MODIFICATIONS AND TESTING OF KAU ARECANUT DE-HUSKER

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Modifications and testing of K A U arecanut de-husker"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Modifications and testing of K A U arecanut de-husker"** is a record of research work done independently by **Mr. Rajmohan. C.K.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Tavanur. **RAJMOHAN**

Dedicated to

My Loving Parents

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SYMBOLS AND ABBREVIATIONS

Agril	-	Agricultural
ASAE	-	American Society of Agricultural Engineers
C	-	Centigrade
cc	-	cubic centimetre(s)
cm	-	centimetre(s)
cm^2	-	square centimetre(s)
cm^3	-	cubic centimetre(s)
d.c	-	direct current
deg.	-	degree
engng.	-	Engineering
et al.	-	and others
fig.	-	figure
g	-	gram
Govt.	-	Government
GI	-	Galvanised steel
h	-	hour(s)
ha	-	hectare(s)
hp	-	horsepower
ICAR	-	Indian Council of Agricultural Research
i.e.	-	that is
IIT	-	Indian Institute of Technology
Ind.	-	India
J.	-	Journal
KAU	-	Kerala Agricultural University
kg	-	kilogram
kW	-	kilo watt

m	-	metre(s)
MS	-	Mild Steel
no.	-	number
Res.	-	research
rpln.	-	replication
rpm	-	revolutions per minute
Rs	-	Rupees
s	-	seconds
sl.	-	serial
std.	-	standard
TNAU	-	Tamil Nadu Agricultural University
Trans	-	Transactions
viz.	-	namely
vol.	-	volume
w.b.	-	wet basis
%	-	percentage
/	-	per
o	-	degree
@	-	at the rate of

Introduction

INTRODUCTION

Arecanut palm (<u>Areca catechu Linn.</u>) is an extensively cultivated tropical palm, the nuts of which form a popular masticatory in India, the Middle-East and the Far-East. It is a tall-stemmed erect palm, reaching heights upto 30 m, depending upon the environmental conditions. The origin of arecanut is obscure. But approximately thirty six species are at present grown over India, Bangladesh, Sri Lanka and Malaysia. The nut of this beautiful palm is called the arecanut or betelnut.

Arecanut is used widely in India and is offered to guests and visitors on ceremonial, festive and religious occasions, along with betel leaves. It is chewed with betel leaves and considered to be of some assistance in promoting digestion. It is an astringent and antihelminthic. The husk of the nuts can be used for manufacturing low grade paper. It is also used as fuel to cook.

India leads in the production of arecanut with 275,000 tonnes annually. This accounts for 85 per cent of the total world production. The major portion of the production comes from Karnataka (41 %), Kerala (25 %) and Assam (20 %). Arecanut is grown to small extent in Maharashtra, Tamil Nadu, West Bengal and Meghalaya.

Statistics reveals that the area under this crop has increased from 1.06 lakh ha in 1985 - 86 to more than 2.39 lakh ha in 1993 - 94, thereby, registering an increase of 225 per cent. Earlier, India was importing arecanut to meet the local demand. Import was completely terminated by 1974 - 75 and India started exporting the nuts to different countries such as Nepal, Singapore, East Asia, Saudi Arabia and the United Kingdom. Presently, the average yield of arecanut per hectare is 1156 kg, in India. One could expect a net return of Rs 40,000/ ha-year from arecanut alone. The palm cultivation provides employment to about 6.25 million people and the marketing of arecanut brings sizeble revenue to the State's exchequer (Survey of Indian Agriculture, 1992).

The nuts are dried in the sun by spreading in single layer for 35 to 40 days. These dried nuts are dehusked to get the whole kernel known as "Kottapak" or "Chali". Nearly one third of total production reaches the consumer as ripe fruit. Trade forms of arecanut are 'Ripe arecanut', 'Ripe dried arecanut' and 'Processed green nuts'.

The cost of production of arecanut under good management in Kasaragode area was Rs 22/kg for Kottapak and farm gate price that could be expected was about Rs 35/kg (1995). As per studies and surveys conducted in Tamil Nadu, it was found that about 35 to 45 percentage of total cost of processing is for dehusking. At present dehusking is done by women folks, who use the locally made country knife to dehusk. But, this conventional method is highly labour intensive and time consuming and above all uneconomical. Even at the small scale level mechanical dehuskers are not available now. The mechanical dehuskers developed earlier have certain disadvantages such as low-capacity, high-cost and complex design .

Taking these factors into consideration an arecanut dehusker was developed in Kerala Agricultural University in 1993. The efficiency and the output of this machine was found to be very low.

Considering the shortcomings in the area of dehusking, the present study was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur with the following objectives.

1) To evaluate the properties of arecanut relevant to dehusking.
2) Modification of KAU Arecanut Dehusker.
3) To evaluate its performance.

Review of Literature

REVIEW OF LITERATURE

This chapter deals with reports and studies on the origin, distribution, production and chemical composition of arecanut. Review of the past studies on the properties, uses, methods of dehusking, marketing and export of arecanut are also comprehensed in this section.

2.1 Origin and distribution

The origin of arecanut is an issue of controversy. In "The Origin of Cultivated Plants", De Candolle (1886) reported that the country of origin of arecanut remain unknown. But at the same time, he pointed out to the possibilities of origin in Sunda Islands.

Beccari (1919) considered Philippines as the origin of arecanut. Also he revealed the existence of four cultivars of *Areca catechu* and nine other species in Philippines and the absence of reports on similar species in other parts of the world.

Petelot *et al*. (1926) reported of the existence of arecanut in Indonesia. Other nations in which existence of arecanut was reported are India and Sri Lanka (Blatter, 1926), South China (Hisiao - Liang, 1936), Taiwan (Yama Moto, 1939) and Jawa (Meijer, 1948).

2.2 Area under arecanut and production

There is an increment in area under cultivation and production of arecanut in India. Area under cultivation increased from 95,000 to 210,000 ha within a span of about 40 years. During the same period the production increased to about three times ; 76,000 tonnes in 1955 - 56 to 275,000 tonnes in 1995-96. Some of the details regarding the area under arecanut and production are presented in Tables 2.1 and 2.2.

Table 2.1. Area under arecanut and production in different countries during 1988 - 89

Country	Area ('000 ha)	Production ('000 tonnes)
India	200.0	228.6
Bangladesh	37.7	21.4
Sri Lanka	28.3	16.1
Malaysia	1.8	1.0

Source : Directorate of Economics and Statistics. Ministry of Agriculture, Government of India.

Table 2.2. Area under arecanut, production and yield of arecanut in some states in India during 1993 - 94

State	Area ('000 ha)	Production ('000 tonnes)	Yield (kg/ha)
Andhra Pradesh	00.2	00.1	500
Assam	70.3	55.3	787
Goa	1.3	1.5	1154
Karnataka	77.0	113.3	1471
Kerala	63.8	70.3	1102
Maharashtra	1.9	3.6	1895
Meghalaya	8.8	9.4	1068
Mizoram	Negligible	0.1	****
Tamil Nadu	2.8	4.3	1536
Tripura	1.4	2.5	1786
West Bengal	6.7	9.5	1418
A & N Islands	3.5	4.9	1400
Pondicherry	0.1	0.2	2000
All India	237.8	275.0	1156

Source : Economics and Statistics Adviser, New Delhi.

2.3 Chemical composition

Polyphenols, fat, polysaccharides, fibre and protein form the major constituents of arecanut. The chemical composition of the nut depends on the maturity of the nut (Shivasankar et al. 1976).

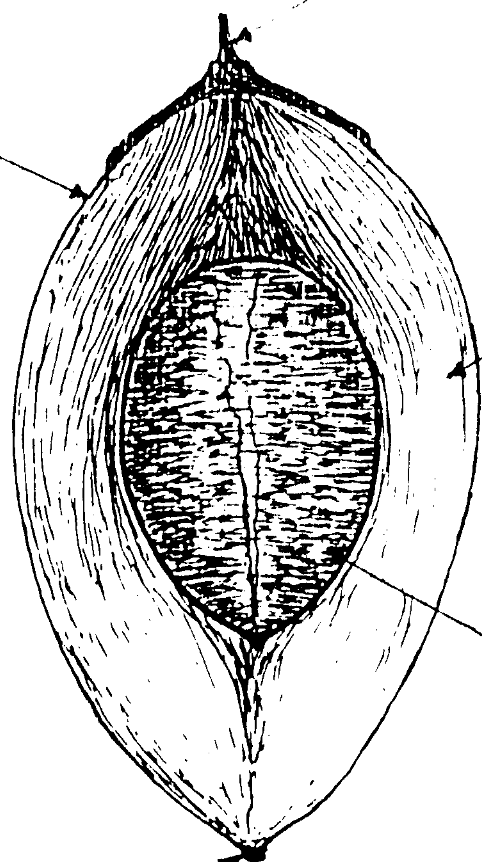


Fig.2.1 Longitudinal cross-section of an arecanut fruit

The arecanut husk contains 35 to 64 per cent hemicellulose and 13 to 26 per cent lignin.

2.4 Multitudinal uses

Arecanut has got multifarious uses, some of which are described below.

2.4.1 Medicinal and other uses

According to Febi (1993) with reference to the medicinal properties of arecanut, Vaghhata (fourth century) has explained its uses against leucoderma, leprosy, cough, fits, worms, anaemia and obesity. Arecanut has been mentioned for its use as a purgative and as an ointment along with several other ingradients, for the treatment of nasal ulcers. Arecanut is mentioned as a stimulant and apetizer. It is also pointed out as pungent, bitter, spicy and sweet and that it expels gas, removes phlegm and bad odour and kills worms.

According to Watt (1889) powdered nuts were used as an antihelminthic for dogs for many centuries as it helps in deportation of tape worms.

Febi (1993) has reported that chewing of arecanut enhanced the production of saliva and gastric juices and that these helped in digestion. It is said to be effective in strengthening gums and teeth and in cleaning and deodouring the mouth. It also finds prominent place in many of the social and religious ceremonies.

2.4.2 Uses of various constituents

In day to day life of human beings, the various constituents of arecanut find various uses.

Selvarangan (1955) found that the arecanut tannins have a lower acid salt ratio and as a result it can produce mellower type of leather.

Arecatannin can be used for making textile dye (Murthi et al.,1982). They also reported that tannin gave a satisfactory colour which could be used as a dye for wool and paper.

Shah (1980) stated that areca fat has comparable characteristics with hydrogenated coconut oil. By refining with an alkali, areca fat can be made edible.

2.4.3 Arecanut husk

The husk fibres predominantly consist of cellulose with varying proportions of hemicellulose, lignin, pectin and protopectin.

Murthi et al. (1982) stated that the husk can be used for the preparation of hard boards. Though its water absorption and swelling properties are not satisfactory, thermal conductivity, thickness, density and strength properties are comparable with standard foreign boards like Masonite.

Raghavan (1957) suggested that husk can be made into insulating felt and wool in an admixture with jute and caddles.

Febi (1993) pointed out that arecanut husk could be used as a manure and is a good source of furfural. Indian Dry Research Laboratory, Pune based on their preliminary investigations put forward the scope of producing activated carbon from the husk.

Blends of arecanut pulp is useful in producing brown wrapping paper (Singh and Guha, 1960).

The relevance of chemical conversion of areca husk was confirmed by plant level studies at Punalur Paper Mills, Kerala in 1975. The pulp was short fibred and could produce paper of low bursting strength and break factor (Febi,1993).

2.4.4 Leaf sheath, stem, and leaf

Leaf sheath, another raw material from arecanut palm could be used for making throw - away cups and ply boards, plates and gin washer. It is also used in preparation of brief cases, bags, spectacle cases and fibre boards.

Annamalai and Nair (1982) reported that, though the tensile strength was moderate, the flat surface of the processed sheath could be used for making a material suitable for ply boards.

2.5 Marketing and export

"Kalipak" and "Kottapak" are the two categories of arecanut which are marketed. Kalipak is made from tender nuts of 6 to 7 months maturity, which is dehusked, sliced, boiled with water and dried to black colour. Kottapak, which is the most widely used trade type of arecanut is made by drying ripe arecanut in sunshine to reduce moisture content to 10 to 12 per cent followed by dehusking (Febi, 1993).

According to the Government of India's estimate, India has achieved self sufficiency when the production reached two lakh tonnes. Subsequently, the country started exporting arecanut to Nepal, Singapore, East Asia, Saudi Arabia and United Kingdom. The quantity exported is about 600 tonnes annually.

Apart from this, the scented supari industry has created a sizeable demand for arecanut. It refers to the green processed arecanut cut into small bits, mixed with powdered spices, and flavoured. Copra and sugar crystals are also added in few cases. Such value added products help to sustain the price even with increased production.

2.6 Physical and mechanical properties of arecanut

The physical as well as mechanical properties of arecanut play an important role in the design of dehusking machine. The various physical properties relevant to dehusking are size, shape, moisture content, weight, true density,bulk density and angle of repose.

Mohsenin et al (1962) reported that a circular platform apparatus was needed to determine the angle of repose. They used the expression

$$0 = \tan^{-1} \frac{2\ (Hc - Hp)}{Dp}$$

where θ = angle of repose

Hc = height of cone, cm

Hp = height of platform, cm

Dp = diameter of platform, cm

Mohsenin (1970) calculated the shear strength of the flesh of fruits by shearing a plug from a slice of the fruit flesh. The shearing strength was determined by the relationship

$$S = F/\pi dt$$

where S = shearing strength, kg/cm^2

F = force, kg

d = diameter of the solid cylindrical plug, cm

t = thickness of the slice, cm

Balasubramanian (1980) studied various physical and engineering properties of locally available arecanut at Coimbatore in order to decide the design parameters of arecanut decorticator. The properties are given in Table 2.3 .

Das (1982) studied some physical properties of arecanut available at different regions. It was established that the nuts produced at different regions were having different sizes and shapes. The nuts produced in Kerala particularly in north Malabar are big and oblong. In Sagar and Thirthhalli areas of Karnataka, the nuts produced are small and round in shape. In the Mettupalayam areas of Tamil Nadu, the nuts produced are very small with oblong shape.

Table 2.3. Physical properties of arecanut (Balasubramanian, 1980)

Sl No.	Physical parameter	Range of variation	Mean value
1	Axial dimensions of fruit		
	i) Length,mm	36 - 47	42.5
	ii) Diameter,mm	22 - 27	25.4
2	Axial dimensions of kernel		
	i) Length,mm	16 - 22	19.5
	ii) Diameter,mm	17 - 20	17.5
3	Dry weight of		
	i) fruit,g	6.1 - 7.1	6.562
	ii) kernel,g	4.0 - 4.5	4.228
	iii) husk,g	1.8 - 2.2	2.012
4	Weight ratio		
	i) $\frac{\text{weight of kernel}}{\text{weight of fruit}}$	0.605 - 0.679	0.644
	ii) $\frac{\text{weight of husk}}{\text{weight of fruit}}$	0.253 - 0.343	0.306
5	Volume		
	i) dried fruit, cm^3	12.5 - 20.5	16.625
	ii) dried kernel, cm^3	4.5 - 8.5	6.475
6	Dry density		
	i) fruit, g/cm^3	0.416 - 0.556	0.493
	ii) kernel, g/cm^3	1.110 - 1.150	1.123
7	Bulk density		
	i) fruit, g/cm^3	0.265 - 0.294	0.284
	ii) kernel, g/cm^3	0.640 - 0.670	0.654
	iii) husk, g/cm^3	0.121 - 0.133	0.128
8	Porosity		
	i) dry fruit, %	-	43.3
	ii) dry kernel, %	-	41.8
9	Angle of repose		
	i) dry fruit, deg	-	32.2
	ii) dry kernel, deg	-	35.5
10	Surface area		
	i) dry fruit, cm^2	17.5 - 29.5	23.125
	ii) dry kernel, cm^2	11.5 - 15.5	13.725

Among the engineering properties, Balasubramanian (1980) determined the effect of compression, impact and shear of arecanut with respect to the force applied in longitudinal and lateral directions. According to him axial loading was desirable as it consumed less energy to deform and to fail the husk.

Shiv Sankar et al. (1976) reported that the shear stress required to fail the husk was less at higher moisture content of the arecanut. Shear force applied in the axial direction of the fruit was more desirable in saving energy during dehusking operation at higher moisture content of the arecanut. However, the saving in energy was negligible at about 10 per cent moisture content (w.b.) of the arecanut.

It was reported that in the case of axial compression, the magnitude of impact required to fail the husk increased with the increase in moisture content of the husk . The impact required to dehusk the arecanut at 10.5 per cent moisture content (w.b.) was estimated to be 3.5 kg-m. In the case of lateral application, the impact required was nearly 2.0 kg-m. Hence, application of impact in lateral direction was more desirable for dehusking of arecanut (Balasubramanian, 1980).

Thomas and Sarkar (1982) measured the lateral compression force required to crush the husk of arecanut. It was reported that as the moisture content of arecanut increased the energy required to fail the husk increased.

They have also reported that the force required to fail the husk in shear sharply increased with the moisture content and the pitch.

2.7 Conventional method of dehusking

In conventional method, dehusking of arecanut was done by a group of women labourers. Normally they cut the outer husk at 2 to 3 different points with the help of locally made country knife(Fig 2.2). Every time they cut the outer husk, they gave a twist to the knife and finally the nut was taken out mostly undamaged. In this method, the normal rate of dehusking was about 3 to 5 kg / woman-hr. This was a very slow process and at the same time labourious. The advantage of this method was that, it minimised damage to the nut. Asokan (1984) estimated that the total cost of dehusking the annual produce of 1.914 lakh tonnes by this method would come to approximately Rs 6.58 crores considering labour charge as Rs 11.0 per 8 hr., and dehusking rate as 4 kg / woman-hr. Further, the data collected indicated that nearly 60 million labourers would be required annually to dehusk the produce.

2.8 Arecanut decorticating machines

Balasubramanian (1980) developed a dehusker for arecanut at Tamil Nadu Agricultural University, Coimbatore. The machine is shown in Fig.2.3. The principle used in dehusking the nuts was of an oscillating, friction type arm, moving over a semicircular concave with a suitable clearance. The separation of the nut from the husk was done by using a centrifugal type blower being driven by the same motor. During the course of investigation,

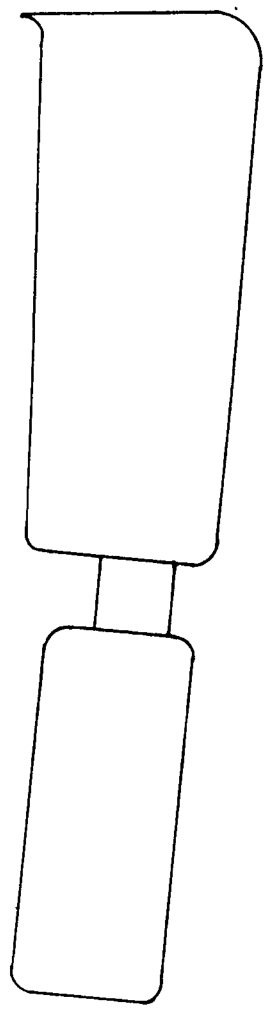
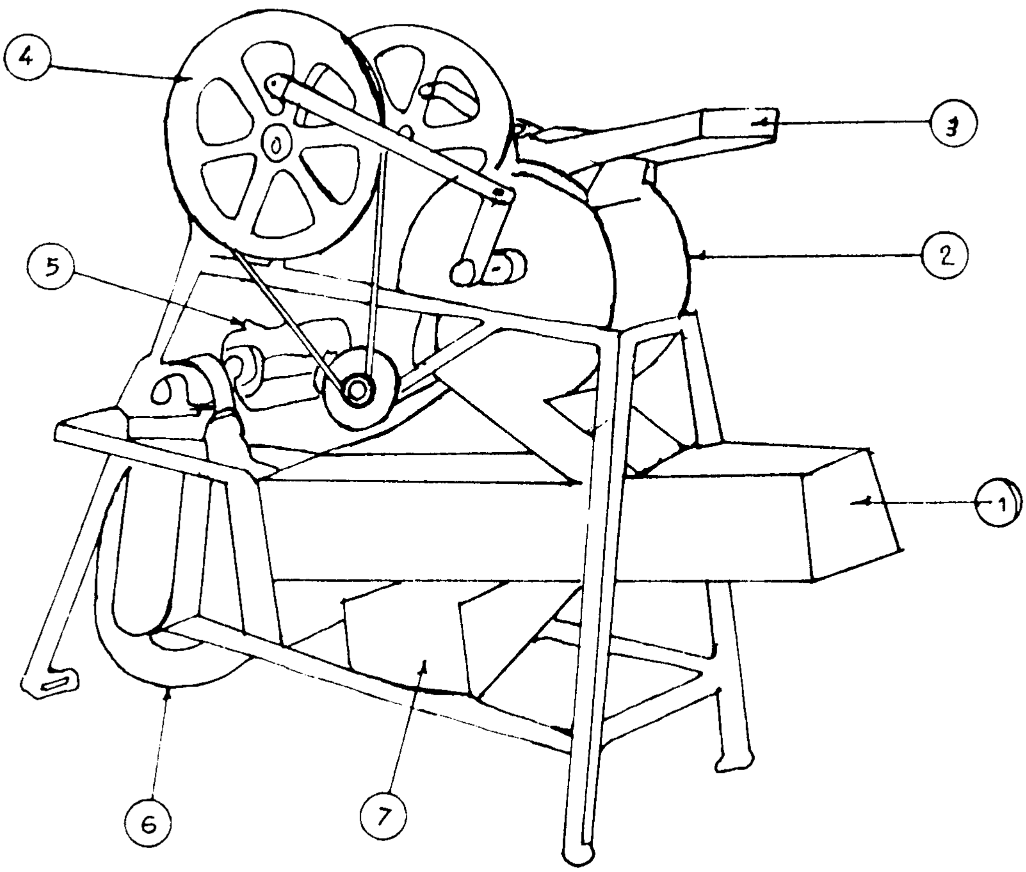


FIG. 2.2 COUNTRY KNIFE USED FOR DEHUSKING

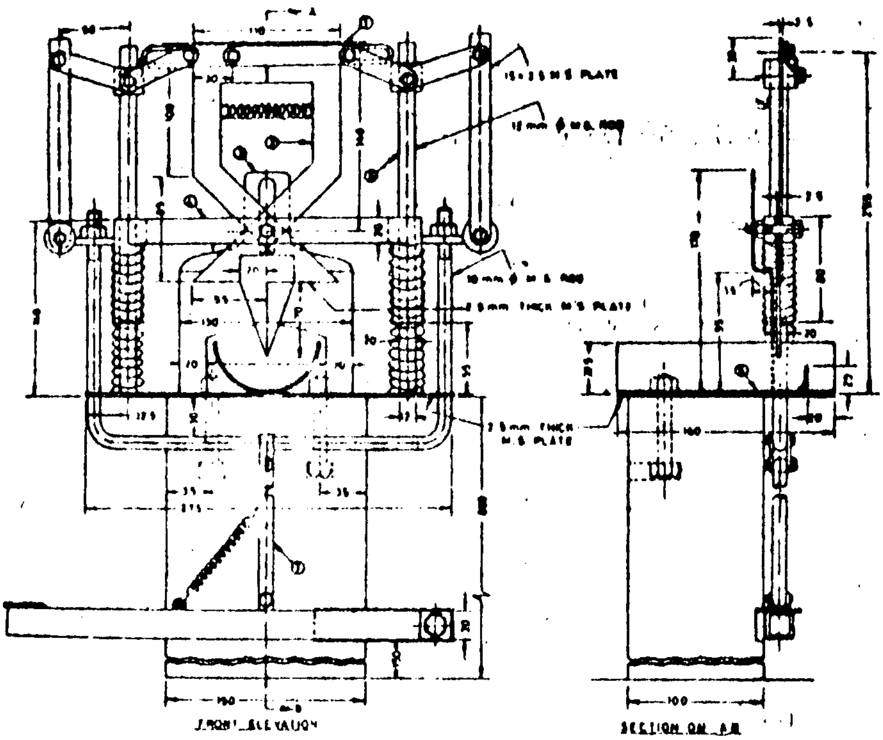


1. HUSK OUTLET
2. DEHUSKING UNIT
3. FEED HOPPER
4. OSCILLATING ASSEMBLY
5. MOTOR
6. BLOWER
7. NUT OUTLET

FIG. 2.3 ARECANUT DEHUSKER (BALASUBRAMANIAN)

Balasubramanian (1980) varied the stroke length, the clearance between the reciprocating arm and the concave, and the material used in creating the friction. It was reported that the reciprocating arm with toothed rubber lining exhibited a better performance with respect to the percentage damage of nuts as against steel reciprocating bar.

Bengali Baboo (1982) developed a device for dehusking arecanut at Indian Institute of Sugarcane Research, Lucknow. It comprised of a scissor mechanism, frame and platform and a pedal operated lever mechanism. The device is as shown in Fig.2.4. A pair of scissors made of steel was mounted on a frame with a guide and compression spring. Two guide rods were provided, each with a mild steel bush on which scissors were mounted. The compression springs around the bush brought back the scissors to normal position after each operation. A half-cut G.I. pipe piece with feed stop was fixed on the platform to guide the position of the nut. The device could be operated by one or two unskilled labourers. The operator sat on a wooden stool keeping his foot on pedal. The nuts were fed one by one below the scissors. The pedal was then pressed. The scissors while moving downwards pierced the husk and was then expanded. This action split the husk into two parts. The nut was taken back by left hand and peeled off with both the hands. The dehusked nut and husk were collected separately. It was found that about 60 to 100 kg nuts could be dehusked in a day of eight hours.



(1) Scissors Linkage
(2) Scissors
(3) Scissors Guide
(4) Movable Frame
(5) Fixed Frame
(6) Platform
(7) Pedal Linkage

All Dimensions in mm

FIG.2.4 ARECANUT DEHUSKING DEVICE

George (1982) designed an arecanut shelling machine at Birla Institute of Technology and Science ,Pilani. It had a builtin arrangement for the separation of the nut and the arecanut shell. It had a provision for automatic collection of the nut and shell in separate compartments. The details of the machine are shown in Fig.2.5. The device was designed for one man to operate. The machine was robust and required little maintenance except cleaning and oiling from time to time.

Thomas and Sarkar (1982) designed, developed and tested a betelnut decorticator at the Indian Institute of Technology, Kharagpur. The machine was operated by a 1-hp electric motor. The betelnuts were fed by gravity from a hopper to a pair of rubber rollers. The rubber rollers applied compressive force and caused partial failure of the husk. These betelnuts were guided by a chute to the cross rollers. The teeth on the iron rollers caused complete failure and separation of the husk by shear action. In order to provide the shear load, the toothed rollers were rotated at different speeds. If the rollers did not cause complete failure and separation of the husk, the toothed plate would be helping to have more effective dehusking. The mixture of husk and nut coming out from the toothed plate were winnowed by a blower. The nut and husk were collected separately through different outlets. The device is shown in Fig.2.6. The advantage of the machine was that the dehusking was done effectively but it required a feeding of nearly same size arecanuts. Hence, grading of arecanut was essential.

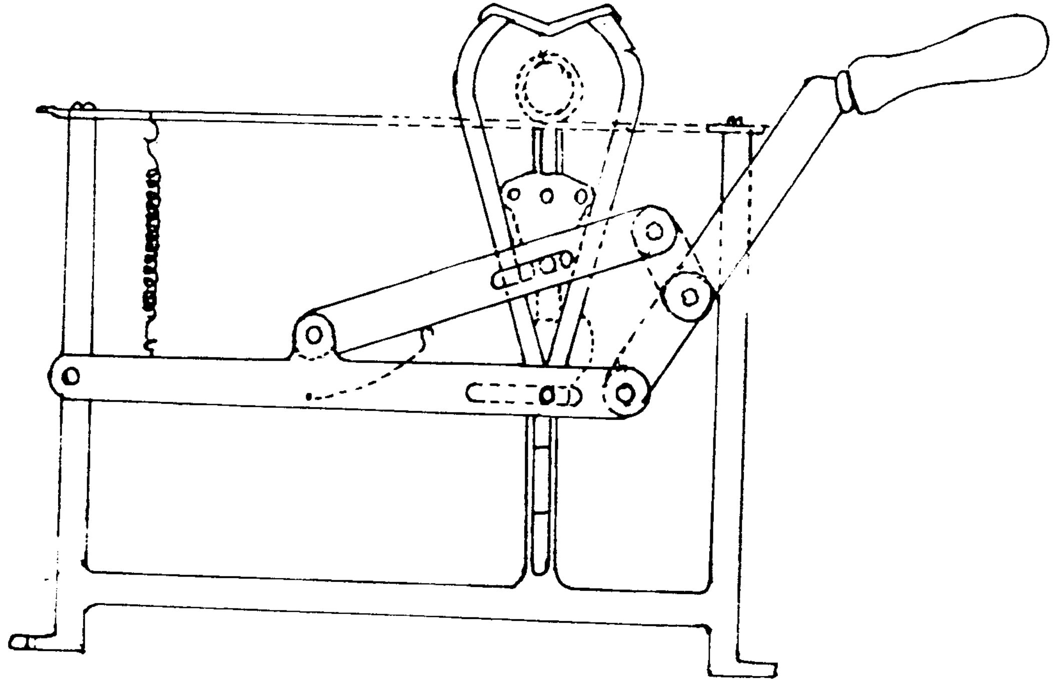


FIG.2.5 ARECANUT SHELLING MACHINE (GEORGE)

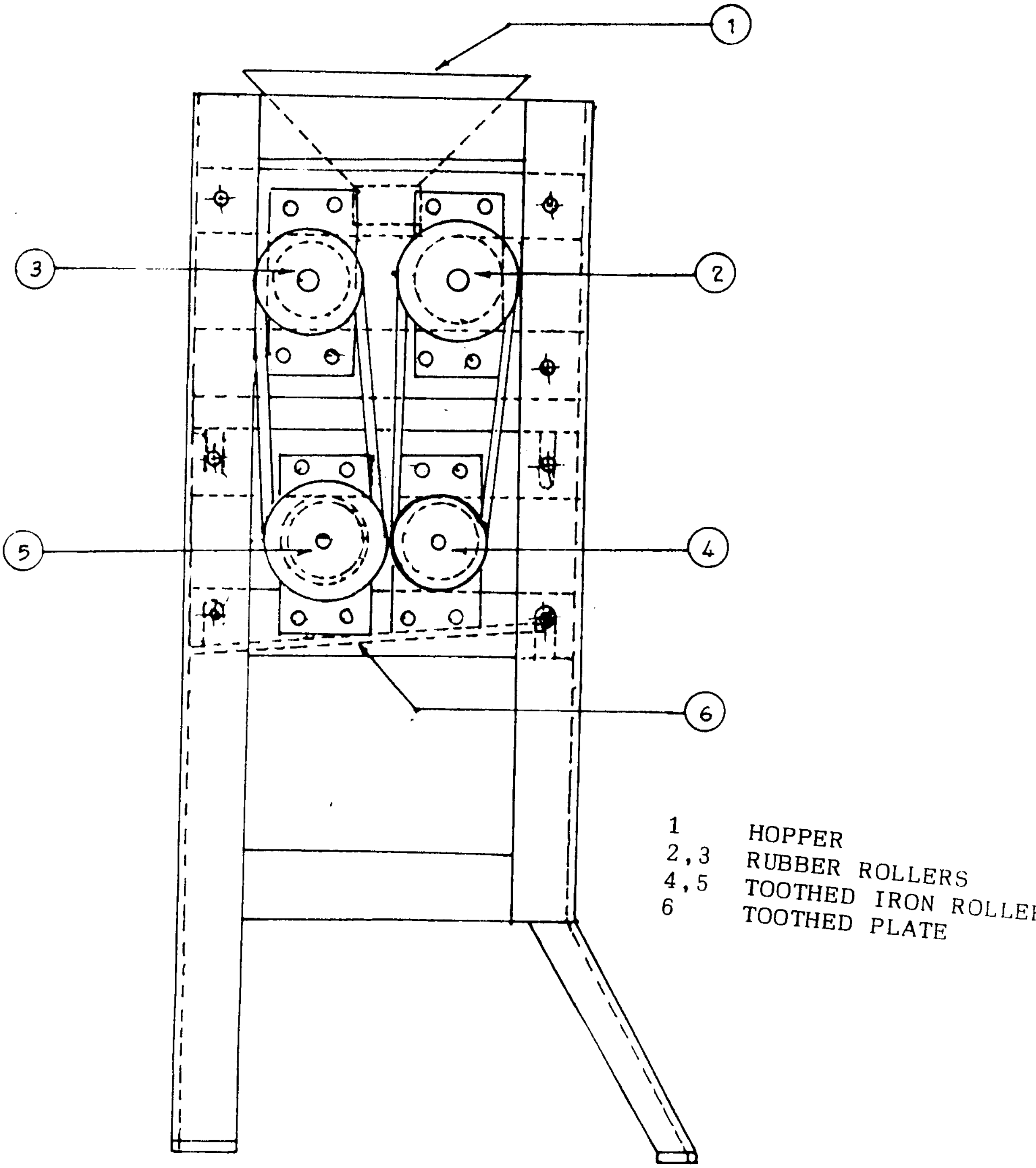


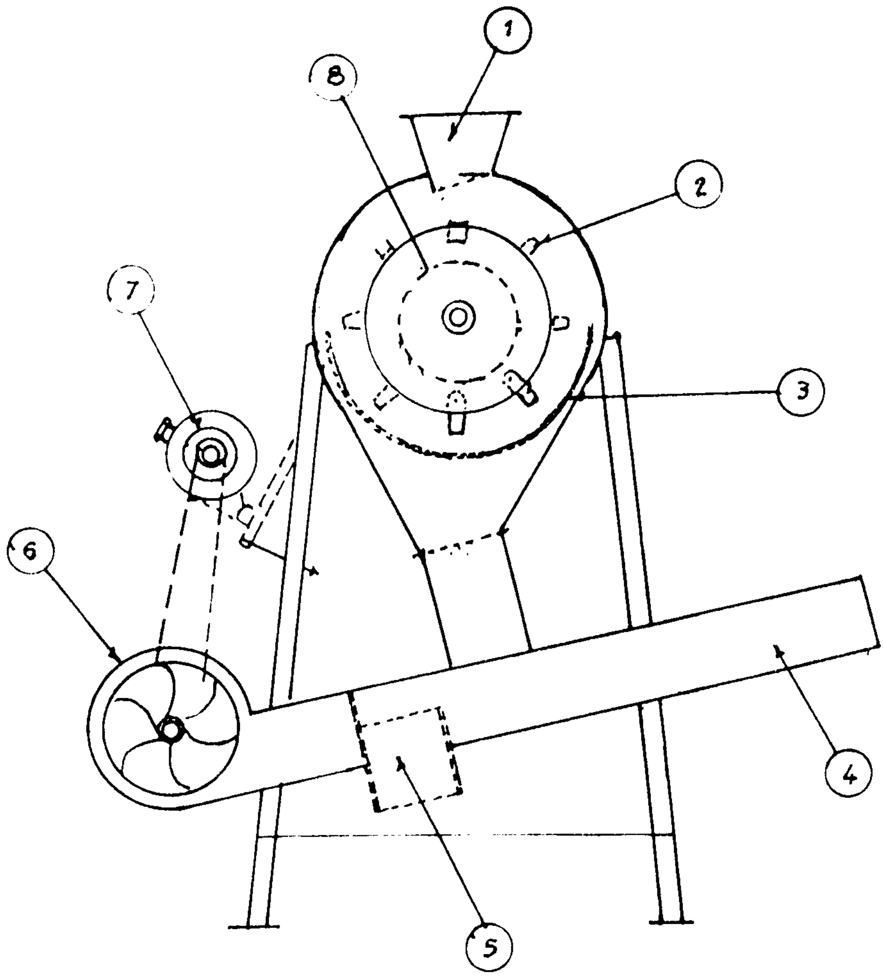
FIG. 2.6. BETEL NUT DECORTICATOR

(Thomas and Sarkar)

Ramanathan (1983) conducted operational research trial on an arecanut dehusker developed at Tamil Nadu Agricultural University, Coimbatore. It consisted of a feed hopper, rotating drum with rubber pads, concave grate and blower assembly, all mounted on a fixed frame. The dried arecanuts were dehusked between the rotating drum and the concave grate fixed below the drum. The clearance between the concave and the rotating drum was adjustable. The blower separated the nut from the husk and the nut was collected through the spout at the bottom. The dehusker is shown in Fig.2.7.

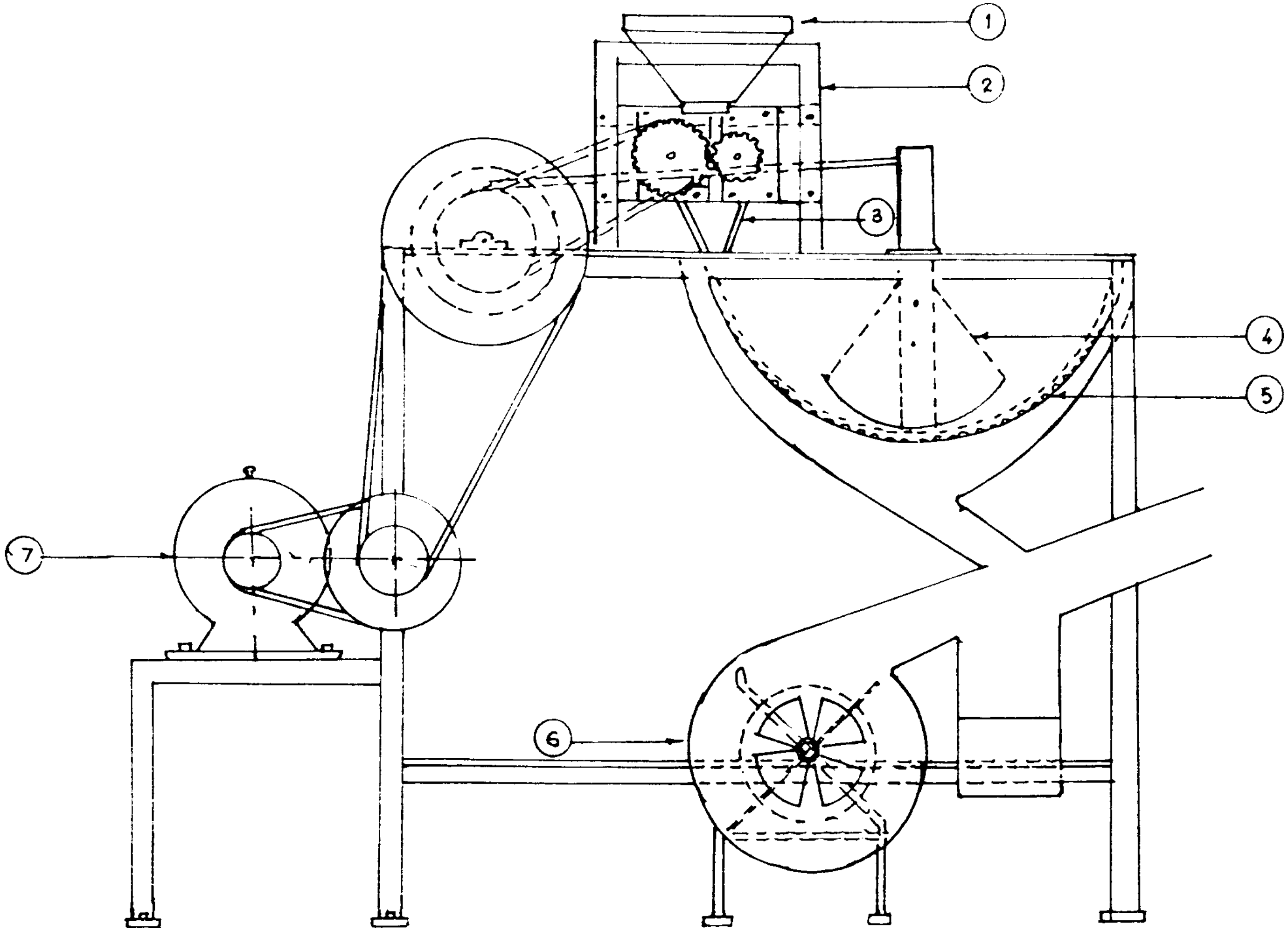
Badhe (1983) designed and developed an arecanut dehusker at the Indian Institute of Technology, Kharagpur. The machine was operated by a 1-hp dc motor. The unit mainly consisted of a crushing roller assembly and a concave oscillating assembly. The arecanuts were fed to the crushing rollers by gravity through hopper. The husk which failed partially under compression, was guided through a passage to an oscillating mechanism which consisted of a concave and an oscillator. The oscillator received motion from a crank wheel through a connecting rod. The surfaces of the concave and the oscillator were made rough using square bars because of which the husk got separated from the arecanut. Through the perforations of the concave the dehusked nut and husk dropped into a separator where the husk was separated by blowing air. The nuts were collected separately. The constructional details of the machine is given in Fig.2.8.

A simple device by which both ripe and tender arecanut could



1. FEED HOPPER
2. SOLID RUBBER
3. CONCAVE SHOE
4 HUSK OUTLET
5. ARECANUT OUTLET
6. BLOWER
7. MOTOR
8. ROTOR

FIG. 2.7 ARECANUT DEHUSKER (RAMANATHAN)

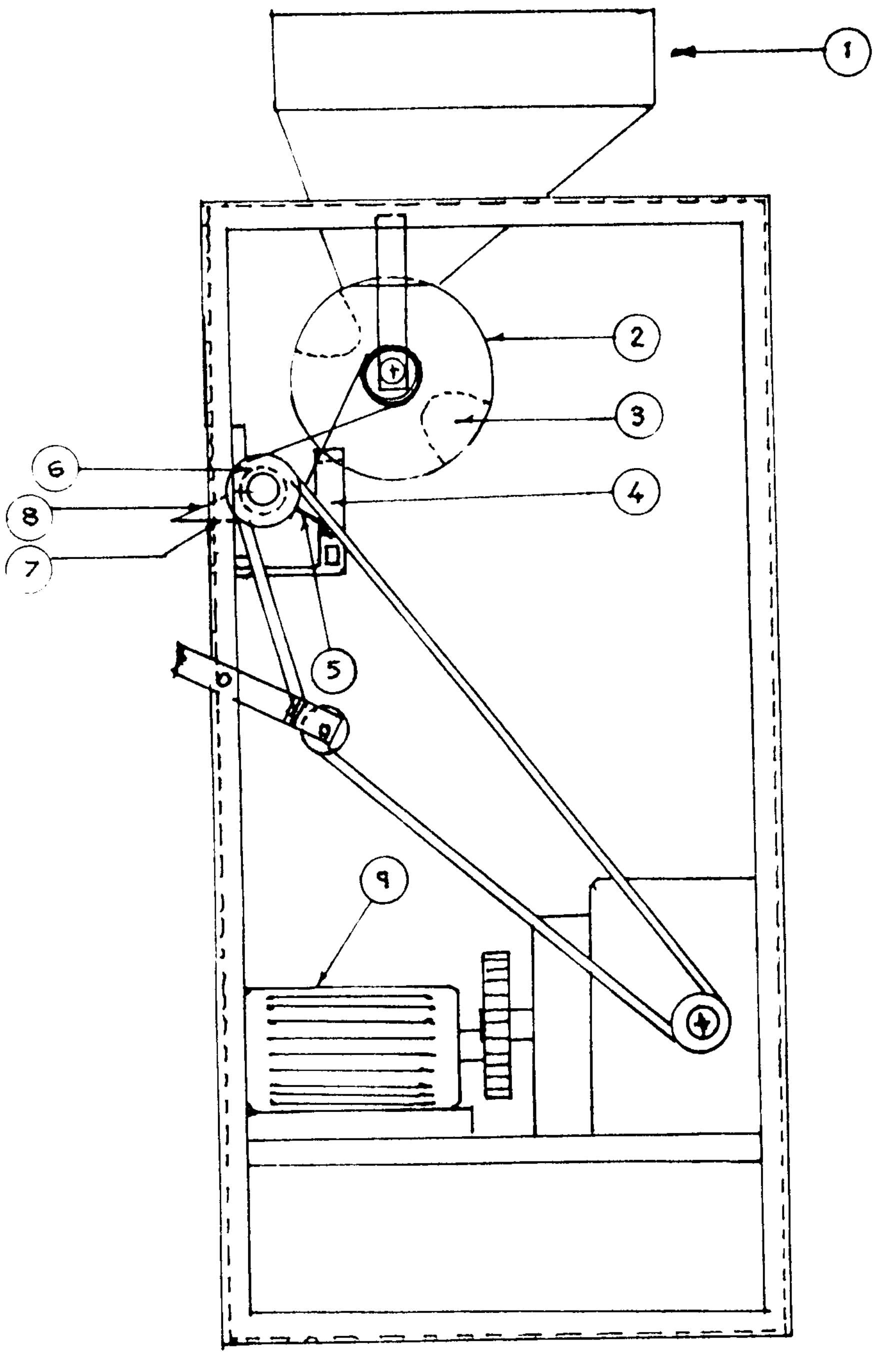


1. HOPPER
2. CRUSHING ASSEMBLY
3. FEEDING CHUTE
4. OSCILLATOR
5. CONCAVE SIEVE
6. BLOWER
7. 1 HP MOTOR

FIG. 2.8 ARECANUT DECORTICATOR (Badhe)

be dehusked was developed at Central Plantation Crop Research Institute at Kasaragode, Kerala (Febi, 1993). A pedel was pressed after manually placing the arecanut below the knife assembly, which pierced and split the arecanut into two halves. The husk was later removed by hand. The disadvantage was that the whole arecanut had to be properly oriented and placed one by one directly below the knife. The blades had to be activated each time by the movement of foot.

Febi (1993) developed a dehusker for dried arecanut fruits at KAU. The major parts of the machine were the hopper, feeder, leadplate, cutting blade, shearing roller, friction plate and scraper. The feeder received the dried fruit from the hopper and delivered it on the leadplate, from where it was lead on to the roller. Because of the convergence of space between the roller and the leadplate the fruit was pressed by the rotating roller against the leadplate. As a result, the teeth, one after the other, pierced the husk and the fruit was further forced down on to the cutting blade. The cutting blade cut the husk and the teeth split open the husk and peeled it off. The peeled off husk was carried past the roller by the rotating roller. When the husk was completely unwound the kernel was released from the husk and was ejected out through the slot at the bottom of the leadplate and the husk was carried away by the roller to its exit. The scraper removed any portion of husk remaining on the roller. The output of the machine was found to be 9.0 kg/h of dried fruit, with dehusking efficiency of 84.5 per cent. The machine is shown in Fig.2.9.



1. HOPPER
2. FEEDER
3. RECESS
4. LEAD PLATE
5. CUTTING BLADE
6. SHEARING ROLLER
7. FRICTION PLATE
8. SCRAPER
9. MOTOR

FIG. 2.9 ARECANUT DEHUSKER (FEBI)

It may be observed from that are stated above that the machines so far developed had its own merits and demerits. Even though a number of dehuskers were developed and tested manual dehusking with the traditional knife still continued to be the method adopted for large scale dehusking. Hence, an attempt was made to develop a power operated arecanut dehusker.

Materials and Methods

MATERIALS AND METHODS

With the objective of modifying the K A U Arecanut Dehusker, the present study was conducted at Kelappaji College of Agricultural Engineering and Technology, Tavanur. The properties of arecanut relevant to dehusking were studied and on the basis of this , a machine for dehusking arecanut was developed. This chapter deals with the various methods adopted in the determination of properties of arecanut relevant to dehusking, the process of development of the arecanut dehusker and the performance evaluation of the machine.

3.1 Properties of arecanut

The properties of arecanut have greater influence in the design and development of a dehusker. These properties include shape, size, weight, moisture content, true density and bulk density.

3.1.1 Shape

The shape of the arecanut fruit varies with region and variety. Generally the shape of fruit is ovate and shape of kernel is almost a segment of an ellipsoid. The shape of 15 arecanuts were subjected to visual observation.

3.1.2 Size

The size of the arecanut is usually expressed by its length and diameter. The maximum length and diameter of randomly selected arecanut fruits and kernels were measured with a vernier caliper of least count 0.01mm. The procedure was repeated for 15 different samples. The mean diameter and length were then calculated.

3.1.3 Weight

The weight of husk and kernel of 15 samples selected at random were measured, separately by using a common balance. The weight ratios of kernel to fruit and husk to fruit were separately calculated and the means were computed.

3.1.4 Moisture content

The moisture content of husk has significant effect on the dehusking of arecanut. Hence the determination of moisture content was important. Moisture content on wet basis of the husk and kernel were determined by gravimetric method. This was achieved by keeping weighed samples of husk and kernel in an oven for 24 hours at 120 C (Febi, 1993). Then the dry weight of each was measured and the moisture content was calculated using the formula ;

$$\text{Moisture content of kernel (w.b.), \%} = \frac{\text{Wet weight of kernel} - \text{Dry weight of kernel}}{\text{Wet weight of kernel}} \times 100$$

$$\text{Moisture content of husk(w.b.), \%} = \frac{\text{Wet weight of husk} - \text{Dry weight of husk}}{\text{Wet weight of husk}} \times 100$$

3.1.5 True density

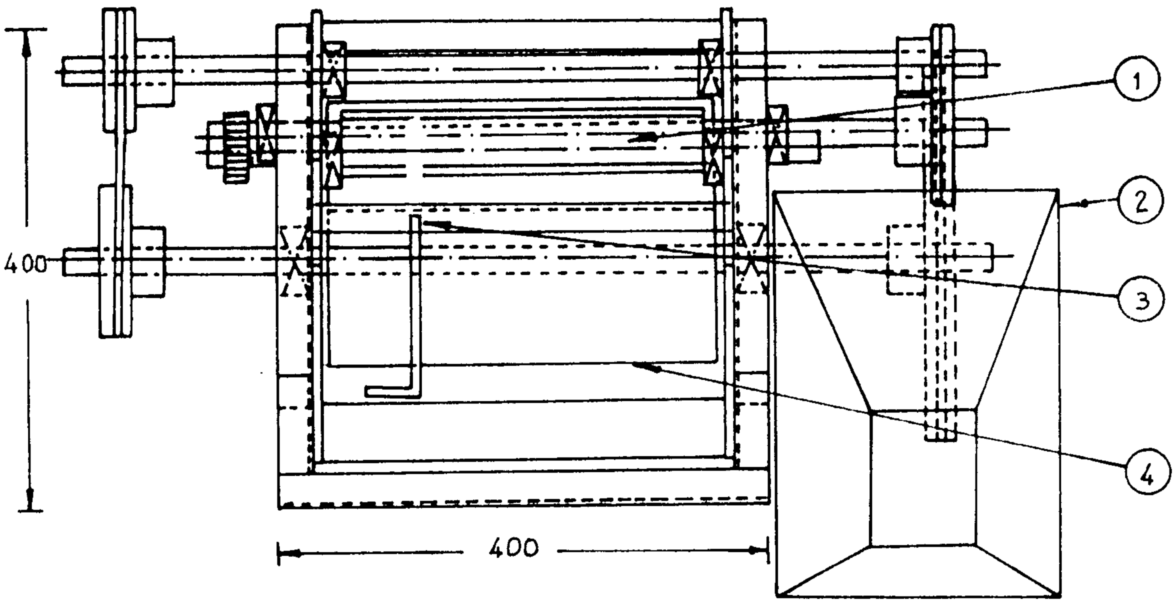
True density of a solid substance is the ratio of its weight to the volume. Weight of the arecanut fruit was already measured. In order to find out the volume of arecanut, a sinker of suitable size was immersed in the water contained in a measuring jar and the rise in the volume of water in the jar was measured. Then the sinker was tied with the already weighed and waxed arecanut fruit and immersed in the water. Again the change in volume of water was noted. The volume of arecanut was obtained by substracting the volume of sinker alone from the combined volume of sinker and arecanut. The procedure was repeated for 15 different samples and the true density for each case was calculated.

3.1.6 Bulk density

Bulk density of grains and fruits plays an important role in their storage. It is the ratio of weight of a definite quantity of material to the total volume. To determine the bulk density, arecanut was filled in a vessel of volume 1075 cm^3. The arecanut in excess was removed with a straight edge. The weight of arecanut to fill the vessel was then measured. The ratio of weight to volume gave the bulk density.

3.2 Experimental set-up

A machine for dehusking of arecanut was developed by modifying the existing KAU arecanut dehusker. In order to study the effect of various parameters on the performance of this machine an experimental set-up consisting of a dehusher and the required instrumentation was developed, the details of which are presented in this section.

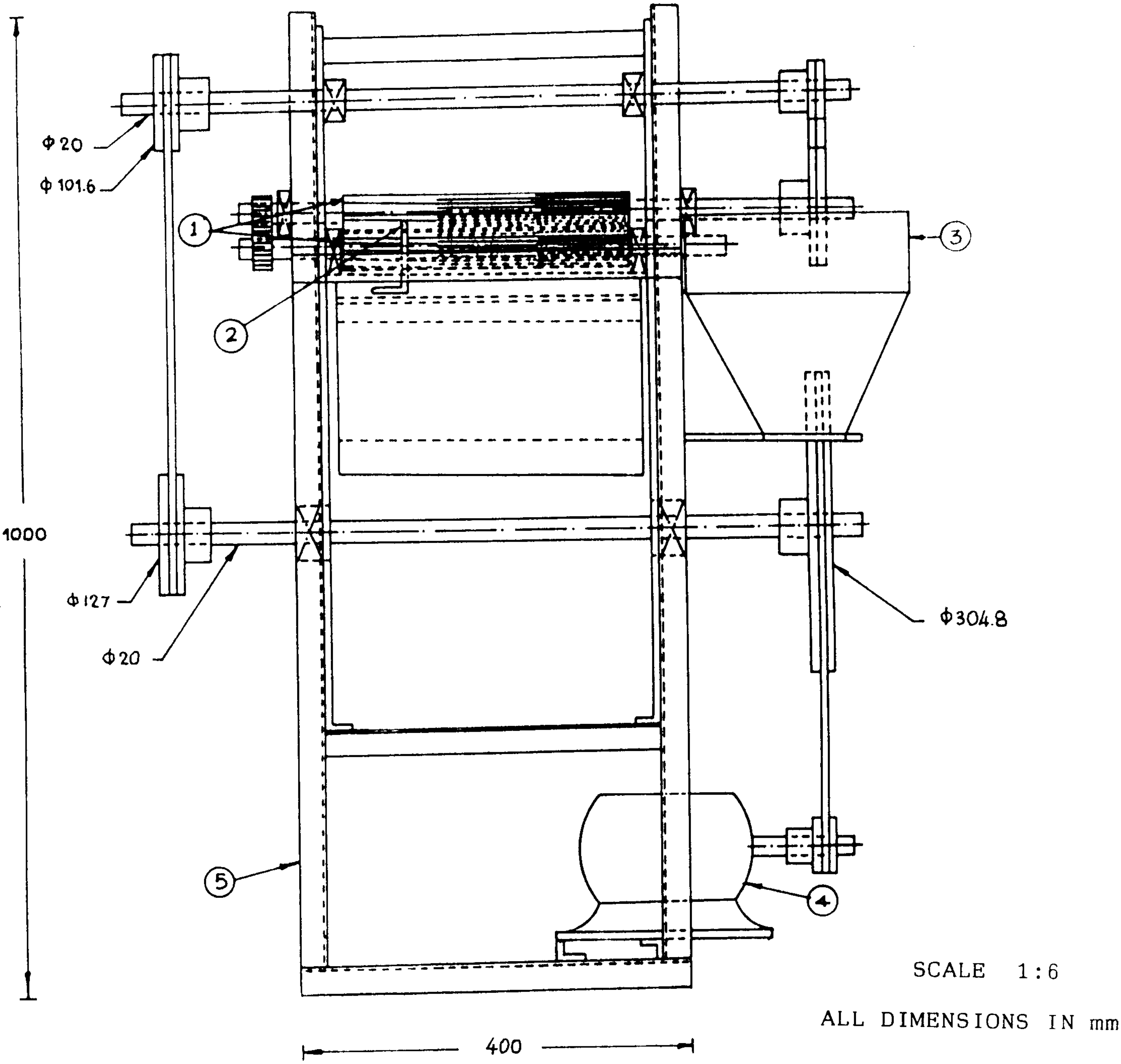


SCALE 1:6

ALL DIMENSIONS IN mm

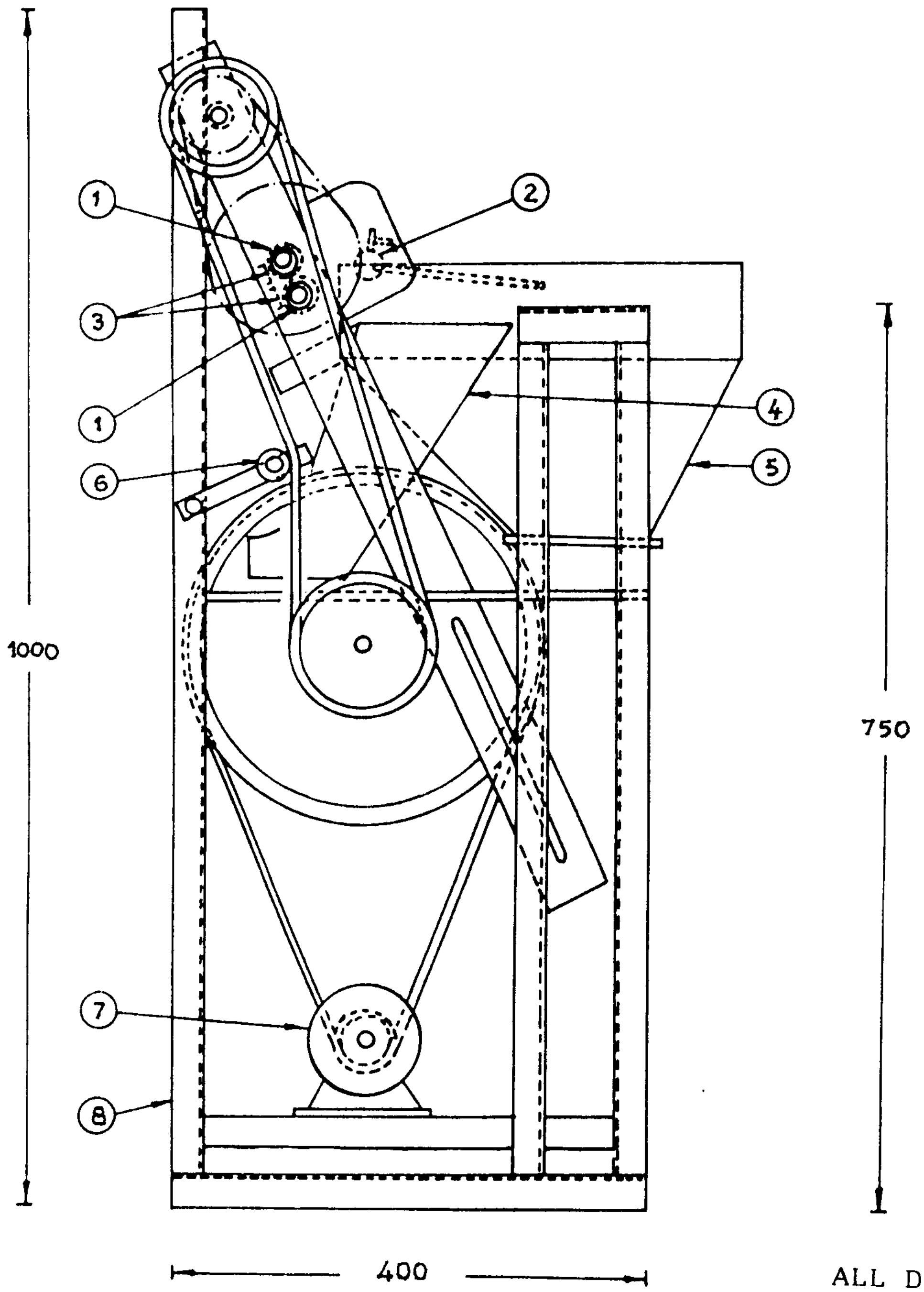
1. Flutted roller assembly
2. Feed tray
3. Pressure roller assembly
4. Guide chute

FIG.3.1 TOP VIEW OF ARECANUT DEHUSKER



1. Fluted rollers
2. Pressure roller assembly
3. Feed tray
4. Electric motor
5. Mainframe

FIG. 3.2 FRONT VIEW OF ARECANUT DEHUSKER



SCALE 1:6

ALL DIMENSIONS IN mm

1. Fluted rollers
2. Pressure roller assembly
3. Scraper assembly
4. Guide Chute
5. Feed tray
6. Idler pulley
7. Electric motor
8. Mainframe

FIG. 3.3 SIDE VIEW OF ARECANUT DEHUSKER

Plate No. 3.1

Front view of Arecanut Dehusker

Plate No. 3.2

Back view of Arecanut dehusker

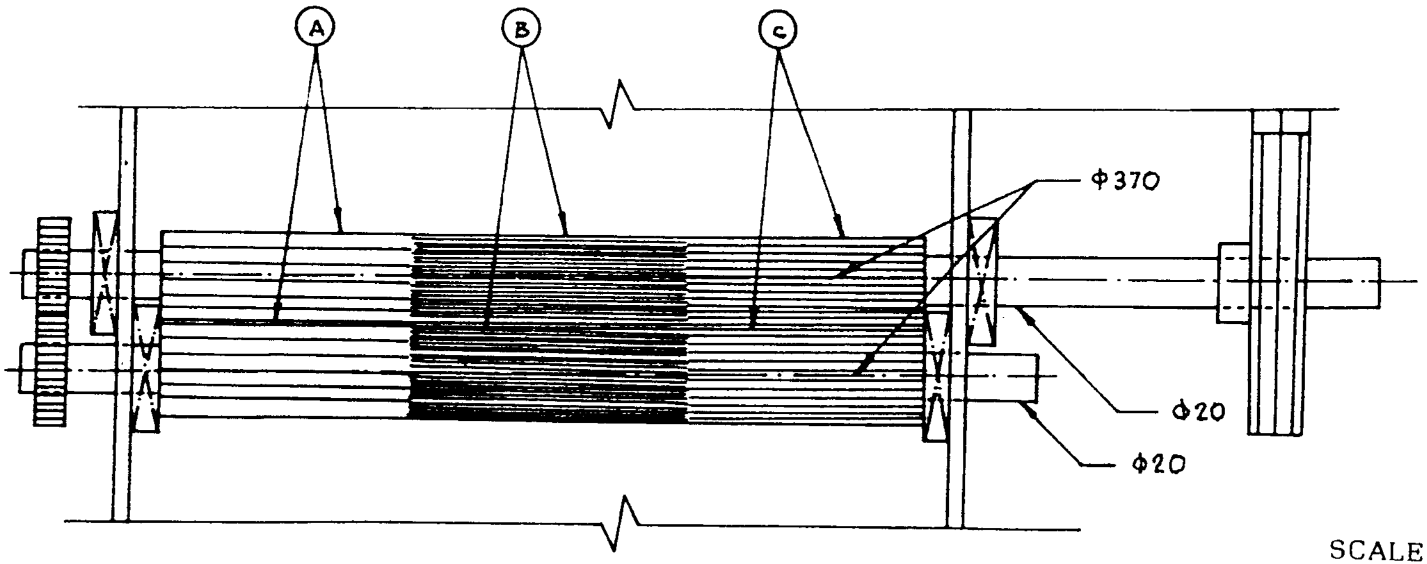
The machine consisted of the following major parts,

1. Fluted roller assembly
2. Pressure roller assembly
3. Scraper assembly
4. Guide chute
5. Feed tray
6. Main frame
7. Power transmission system
8. Power source (Electric motor)

These components were arranged in a systematic order to dehusk the arecanut fed between two counter-rotating rollers and pressed against them by the pressure roller . The two rollers gripped, squeezed the husk and pulled it to the rear side of the rollers in a continuous flow as in scutching. In the process the husk was ripped open and the kernel was ejected from its shell.

3.2.1 Fluted roller assembly

This was the most important part of the machine (Fig.3.4) Two M.S rollers of diameter 37 mm and length 350 mm were used. The rollers were provided with three different types of teeth on their periphery. These teeth differed in pitch, width and depth. The first set consisted of 20 teeth having a pitch 5.9 mm, width 3.0 mm and depth 2.6 mm. Similarly the second set consisted of 30 teeth with a pitch 3.9 mm, width 1.0 mm and depth 2.0 mm and the third set was of 30 teeth with pitch 3.9 mm, width 2.0 mm and depth 1.0 mm. The roller assembly was mounted on a frame made of M.S flat and angles. Ends of the rollers were fixed in ball



SCALE 1:3

ALL DIMENSIONS IN mm

A. SURFACE CONSISTING OF 20 TEETH WITH PITCH 5.9mm WIDTH 3mm & DEPTH 26mm

B. SURFACE CONSISTING OF 30 TEETH WITH PITCH 3.9mm WIDTH 1mm & DEPTH 2mm

C. SURFACE CONSISTING OF 30 TEETH WITH PITCH 3.9mm WIDTH 2mm & DEPTH 1mm

FIG. 3.4 FLUTED ROLLER ASSEMBLY

Plate No. 3.3

Side view (Left) of Arecanut dehus

Plate No. 3.4

Side view (Right) of Arecanut dehusker

bearings. Two spur gears of 40 teeth and outer diameter 40 mm were used at one end of the rollers for rotating in counter-clockwise direction. Drive from the electric motor was transmitted to one of the shafts and this in turn rotated the other shaft.

3.2.2 Pressure roller assembly

A roller of 27 mm diameter and 350 mm length was placed 40 mm in front of the fluted roller in order to hold and force the arecanut fruit towards the two fluted rollers (Fig.3.5). Two narrow flat pieces were welded on the periphery of the pressure roller longitudinally to adjust the clearance with respect to the size of the arecanut fruit. A lever was provided to control the movement of the roller.

3.2.3 Scraper assembly

Each fluted roller was provided with a husk scraper at their rear side which scraped off the fibrous husk sticking to the roller during dehusking.

3.2.4 Feed tray

A tray was provided on one side of the frame to store the arecanut fruit before being taken for dehusking (Fig.3.6). The tray was trapezoidal in shape and made of 24 gauge G.I sheet. It had a capacity to carry 2 kg of dried arecanut.

3.2.5 Guide chute

A guide chute made of G.I sheet was fitted on the frame

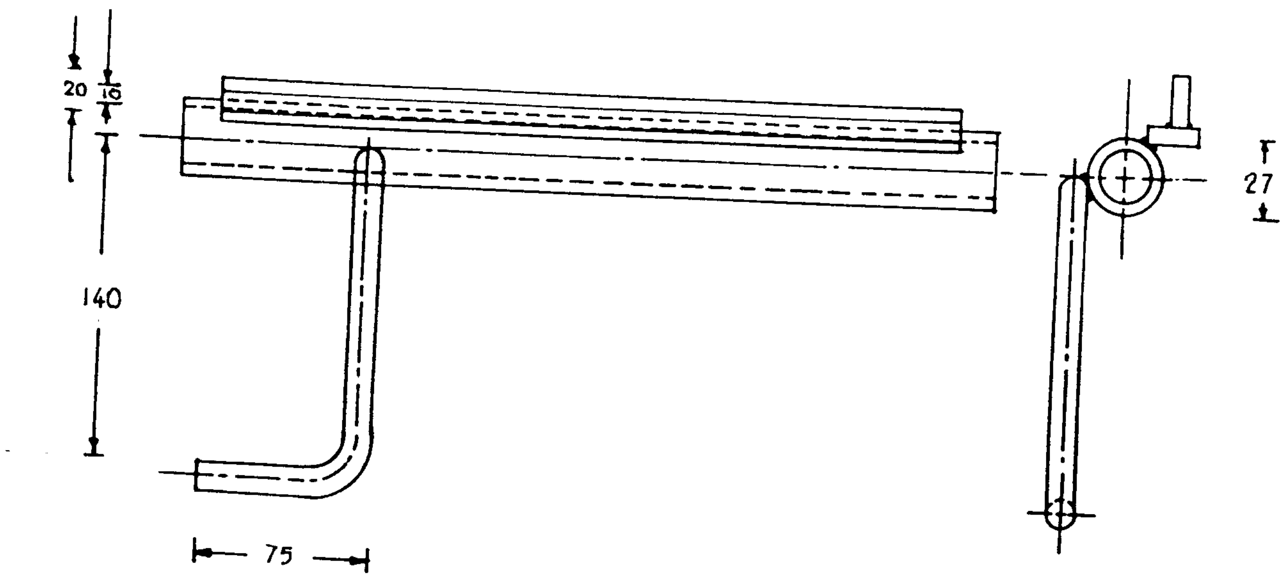


FIG. 3.5 PRESSURE ROLLER ASSEMBLY

SCALE 1:3

ALL DIMENSIONS IN mm

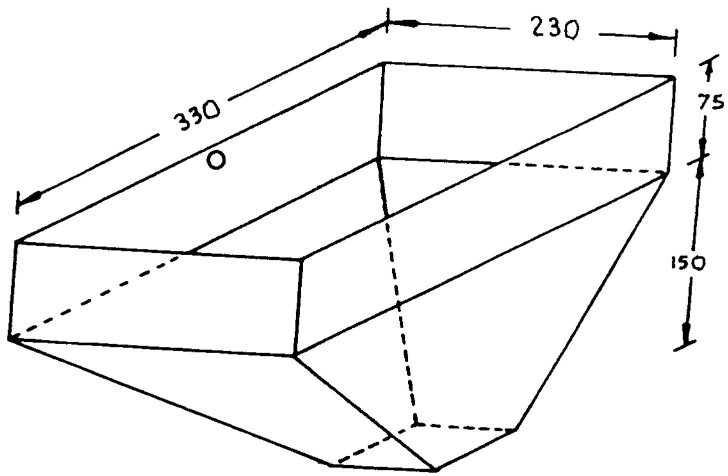


FIG. 3.6 FEED TRAY

SCALE 1:3

ALL DIMENSIONS IN mm

Plate No. 3.5

Overall view of Arecanut dehusker

Plate No. 3.6

Arecanut dehusker in operation

below the fluted rollers. The function of the guide chute was to guide the dehusked kernels to the outlet.

3.2.6 Main frame

All the components were mounted on an angle iron frame of size 750 mm x 400 mm x 400 mm.

3.2.7 Power transmission system

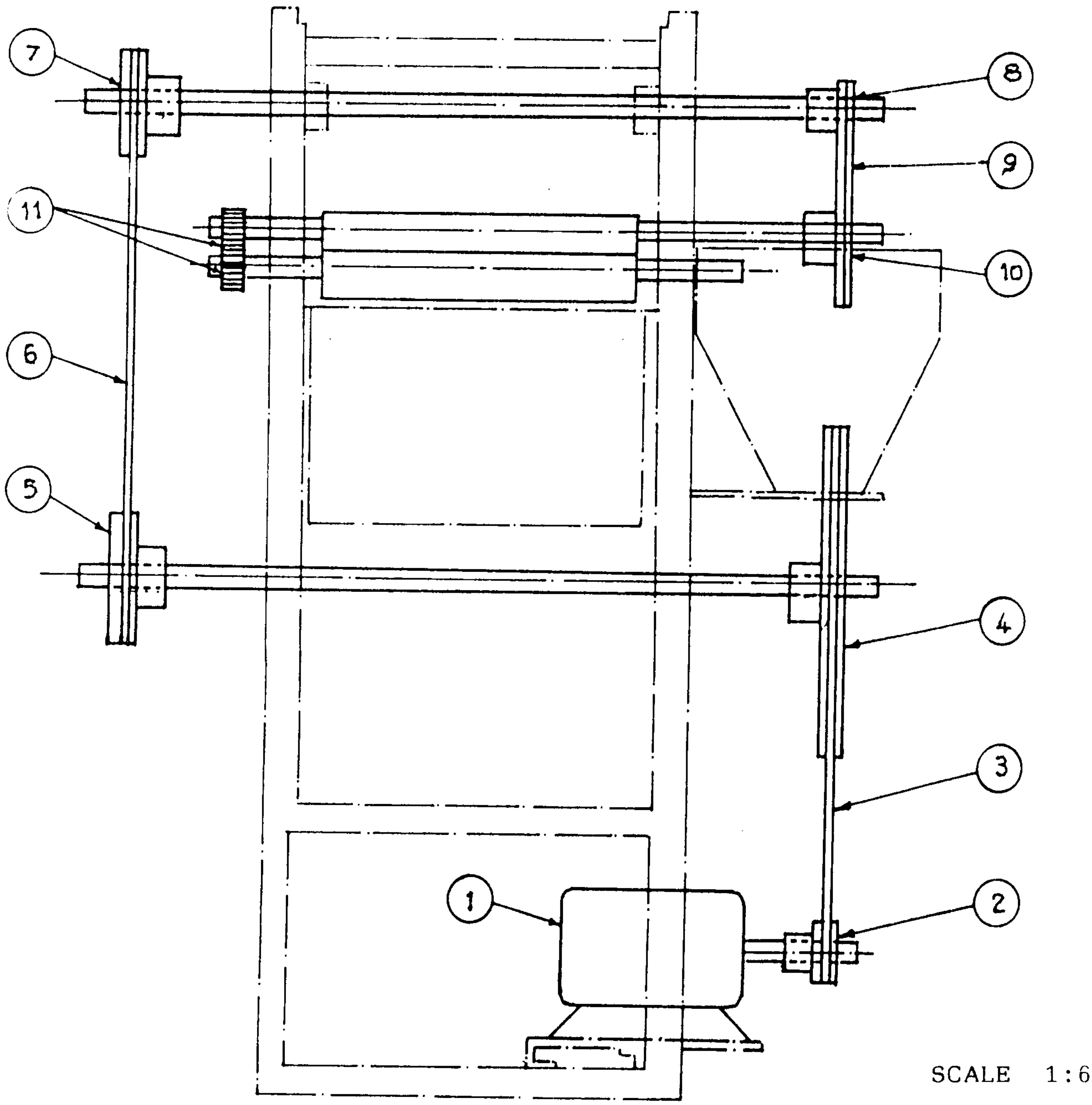
The power was transmitted to the fluted roller at the top by means of sprocket and chain drive from an intermediate shaft (Fig. 3.7). Intermediate shaft was driven by another intermediate shaft which received the power from an electric motor. Belt and pulley arrangements were used for the transmission of power from motor to the first intermediate shaft and from there to the second intermediate shaft. Pulleys of differeent diameters were used to vary the velocity ratio in order to operate the machine at different levels of speed.

3.2.8 Power source

A three phase, 0.5-hp electric motor was used as the power source. The rated speed of the motor was 1440 rpm.

3.2.9 Instrumentation

An energy meter was used for measuring the energy requirement of the machine. The three phase energy meter was connected in series with the motor. The circuit connections are shown in Fig.3.8. Energy requirement at no load and with load conditions were determined. The energy meter specifications are



1. ELECTRIC MOTOR
2. MOTOR SHAFT PULLEY
3. V-BELT
4. INTERMEDIATE PULLEY I
5. INTERMEDIATE PULLEY II
6. V-BELT
7. INTERMEDIATE PULLEY III
8. SPROCKET (20 TEETH)
9. CHAIN
10. SPROCKET (38 TEETH)
11. GEARS (40 TEETH)

FIG.3.7 POWER TRANSMISSION SYSTEM OF ARECANUT DEHUSKER given in Appendix - VI.

3.3 Experimental design

Studies were conducted to determine the effects of various machine parameters and the performance of the machine. A 2-factor factorial experiment in Completely Randomised Design (CRD) was selected in this study. The various factors and their levels were as follows

I Independent variable

	Level
i) Speed (rpm)	60, 90, 120, 150, 180
ii) Surface	A - Surface consisting of 20 teeth with a pitch 5.9 mm, width 3.0 mm and depth 2.6 mm.
	B - Surface consisting of 30 teeth with a pitch 3.9 mm, width 1.0 mm and depth 2.0 mm.
	C - Surface consisting of 30 teeth with a pitch 3.9 mm, width 2.0 mm and depth 1.0 mm.

II Dependent variable

i) Dehusking efficiency

ii) Percentage of nuts damaged

iii) Power requirement

Accordingly the number of experiments for the different factor -level combinations were 15. Each experiment was replicated three times. Thus the total number of experiments were 5 x 3 x 3, i.e. 45.

Preliminary trials were conducted to determine the levels of different variables. The machine was operated at different speeds. A speed of 120 rpm was found to be giving reasonably satisfactory results and was selected as the median of the level. Two lower and upper levels of speeds were then opted with an interval of 30 rpm.

Trials were conducted with three different roller surfaces viz; plane surface, knurled surface and toothed surface. From these trials it was observed that roller with toothed surface was found to be giving satisfactory results because of improved grip between arecanut fruit and the rollers. Then, teeth of varying pitch, depth and width were provided on the periphery of rollers. Thus, three such conditions for testing were created.

3.4 Experimental procedure

A sample consisting of 270 arecanuts were collected from the farmer's field. This was divided into 45 batches, each consisting of six nuts. This six arecanuts formed the feedstock for each experiment. After setting up the machine at one factor - level combination, the arecanuts from one batch was fed to the machine one by one. Number of nuts dehusked in each batch was noted. The number of kernels damaged was also noted. Besides, the number of unhusked arecanuts damaged were also recorded. The electrical energy consumed by the motor was recorded from the energy meter.

3.4.1 Evaluation of performance

The dehusking efficiency, percentage of the number of dehusked kernels damaged, percentage of the number of unhusked arecanut fruits damaged and power requirement were determined as follows.

Dehusking efficiency was expressed as the percentage of the number of kernels recovered from the fruit to the total number of fruits fed to the machine. The numerator included both the undamaged (whole) and damaged kernels. It was then expressed as ;

$$\eta_h = \frac{n_h}{n} \times 100$$

where η_h = dehusking efficiency, %

n_h = number of kernels recovered and includes both the damaged and undamaged kernels

n = total number of fruits fed to the machine

Percentage of the number of dehusked nuts damaged was defined as the percentage of the number of damaged kernels to the total number of kernels recovered through dehusking. It was expressed as;

$$d_h = \frac{n_{hd} \times 100}{n_h}$$

where d_h = percentage of the number of dehusked kernels damaged, %

n_{hd} = number of dehusked kernels damaged

n_h = number of dehusked kernels includes both damaged and undamaged

Percentage of the number of unhusked nuts damaged was defined as the percentage of the number of unhusked fruits damaged to the total number of unhusked fruits. It was expressed as;

$$d_u = \frac{n_{ud} \times 100}{n_u}$$

where d_u = percentage of the number of unhusked fruits damaged, %

n_{ud} = number of unhusked fruits damaged

n_u = number of unhusked fruits

3.4.2 Power requirement

The power requirement was determined from the values of energy meter readings and the time taken for the experiments. One kilowatt-hour is equivalent to 112.5 revolution of energy meter disc. The machine was operated at load and no-load conditions for a certain period. The number of revolutions of energy meter disc and the time of operation were noted. From the number of revolutions and time taken, the energy required for operating the machine was calculated.

3.4.3 Economic analysis

The operating cost of the machine was calculated. Operating cost included both fixed and variable costs. The total fixed cost was the sum of depreciation and interest on investment. Depreciation was computed using straight line method by assuming an average life period of 20 years for the motor and 10 years for the machine. The rate of interest was taken as 15 per cent.

Variable cost included electricity charges and labour charges. Labour charges were computed for two labourers working 8 hours per day at a rate of Rs 60 / day. The cost of electric power was at a rate of Re 1.00/kW-h. Ten per cent of initial investment per annum was considered as being utilized for repair and maintenance.

Results and Discussion

RESULTS AND DISCUSSION

Results of the study conducted for the determination of various properties of arecanut relevant to dehusking and for the performance evaluation of the newly developed arecanut dehusking machine are presented in this chapter.

4.1 Physical properties of arecanut

The properties such as shape, size, weight, moisture content, true density and bulk density were determined and are discussed and presented below.

4.1.1 Shape

By visual observation it was found that the shape of arecanut fruit was oblong. The length of longitudinal axis was more than that of the lateral axis. The kernels were found to be either ovate or conic in shape.

4.1.2 Size

Results of the observations on the size are presented in Table 4.1. Length of the major axis of the samples ranged from 44.2 to 64.6 mm, with a mean of 54.06 mm. Length of the minor axis varied from 28.8 to 38.6 mm, with a mean of 32.41 mm.

The length of kernel varied from 17.8 to 28.4 mm, with a mean of 24.21 mm while the diameter ranged from 22.4 to 29.4 mm, with a mean of 24.36 mm.

The size of the arecanut fruit and the kernel are important

Table 4.1 Axial and lateral dimensions of the arecanut fruits and the kernels

Sample no	Length of fruit (mm)	Diameter of fruit (mm)	Length of kernel (mm)	Diameter of kernel (mm)
1	52.3	32.2	22.7	22.3
2	53.7	30.2	26.2	25.2
3	56.2	38.6	28.4	29.4
4	50.2	30.1	25.6	23.7
5	54.6	35.4	23.1	22.1
6	55.0	30.3	21.4	22.5
7	50.5	29.5	24.2	23.7
8	55.8	31.2	26.1	25.2
9	47.9	29.3	18.7	22.7
10	54.2	32.7	22.6	24.3
11	64.6	36.5	26.2	25.2
12	55.8	34.1	27.4	25.4
13	44.4	28.8	17.8	22.2
14	60.5	37.0	27.6	28.8
15	55.1	30.1	25.2	22.6
Mean	54.06	32.41	24.21	24.36
Std. deviation	4.82	3.17	3.15	2.28

in the design of a twin-roller dehusking machine. The gap between the two rollers was maintained less than the lateral diameter of the kernel, to prevent it from getting crushed between the rollers. In the present study the gap was maintained at 2.0 mm. The roller diameter was 1.5 times the mean diameter of the kernel. This reduced the holding of nuts by the teeth of the roller.

4.1.3 Weight

Weight of the arecanut fruit ranged from 10.9 to 20.9 g, with an average of 15.87 g. The kernels weighed from 6.5 to 10.5 g, with a mean of 8.9 g and the weight of husk ranged from 3.3 to 9.7 g, wih an average of 6.97 g.

The ratio of kernel to fruit and that of husk to fruit were calculated. Mean of the kernel to fruit ratio was 0.568 and the ratio of husk to fruit was 0.432. It revealed that 56.8 per cent of arecanut fruit was contributed by kernel and 43.2 per cent by husk. The results in detail are presented in Table 4.2 .

4.1.4 Moisture content

Results of the experiment for the determination of moisture content on wet basis are shown in Table 4.3 . The average moisture content of kernel and husk were 9.59 and 10.70 per cent respectively. The moisture content varied from 8.2 to 15.2 per cent in the case of husk and 7.7 to 12.6 per cent in the case of kernel. This moisture content was well within the range accepted for safe storage.

Table 4.2. Weight of kernel, husk and arecanut fruits and their ratios

Sample No.	Weight of fruit Wa (g)	Weight of kernel Wk (g)	Weight of husk Wh (g)	Kernel to fruit ratio Wk/Wa	Husk to fruit ratio Wh/Wa
1	12.1	7.3	4.8	0.6	0.4
2	18.7	9.5	9.2	0.51	0.49
3	13.5	8.2	5.3	0.61	0.39
4	10.9	7.6	3.3	0.697	0.303
5	18.6	10.1	8.5	0.543	0.457
6	15.3	9.6	5.7	0.627	0.373
7	20.2	10.6	9.7	0.52	0.48
8	14.6	8.5	6.1	0.58	0.42
9	17.9	10.2	7.7	0.57	0.43
10	13.7	6.5	7.2	0.47	0.53
11	15.8	9.0	6.8	0.57	0.43
12	18.5	9.3	9.2	0.502	0.498
13	12.3	7.8	4.5	0.634	0.366
14	19.5	10.3	9.2	0.53	0.47
15	16.4	9.1	7.3	0.55	0.45
Mean	15.87	8.9	6.97	0.568	0.432
Std. deviation	2.96	1.21	1.98	0.0594	0.0594

Table 4.3. Moisture content of husk and kernel (w.b)

Sl No.	Wet weight		Dry weight		Moisture content	
	kernel (g)	husk (g)	kernel (g)	husk (g)	kernel (%)	husk (%)
1	10.3	9.2	9.0	8.4	12.6	8.6
2	7.3	4.8	6.7	4.2	8.2	12.5
3	9.5	9.2	8.5	8.1	10.5	9.8
4	8.2	5.3	7.5	4.6	8.5	15.2
5	7.6	3.3	6.9	2.9	9.2	12.1
6	10.1	8.5	8.9	7.6	11.8	10.6
7	9.6	5.7	8.5	5.0	9.4	12.3
8	10.5	9.7	9.4	8.5	10.5	12.4
9	8.5	6.1	7.7	5.6	9.4	8.2
10	10.2	7.7	9.0	7.1	11.7	7.8
11	6.5	7.2	5.9	6.3	9.2	12.5
12	9.0	6.8	8.3	6.1	7.7	10.3
13	9.3	9.2	8.5	8.3	8.6	9.8
14	7.8	4.5	7.1	4.0	7.7	8.8
15	9.1	7.3	8.3	6.6	8.8	9.6
				Mean	9.59	10.7
				Std. deviation	1.52	2.067

4.1.5 True density

Volume of the arecanut fruit varied from 17 to 37 cm^3 and the true density ranged from 0.46 to 0.55 g/cm^3. The average density of arecanut was 0.513 g/cm^3. Table 4.4 represents the results of the observations.

It was seen that the arecanut fruit remained afloat in water because of its lower density. The air space within the husk and that between the kernel and its shell was responsible for its lower density.

4.1.6 Bulk density

Bulk density was observed to vary from 0.287 to 0.312 g/cm^3, with a mean of 0.302 g/cm^3. The details of observations are presented in Table 4.5 . The lower bulk density is partially because of the air column within the arecanut fruit and partially because of the shape and larger size of the nut.

4.2 Performance evaluation of machine

The newly developed machine was operated at the following levels of speed and surface conditions.

Variable		Level
Speed(rpm)	:	60, 90, 120, 150, 180
Surface	:	A - Surface consisting of 20 teeth with a pitch 5.9 mm, width 3.0 mm and depth 2.6 mm

Table 4.4. True density of dried arecanut

Sample No.	Weight of fruit Wa (g)	Volume of fruit Va (cm^3)	Density Wa/Va (g/cm^3)
1	9.8	18	0.544
2	19.0	37	0.51
3	15.5	30	0.516
4	13.2	24	0.55
5	11.4	22	0.52
6	18.1	38	0.48
7	7.8	17	0.46
8	14.6	27	0.54
9	15.3	32	0.48
10	12.4	23	0.54
11	16.3	32	0.51
12	17.2	35	0.49
13	13.7	28	0.49
14	18.4	36	0.51
15	19.2	35	0.55
		Mean	0.513
		Std. deviation.	0.0283

Table 4.5. Bulk density of arecanut

Sl No.	Volume of vessel, (cm^3)	Weight of fruit, (g)	Bulk density (g/cm^3)
1	1075	330	0.306
2	1075	308	0.287
3	1075	335	0.312
4	1075	329	0.306
5	1075	319	0.297
		Mean	0.3016
		Std. deviation	0.00976

B - Surface consisting of 30 teeth with a pitch 3.9 mm, width 1.0 mm and depth 2.0 mm

C - Surface consisting of 30 teeth with a pitch 3.9 mm, width 2.0 mm and depth 1.0 mm.

The machine was operated at 15 different speed-surface conditions and the dehusking efficiency, percentage of the number of dehusked kernels damaged and the percentage of the number of unhusked fruits damaged were noted.

The dehusking efficiency was found to vary from 66.66 to 94.44 per cent under differnt set-ups of the machine. Similarly the percentage of the number of dehusked kernels damaged, varied from 5.88 to 28.57 per cent and the percentage of the number of unhusked fruits damaged varied from 0 to 100 per cent. The results are shown in Table 4.6 .

Figures 4.1 to 4.8 graphically represent the dehusking efficiency and the percentage of the number of kernels damaged under different levels of speed and surface.

As the speed was increased from 60 to 180 rpm for one surface condition, the dehusking efficiency was found to increase. This was observed for all the three surfaces (Fig.4.1 - 4.3). At the same time the percentage of the number of dehusked

Table 4.6 **Dehusking efficiency and damages at different machine set-ups**

Speed rpm	Surface	Dehusking efficiency (%)	Damage of dehusked kernel (%)	Damage of un-husked fruit (%)
60	A	66.66	16.66	16.66
60	B	77.77	28.57	50.00
60	C	77.77	7.14	0.00
90	A	72.22	15.38	20.00
90	B	77.77	21.42	25.00
90	C	83.33	6.66	0.00
120	A	77.77	14.28	25.00
120	B	83.33	20.00	33.33
120	C	88.88	6.25	0.00
150	A	83.33	13.33	0.00
150	B	88.88	18.75	50.00
150	C	94.44	5.88	0.00
180	A	88.88	18.75	0.00
180	B	94.44	23.53	100.00
180	C	94.44	11.76	0.00

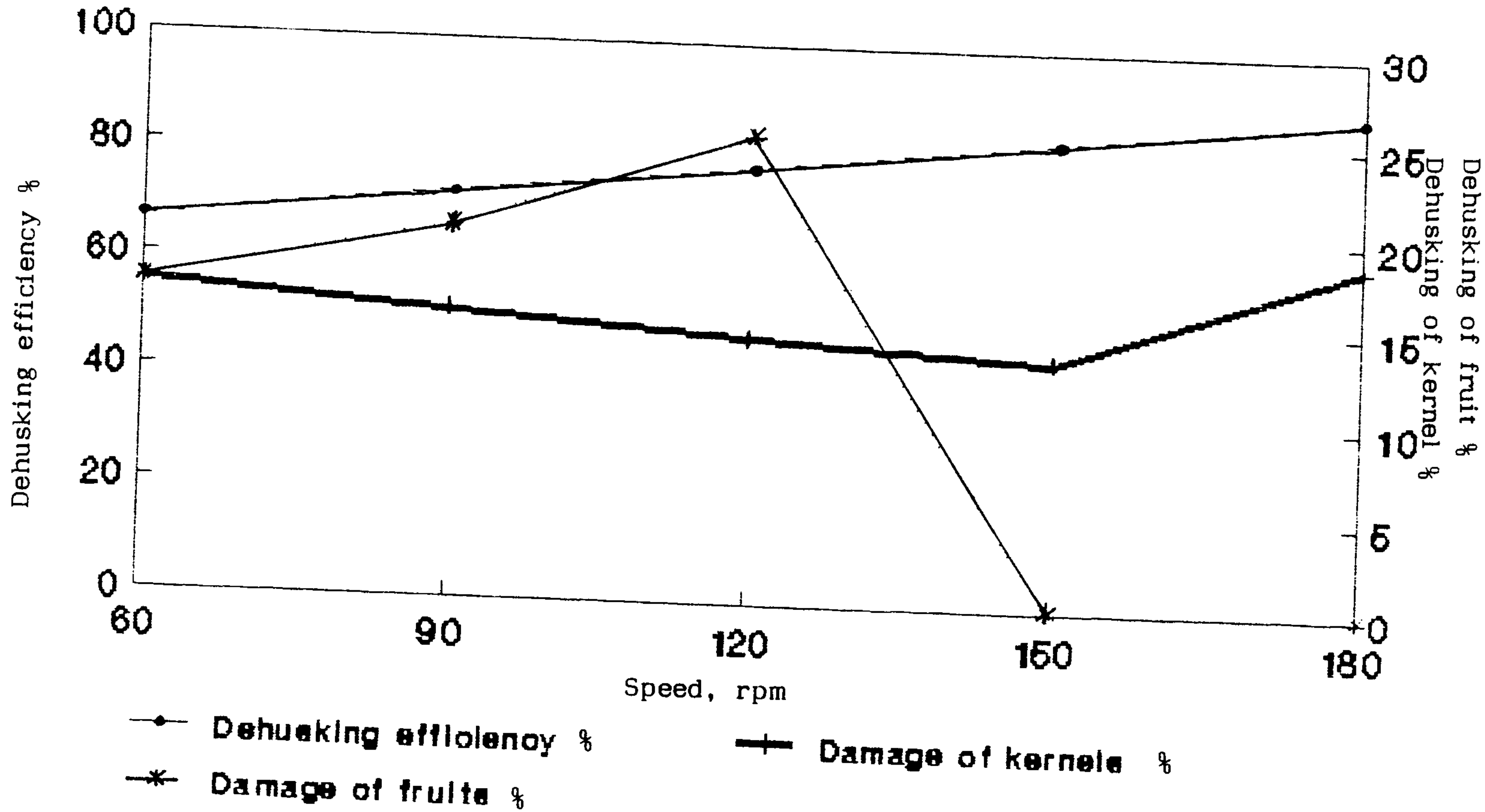


Fig.4.1 Dehusking Efficiency and Damage of Kernels and Fruits at surface A

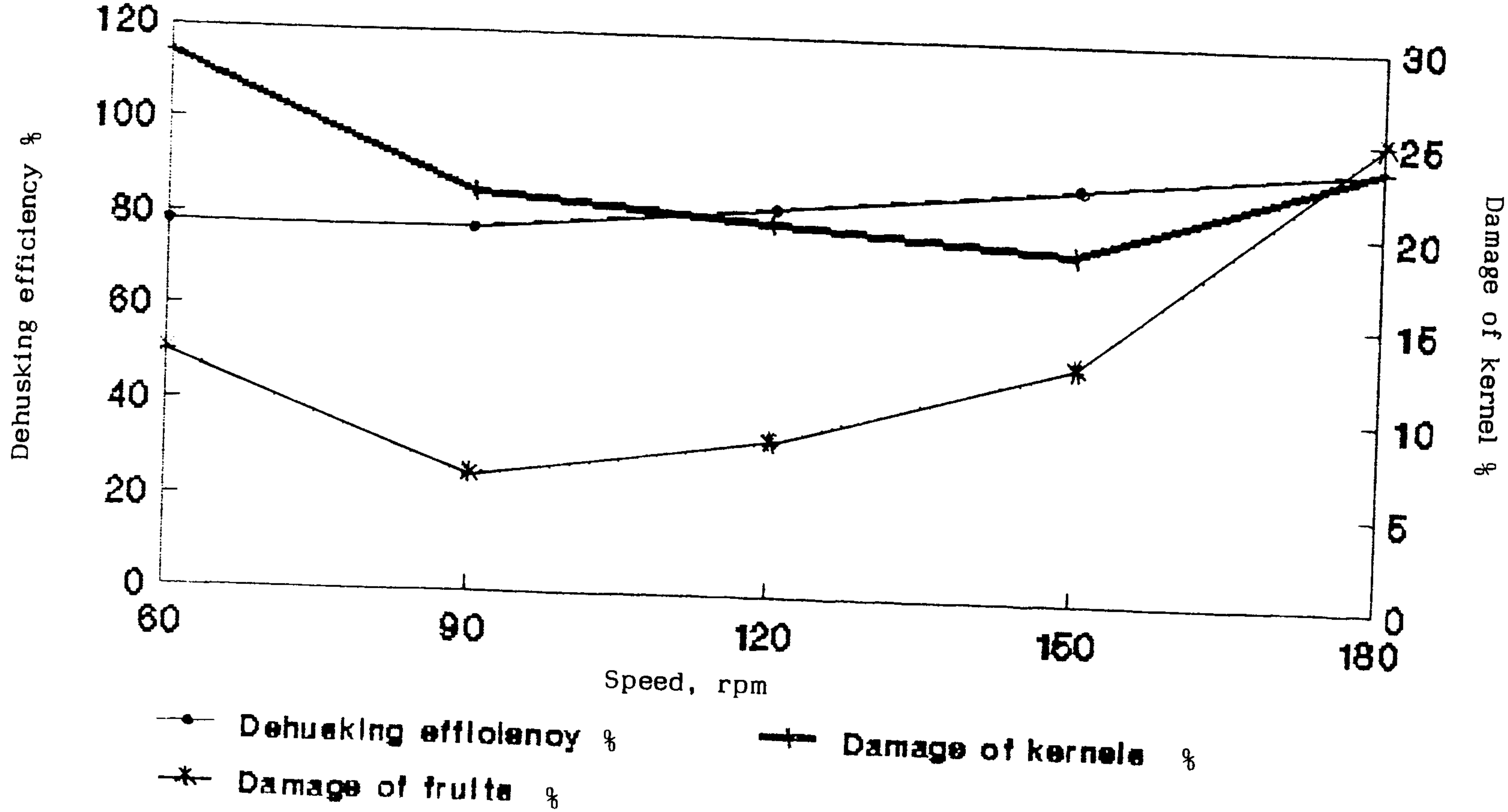


Fig.4.2 Dehusking efficiency and Damage of Kernels and Fruits at surface B

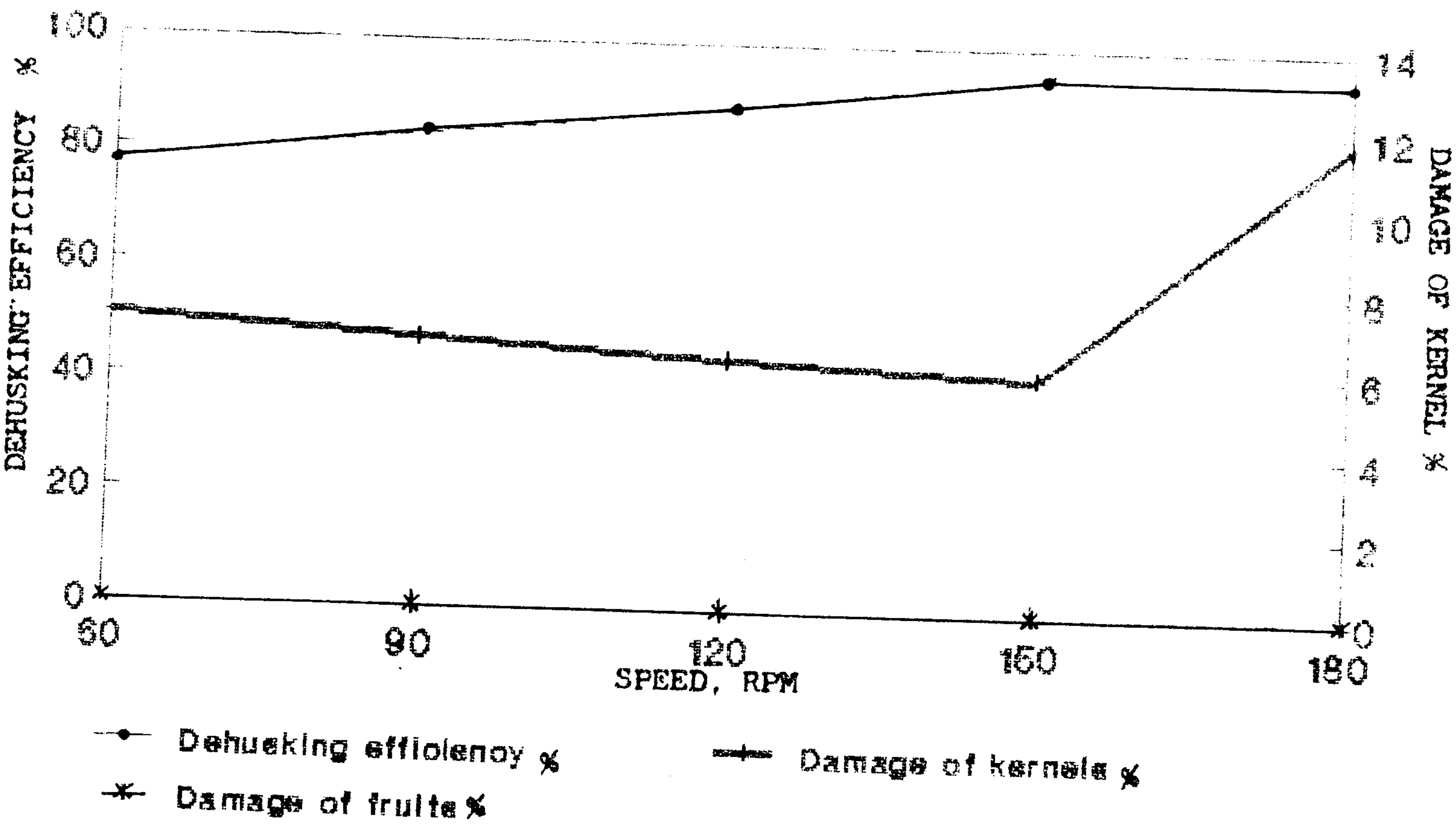


Fig.4.3 Dehusking Efficiency and Damage of Kernels and Fruits at surface C

kernels damaged decreased with speed upto 150 rpm, but for speeds greater than 150 rpm the damage was again found to be increasing. Maximum efficiency for all the three surfaces were obtained at 180 rpm, whereas the damage of dehusked kernel was minimum at 150 rpm. The increase in efficiency with respect to speed was because of the increased grip over the husk of the arecanut fruit. Speeds lower than 150 rpm were observed to damage the kernel more because at lower speeds the kernel was carried more towards the rollers and the teeth tended to bite the kernel. At speeds higher than 150 rpm the impact caused by the teeth of the revolving rollers inflicted damage to kernel.

On analysing the results, it was found that the surface C yielded better results than the other two surfaces. The dehusking efficiency corresponding to surface C ranged from 77.77 to 94.44 per cent (Fig.4.3). The percentage of the number of dehusked kernels was 5.88 to 7.14 per cent. The values of dehusking efficiency and the percentage of the number of dehusked kernels damaged corresponding to surface A ranged from 66.66 to 88.88 per cent and 13.33 to 18.75 per cent respectively (Fig. 4.1) whereas with respect to surface B these were 77.77 to 94.44 per cent and 18.75 to 28.57 per cent respectively (Fig.4.2). The efficiencies were observed to be more in the case of surfaces B and C (Fig 4.4 -4.8). This was because of the increased grip provided by these surfaces. They possesed more number of teeth. The percentages of the number of dehusked kernels damaged were minimum on surface C. This was because of the smaller height of the teeth. Even though the surface B also gave higher dehusking efficiencies, the

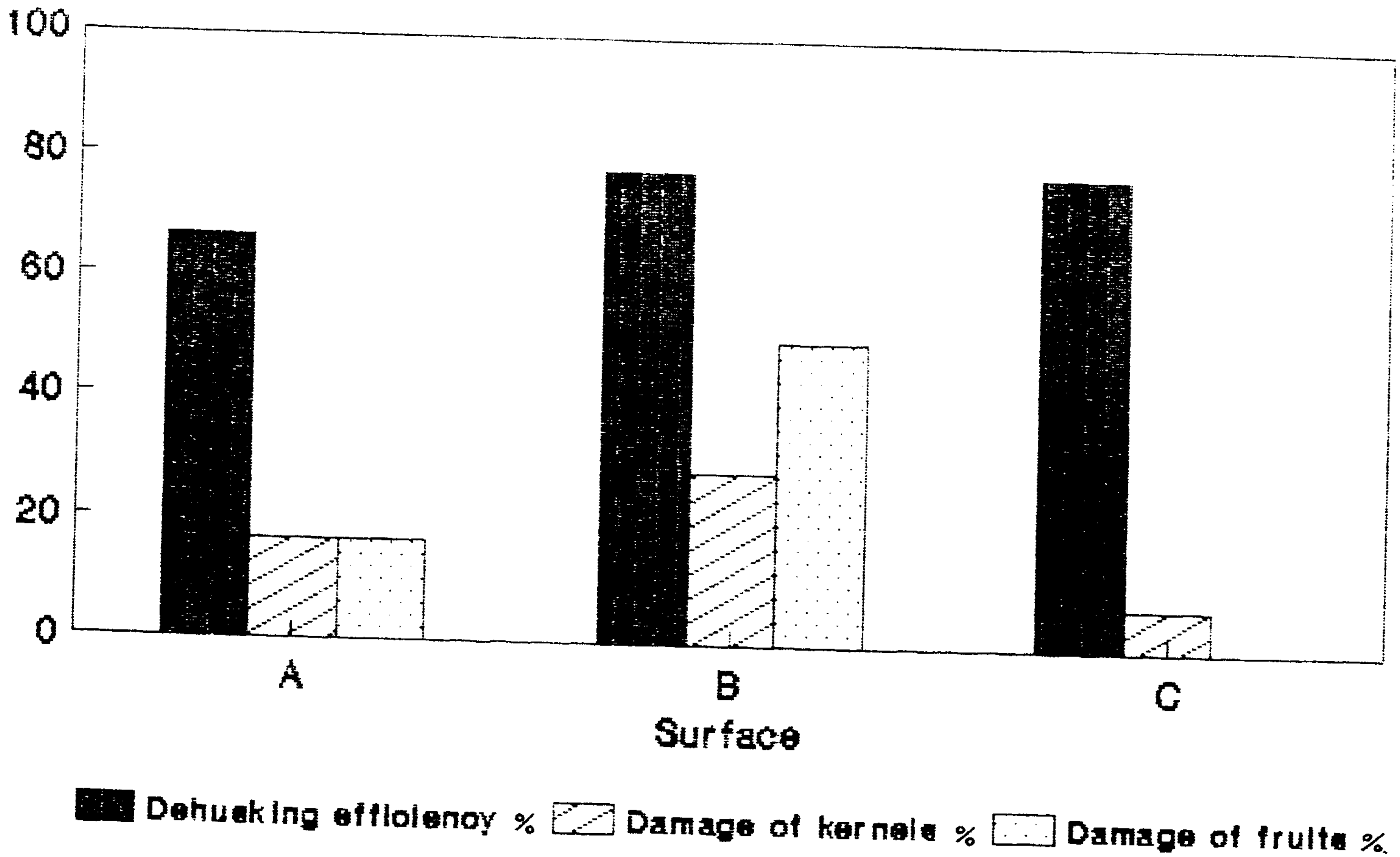


Fig.4.4 Dehusking Efficiency and Damage of Kernels and Fruits at 60 rpm

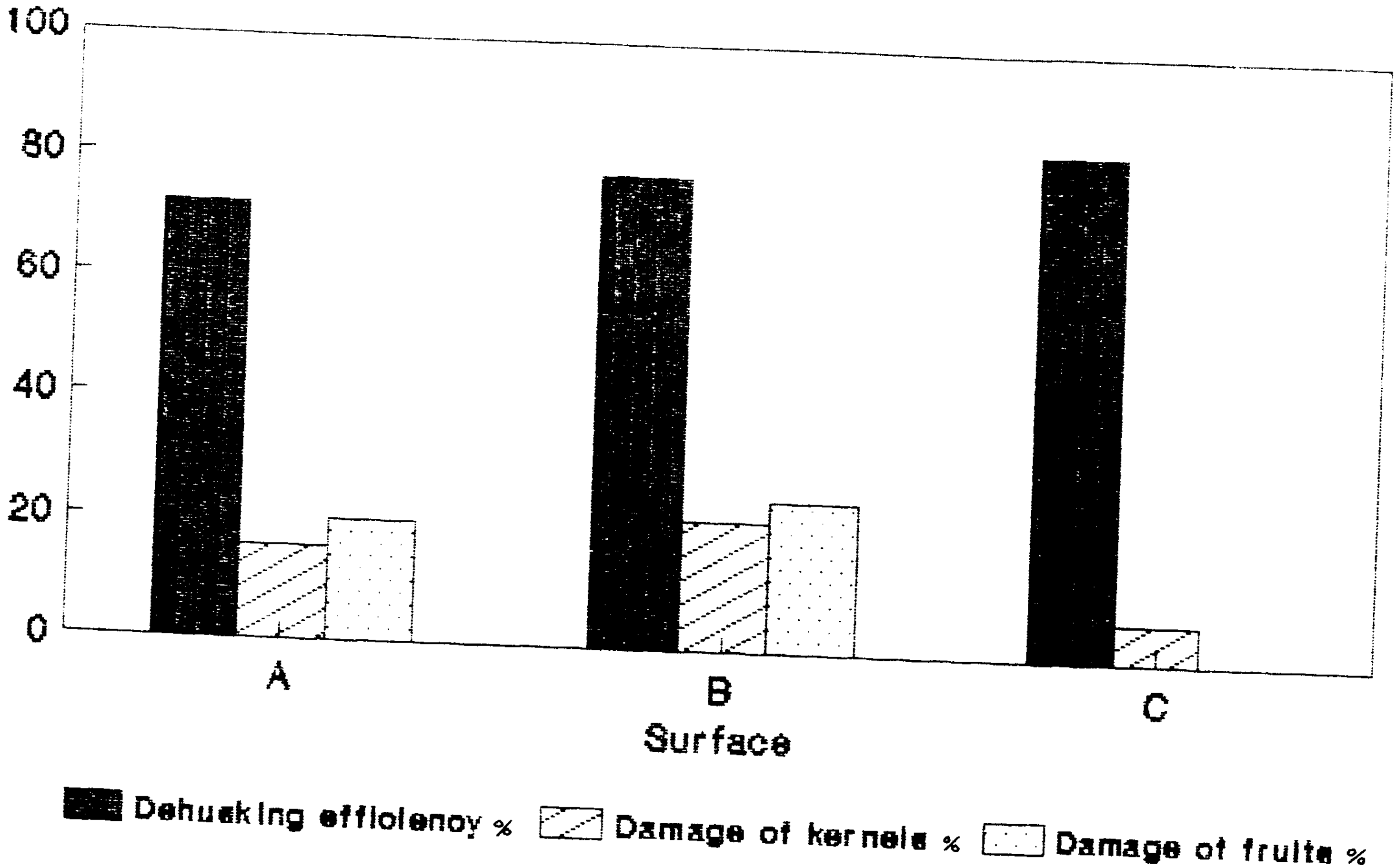


Fig.4.5 Dehusking Efficiency and Damage of Kernels and Fruits at 90 rpm

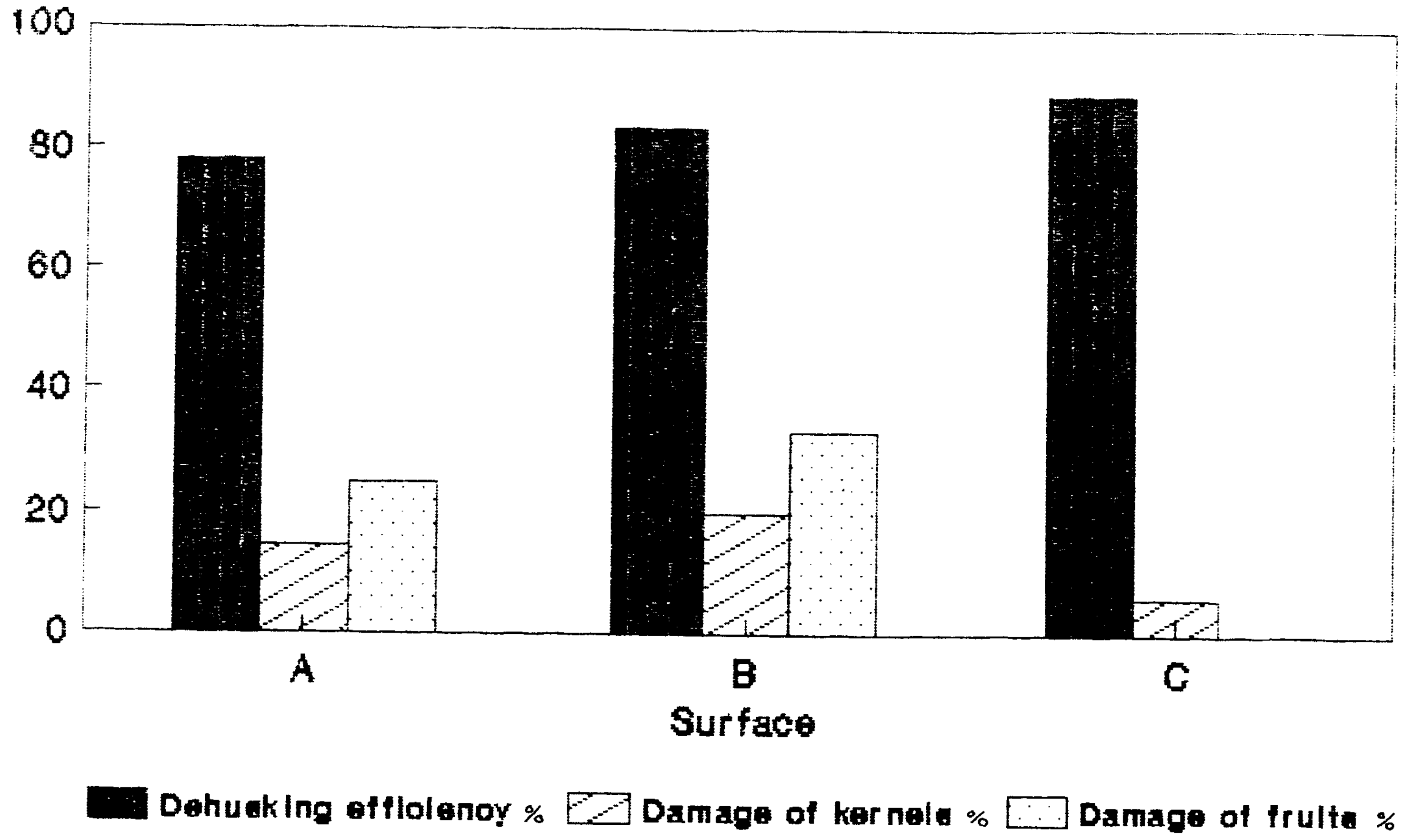


Fig.4.6 Dehusking Efficiency and Damage of Kernels and Fruits at 120 rpm

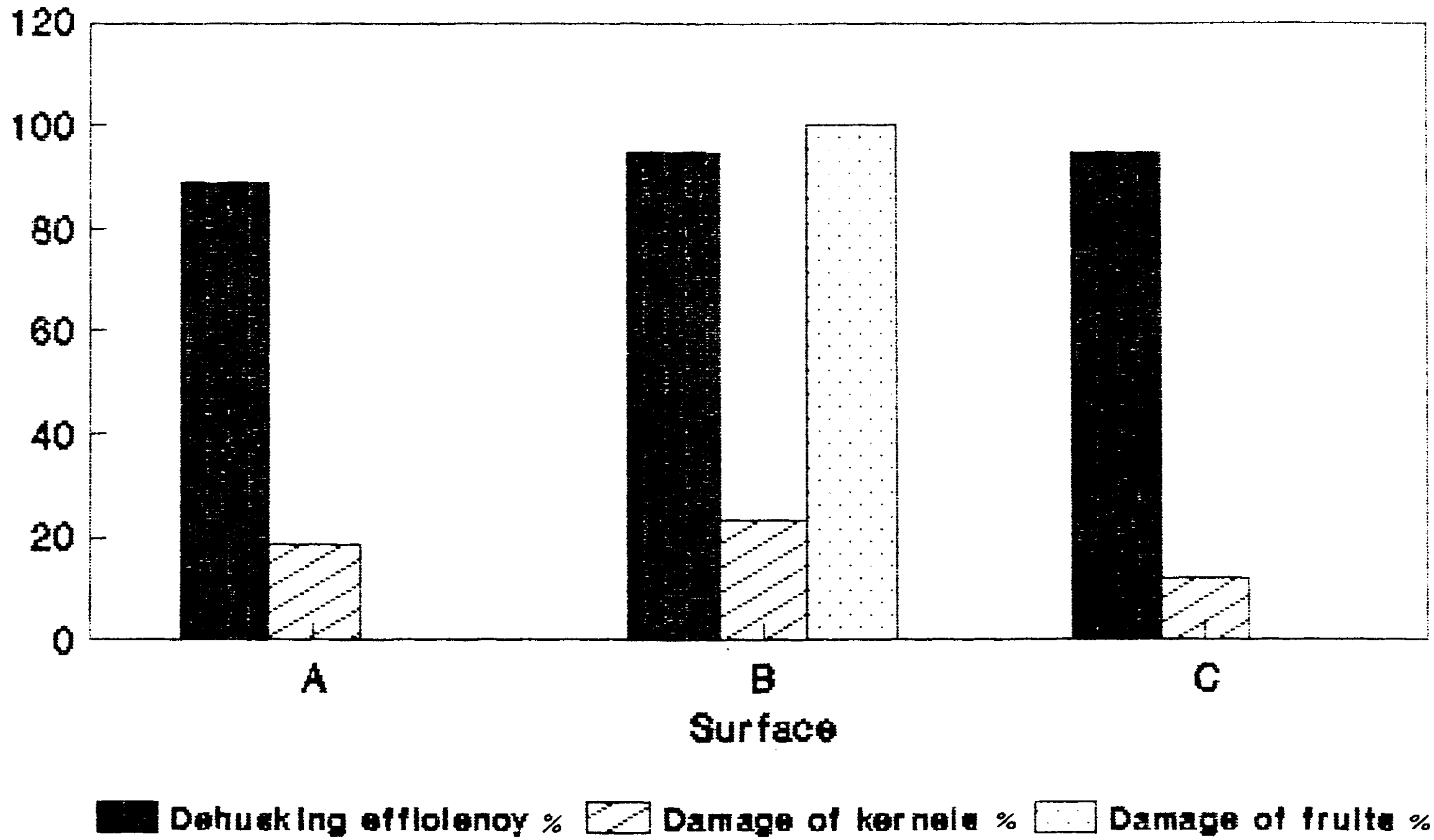


Fig.4.8 Dehusking Efficiency and Damage of Kernels and Fruits at 180 rpm

percentages of the number of dehusked kernels damaged were more because of the larger tooth height and the smaller width of the tooth tip. As the width decreased the tooth became more sharper which in turn caused damage to the outer layer of kernel.

The maximum dehusking efficiency of 94.44 per cent was obtained at speeds of 150 rpm against the surface C and at 180 rpm against the surfaces B and C. Analysis of the percentage of the number of dehusked kernels damaged revealed that the minimum damage of 5.88 per cent was obtained at speed 150 rpm against surface C. The damage was maximum at a speed of 60 rpm against surface B.

The percentage of the number of unhusked fruits damaged was another parameter to be observed. The values of this ranged from 0 to 100 per cent. The maximum value was related to speed 180 rpm and surface B. Based on this aspect, surface C was considered as the best surface, since it gave zero damage for all levels of speed.

From the above findings the optimum set up which gave maximum dehusking efficiency with minimum damage of kernels and unhusked fruits was identified. The parameters of the optimum set-up were

Speed of roller	-	150 rpm
Surface	-	C

4.3 Effect of speed and surface characteristics of rollers on the dehusking efficiency

The effect of each parameter on the dehusking efficiency was analysed, using a 5 x 3 factorial experiment for Completely Randomised Design.

The analysis of variance revealed that only speed had influence on the dehusking efficiency of the machine. The computed F-value correponding to the speed was greater than the table value of F. The computed F-value corresponding to the surface was lower than the table value. Hence the effect of surface on dehusking efficiency was non-significant. Similarly the effect of speed-surface combination was also found to be non-significant for the range of levels selected for speed in this study.

The description of the analysis is given in Appendix-III.

4.4 Power requirement

The energy required for operating the dehusking machine at different speeds under load and no-load conditions varied from 0.259 to 0.318 kW-h. Energy requirement for operating the machine under loaded condition ranged from 0.363 to 0.442 kW-h for machine speeds of the range 60 -180 rpm. It was also noticed that the energy corresponding to the maximum dehusking efficiency was 0.420 kW-h , and this was observed at the speed of 150 rpm. The observations are shown in Appendix - IV.

Regression curve was plotted with speed against energy (Fig. 4.9) and an equation of the form Y = mX + c was derived. The derived equation was,

$$E = 0.00064\ S + 0.327$$

where E = energy consumption, kW-h

S = speed, rpm.

4.5 Economic analysis

The fabrication cost of the machine was Rs 3000/- and the cost of the motor was Rs 4000/- . The depreciation and other operating costs were calculated separately. The total fixed cost was Rs 0.64/h while the variable cost was Rs 15.86/h. Therefore the total operating cost of the machine was obtainted as Rs 16.50/h. Calculations of the operating cost of the machine are shown in Appendix - V.

The cost of operation of dehusking machine was compared with the cost of conventional method. As the average time for husking a single arecanut at optimum set-up was 2.4 s, the quantity of arecanut fruit that could be dehusked in one hour was calculated as 1500 arecanuts and was about 23 kg. At the prevailing wage rate of Rs 2.00/kg, the cost of dehusking the same quantity of arecanut by the traditional method was Rs 46.00/- which was much higher than that of the machine dehusking.

4.6 Comparative study with previous K A U model

The performance of newly developed machine was compared with that of the model previously developed at KAU. The dehusking

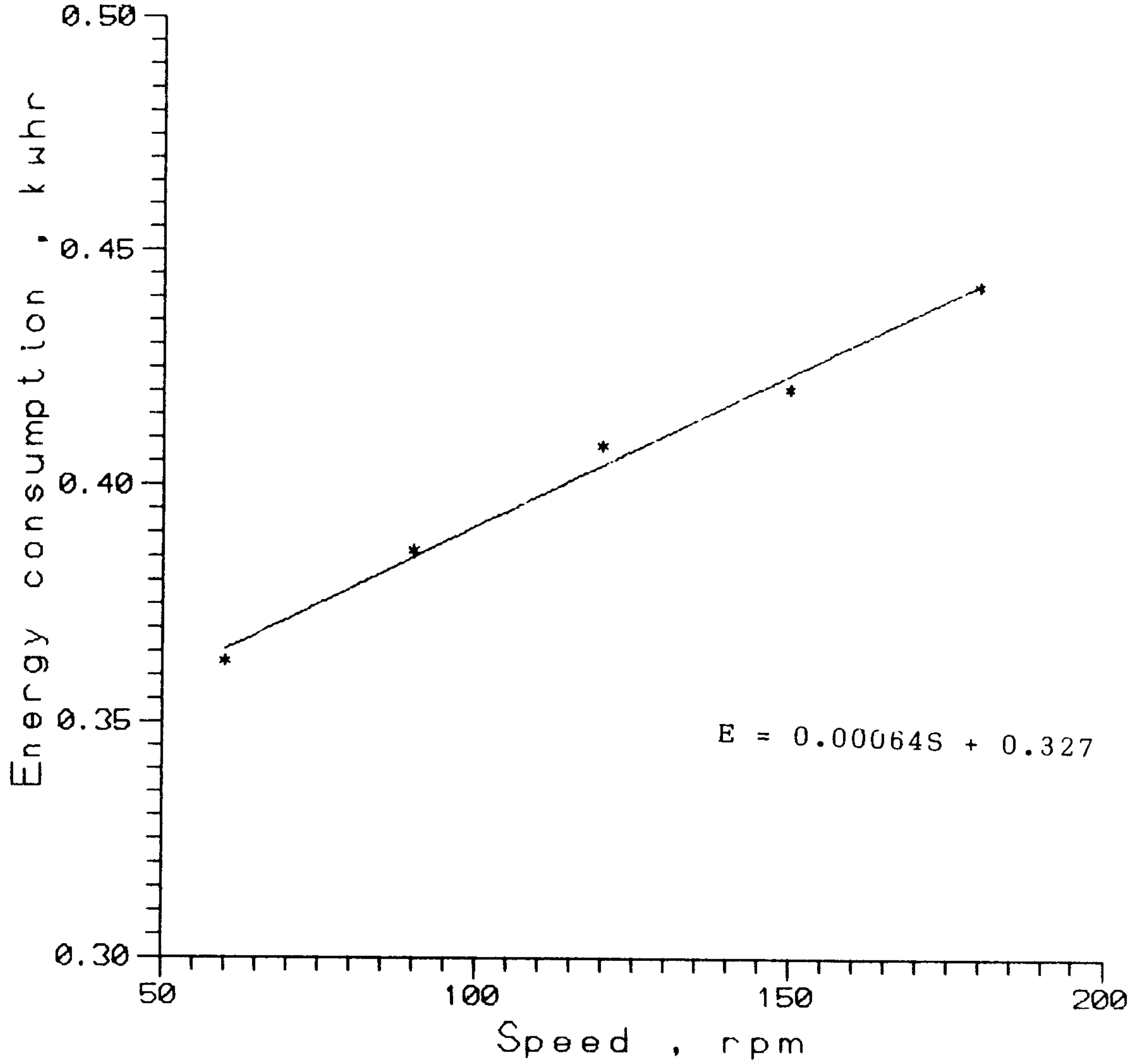


FIG.4.9 SPEED-ENERGY RELATIONSHIP

efficiency of the new machine was found to be higher than the previous model. And also the damage of dehusked kernels and unhusked fruits were observed less for newly developed machine. The output of new machine was more since the average time for husking was less . The comparison of performance of the two models are presented in Table 4.7.

Table 4.7 Comparative study of two models of arecanut dehuskers

Sl. no.	Parameters under optimum set-up	Previous model	Newly developed model
1	Dehusking efficiency	84.50 %	94.44 %
2	Damage of dehusked kernel	10.90 %	5.88 %
3	Avarage time for husking one fruit	5.0 s	2.4 s
4	Output per hour	9 kg	23 kg

Summary

SUMMARY

Arecanut is an important commercial crop which occupies a special position in the cultural and social life of the people of India. The crop plays also a vital role in the agricultural economy of the country. Presently the area under the crop is 237000 ha and the production is 275000 tonnes.

In preparing arecanut for consumption, dehusking is the major post-harvest operation to be carried out. Dehusking accounts for 35 - 40 per cent of the total cost of its processing. The present manual dehusking is laborious, time consuming and uneconomical. Mechanical dehuskers are not commercially available even for small scale dehusking and those developed are not fully successful in meeting the requirements. The arecanut dehusker developed by K A U in 1993 was found to have low efficiency and output.

In an attempt to modify the KAU arecanut dehusker the present study was undertaken, with the following objectives.

1 To evaluate the properties of arecanut relevant to dehusking.

2 Modification of KAU arecanut dehusker.

3 To evaluate its performance.

In order to achieve the objectives, samples of arecanut and its kernels were collected and propertis were studied using existing techniques. Besides, an experimental set-up consisting of an arecanut dehusker was developed and its performance

evaluated.

The dehusker consisted mainly of a pair of fluted rollers, a pressure roller assembly, a scraper assembly, a guide chute and a feed tray. The arecanut was fed between the two counter-rotating rollers having flutes cut on its surface and parallel to its axis. The arecanut was pressed against these rollers by the pressure roller. The rollers gripped the husk and pulled it to the rear side of the rollers. In the process the kernel was ejected from the husk. The kernel was discharged in front of the rollers and the husk from the rear side of the rollers. The scraper assembly provided on the rear side of the roller scraped off any husk sticking to the roller.

The machine was tested at 5 levels of speeds and 3 levels of surface characteristic. The speeds selected were 60, 90, 120, 150 and 180 rpm. The surface characteristics were (i) fluted rollers having 20 teeth with a pitch 5.9 mm , width 3.0 mm and depth 2.6 mm, (ii) rollers having 30 teeth with a pitch 3.9 mm, width 1.0 mm and depth 2.0 mm, (iii) rollers having 30 teeth with a pitch 3.9 mm, width 2.0 mm and depth 1.0 mm. A total of fifteen machine set-ups with different combinations of speed and surface were studied. The dehusking efficiency , percentage of the number of dehusked kernels damaged and percentage of the number of unhusked arecanut fruits damaged were determined and the results were analysed.

In the studies relating to properties of arecanut fruit and its kernel it was, from visual observation, found that arecanut fruits were oblong in shape while the kernels were observed to be either conic or ovate. Mean length of the major axis of arecanut fruit was 54.06 mm and that of kernel was 24.21 mm. The mean length of the minor axis of the fruit was 32.41 mm and that of kernel was 24.36 mm. Average weights of dried arecanut fruit, husk and kernel were 15.87, 6.96 and 8.90 g respectively. From the study it was inferred that 56.80 per cent of the weight of arecanut fruit was contributed by the kernel and 43.33 per cent by the husk. The average moisture content (w.b.) of the husk and kernel were 10.70 and 9.59 per cent respectively. The mean volume of the fruit was 28.93 cm^3 and the average true density was 0.51 g/cm^3. The mean bulk density of the fruit was found to be 0.30 g/cm^3.

From the performance evaluation of the machine it was observed that the dehusking efficiency varied from 66.40 to 94.44 per cent and the percentage of the number of dehusked kernels damaged varied from 5.88 to 28.57 per cent. The percentage of the number of unhusked fruits damaged varied from 0 to 100 per cent. It was also noticed that the dehusking efficiency was found to increase with the speed. The percentage of the number of dehusked kernels damaged decreased with speed upto 150 rpm and again increased for speeds greater than 150 rpm. Further, it was found that the surface having 30 teeth with a pitch 3.9 mm, width 2.00 mm and depth 1.00 mm produced better results than the other two surfaces. The values of dehusking efficiency were more with this surface while the percentages of the number of dehusked kernels and unhusked fruits damaged were minimum. Hence the optimum the set-up of the machine was identified as 150 rpm and a roller surface having 30 teeth with pitch 3.90 mm, width 2.00 mm and depth 1.00 mm.

The maximum dehusking efficiency of 94.44 per cent was obtained at the machine set-up with speed 150 rpm and roller surface having 30 teeth with pitch 3.90 mm, width 2.00 mm and depth 1.00 mm. The respective values of the percentage of the number of dehusked kernels damaged and the percentage of the number of unhusked fruits damaged were 5.5 and zero per cent. These values were found to be the minimum for all the set-ups of the machine.

From the analysis of the data it was revealed that only the speed of the rollers influenced the dehusking efficiency at all levels. The effects of surface and that of speed-surface combination were non-significant for all the levels of speed.

The average time required for husking a single arecanut was 2.4 s with the optimum machine set-up. The output of the machine at this rate was 23 kg/h.

The energy required to operate the machine under optimum set-up was 0.42 kW-h. The operating cost of the machine was Rs 0.72/ kg while that of the conventional method was Rs 2.00/kg.

The machine developed under the present study showed improved dehusking efficiency, and lower percentages of damage to both kernels and unhusked fruits when compared to the previous K A U model of dehusker. The output per hour was also more.

Considering the above it was concluded that the machine developed in this study can be utilized for dehusking arecanut fruit, particularly the matured as well as dried arecanut fruits. However, it was felt that its performance could be improved further if the modification as suggested below are incorporated in the design. Hence, the following works are suggested for further investigations.

1 Study of its performance at different relative speeds of the counter-rotating rollers.

2 Replacement of pressure roller assembly with a pressure plate mechanism.

3 Incorporation of a mechanism to sweep off the immature fruits held betwen the rollers.

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Appendices

APPENDIX : I

Table .1. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 60 rpm Surface - A

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	3	husked	η_h = 83.33 %
	2	3	husked	dh = 20.00 %
	3	-	not husked	du = 0.00 %
	4	4	husked + damaged	
	5	6	husked	
	6	5	husked	
II	1	-	not husked	η_h = 50.00 %
	2	-	not husked	dh = 0.00 %
	3	3	husked	du = 0.00 %
	4	4	husked	
	5	3	husked	
	6	-	not husked	
III	1	3	husked	η_h = 66.66 %
	2	4	husked	dh = 25.00 %
	3	-	not husked	du = 50.00 %
	4	6	husked	
	5	3	husked + damaged	
	6	-	not husked + damaged	

Average : Dehusking efficiency, η_h = 66.66 %

Damage of dehusked kernel, dh = 16.66 %

Damage of unhusked fruits, du = 16.66 %

Table 2. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 60 rpm   Surface B

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	-	not husked + damaged	η_h = 83.33 %
	2	3	husked	dh = 20.00 %
	3	5	husked	du = 100.00 %
	4	4	husked	
	5	3	husked	
	6	6	husked + damaged	
II	1	5	husked	η_h = 66.66 %
	2	-	not husked	dh = 0.00 %
	3	4	husked	du = 0.00 %
	4	4	husked	
	5	-	not husked	
	6	5	husked	
III	1	3	husked + damaged	η_h = 83.33 %
	2	3	husked + damaged	dh = 60.00 %
	3	4	husked	du = 100.00 %
	4	-	not husked + damaged	
	5	5	husked	
	6	3	husked + damaged	

Average : Dehusking efficiency, η_h = 77.77 %

Damage of dehusked kernel, dh = 28.57 %

Damage of unhusked fruits, du = 50.00 %

Table 3. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 60 rpm   Surface - C

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	3	husked	η_h = 83.33 %
	2	6	husked	dh = 0.00 %
	3	3	husked	du = 0.00 %
	4	3	husked	
	5	-	not husked	
	6	6	husked	
II	1	5	husked	η_h = 66.66 %
	2	-	not husked	dh = 25.00 %
	3	3	husked	du = 0.00 %
	4	-	not husked	
	5	4	husked + damaged	
	6	4	husked	
III	1	3	husked	η_h = 83.33 %
	2	7	husked	dh = 0.00 %
	3	4	husked	du = 0.00 %
	4	3	husked	
	5	-	not husked	
	6	3	husked	

Average : Dehusking efficiency, η_h = 77.77 %

Damage of dehusked kernel, dh = 7.14 %

Damage of unhusked fruits, du = 0.00 %

Table 4. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 90 rpm Surface - A

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	4	husked	η_h = 83.33 %
	2	3	husked	dh = 0.00 %
	3	3	husked	du = 0.00 %
	4	-	not husked	
	5	6	husked	
	6	3	husked	
II	1	3	husked	η_h = 66.66 %
	2	-	not husked + damaged	dh = 25.00 %
	3	3	husked	du = 50.00 %
	4	3	husked + damaged	
	5	4	husked	
	6	-	not husked	
III	1	3	damaged	η_h = 66.66 %
	2	4	husked	dh = 25.00 %
	3	3	husked	du = 0.00 %
	4	-	not husked	
	5	-	not husked	
	6	5	husked	

Average : Dehusking efficiency, η_h = 72.22%

Damage of dehusked kernel, dh = 15.38 %

Damage of unhusked fruits, du = 20.00 %

Table 5. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 90 rpm Surface - B

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	-	not husked	η_h = 66.66 %
	2	4	husked	dh = 0.00 %
	3	3	husked	du = 50.00 %
	4	6	husked	
	5	-	not husked + damaged	
	6	3	husked	
II	1	3	husked +damaged	η_h = 83.33 %
	2	5	husked	dh = 40.00 %
	3	3	husked	du = 0.00 %
	4	-	not husked	
	5	6	husked + damaged	
	6	3	husked	
III	1	-	not husked	η_h = 83.33 %
	2	4	husked	dh = 20.00 %
	3	3	husked + damaged	du = 0.00 %
	4	6	husked	
	5	4	husked	
	6	4	husked	

Average : Dehusking efficiency, η_h = 77.77 %

Damage of dehusked kernel, dh = 21.42 %

Damage of unhusked fruits, du = 25.00 %

Table 6. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 90 rpm Surface - C

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	6	husked	η_h = 100.00 %
	2	3	husked	dh = 16.66 %
	3	3	husked+ damaged	du = 0.00 %
	4	2	husked	
	5	3	husked	
	6	3	husked	
II	1	-	not husked	η_h = 60.00 %
	2	3	husked	dh = 0.00 %
	3	3	husked	du = 0.00 %
	4	4	husked	
	5	3	husked	
	6	-	not husked	
III	1	3	husked	η_h = 83.33 %
	2	3	husked	dh = 0.00 %
	3	6	husked	du = 0.00 %
	4	-	not husked	
	5	3	husked	
	6	3	husked	

Average : Dehusking efficiency, η_h = 83.33 %

Damage of dehusked kernel, dh = 6.66 %

Damage of unhusked fruits, du = 0.00 %

Table 7. Time for husking and performance evaluation of the machine at different machine set- ups

Speed 120 rpm Surface - A

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	5	husked	η_h = 83.33 %
	2	2	husked	dh = 0.00 %
	3	-	not husked	du = 0.00 %
	4	3	husked	
	5	4	husked	
	6	3	husked	
II	1	5	husked	η_h = 83.33 %
	2	-	not husked + damaged	dh = 0.00 %
	3	4	husked	du = 100.00 %
	4	3	husked	
	5	2	husked	
	6	2	husked	
III	1	3	husked + damaged	η_h = 66.66 %
	2	-	not husked	dh = 50.00 %
	3	3	husked	du = 0.00 %
	4	3	husked+damaged	
	5	2	husked	
	6	-	not husked	

Average : Dehusking efficiency, η_h = 77.77 %

Damage of dehusked kernel, dh = 14.28 %

Damage of unhusked fruits, du = 25.00 %

Table 8. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 120 rpm Surface - B

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	-	not husked	η_h = 66.66 %
	2	2	husked	dh = 25.00 %
	3	3	husked + damaged	du = 0.00 %
	4	2	husked	
	5	-	not husked	
	6	2	husked	
II	1	2	husked	η_h = 100.00 %
	2	2	husked + damaged	dh = 16.66 %
	3	3	husked	du = 0.00 %
	4	2	husked	
	5	5	husked	
	6	2	husked	
III	1	2	husked + damaged	η_h = 83.33 %
	2	2	husked	dh = 20.00 %
	3	3	husked	du = 100.00 %
	4	3	husked	
	5	-	not husked + damaged	
	6	3	husked	

Average : Dehusking efficiency, η_h = 83.33 %

Damage of dehusked kernel, dh = 20.00 %

Damage of unhusked fruits, du = 33.33 %

Table 9. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 120 rpm Surface - C

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	3	husked	η_h = 83.33 %
	2	2	husked	dh = 0.00 %
	3	2	husked	du = 0.00 %
	4	-	not husked	
	5	2	husked	
	6	3	husked	
II	1	2	husked	η_h = 100.00 %
	2	2	husked	dh = 16.66 %
	3	2	husked	du = 0.00 %
	4	2	husked	
	5	3	husked	
	6	2	husked + damaged	
III	1	5	husked	η_h = 83.33 %
	2	3	husked	dh = 0.00 %
	3	3	husked	du = 0.00 %
	4	2	husked	
	5	-	not husked	
	6	3	husked	

Average : Dehusking efficiency, η_h = 88.88 %

Damage of dehusked kernel, dh = 6.25 %

Damage of unhusked fruits, du = 0.00 %

Table 10. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 150 rpm Surface - A

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	2	husked	η_h = 83.33 %
	2	3	not husked	dh = 0.00 %
	3	5	husked	du = 0.00 %
	4	3	husked	
	5	3	husked	
	6	4	husked	
II	1	2	husked	η_h = 100.00 %
	2	4	husked + damaged	dh = 16.66 %
	3	4	husked	du = 100.00 %
	4	3	husked	
	5	3	husked	
	6	3	husked	
III	1	2	husked + damaged	η_h = 66.66 %
	2	2	husked	dh = 25.00 %
	3	2	husked	du = 0.00 %
	4	-	not husked	
	5	3	husked	
	6	-	not husked	

Average : Dehusking efficiency, η_h = 83.33 %

Damage of dehusked kernel, dh = 13.33 %

Damage of unhusked fruits, du = 0.00 %

Table 11. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 150 rpm   Surface - B

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	3	husked	η_h = 100.00 %
	2	3	husked	dh = 16.66 %
	3	3	husked	du = 0.00 %
	4	2	husked +damaged	
	5	3	husked	
	6	3	husked	
II	1	2	husked + damaged	η_h = 83.33 %
	2	5	husked	dh = 40.00 %
	3	3	husked	du = 0.00 %
	4	2	husked	
	5	-	not husked	
	6	3	husked + damaged	
III	1	2	husked	η_h = 83.33 %
	2	2	husked	dh = 0.00 %
	3	-	not husked + damaged	du = 0.00 %
	4	3	husked	
	5	3	husked	
	6	3	husked	

Average : Dehusking efficiency, η_h = 88.88 %

Damage of dehusked kernel, dh = 18.75 %

Damage of unhusked fruits, du = 50.00 %

Table 12. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 150 rpm Surface - C

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	2	husked	η_h = 100.00 %
	2	3	husked	dh = 0.00 %
	3	2	husked	du = 0.00 %
	4	3	husked	
	5	3	husked	
	6	2	husked	
II	1	2	husked	η_h = 100.00 %
	2	2	husked	dh = 16.66 %
	3	2	husked	du = 0.00 %
	4	3	husked + damaged	
	5	2	husked	
	6	4	husked	
III	1	2	husked	η_h = 83.33 %
	2	2	husked	dh = 0.00 %
	3	2	husked	du = 0.00 %
	4	-	not husked	
	5	2	husked	
	6	2	husked	

Average : Dehusking efficiency, η_h = 94.44 %

Damage of dehusked kernel, dh = 5.85 %

Damage of unhusked fruits, du = 0.00 %

Table 13. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 180 rpm Surface - A

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	3	husked	η_h = 83.33 %
	2	-	not husked	dh = 0.00 %
	3	2	husked	du = 0.00 %
	4	4	husked	
	5	2	husked	
	6	2	husked	
II	1	2	husked	η_h = 83.33 %
	2	2	husked	dh = 40.00 %
	3	3	husked + damaged	du = 100.00 %
	4	2	husked + damaged	
	5	2	husked	
	6	-	not husked	
III	1	2	husked	η_h = 100.00 %
	2	2	husked	dh = 16.66 %
	3	2	husked	du = 0.00 %
	4	2	husked	
	5	4	husked	
	6	3	husked + damaged	

Average : Dehusking efficiency, η_h = 88.88 %

Damage of dehusked kernel, dh = 18.75 %

Damage of unhusked fruits, du = 0.00 %

Table 14. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 180 rpm   Surface - B

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	2	husked	η_h = 100.00 %
	2	2	husked + damaged	dh = 33.33 %
	3	2	husked	du = 0.00 %
	4	2	husked	
	5	3	husked + damaged	
	6	2	husked	
II	1	2	husked	η_h = 83.33 %
	2	2	husked + damaged	dh = 20.00 %
	3	2	husked	du = 100.00 %
	4	2	husked	
	5	2	husked	
	6	-	not husked + damaged	
III	1	2	husked	η_h = 100.00 %
	2	2	husked	dh = 16.66 %
	3	2	husked + damaged	du = 0.00 %
	4	2	husked	
	5	3	husked	
	6	2	husked	

Average : Dehusking efficiency, η_h = 94.44 %

Damage of dehusked kernel, dh = 23.53 %

Damage of unhusked fruits, du = 100.00 %

Table 15. Time for husking and performance evaluation of the machine at different machine set-ups

Speed 180 rpm Surface - C

Rpln No.	Sl No.	Time for husking (s)	Remarks	
I	1	2	husked	η_h = 100.00 %
	2	2	husked	dh = 0.00 %
	3	2	husked	du = 0.00 %
	4	2	husked	
	5	2	husked	
	6	4	husked	
II	1	-	not husked	η_h = 83.33 %
	2	2	husked	dh = 20.00 %
	3	2	husked + damaged	du = 0.00 %
	4	2	husked	
	5	2	husked	
	6	2	husked	
III	1	2	husked	η_h = 100.00 %
	2	2	husked+damaged	dh = 16.66 %
	3	2	husked	du = 0.00 %
	4	2	husked	
	5	2	husked	
	6	2	husked	

Average : Dehusking efficiency, η_h = 94.44 %

Damage of dehusked kernel, dh = 11.76 %

Damage of unhusked fruits, du = 0.00 %

APPENDIX II

Set-up for the computerised statistical analysis of the data

Sl.No.	RPM	Surface	Replication	Efficiency %
1	1	1	1	83.3
2	1	1	2	50.0
3	1	1	3	66.7
4	1	2	1	83.3
5	1	2	2	66.7
6	1	2	3	83.3
7	1	3	1	83.3
8	1	3	2	66.7
9	1	3	3	83.3
10	2	1	1	83.3
11	2	1	2	66.7
12	2	1	3	66.7
13	2	2	1	66.7
14	2	2	2	83.3
15	2	2	3	83.3
16	2	3	1	100.0
17	2	3	2	66.7
18	2	3	3	83.3
19	3	1	1	83.3
20	3	1	2	83.3
21	3	1	3	66.7
22	3	2	1	66.7
23	3	2	2	100.0
24	3	2	3	83.3
25	3	3	1	83.3
26	3	3	2	100.0
27	3	3	3	83.3
28	4	1	1	83.3
29	4	1	2	100.0
30	4	1	3	66.7
31	4	2	1	100.0
32	4	2	2	83.3
33	4	2	3	83.3
34	4	3	1	100.0
35	4	3	2	100.0
36	4	3	3	83.3
37	5	1	1	83.3
38	5	1	2	83.3
39	5	1	3	100.0
40	5	2	1	100.0
41	5	2	2	83.3
42	5	2	3	100.0
43	5	3	1	100.0
44	5	3	2	83.3
45	5	3	3	100.0

APPENDIX III

RESULTS OF THE COMPUTERISED STATISTICAL ANALYSIS OF THE DATA

Data file: DEHUSKER

Title:

Function: FACTOR

Experiment Model Number 1:
Two Factor Completely Randomized Design

Data case no. 1 to 45.

Factorial ANOVA for the factors:
Replication (Var 3: RPLN) with values from 1 to 3
Factor A (Var 1: RPM) with values from 1 to 5
Factor B (Var 2: SURFACE) with values from 1 to 3

Variable 4: EFFNCY

Grand Mean = 83.330   Grand Sum = 3749.850   Total Count = 45

T A B L E   O F   M E A N S

3	1	2	4	Total
*	1	*	74.070	666.630
*	2	*	77.773	699.960
*	3	*	83.329	749.960
*	4	*	88.887	799.980
*	5	*	92.591	833.320
*	*	1	77.777	1166.650
*	*	2	84.442	1266.630
*	*	3	87.771	1316.570
*	1	1	66.663	199.990
*	1	2	77.773	233.320
*	1	3	77.773	233.320
*	2	1	72.217	216.650
*	2	2	77.773	233.320
*	2	3	83.330	249.990
*	3	1	77.787	233.360
*	3	2	83.333	250.000
*	3	3	88.867	266.600
*	4	1	83.330	249.990
*	4	2	88.887	266.660
*	4	3	94.443	283.330
*	5	1	88.887	266.660
*	5	2	94.443	283.330
*	5	3	94.443	283.330

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	4	2099.419	524.855	3.6970	0.0146
4	Factor B	2	777.022	388.511	2.7366	0.0810
6	AB	8	86.263	10.783	0.0760	
-7	Error	30	4259.078	141.969		
	Total	44	7221.782			

Coefficient of Variation: 14.30%

$s_{\bar{y}}$ for means group 2: 3.9717 Number of Observations: 9

$s_{\bar{y}}$ for means group 4: 3.0765 Number of Observations: 15

$s_{\bar{y}}$ for means group 6: 6.8792 Number of Observations: 3

APPENDIX IV

Energy requirement of the machine at no - load and load conditions

Output speed of motor (rpm)	Speed of machine (rpm)	Energy consumed at no load condn. 1 (kW-h)	2	Mean	Energy consumed at load condn. 1 (kW-h)	2	Mean
1440	60	.257	.261	0.259	.361	.365	0.363
1440	90	.268	.271	0.270	.384	.387	0.386
1440	120	.279	.284	0.282	.407	.408	0.408
1440	150	.309	.312	0.311	.419	.421	0.420
1440	180	.318	.319	0.318	.441	.443	0.442

APPENDIX V

Calculation of operating cost

Initial cost (C)

Fabrication cost of dehusking machine including cost of material	=	Rs 3000/-
Initial cost of motor	=	Rs 4000/-
Average life of dehusking machine	=	10 years
Average life of motor	=	20 years
Working hours per year	=	1600
Salvage value	=	10% of initial cost
For motor	=	Rs 400/-
For machine	=	Rs 300/-

A. Fixed cost

I Depreciation = (C - S) / (L x H)

For dehusking machine = (3000 - 300)/(10 x 1600)

= Rs 0.17/h

For motor = (4000 - 400)/(20 x 1600)

= Rs 0.11/h

II Interest on investment at the rate of 15%

$$= \frac{(C + S) \times 15}{2 \times H \times 100}$$

For machine

$$= \frac{(3000 + 300) \times 15}{2 \times 1600 \times 100}$$

= Rs 0.15/h

For motor

$$= \frac{(4000 + 400) \times 15}{2 \times 1600 \times 100}$$

= Rs 0.21/h

Total fixed cost = Rs 0.17 + 0.11 + 0.15 + 0.21

= Rs 0.64/h

B. Variable cost

i) Labour wages

Wages of a labourer = Rs 60 .00/day of 8 h

For 2 labourers = Rs 15.00 / h

ii) Cost of electrical energy

Unit cost of electricity = Rs 1 / kW-h

Energy consumption of machine = 0.42 kW-h

Cost of electricity = Rs 0.42/h

iii) Repair and maintenance

@ 10% of initial cost per annum

For machine = $\frac{3000 \times 10 \times 1}{100 \times 1600}$

= Rs 0.19/h

For motor = $\frac{4000 \times 10 \times 1}{100 \times 1600}$

= Rs 0.25/h

Total variable cost = Rs 15 + 0.42 + 0.19 + 0.25

= Rs 15.86 / h

Total operating cost = Rs 0.64 + 15.86

= Rs 16.5 / h

APPENDIX VI

Specification of energy meter

Ampere	:	3 x 10
Volt	:	3 x 400
Cycles	:	50 Hz
1 kW-h	:	112.5 revolution of disc made by General Electric Co. India (Pvt. Ltd.), Calcutta.

APPENDIX VII

Specification of 3 phase induction motor

Ampere	:	1.2
Volt	:	4.5
Cycles	:	50 Hz
kW	:	0.37
rpm	:	1440

Made by Kirloskar Electric Co. Ltd., Bangalore.

MODIFICATIONS AND TESTING OF KAU ARECANUT DE-HUSKER

By

RAJMOHAN, C. K.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Technology
in
Agricultural Engineering

Faculty of Agricultural Engineering & Technology

KERALA AGRICULTURAL UNIVERSITY

Department of Farm Power Machinery and Energy
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
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1996

ABSTRACT

An arecanut dehusker consisting of mainly a pair of fluted rollers, a pressure roller assembly, a scraper assembly, a guide chute and a feed tray was developed in this study. The arecanut was fed between the two counter-rotating fluted rollers and was pressed against these rollers by the pressure roller. The fluted rollers gripped the husk and pulled it to the rear side of the rollers. In the process the husk was ripped open and the kernel was ejected from its shell.

The performace of the machine was studied at speeds of 60, 90, 120, 150, and 180 rpm and with three different surface characteristics of the rollers. The surface characteristics of the rollers were varied by having different number of teeth and pitch. From the studies, the optimum set-up of the machine for deriving maximum dehusking efficiency and minimum damage to the dehusked kernels and unhusked fruits was obtained. This was at a speed of 150 rpm against a roller surface having 30 teeth with pitch 3.9 mm, width 2.0 mm, and depth 1.0 mm. At this set-up the dehusking efficiency, percentages of the number of dehusked kernels and unhusked fruits damaged were 94.4, 5.5 and zero percent respectively. And also this set-up yielded an out put of 23 kg of arecanut kernels per hour.