and the captured images of date fruits are transmitted to the computer card which works as an analogue to digital converter. The digitized images are then processed in image processing window by computer software to provide the three orthogonal images of fruit that determines fruit size and projected area.

Jannatizadeh *et al*. (2008) conducted the studies on physical properties of Iranian apricot *(Prunusarmeniaca L*.) fruit by image processing to understand the behaviour of the product during the postharvest operations. The fruit linear dimensions viz., length, width and thickness as well as projected areas perpendicular to these dimensions were determined using a area measurement system Delta-T, England. Total error for these objects was less than 2%.

Lino *et al*. (2008) conducted the studies on image processing techniques for lemons and tomatoes classification. The classification of tomatoes and lemons was done based on color and size, respectively using Image J software.

Ullah and Haque (2008) conducted the studies on fruiting, bearing habit and fruit growth of jackfruit germplasm. The digital vernier calipers and measuring tape were used to measure the fruit dimensions viz., length, diameter etc. In order to determine fruit dimensions, the equivalent distance of the apex to the base and longest dimensions perpendicular to the length are to be considered as fruit length and diameter respectively.

Shamsudin *et al*. (2009) conducted the experiments on physical properties of pineapple fruit. Digital vernier calipers were used for determining the fruit length and diameter for both with and without peel. The observed values for length and diameter of fruit with peel were varied from 119.26-136.51 mm and 93.85-106.93 mm, respectively whereas, values for the fruit without peel were found 103.49-124.59 mm and 82.93-98.17 mm respectively.

Chakespari *et al*. (2010) studied about mass modeling of two apple varieties by geometrical attributes. Digital calipers (0.01 mm accuracy) were used for determining the fruit size. In order to obtain average size, they considered three linear dimensions viz., length (equivalent distance of the stem from top to the bottom calyx), width (longest dimension perpendicular to length) and thickness (longest dimension perpendicular to length and width). Whereas, projected area of each fruit which are perpendicular to length, width and thickness were recorded with an accuracy of 0.05 mm using a Win Area UT-06 system.

Mohan (2012) determined some physical properties of ash gourd and cucumber by image analysis method to develop a seed extractor. Experiments were carried out using a standard digital camera, camera stand, computer and the AutoCAD software. The photographs were taken by fixing the camera in stand and the captured images of each fruit were processed in the computer using AutoCAD software. The outlines of the fruits were drawn and the dimension viz., diameter, length and placental diameter was measured by providing proper scale factor (Fig.2.17). The length and diameter of ash gourd varied from 190-395 and 156-205 mm respectively whereas in cucumber, values were found to be 178-258 and 96-147 mm respectively.

Jagadeesh*et al*. (2007) studied the important physicochemical 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.

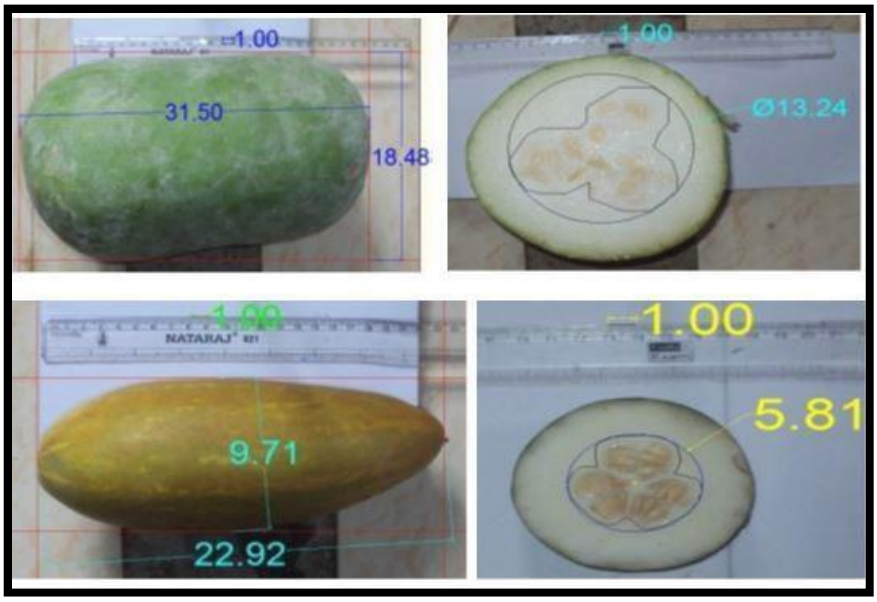

Fig.2.17. Measurement of diameter, length and placental diameter of cucumber and ash gourd

Gomez *et al*. (2015) studied the physicomorphological 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

2.14.2. **Mass**

Azad (1989) investigated the physical properties of jackfruits harvested from late and early season. The mass of the whole fruit was recorded by electronic balance. Study revealed that, harvesting from the early season produced the fruits of biggest size (8.67 kg). The smallest jackfruit of 4.57 kg was observed in late season

Mitra and Mani (2000) evaluated over 1,460 jackfruit trees in West Bengal. Wide variability was noticed in fruit weight which ranged from 1.22-17.30 kg among the genotypes evaluated

Reddy *et al*. (2004) studied the physico-chemical characteristics of nine jackfruit clones from south Karnataka and found diversity in several characters. In these clones, maximum variability was noticed for the characters like fruit weight, weight of carpel and seed weight, which were ranged from 7.0-20.0 kg, 21.25-49.25 g per carpel (without seed) and 5.00-12.30 g, respectively.

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.

Haq (2011) investigated the variation in jackfruit characteristics. Wide variation was observed in fruit weight ranging from 1.2-22.0 kg 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 weight (2.16-10.66 kg), rind weight (1.01-6.26 kg) and weight of flakes per kg of fruit ranged from 0.34-0.76 kg 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 observed values of fruit weight, fruit rind weight and weight of flakes per kg of fruit in the different jackfruit genotype were ranges from 0.58-15.45 kg, 0.02-1.23 kg and 0.06-0.37 kg, respectively 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 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 physicomorphological characteristics of jackfruit accessions in Kerala. The observed value of fruit weight among the jackfruit accessions ranged from 3.95-20.13 kg.

2.15. REVIEWS REGARDING PERFORMANCE EVALUATION OF PEELER AND SLICER MACHINES

Agrawal (1987) evaluated the performance of a ginger peeler machine. The peeling efficiency and the ginger meat loss were determined by the following formula

$$\text{Peeling efficiency} = \frac{\text{weight of the total skin removed by machine}}{\text{weight of total skin on ginger}} \times 100$$

$$\text{Meatloss} = \frac{\text{weight of ginger meat loss during mechanical peeling}}{\text{total weight of sample}} \times 100$$

The peeling efficiency and meat loss of the machine at full capacity (20 kg/h) were found as 71% and 1.6%, respectively.

Singh and Shukla (1995) reported the peeling efficiency and peel losses of developed a potato peeler which was calculated by using the formula shown below. Peeling efficiency given as

$$\text{Peeling efficiency} = \frac{\text{Fraction of peel on raw potato - fraction of remaining peel on peeled potato}}{\text{fraction of peel on raw potato}} \times 100$$

$$\text{Peeling loss} = \frac{\text{weight of raw potatoes - weight of peeled potatoes}}{\text{weight of raw potatoes}} \times 100$$

Ukatu (2005) calculated the peeling efficiency and peel losses of yam peeler as follows

$$\text{Peelingefficiency} = \frac{\text{surface area of un peeled tuber - total surface are of un peeled patches}}{\text{surface area of unpeeled tuber}} \times 100$$

$$\text{Peeling loss} = \frac{\text{Mass of tuber before peeling - Mass of tuber after peeling}}{\text{Mass of tuber before peelng}} \times 100$$

The peeling efficiency and peel loss (the lost tuber flesh) of the yam peeler were found 60-80% and 11.22-17.30% respectively.

Jain et al. (2007) evaluated the abrasive peeler cum polisher for ginger. Peeling efficiency and peel losses of peeler were calculated as follows

$$\eta = \frac{(y - x)}{(y)} \times 100$$

$$M = \frac{w - (y - x)}{(w)} \times 100$$

Where,

Ƞ= peeling efficiency (%)

Y = weight of total skin on ginger (g)

X = weight of skin removed by hand trimming after mechanical peeling (g)

M = meat loss (%)

w = total reduction in weight during mechanical peeling (g),

W = total weight of the sample (g)

The average peeling efficiency of the machine was found as 74, 81.2 and 81.7% at operation time of 8, 10 and 12 minute with a meat loss of 1.54, 2.58 and 3.82% respectively. The data reveals that peeling efficiency and meat loss increased with the increasing holding time for ginger in the peeler drum.

Singh *et al*. (2013) evaluated the performance evaluation of pineapple peeler-cum-slicer. The machine was found to operate with higher capacity of 20 fruits/h and peeling efficiency of 97.2% with less flesh wastage of 5.3%.

CHAPTER-3

MATERIALS AND METHODS

The materials used for fabrication of various components and dimension of each part were explained. Mainly this chapter deals with materials used, methodology opted for development and evaluation of pineapple peeler. A conceptual design was conceived and then the machine was fabricated in the workshop of KCAET, Tavanur.

3.1 EXPERIMENTAL PROCEDURES

3.1.1 **Development of first machine**

From the beginning of project we developed a simple manually operating machine (Plate 3.1).The main parts of the machine was a handle, where the force is applied for peeling process and circular blade which aid peeling of pineapple. The circular blade consists of a screw which helps in the diameter adjusting mechanism. But this screw made a difficulty in downward movement of handle along with blade. So, the peeling process was a failure and also the flesh remove from the pineapple was more. General layout and details of the machine is given below,

The machine consists of the following units.

1. Base
2. Frame with handle
3. Holding unit
4. Cutting blade

3.1.1.1 ***Base***

Frame was made into rectangular shape using GP (galvanized plane sheet) square pipe of 1.0 mm thickness and width of 20 mm and this frame was covered by a stainless steel sheet of 1.0 mm thickness. The base having length of 300 mm and width of 150 mm. on to this a supporting rod and handle were mounted.

3.1.1.2 ***Handle***

Handle made up of mild steel and a length of 400 mm. it is connected with base and supporting road. There is a spring mechanism inside the supporting road. The maximum height of the handle from the base is 350 mm. There is holding unit mounted on to the handle.

3.1.1.3 ***Holding unit***

The holding unit is made up of stainless steel. It is connected to handle and supporting rod. The purpose of holding unit is for fix the cutting blade.

3.1.1.4 ***Cutting blade***

The blade is made up of stainless steel, used for the peeling process as shown in Plate 3.2. A SS sheet of 220 mm length, 20 mm width and 1.0 mm thickness is shaped into a circular shape. Diameter of the cutting blade can adjust according to the size of the pineapple by using screw and thread mechanism. The diameter is reducing by overlapping the one end over other end. Maximum adjustable diameter was 100 mm and minimum 80 mm.

Plate 3.1 First developed machine

Plate 3.2 cutting blade

3.1.2 **Development of second machine**

To overcome the failure of first developed machine a new Pineapple peeling machine was developed and fabricated in workshop of Kelappaji College of Agricultural Engineering and Technology, Tavanur. It consist mainly a frame, motor, cutting and diameter adjusting system. General Layout and Details of the machine is given below,

The machine consists of the following units:

1. Frame Assembly
2. Holding unit
3. Motor
4. Cutting Blade
5. Diameter Adjustment System (DAS)
6. Frame covering

3.1.2.1. ***Frame Assembly***

Frame was fabricated by using GP (galvanized plane sheet) square pipe of 1.0 mm thickness and a width of 20.0 mm. On to this frame assembly, other sub-assemblies like motor, holding unit, cutting blade, DAS were mounted.

3.1.2.2 ***Holding Unit***

The machine consists of a Top holding unit and a bottom holding unit. The purpose of top holding unit is for rotating the pineapple. This holding unit is connected with the second motor. It is made up of SS with 62 mm diameter.

The bottom holding unit consists of two main parts. One is a SS circular section of 62mm diameter and other is of MS section having a length 200mm and a diameter of 25 mm threaded shaft. This unit has a four leg nut mechanism for the purpose of adjusting length. When rotating the leg nut mechanism, the threaded shaft will move upward and downward through a slot provided at the bottom. In order to prevent the rotation of threaded shaft, a socket mechanism provided at the bottom for holding the shaft. Inside both holding units a cross shape blade of 60 mm length and a 1.0 mm thickness has provided for gripping purpose. The plate of upper holding unit and lower holding unit are shown in Plate 3.3 and 3.4.

Plate 3.3Upper holding unit

Plate 3.4 Lower holding unit

3.1.2.3 ***Motor***

This machine is equipped with two motors called as first motor and second motor. First motor is having an rpm of 300 and 12 volts and the second motor are having 500 rpm and 12 volts. The purpose of first motor is for controlling the movements of blades to upward and downward where the function of second motor is to rotate the pineapple.

When the switch is ON both motor will start to work. Both forward and reverse connection has done for the upward and downward movement of the blades. The blade is always kept at the bottom position for the peeling purpose.

The motor has been mounted on a metal sheet having 309 mm length, 100 mm width and a thickness of 3 mm. The motor is shown in Plate 3.5.

Plate 3.5 Motor

3.1.2.4 ***Cutting Blade***

A square pipe of SS cut and made in to a cutting edge of 40 mm length and 20 mm width. Cutting edge has been sharpened by using a file. The blade has been connected to the diameter adjusting system. The cutting blade helps to the peeling process. The cutting blade is shown in Plate 3.6.

3.1.2.5 ***Diameter Adjustment System (DAS)***

The purpose of this diameter adjusting system (Plate.3.7) is to set the blade with respect to various diameters of pineapples. The DAS has consisted of a horizontal shaft of 225 mm length and 10.5 mm width and having threads on it. A 45 mm length and 20mm diameter of internal threaded socket mounded on it.

DAS having a 60 mm diameter handle for the forward and backward movement of blade This system having an another horizontal shaft of length 85mm inside and 90 mm outside were the blade is mounted on it and its purpose is to set the blade on permanent position while the other shaft is rotating.

DAS is connected on a vertical shaft of length 400 mm, and width of 10.5 mm. The purpose of the vertical shaft is to moving the DAS to upward and downward for the purpose of pineapple peeling.

Plate 3.6 Cutting blade

Plate 3.7 Diameter Adjustment System

3.1.2.6 ***Frame covering***

The frame is covered with stainless steel sheet of 1.0 mm thickness. The door of machine is made by using transparent acrylic sheet of 1.0 mm thickness. This door will prevent the splashing of pineapple juice during working.

3.1.3 ***Operational procedures***

The pineapple bought from the shop and cut 16 mm from the bottom and 20 mm from the top. The crown of pineapple has been removed. The operating procedures are given below

1. Place the pineapple on the bottom holding unit. By using the four leg nut mechanism, moving the pineapple upward and fix it with respect to the length
2. Bring the cutting blade bottom and by using the diameter adjusting system it's possible to choose various diameter proportions
3. Close the frame door of the equipment
4. Switch on the power and start the operation
5. Depending up on the pineapple size, we can adjust the blade
6. The pineapple peeling will take place
7. After the operation has been done, take out the peeled pineapple and clean the equipment

3.1.4 **Performance evaluation**

3.1.4.1 ***Peeling efficiency***

Each sample of pineapple was subjected to peeling action. After the peeling was completed, the peels remaining on the pineapple were removed manually for

each of the samples and their weights were noted. Peeling efficiency was then calculated by using the formula, suggestedby Singh and Shukla (1995).

$$\text{Peeling Efficiency} = \frac{(y - x)}{(x)} \times 100 \qquad \ldots\ldots 3.1$$

Where Y is the weight of peel on pineapple, X is the weight of peel remaining on the pineapple which is removed by hand trimming after mechanical peeling.

3.1.4.2 ***Material loss***

Material loss for each sample of pineapple was calculated based on following formula, suggested by Agrawal (1987)

$$\text{Material loss (\%)} = \frac{(z)}{(w + z)} \times 100 \qquad \ldots...3.2$$

Where Z is the weight of pineapple after mechanical peeling (g) for canning purposes, ¾ of the eyes have to be removed.

3.1.4.3 ***Capacity of the machine***

The capacity of the peeler, which is the number of kg pineapple produced by the machine in one hour was calculated by noting the weight of the peeled, cored pineapple produced and the time taken for the same. It was then expressed in kg/hr

The newly developed pineapple peeling machine, pineapple after peeling process and the peel obtained after peeling process are given in Plate 3.8, 3.9 and 3.10 respectively.

Plate 3.8 Pineapple peeling machine

Plate 3.9 Peeled pineapple

Plate 3.10 Peel obtained

CHAPTER-4

RESULT AND DISCUSSION

This chapter deals with the results of experiments conducted to evaluate the performance of pineapple peeler and its comparative performance with manual peeling method

4.1 TEST RESULTS

The first developed machine was subjected to experimental evaluation. For the experimental procedure we selected a pineapple of length 180 mm and a width of 80 mm, and placed it on the base. The diameter of the blade was adjusted according to the size of pineapple. Then Pulled down the handle to peel the pineapple but the attempt was failed because the applied force is not enough to cut the peel and also there is a disturbance caused by the screw thread. During the peeling time the blade is stuck on the pineapple due to the inward projection of screw thread and thus peeling efficiency of equipment was very poor. Also the maintenance of diameter adjusting mechanism of the blade become more difficult throughout the peeling process since the pineapple is having different symmetry. So to overcome these demerits we developed a new semi automated pineapple peeling machine.

4.2 RAW MATERIAL

Pineapples of different varieties and of different maturity were purchased from the market. The weight, diameter and length of each pineapple were measured. The weight of the pineapple ranges from 1721 kg to 1627 kg. The diameter varies from 80 mm to 95 mm and the length of pineapple varies between 180 mm to 200 mm. the details of sample shown in Table 4.1.

Table 4.1 specification of pineapple

Sample	Weight (kg)	Diameter (mm)	Length (mm)
1	1628.2	80	180
2	1648.6	83	183
3	1720.1	95	200
4	1672.5	88	190
5	1643.8	82	182
6	1701.3	91	195

4.3 PERFORMANCE EVALUATION

The model was evaluated for its overall capacity, peeling efficiency and material loss

4.3.1 **Overall Capacity**

The theoretical capacity was found to be 304.7 kg/hr. A time lag of 35seconds for peeling to account for counting and opening the doorway and to take the pineapple from the clamped surface is taken for a skilled worker between successive feedings, so the effective capacity is 109.7 kg/hr. The actual capacity of the machine ranges between 108 kg/hr to 111 kg/hr. Also the overall capacity of the machine ranges between 303 kg/hr to 308 kg/hr. The results are shown in the Table 4.2. The lowest value obtained in overall capacity is 303.4 kg/hr and the highest value

is 308.46 kg/hr. Similarly the lowest and highest values obtained in actual capacity are 108.5 Kg/hr, 111.7 kg/hr respectively.

Table 4.2 Overall capacity of the pineapple peeler

Sl. No	**Weight Of Peeled Pineapple (g)**	**Time Taken for Peeling (s)**	**Overall Capacity (kg/hr)**	**Actual Capacity (kg/hr)**
1	1628.2	19	308.46	108.5
2	1648.6	19.5	304.4	108.9
3	1720.1	20.4	303.4	111.7
4	1672.5	19.8	304.09	109.87
5	1643.8	19.5	303.47	108.58
6	1701.3	20.1	304.71	111.15
	Average		304.7	109.7

From the Table 4.2, it is seen that the capacity of machine does not shows a wide range difference, according to the change in weight of pineapple. Also the time taken for peeling might be changed based on the height or length of pineapple.

4.3.2 **Peeling Efficiency**

The peeling efficiency was calculated by using the formula (equation 3.1) and the average peeling efficiency was found to be 99.2%. The results are shown in table 4.3

Table 4.3 Peeling efficiency of pineapple peeler

SI. No	**Weight of peel on pineapple (g)**	**Weight of peel remaining on pineapple (g)**	**Peeling efficiency (%)**
1	400	0	100
2	430	3.9	99.1
3	460	4.6	99
4	440	4.0	99
5	425	3.4	99.2
6	451	4.2	99
	Average		99.2

From the results it is observed that peeling efficiency is not changing according to the diameter of pineapple and weight of the pineapple. The efficiency value ranges from 99-100 %.

4.3.3 **Material loss**

It was calculated by the equation (3.2) given in chapter 3. As per the calculation the average material loss was found to be 1.73 %. The material loss ranges from 1.6 to 1.8 %. The results are shown in table 4.4.

Table 4.4 Calculated material loss

Sl.No	**Weight of peeled pineapple (g)**	**Weight of flesh obtained from the peel (g)**	**Material loss (%)**
1	1228.2	20	1.6
2	1218.6	21	1.69
3	1260.1	23	1.79
4	1232.5	21	1.7
5	1218.8	22	1.8
6	1250.3	23	1.8
Average			1.73

From the table it is concluded that the loss obtained from the equipment during peeling is very less while compared to other peelers and other peeling methods.

CHAPTER 5

SUMMARY AND CONCLUSION

Fruit plays an important role in human diet. India is known as fruit basket of the world. Our country holds second position in fruit production and we are producing 45 MT per year. Post harvest losses in fruits are one of the most processing problems. About 35 % of loss is happening due to improper processing method. A substantial return can be obtained by processing and marketing that product on small scale. The pineapple is one of the major fruit and India produce about 1438.5 T. A plenty of value added products of pineapple are available in our market. The major problem faced in the processing of pineapple is the peeling. The peel of the pineapple should be properly removed, so as to avoid the itching and allergy caused by the peel. The peel is generally thick and non uniform. Due to this reason there need a more force to remove the peel. In most of the peeling is done by using knives. It may cause muscular disease and also it is a labor intensive and time consuming process. Though some of the pineapple peeling machine are available in market they are exorbitantly, priced, not that much flexible, not at all user friendly. Most of them made up of plastics. So that they are has been less strength. Therefore, it becomes necessary to develop a machine for pineapple peeling process which is simple in operation, easy to maintain and suitable for small scale industry.

A pineapple peeling machine was developed and fabricated, it consist of mainly frame assembly, holding unit, driving unit, diameter adjusting system, cutting unit(blade) these part are mounted on a frame assembly. The driving unit consists of two motor which helps in rotation of pineapple and upward and downward movement

of blade. Pineapples are different in their size and symmetry. So during peeling time the wastage is more so that it having a diameter adjusting system which facilitate the movement of blade according to the size of pineapple.

The overall capacity of newly developed machine is 305.4 kg/hr, and peeling efficiency is 99.3 %. While comparing the capacity with the manual peeling process it found that the material loss is very less .i.e., about 1.69 %.

Modification of machine can further improve the performance. Some suggestions that may help future research work are listed below

1. Incorporation of an automatic centering mechanism, so that pineapple can be centered automatically and a placed it in position more easily with in less time
2. A coring and slicing unit can also be included

REFERENCES

[Anonymous].2016 United Nations On Trade and Development(UNTD). *UNCTAD trust fund on market information on agricultural commodities,* p.6.

[Anonymous].2017a.Times of india.indiatimes.com/india/india-2nd-largest-fruit-producer-in world/article show/50618234.cms [5 April 2017].

[Anonymous].2017b.apeda.gov.in/apeda website/six head products/ffv.htm.[5 April 2017].

[Anonymous].2017c.https://en.wikipedia.org [5 April 2017].

[Anonymous].2017d.https://en.wikipedia.org/wiki/pineapple [5 April 2017].

[Anonymous].2017e.Wikipedia.Available: http://en.wikipedia.org/wiki/pineapple [15 Jan. 2017].

[Anonymous].2017f.www.itfnet.org/v1/projects-activities/what-we-do/ [6 April 2017].

[Anonymous].2017g.vazhakkulam pineapple.org/technology [20 Jan 2017]

[Anonymous]. 2017h. Official Portal of Malaysian Pineapple Industry Board.Available: http://mpib.gov.my/en/produk [17Jan 2017].

Agrawal, Y.C., Singhvi, A., and Sodhi, R.S. 1983. Development of an abrasive brush-type ginger peeling machine. *J. Agric. Eng.* 384(11): 179-182.

Agricultural statistics. 2015. Department of economics and statistics Thiruvananthapuram, Kerala.

Asselbergs, E. A. n.d. Research: Equipment for peeling fruits and vegetables by infrared process. Canada department of agriculture, Ottawa.ontario.

Azad, A.K. 1989. Studies on floral biology, pattern of fruit set and quality of fruit borne in different sections of jackfruit plants. M.Sc. (Ag.) thesis.Faculty of Agriculture, BAU, Mymensingh, Bangladesh. 77p.

Campbell, J. K. 1982. Machinery for village level processing of potatoes. *Am. Soc. Agric. Eng*. 82:1-9.

Chakespari, A.G., Rajabipour, A., and Mobli, H. 2010. Mass modeling of two apple varieties by geometrical attributes. *Aust. J. Agric. Eng*. 1(3): 112-118.

Coady, J., Eng, P., McKenna, M., and Eng, P. 2000. Good manufacturing and material selection in the design and fabrication of food processing equipment.[on-line].Available:http://www.engineersedge.com/ foodprocess.htm [20 Mar.2017].

Cohen, M.L. and Siegel, J. 1994. Fruit and vegetable peeler. United States Patent No. 5279035. Available: http://www.freepatentsonline.com/5279035.html [20 Mar.2017].

Emadi, B., Abbaspour-Fard, M.H., and Yarlagadda, P.K.D.V. 2008. Mechanical peeling of pumpkins. Part 1: Using an abrasive-cutter brush. *J. Food. Engg*. 89: 448-452.

Ewald, H.H. 1986. Apple corer with a core remover. United States Patent No. 4596073. Available: http://www.freepatentsonline.com/4596073.html [23 Mar.2017]

Food science home-Available: http://foodscience.wikispaces.com [18mar 2017].

Fox, G. B. 1955. Vegetable peeler having spray disperser. United States Patent No. 2838083. Available: http://www.patents.google.com/patent/ US2838083 [18 Mar 2017].

Gingras, M. 2001. Apparatus for peeling and optionally cutting vegetables. United States Patent No. 6253670. Available: http:// www.freepatentsonline.com/6253670.html [19 Mar 2017]

Gomez, S., Joseph, P.M., Sheela, K.B., Sruthi, C.V., and Lal, L. 2015. Variability in fruiting season and quality attributes of jackfruit (Artocarpusheterophyllus Lam.) accessions in Kerala. *Int. J. Trop. Agric.* 33(2): 1249-1255.

Hajar, N., Zainal, S., Nadzirah, K. Z., SitiRoha A. M., Atikah, O. and TengkuHida, T. Z. M. 2012. Physico chemical properties analysis of three indexes of pineapple peelextraxt variety N 36. APCBEE Procedia. 4: 115-121.

Hamlin, J. H. 1917. Fruits and vegetable peeling machine. United States Patent No. 1244452. Available: http://www.Google.com/patents/124452 [23 Mar.2017].

Haq, N. 2011.Genetic resources and crop improvement in the jackfruit. Thottappilly G, Peter KV and Valavi SG, ed., Studium Press India Pvt. Ltd, New Delhi.

Harding, G.J. 2001.Peeler for fruits and vegetables. United States Patent No. 6324969.Available:http://www.freepatentsonline.com/ 6324969.html [19 Mar2017].

Hart, M. R. 1971. System for peeling fruits and vegetables. United states Patent No.3618651. Available: http://www.google.com/pattents/US3618651 [19 Mar 2017]

He, S.L. and Tardif, P. 2000. Vegetable peeling apparatus.United States Patent No.D422173.Available:http://www.freepatentsonline.com/ D422173.html [20 Mar 2017].

Hossain, M. F., Akhtar, S., Anwar, M. 2015. Nutritional value and medicinal benefits of pineapple. *Int. J. Nutr. Food Sci.* 4(1): 84-88.

Indian Horticulture Database. 2013.

Jagadeesh, S.L., Reddy, B.S., Basavaraj, N., Swamy, G.S.K., Gorbal, K., Hegde, L., Raghavan, G.S.V., and Kajjidoni, S.T. 2007. Inter tree variability for fruit quality in jackfruit selections of Western Ghats of India. *Scientia Horticulturae*. 112: 382-387.

Jahromi, K.M., Rafiee, S., Jafari, A., GhasemiBousejin, M.R., Mirasheh., R., and Mohtasebi, S.S. 2008. Some physical properties of date fruit (cv. Dairi). *Int. Agrophy*. 22: 221-224.

Jain, N.K., Doharey, D.S., and Sharma, K.C. 2007. Development of abrasive peeler cum polisher for ginger. *J. Agric. Eng*. 44 (3): 84-86.

Jha, S.N., Kingsly, A.R.P., and Chopra, S. 2006. Physical and mechanical properties of mango during growth and storage for determination of maturity. *J. Food. Eng*. 72: 73-76.

Jannatizadeh, A., NaderiBoldaji, M., Fatahi, R., GhasemiVarnamkhasti, M., and Tabatabaeefar, A. 2008. Some postharvest physical properties of Iranian apricot (Prunusarmeniaca L). *Int. J. Agrophy*. 22: 125-131.

John, A., Manoj P. K., Nizar, M. U .A. and Sathyan , K. 1996. Development and testing of a semi mechanical ginger peeler. Unpublished B.Tech, (AgriEngg).

Kafejiev, I. C. 1973. Method of peeling fruits and vegetables. United States PatentNo.3769439.Available:http://www.google.com/patents/US3769439 [21 Mar 2017].

Kalita, D.N., Deka, B., Sonowal, P., and Bhagawati, M. 2014. Assessment of morphological characters of Jackfruit in lower and central Brahmaputra valley zone and North bank plains of Assam. *International Symposium on Jackfruit Breadfruit Tropics*. 21-33.

Kim, S.S. 2006. Fruits peeler.United States Patent No. US20060042097. Available: http://www.freepatentsonline.com/y2006/0042097.html [21Mar 2017].

Kotoky, U., Saikia, I., Gogoi. Baruah, B., Baruah, S., and Bhuyan, P. 2014. Qualitative traits of jackfruit genotypes of Assam. *International Symposium on Jackfruit Breadfruit Tropics*. 40-43.

Kyu Hong. C, Gewn, O., Weon, L., and Jong Tae, J.H. 1995. Development of vaccum sucking type Persimmon, peeler. R.D.A- J. *Agric. Sci. Farm. Manag.*, 37(1):624-628.

Lazzarini, L. P. 1974. Peeling machine and method. United states Patent No 3811000. Available: http://www.google.ch/patents/US3811000 [22Mar 2017].

Lino, A.C.L., Sanches, J., Maria, I., and Fabbro, I.M.D. 2008. Bragantia, Campinas. 67 (3): 785-789.

Mandher, S. C and Kumaran, G. 1995. Development of a continuous motorized peeler for raw mangoes. *J. Food. Sci. Technol.* 32(1):65-67

Martin, R. 2000. Fruit peeler. United States Patent No. 6125744. Available: http://www.freepatentsonline.com/6125744.html [23 Mar 2017].

Mitra, S.K. and Mani, D. 2000. Conservation and utilization of genetic resources in jackfruit (Artocarpusheterophyllus L) - a potential underutilized fruit. *Acta Horticulturae.* 523: 229-232.

Mohamad, A.H.B. 2010. Design and development of portable pineapple peeler An ergonomics approach [Lecture notes] University Malayasia Pahang.

Mohan, A. 2012. Development and evaluation of a seed extractor for ash gourd and cucumber. Un published M.Tech. (Ag. Eng) thesis, Kerala Agricultural University, Thrissur, 39p.

Murphy, M. J. 1946. Egg, Fruit and vegetable peeler.United States Patent No. 2521245.Available: http://www.freepatentsonline.com/2521245.html [22 Mar 2017].

Nadzirah, K. Z., Zainale, S., Norihum, A., Normah, I., Sitiroha, A. M., and Nadya,H.2013. Physico-chemical properties of pineapple variety N 36 harvested and stored at different maturity stages. *Int. Food Res. J.* 20(1):225-231.

National Horticulture Board - Horticultural statistics at a glance. 2015. Oxford university press publication, New Delhi, India.

Odigboh, E.U. 1976. A cassava peeling machine: Development, design and construction. *J. Agric. Engg. Res.* 21: 361-369.

Oluwole, O. O. and Adio, M. A. 2013. Design and costruction of a batch cassava peeling machine. *J. Mech. Eng. Automation.* 3(1): 16-21.

Owolarafe, O.K. and Shotonde, H.O. 2004.Some physical properties of fresh okro fruit. *J. Food. Eng*. 63 (3): 299-302.

Pandey, P.H.1997.Post harvest technology of fruits and vegetables, Saroj Prakasan, Alahabad, PP: 100-110.

Pineapple-An industrial profile 1985. CFTRI , Mysore.

PineappleVarieties.Available:http://nhb.gov.in/bulletin_files/fruits/pineapple/pin013.pdf [17 Jan 2017].

Joy. P.P. 2013. Pineapple sector in kerala; status, opportunities, challenges and stackholders.KAU,Vazhakulam.Available;http://www.kau.edu/prsvkm.pdf [17 Jan 2017].

Primavera, R.R. 2007.Vegetables and fruits peeler. United States Pattent No. 0036886. Available: http://www.google.ch/patents/US20070036886 [20 Mar 2017].

Protte, C. 1999. Peeling machine. United States Patent No. 5857404. Available: http://www.freepatentsonline.com/5857404.html [22Mar 2017].

Rafiee, S., Jahromi, K.M., Jafari, A., Sharifi, M., Mirasheh, R., and Mobli, H. 2007. Determining some physical properties of bergamot (Citrus medica). *Int. Agrophy*. 21: 293-297.

Reddy, B.M.C., Patil, P., Kumar, S.S., and Govindaraju, L.R. 2004. Studies on physico-chemical characteristics of jackfruit clones of south Karnataka. *Karnataka J. Agri. Sci.* 17 (2): 279-282.

Ridler, D.G. 2001. Fruit and vegetable peeler. United States Patent No. 6327971. Available: http://www.freepatentsonline.com/6327971.html [21Mar 2017].

Rose, E.D., Rafael, San., and Calif. 1987. Apparatus for peeling pineapples. United States Patent No. 4653393. Available: http://www.freepatentsonline.com/4653393.html [23 Mar 2017].

Sahay, K.M. and Singh, K.K. 1994. Drying in unit operations of agricultural processing.Vikas publishing house private limited, New Delhi. 107.

Radhakrishnaiah Setty, Vijalakshmi, M.R and Ushadevi, A. 1993. Methods for peeling fruits and vegetables; A critical evaluation, *J. Food.Sci. Technol*, 30 :(3).pp 155-162

Shamsudin, R., Daud, W.R.W., Takrif, M.S., and Hassan, O. 2009. Physico-mechanical properties of the josapine pineapple fruits. Pertanika. *J. Sci. Technol*. 17 (1): 117-123.

Sharifi, M., Rafiee, S., Keyhani, A., Jafari, A., Mobli, H., Rajabipour, A., and Ahram, A. 2007. Some physical properties of orange (var. Thompson). *Int. Agrophysics*. 21: 391-397.

Shyamalamma, S., Priyanka, S., Bhaskarareddy, D.V., Ramya, K.G., Veena, R., Munishamanna, K.B., and Kalpana, B. 2014. Genetic diversity assessment in selected genotypes of jackfruit in Bangalore and Tumkur districts of Karnataka. *International Symposium on Jackfruit Breadfruit Tropics*, pp. 82-88.

Singh, K.K. and Shukla, B.D. 1995. Abrasive peeling of potatoes. *J. Food. Eng*. 26: 431-442.

Singh, V., Verma, D.K., and Singh, G. 2013. Development of pineapple peeler-cum- slicer. Pop. Kheti, 1(2): 21-24.

Siti Mazlina, M.K., Nur Aliaa, A.R., Nor Hidayati, H., and Intan Shaidatul Shima, M.S. 2010. Design and development of an apparatus for grating and peeling fruits and vegetables. *Am. J. Food. Technol*. 5(6): 385-393.

Sommer, F. 1997. Device for peeling elongated vegetables. United States Patent No.5669293.Available: http://www.freepatentsonline.com/5669293 .html [24 Mar.2017].

The fruit and vegetable sector in the EU - a statistical overview. Fruit world production by type 2014 statistic. Available: www.statista.com [24 Mar.2017].

Thongsroy, B. and Klajring, V. 2015.Development of fruit peeling machine using a two-way blade. The 16th TSAE national conference and the 8th TSAE international conference. 53-56.

Ukatu, A.C. 2005. Development of an industrial yam peeler. *Agric. Mechanization Asia Africa Latin Am*. 36 (2): 21-27.

Ullah, M.A. and Haque, M.A. 2008. Studies on fruiting, bearing habit and fruit growth of jackfruit germplasm. *Bangladesh J. Agric. Res*. 33 (3): 391-397.

Vidhu,k.p.,George,b.k., and bindhu.k.(2002).development of pineapple peeler cum corer cum slicer.unpublished B.Tech,(Agri Engg).

Willard, M. J. 1968. Apparatus and method for peeling fruits and vegetables. United States Patent No.3370627.Available: http://www.google.co.in/ patents/US3370627 [26 Mar.2017].

Young, E. C. 1957. Potato peeler. United States Patent No. 2958355. Available: http://www.google.co.in/patent/US2958355 [26 Mar.2017].

APPENDIX I

CALCULATION OF OPERATING COST

Initial cost (C)

Fabrication cost of pineapple peeler

Including cost of material = Rs. 10000

Average life of machine =10 years

Working hours per year =3650

Salvage value =10% of initial cost

A) Fixed cost

1. Depreciation $= \frac{C - S}{LH}$

$= \frac{10000 - 1000}{10 \times 3650}$

$=0.246$

2. Interest on investment@ 12% $= \frac{(C + S) \times 12}{2 \times H \times 100}$

$$= \frac{(10000+1000)\times 12}{2\times 3650\times 100}$$

=0.180

Total fixed cost =0.426

B) Variable cost

1. Labour wages

Wages of labour = Rs. 400/day 0f 10 h

2. Cost of electrical energy

Unit cost of electricity =Rs. 7/kwh

Energy consumption of machine =0.402

Cost of electricity =2.814/h

3. Repair and maintenance cost

@ 10% of initial cost p.a. $= \frac{100000\times 10}{3650\times 100}$

=0.27/h

Total variable cost =43.084/h

Total operating cost =43.51/h

DEVELOPMENT AND PERFORMANCE EVALUATION OF A SEMI-AUTOMATIC PINEAPPLE PEELING MACHINE

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ABSTRACT

Submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

FOOD ENGINEERING

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ABSTRACT

Pineapple is one of the major fruit produced in India. The major problem related with the processing of pineapple is peeling. Peeling of pineapple manually is a time consuming, labour intensive process and causes drudgery, Therefore a simple, semi mechanical pineapple peeling machine which is easy to operate, maintain, and economical was fabricated. The peeler removes the peel effectively and makes the further processing easy. The equipment consist of mainly three parts two motors, cutting blade and diameter adjustment system. One motor of 300 rpm and12v which control the movement of blade and another of 500 rpm and 12v used to rotate pineapple. The wedge shaped cutting blade made from stainless steel square pipe having 0.1mm thickness, 4mm length and 2mm width. The blade is attached to diameter adjustment system which facilitates the movement of blade according to shape of pineapple. The simultaneous movement of two motors helps in rotation of pineapple and upward and downward movement of blade, respectively.This results in peeling of pineapple. The designed pineapple peeler also proved to have a high efficiency (99.3%) with less material loss (1.69%) and capacity about 305.5kg/hr.