DEVELOPMENT AND PERFORMANCE EVALUATION OF A BLACK PEPPER SKINNER

By

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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

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573

MALAPPURAM

1996

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I hereby declare that this thesis entitled **"Development and performance evaluation of a Black pepper skinner"** 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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Certified that this thesis entitled **"Development and performance evaluation of a Black pepper skinner"** is a record of research work done independently by **Mr. Anandabose. D** 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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ACKNOWLEDGEMENT

I keep record of my sincere gratitude to my guide and chairman of advisory committee, **Er. Jippu Jacob**, Associate Professor, Department of Farm Power Machinery and Energy, KCAET, Tavanur, whose fervour, didactic criticism and meticulous guidance evinced amidst his multifarious engagements, which egged me up greatly.

I remember with thanks **Prof. C.P. Muhammed**, Head of the Department, FPME, for the concern and consideration he has shown all through this research.

It gives me great pleasure in expressing my thanks to **Dr.M. Sivaswami**, Assistant Professor, Department of FPME, and **Dr. Jobi V.Paul**, Associate Professor, Department of IDE, members of the Advisory Committee for their timely guidance and support during this course of work.

I gratefully appreciate the co-operation received from **Dr. K. I. Koshy**, Professor and Head, SAC and **Miss Josephina Paul**, Assistant Professor, Department of SAC for permitting me to avail the facilities of the computer centre during the analysis of data.

I am immensely thankful to **Er. V.R.Ramachandran**, Assistant Professor, Department of FPME, KCAET, for giving valueble suggestions and guidance at the initial phase of this research work.

I am immensely thankful to all the staff members especially to **Mrs. Santhy Mary Mathew** for their enthusiastic co-operation for the completion of this work.

Thanks to all technicians and supervisors of the workshop, for their timely support.

Succour rendered by my dear friends at KCAET, especially Sudheer, Rajmohan, Jijimon, Jayaraj, Prince, Balu and Saji of START, Edapal during this research work was highly encouraging.

The award of Junior Fellowship of Kerala Agricultural University is thankfully acknowledged.

I express my deep sense of gratitude to my loving parents and family members for their continuous support and inspiration all through my studies.

A word of gratitude to M/s RK computer center, Coimbatore for the prompt service rendered.

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Dedicated to

My Loving Parents

C O N T E N T S

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SYMBOLS AND ABBREVIATIONS

ANOVA	-	Analysis of Variance
cm	-	centimetre(s)
d.b	-	dry basis
GI	-	Galvanised Iron
h	-	hour(s)
kg	-	kilogram
kW	-	kilo watt
L	-	Linn
m	-	metre(s)
mm	-	milli metre(s)
rpm	-	revolutions per minute
s	-	seconds
USA	-	United States of America
viz.	-	namely
wt	-	weight
/	-	per
%	-	per cent

Introduction

INTRODUCTION

India is known the world over as the home of spices and about thirty five spices are grown in the country. Among these, black pepper is the most sought-after spice in the world. Black pepper is the dried mature berries of the pepper vine, (Piper nigrum.L) belonging to the Piperaceae family. White pepper is obtained on removal of the mesocarp of the ripe red or green berries by microbial fermentation, steaming, or mechanial decortication, and has the same flavour of black pepper, but with less pungency. Because of the absence of the fibrous skin, it can be ground finer.

It is not known, as to when and why pepper started being made in this unusual form. It is possible that, the Dutch colonists might not have liked the strong pungency, aroma, and the harsh taste of black pepper, caused by its mesocarp. And this might have resulted in the creation of this new product called 'White Pepper'. The white appearance and the flavour of white pepper appealed to them and resulted in this unusual form of pepper being popularized in Europe.

Today in USA and Canada white pepper is used primarily in dishes and food products such as light coloured sauces, salad dressings, cream soups, etc., where presence of dark particles is undesirable. In Europe, however, white pepper is traditionally preferred over black pepper for household and restaurant use.

Major portion of world's total black pepper output is shared among the countries India, Indonesia, Malaysia, Sri Lanka, and Thailand. In 1991, the world production of black pepper was estimated to be around 2,37,000 tonnes. Out of this, Indonesia ranked first with a production of 61,000 tonnes. India occupied the second slot with a production of 55,000 tonnes. Production of black pepper in the last few years in Kerala and India is given in Table 1.1.

Table 1.1.

Production of black pepper in Kerala and India

Sl.No	Year	Production (million tonnes)	
		Kerala	India
1.	1989 - 1990	54.14	56.19
2.	1990 - 1991	46.80	47.95
3.	1991 - 1992	50.31	52.01
4.	1992 - 1993	49.67	54.93
5.	1993 - 1994	46.10	49.55

Source : Economic Review - 96
Government of Kerala, Thiruvananthapuram.

In the case of white pepper, India is at present only a minor player where as major players are Indonesia, Malaysia, Brazil, and Thailand. The white pepper production in India for the last two or three years has been centering around only 50 tonnes annually while the world production has been a whopping 30,000 - 40,000 tonnes, in the corresponding period. From these data, it is quite obvious that, India is lagging far behind other pepper producing countries in white pepper output, not withstanding the fact that India accounts for more than half of the world area cultivating pepper and a production of over 1/3rd of the total world production of pepper.

There is 50 - 75 per cent price advantage in white pepper over black pepper as observed in the last three months, source market in Brazil, Indonesia, Thailand, and Malaysia. A 25 per cent price advantage on white pepper is adequate to justify its production. Comparative prices of black pepper and white pepper in the international market from 1989 to '93 are given in Table 1.2.

The price advantages of 98.45 and 69.62 that were observed in the year 1993 in Germany and America respectively, clearly indicate that, farmers and manufacturers could make an additional income by resorting to white pepper production. There was also a time (1990 - '91) when white pepper price dropped compared to that of black pepper. This was unusual and the reason for this is not exactly known. However, the trend thereafter has been a higher unit value for white pepper.

Table 1.2

Comparative prices of black pepper and white pepper in the International market

Year/ Month	GERMANY			U.S.A.		
	White pepper	Black pepper	Increase over black pepper (%)	White pepper	Black pepper	Increase overblack pepper(%)
1989	48.43	48.23	Negligible	52.45	49.97	4.96
1990	31.00	37.17	-16.60	34.71	37.74	-8.03
1991	32.02	42.41	-24.40	35.24	36.14	-2.49
1992	38.97	36.00	8.25	43.29	34.57	20.10
1993	63.63	34.96	98.45	67.10	39.56	69.62

Source : Spices Board Publication, Kochi

Despite the price advantage that the white pepper enjoys, the farmers are reluctant to resort to white pepper production. This is due to the absence of a convenient and easy method for preparing white pepper. The existing methods for white pepper production are microbial fermentation, steaming, and mechanical decortication. Among these, method widely adopted for producing white pepper employs retting of ripe red or green berries. This method is time consuming and the fermentation that takes place is found to deteriorate the quality of the produce.

It requires a running water facility or a water tank and involves huge labour. The steaming method requires an additional facility for steam generation which is costly and the cooking that happens during the process, affects the quality of the product. The advantages of mechanical decorticators are that it does not require additional facilities like running water, water tank, etc. and large volumes of material can be processed in a short time. Despite all these advantages, the mechanical decortication has not become popular, due to the absence of suitable machines.

In the light of above facts, it was proposed to develop a low-cost black pepper skinner for the production of white pepper. This will help in a long way to perform the operations in a quicker and better way and ensure quality of the produce, thereby increasing the income of pepper growers. The study was undertaken with the following objectives.

1. To develop an equipment for removing the outer skin of ripe pepper berries.
2. To evaluate its performance.
3. To evaluate the economy of operation.

Review of Literature

REVIEW OF LITERATURE

A brief review of the past studies on pepper products, structure and composition, standards of white pepper by some countries, processes of white pepper production, major production centres are given below. The experimental trials that had been done in India are also included.

2.1 ORIGIN AND AGRONOMIC ASPECTS

As indicated in the Handbook of Agriculture (1980), pepper (Piper nigrum Linn) is one of the most important and earliest known spice crops of India. It is a perennial climbing vine belonging to the family Piperaceae and is indigenous to the west coast of Southern India. Pepper is propagated, best from cuttings of runner shoots which originate from the base of the vines. Cuttings from lateral fruiting branches can also be used for planting.

The stem and branches bear alternate, shiny, dark-green leaves. Hanging spikes or catkins which originate from the nodes, bear the sessile, small, and white flowers without perianth. Mature spikes vary from 5 - 30 cm in length, and support 30 - 150 flowers. Flowers develop into fruits upon fertilization and aided by light showers received during the flowering period from May to June. The fruit is a small, sessile, indehiscent berry, dark green when immature, which turns yellowish and finally red as it ripens. It takes nearly 6-8 months from flowering to harvesting. Harvesting is done by plucking the spikes. The spikes are spread on the floor or on mats and the berries are seperated by trampling.

2.2 RIPE PEPPER

According to Pruthi (1979) mature, ripe or unripe pepper berries are converted to black pepper, green pepper and white pepper.

2.2.1 Black Pepper

Black pepper is obtained by drying the mature, ripe or unripe berries in the sun for 4-7 days until the outer skin become black and shrink. U.S. standards for black pepper are given in Table 2.1.

Table 2.1

U.S. Standards of black pepper and white pepper

Components	In Black pepper(%)	In White pepper(%)
Ash (Maximum)	7.00	3.50
Acid insoluble	1.50	0.30
Crude fibre	15.00	5.00
Non volatile ether	6.75	7.00
Starch	30.00	52.00
Foreign matter	2.00	2.00

2.2.2 Green Pepper

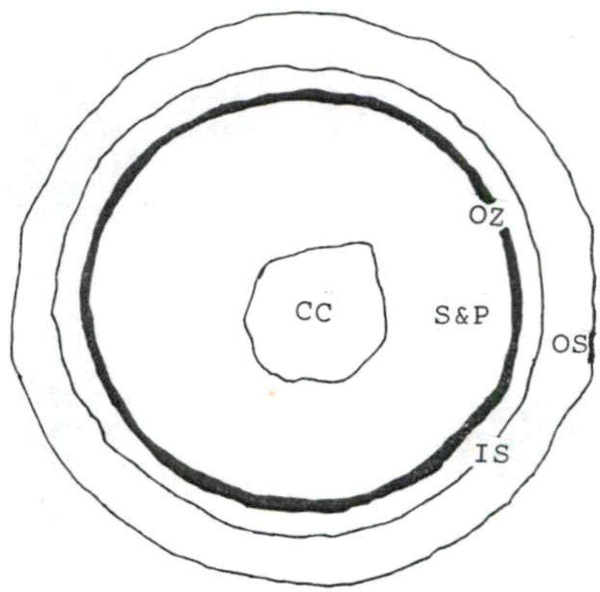
Green pepper is obtained when the tender green berries are dehydrated, with the characteristic green colour preserved. Lewis et al. (1976) briefly describe a process for the preparation of dehydrated green pepper in which the enzyme for normal browning reaction are first deactivated by blanching and sulpher dioxide treatment and then the berries are dehydrated.

2.2.3 White Pepper

White pepper is prepared by removing the outer mesocarp (skin) of harvested ripe red or green berries, either before or after drying by water-retting technique, steaming or water boiling technique, and decortication technique. U.S. standards for white pepper are given in Table 2.1.

2.2.4 Structure and Composition

The cross-sectional view of the ripe red which is given by Lewis et al. (1969) is shown (Fig. 2.1.). In the figure OS shows the outer skin (mesocarp) which has to be removed while converting to white pepper. IS is the silver skin that gives attractive appearance to the core. Brown surface beneath the silver skin is called oil zone (OZ). Starch and piperine form the core with a central cavity (CC).



OS - Outer skin
IS - Inner silver skin
OZ - Oil zone
S&P - Starch and piperine
CC - Central cavity

Fig 2.1 Cross sectional view of a ripe pepper berry

2.2.4.1 Comparison between black pepper and white pepper

The composition of white pepper as compared with black pepper given by Lewis et al. (1969) is shown (Table 2.2). The significant difference between black and white pepper is in the content of starch and fibre. Because of its origin from ripe pepper, white pepper contains more starch. Since fibrous skin is removed it contains less fibre. They also pointed out that the common belief that white pepper is mild in flavour compared to black pepper is not substantiated by their experiments.

Table 2.2

Composition of black pepper and white pepper

Components	Black pepper %	White pepper %
Volatile oil	2.00	2.20
Non volatile oil	7.67	8.09
Starch	48.20	59.20
Crude fibre	12.20	5.20

2.2.4.2 Comparison between different varieties of white pepper

Results of the analysis of different trade varieties of white pepper by Krishna Murthy et al. (1969) are given in Table 2.3. They found that Indian white pepper samples have more volatile oil content. Some differences in composition due to geographic origin were also observed.

Table 2.3

Analysis of white pepper varieties

Variety	Volatile Oil (%)	Non-volatile ether extract (%)	Piperine in Non-volatile ether extract (%)	Piperine in pepper (%)
Indian	2.51	7.60	60.70	4.61
Sarawak (Malaysia)	1.95	8.72	54.00	4.71
Brazil	1.96	8.68	50.00	4.34
Muntok (Indonesia)	2.03	8.47	57.00	4.83

2.3 PRODUCTION CENTRES

2.3.1 Muntok White Pepper from Indonesia

The Island of Banka, which lies off the south-east coast of Sumatra, is a major source of white peper for USA. It is shipped from the port of Muntok; hence the name. It has a characteristic aroma and relatively mild flavour.

2.3.2 Brazilian White Pepper

A portion of the Brazilian pepper berries are left on the vine to mature and then turned into white pepper. The Brazilian ground white pepper is lighter in colour and less pungent than the Muntok white pepper.

2.3.3 Sarawak White Pepper from Malaysia

Major portion of the Sarawak crop is reserved for preparing white pepper . They produce small quantities of black pepper also. Most of their produce is exported to Europe and British Common Wealth Countries.

2.4 WHITE PEPPER PRODUCTION PROCESSES

Guenther,E (1952) lists the following conventional processes for making white pepper.

2.4.1 By the Retting of Pepper

At present, major portion of global white pepper production is by this method. The pepper spike is allowed to ripe on the vine. This is then harvested and threshed. The ripe fruits so obtained are soaked in water for a few days. Due to retting, evidently by micro-organisms, the outer skin becomes very soft and can be easily rubbed off. This is achieved by treading in mass and then washing in running water. The core or white pepper is then kept in the sun to dry.

2.4.2 Mechanical Decortication

In large estates in East Asia white pepper is prepared by decorticating the fully ripe barries and the dried black pepper in specially designed machines. Though it is mentioned in many books about mechanical decorticators, details about their construction and operation are not given. Krishna Murthy et al. (1969) report that some manufacturers in USA are using milling and brushing techniques.

2.4.3 Steaming or Water Boiling Technique

Softening of green pepper is achieved by blanching in steam or in boiling water. The loosened skin is then removed by passing it through a fruit pulping machine. The product so obtained is then sun dried to yield white pepper.

2.5 EXPERIMENTAL TRIALS IN INDIA

As stated in the introduction, white pepper is never made in India on a large scale for commercial purpose. However, a sizable market seems to have been built up within India and neighbouring Nepal in recent years for white pepper. This demand is addressed by preparing white pepper by the retting of ripe pepper berries. After the removal of the mucilage either by fruit pulping machine or hand treading, the cores are treated with a bleaching agent before drying. The product has a disagreeable smell and bleached appearance.

2.5.1 Retting of Ripe Pepper

In India, growers are used to harvesting pepper at the green stage, when the berries are still unripe. This is best suited for making conventional black pepper. Besides, they have the following valid objections in leaving the pepper on the vine till it ripens. As all the spikes in the vine do not ripe at the same time, selective harvesting has to be done which makes the harvesting more costly. Also if one waits till, the berries become red, many fruits would drop off at a mere touch and harvesting would become a problem. There is also a traditional feeling among our farmers that if berries are allowed to ripen on the vine, it may seriously affect the life of the vine.

Krishna Murthy et al. (1969) have done research work on retting of ripe berries in a water tank. They have observed vigorous fermentation commencing within twenty four hours. In forty hours the skin was sufficiently soft to be easily rubbed off. The ordours developed were pleasant and the organisms involved were predominantly yeasts. The material was passed through a fruit pulping machine to remove skin, and the cores were dried. A light brown coloured product was obtained. The cores were firm, full and striated. Treatment with a small amount of sulphur dioxide or chlorine before drying gave an attractive white product.

2.5.2 Retting of Green Pepper

For reasons stated before, it seems unlikely that ripe pepper will ever be used as raw material for white pepper production. So, many Research Centres in India have made attempts to use mature green pepper for this purpose. The Pepper Research Station at Thaliparamba, Kerala has tried this by putting the green pepper in jute bags and keeping in running water for several days. Twelve to fourteen days were found required for softening the skin. Bad smell developed due to the growth of putrifactive organisms. The skin was rubbed off manually and cores dried. A satisfactory product was obtained, although somewhat unpleasant in smell.

Natarajan et al. (1969) have tried fruit pulping machine to remove the skin from soaked green pepper. Drying the core in the sun gave a light brown product, closely resembling the trade varieties (Muntok and Sarawak).

2.5.3 Steaming of Green Pepper

Softening of the skin of green pepper can be achieved in a short time (ten to fifteen minutes) by blanching in steam or boiling water. Though the process required an extra facility to generate steam, very large quantities of material can be processed in a short time. Also, since the material is green, the small quantities of oil present in the skin could be recovered as a by-product. The product obtained during skinning and drying looked just as satisfactory as the one obtained by retting. In addition it has a very nice aroma. However, due to heat treatment, gelatinisation occurred, and consequently the core developed a brown appearance. This affected the colour of the ground product.

2.5.4 Retting of Black Pepper

Green pepper is only a seasonal commodity and its collection at reasonable price for processing would be difficult to organize. Also the harvest is quickly dried to avoid spoilage due to fungal growth. So, if there is a tilt in market towards white pepper, traders are interested in converting dried black pepper into white pepper. Nampoothiri et al. (1969) carried out trial on retting the black pepper in the same time with mature ripe berries and green pepper. They found that the retting took a very long time and maggots entered and spoiled the material. So the material was kept under water in closed containers with one narrow opening plugged with cotton wool. No unpleasant odour was developed. The material was passed through pulping machine and cores thoroughly washed in running water. But the direct drying of the product was found to give a dark brown product. A treatment with a bleaching agent was absolutely necessary to get a white product.

2.5.5 Decorticating

In USA, some traders used milling technique to remove the skin of black pepper. Lewis et al. (1969) tried barley peeling machine, grain polisher, etc, without much success. The dried black pepper got crushed in the process of decortication. The product obtained were dark in colour and less attractive in appearance.

From the literature surveyed it was seen that only a few studies were reported on mechanical decortication of ripe red or green pepper berries. Besides, all the studies showed that the success with such machines were limited. Hence, an attempt was made to develop a black pepper skinner for removing the outer skin of fully ripe red or green pepper berries to obtain white pepper.

Materials and Methods

MATERIALS AND METHODS

Details of the methods adopted in the determination of various properties of ripe pepper relevant to decortication, the development of black pepper skinner, and the experimental design are discussed in this chapter.

3.1 PROPERTIES OF RIPE PEPPER

The properties such as shape, size, weight, moisture content, bulk density, true density, volume, specific gravity, coefficients of sliding and rolling friction were determined for ripe berries of the Karimunda variety. Based on the past studies reported in the literature appropriate methods for the determination of each property was selected. Freshly harvested and threshed pepper berries from the farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur, was used for the experiments.

3.1.1 Shape and Size

The mature ripe berries were spread over a clean surface and roughly divided into a number of sectors. From each sector, berries were randomly selected. The shape of selected pepper grain was observed. Similarly size of pepper berries were determined using a dial caliper with least count of 0.05 mm. Measurements along three perpendicular axes viz; major, intermediate, and minor, were determined.

3.1.2 Sphericity

Sphericity is expressed by the formula:

$$\text{Sphericity} = \frac{\text{Volume of solid}}{\text{Volume of smallest circumscribing sphere}} \quad \ldots(3.1)$$

$$= \frac{\text{Geometric mean diameter}}{\text{major diameter}} \quad \ldots(3.2)$$

$$= \frac{(abc)^{1/3}}{a} \quad \ldots(3.3)$$

where, a = largest intercept

b = largest intercept normal to a

c = largest intercept normal to a and b

3.1.3 Weight

Weight of mature berries was determined using a common balance. Different groups of ten numbers of berries were selected randomly and weighed separately using a common balance. The average weight of a single berry was then determined.

3.1.4 Volume

Mature ripe berries of pepper were filled in a jar of 25 cm^3 volume. Number of pepper berries (N) used to fill a volume of 25 cm^3 was noted. The air trapped in pore spaces was replaced by water and the water required to fill the jar (V_w) was measured. The process was repeated for different groups of samples. The average volume of mature pepper berries were determined as described below. As the duration of experiments was very short, the moisture content of pepper beries was found to be not varying. The volume was determined as follows:

$$\text{Average volume of pepper berry} = \frac{25 - V_w}{N} \text{ cm}^3 \qquad \ldots.(3.4)$$

3.1.5 True Density

Pepper berries were filled in a jar of 25 cm^3 volume. The air trapped in the pore spaces was replaced by pouring water into the jar. The volume of water needed to fill the jar was found out(V_w). By keeping the duration of experiments short, absorption of moisture by berries was reduced to negligible limits. The procedure was repeated for different groups of samples and true density was calculated by the formula,

$$\text{True density of pepper berries} = \frac{W_c}{V_c} \text{ gm/cm}^3 \qquad \ldots(3.5)$$

where, W_c = weight of pepper sample

V_c = volume of pepper berries in the jar

$= 25 - V_w$

3.1.6 Bulk Density

Pepper berries were filled in a jar of volume 25 cm^3. The weight of pepper used to fill the vessel was determined. The bulk density was then calculated using the formula,

$$\text{Bulk density} = \frac{W_a}{V_v} \text{ gm/cm}^3 \qquad \ldots(3.6)$$

where, W_a = weight of pepper used to fill the vessel (gms)

V_v = volume of vessel (cm^3)

3.1.7 Moisture Content (d.b.)

Moisture content of the mature pepper berries was determined by the oven drying method. The weight of pepper berries was measured using a common balance and it was kept in the ovan for 24 hours under 378 K. Then the dry weight was measured and moisture content was determined using the formula,

$$\text{moisture contente(d.b.)} = \frac{\text{wet wt. of berries-dry wt. of berries}}{\text{dry wt. of berries}} \times 100 \qquad \ldots(3.7)$$

3.1.8 Specific gravity

The weight of pepper berries in air was determined. It was then submerged in a bottle containing water. Weight of displaced water was then measured. As earlier, the duration of experiment was short. Specific gravity was calculated using the formula,

$$\text{specific gravity} = \frac{\text{wt. in air}}{\text{wt. of displaced water}} \qquad \ldots(3.8)$$

3.1.9 Coefficient of Sliding Friction and Rolling Friction

Coefficient of sliding friction and rolling friction of pepper berries were determined on the surfaces of coir-mat and rubber surface. A tilting surface was used for the purpose. The pepper berries were placed on the surface and the surface was tilted gradually. The angle at which the pepper started sliding and rolling down were noted. The tangent of the mean of the angles observed were taken as the coefficients.

3.2 DEVELOPMENT OF BLACK PEPPER SKINNER

The underlying principle of the machine was to subject the berries to compression and shear. As the compressive forces crush the skin, the shear forces separated the crushed skin from the core. Based on preliminary studies a cylinder and concave type black pepper skinner was developed and its performance was evaluated. The principal parts comprising the black pepper skinner were;

1. Two cylinder-concave assemblies
2. A feed roll
3. A hopper
4. A separator assembly
5. Main frame.

3.2.1 Cylinder and Concave Assembly

It consists of two cylinders and matching concaves as shown in Fig. 3.1. The top cylinder and concave mechanism formed, the main functional part of the machine.

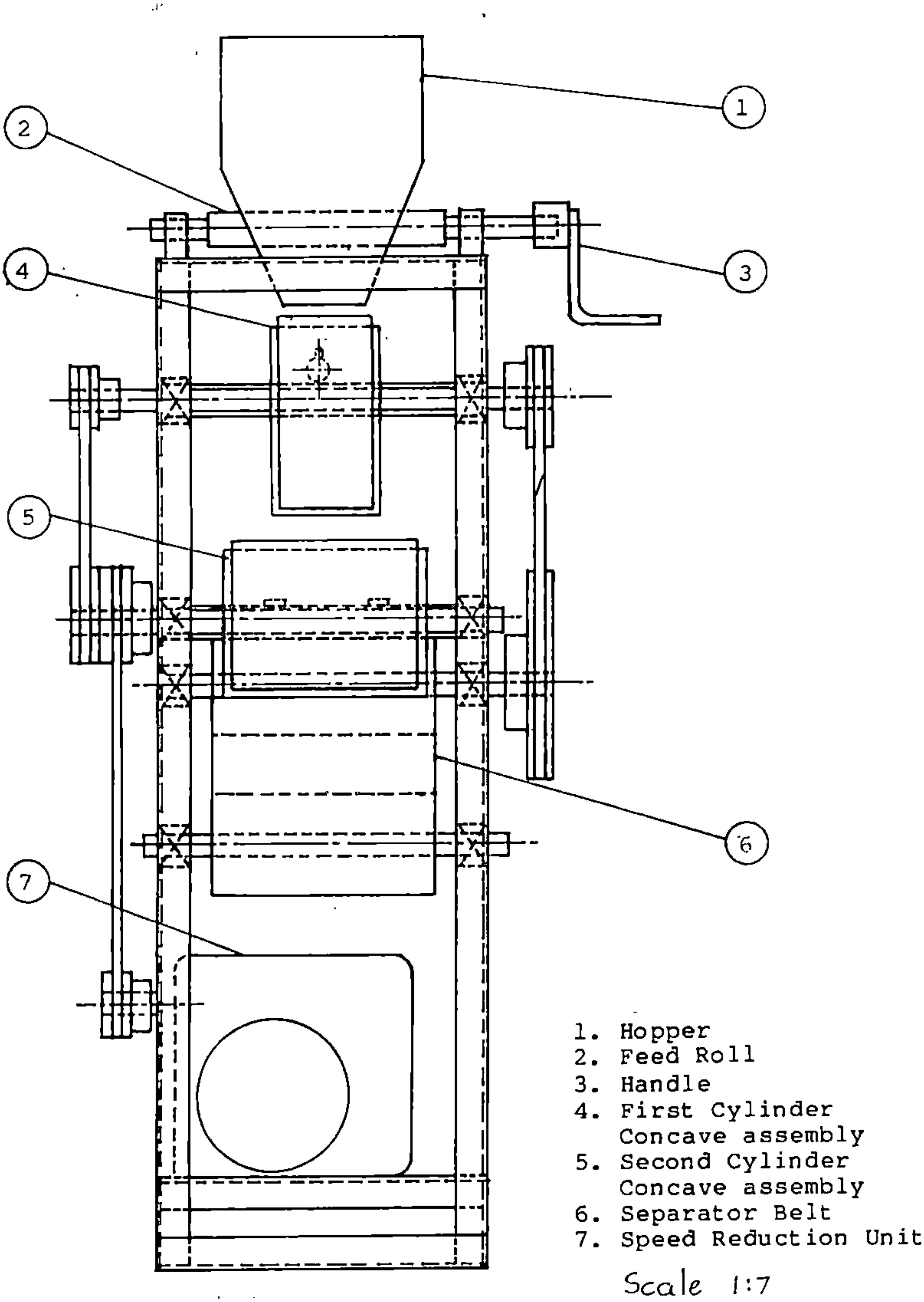
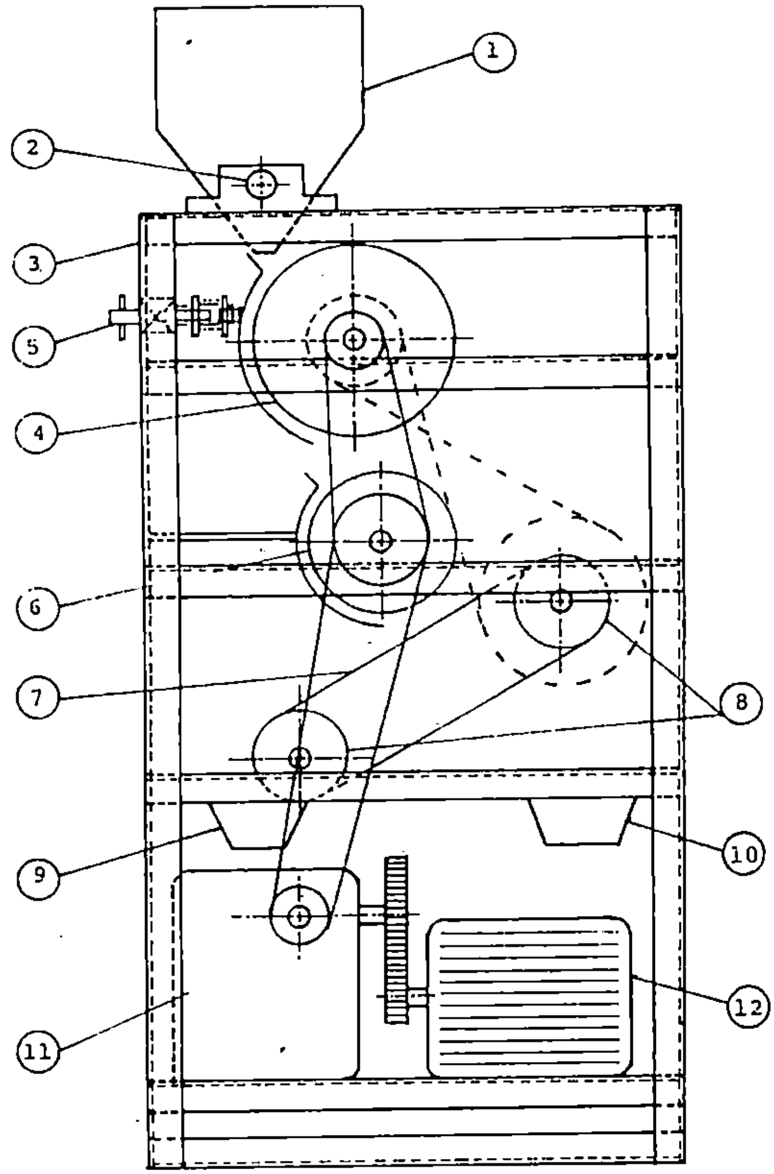


Fig 3.1 Front view of the black pepper skinner



1. Hopper
2. Feed roll
3. Main frame
4. First cylinder-concave assembly
5. Clearance adjusting mechanism
6. Second cylinder-concave assembly
7. Separator belt
8. Separator rollers
9. White pepper outlet
10. Skin outlet
11. Speed reduction unit
12. Electric motor

Scale 1:8

Fig 3.2 Side view of the black pepper skinner

Plate 3.1 Front view of the black pepper skinner

Plate 3.2 Side view of the black pepper skinner

The concave was spring loaded so that the clearance between cylinder and concave could be automatically adjusted.

The diameter of the first cylinder was 27 cm and the operational width was 10 cm. The diameter of the second roller was 11 cm and its width was 20 cm. Both the cylinders were provided with matching concaves which covered nearly 3/8th of surface area of the corresponding cylinders. The hollow cylinders were made out of mild steel. The concaves were made from 22 gauge mild steel sheets.

Discharge from the first cyclinder-concave assembly was lead into the second set. The latter had a lesser clearance than the former and ensured further cleaninq. The cylinders were connected to shafts of diameter 2.5 cm and length 40 cm. The shafts were placed in ball bearings. Pulleys were attached to the shafts for enabling transmission of drive.

3.2.2 Feed Roll

The feed roll was made of wood. The middle 12 cm length of the feed roll was provided with holes of diameter 8 mm and depth 6 mm. The feed roll could be rotated by means of a handle provided at one end of it. The feed roll was placed at the bottom of the hopper and fastened to the main frame by means of wooden blocks. Different feed rates were obtained by sealing off alternate holes by means of cello tape.

3.2.3 Hopper

A hopper of 3 kg capacity was provided at the top so that pepper could be fed easily. The hopper was made of 22 gauge GI sheet.

3.2.4 Separator Assembly

The separation unit separated the different fractions in the output from the second cylinder and concave assembly. These fractions consisted of skin, the core, the partially crushed berries, and the whole berries. Using an inclined belt separator this was separated. The separator assembly consisted of an endless belt, running in an inclined direction over two rollers. The diameter of both rollers was 9 cm. The spherical or nearly spherical fractions such as cores and the wholes, rolled down the belt surface and non-spherical particles such as the skin and partially damaged berries were carried along with the belt up the inclination and discharged over the upper end. The direction of rotation of upper portion of belt drive, i.e., the tight side, was up slope.

3.2.5 Main Frame

The hopper, feed roll, cylinder-concave assemblies, and separator assemblies were mounted on a main frame of size 110 x 60 x 35 cm. Provisions for mounting power source with reduction gear system was also provided. Angle iron of size 35 x 35 x 3 mm was used for fabricating the main frame.

3.2.6 Power Source

A three phase, 0.5 hp variable speed dynodrive motor was used as the prime mover. The speed could be changed between the range 300-1400 rpm by using a variable dyno-drive electronic mechanism. The motor was geared to a reduction gear mechanism which reduced the speed in the ratio 40:1. Hence, the desired speed of 10-25 rpm was obtained at the first cylinder.

3.3 POWER TRANSMISSION SYSTEM

Power was transmitted for the rotation of the two cylinders and driver pulley of the separator unit (Fig 3.2). Using a gear ratio of 4:1, drive from variable speed motor was transmitted to a speed reduction gear box, which had a gear reduction ratio of 10:1. The power from speed reduction gear box was transmitted to the second cylinder with the help of a belt drive having pulleys of diameter 10 cm and 6.25 cm. This enabled a speed reduction of 1.6:1. The shaft of first cylinder-concave assembly was operated by taking the power from the second cylinder shaft. Two pulleys of diameter 10 cm and 6.25 cm were used and a belt drive of speed ratio 1.6:1 were used in this. The driver shaft of the separation unit was driven by the first cylinder shaft by a cross-belt of speed ratio of 2.25:1. The pulleys on the cylinder shafts and counter shafts were of the diameter 10 cm and 22.5 cm respectively.

The speed reductions that were achieved between the motor and principal components of the machine are given below:

1. Between the motor and second cyclinder = 64 : 1
2. Between the motor and first cyclinder = 40 : 1
3. Between the motor and separator unit = 144 : 1

3.4 EXPERIMENTAL DESIGN

A Completely Randomised Design (CRD) was selected for the study. The factors were feed rate, drum speed and surface type with the following levels.

Variable	Levels of treatment			
Feed rate (kg/h)		8	12	16
Speed of drum (rpm)	10	15	20	25
Cylinder-concave surface type	coir mat, rubber sheet			

Accordingly, the total number of treatments were 3 x 4 x 2 = 24 and with three replications the total number of experiments become 72.

3.4.1 Selection of Various Parameter Levels

From preliminary studies, it was found that materials like coir-mat and rubber sheet pasted on the cylinder and the concave helped in skinning pepper to satisfactory levels. Hence, these two surfaces were selected for the studies. Preliminary studies also revealed that a feed rate of 12 kg/h was capable of ensuring reasonably good results in skinning. Hence this was selected as the median level and two other levels, each on either side were also selected. Similarly from initial trials, it was found that rotational speed of 15 and 20 rpm gave acceptable performance in terms of skinning. Therefore, in addition to these, 10 rpm and 25 rpm were also included among the levels.

3.5 EXPERIMENTAL PROCEDURE

A measured quantity of ripe pepper was fed between the first cylinder-concave assembly at the prescribed feed rates. The clearance between the cylinder and concave was so adjusted that the mesocarp was rubbed off from the cores. Care was taken to see that berries were not crushed. The speed of drum was selected according to the treatment by adjusting the knob of the thyristor unit. The decorticated and undecorticated berries were separated, and individually weighed and recorded.

The mean for each treatment was taken for determining the decorticating efficiency, effectiveness of wholeness of kernels and overall decorticating efficiency. These were determined as follows.

3.5.1. Decorticating Efficiency (ηd)

Decorticating Efficiency is defined as the ratio of weight undecorticated berries to that of total whole berries fed to the system.

It was calculated by the following equation,

$$\eta_d = \frac{W_0 - W_1}{W_0} \times 100 \qquad \ldots(3.9)$$

where, W_0 = Weight of berries before decortication

W_1 = Weight of undecorticated berries after decortication

3.5.2. Effectiveness of Wholeness of Kernels

The effectiveness of wholeness of kernels, (Ewk) is defined as the proportion of whole kernels extracted to the total quantity of kernels (whole kernels + crushed berries) fed to the system.

It was determined by the following equation

$$Ewk = \frac{K_2 - K_1}{(K_2 - K_1) + (d_2 - d_1)} \qquad \ldots(3.10)$$

where,

K_2 = content of whole kernels after decortication

K_1 = content of whole kernels before decortication

d_2 = content of crushed kernels after decortication

d_1 = content of crushed kernels before decortication

In this, the values of K_1 and d_1 are normally zero or negligible as there are no or very little whole kernels or crushed kernels before decortication.

3.5.3. Overall Decorticating Efficiency

Overall decorticating efficiency (η_{od}) is defined as the product of the decorticating efficiency and the effectiveness of wholeness of kernels. The overall performance of the machine is expressed by this which takes into account both qualitative and quantitative aspects of operations carried out.

$$\eta_{od} = \eta_d \times E_{wk} \qquad \dots (3.11)$$

where η_d = decorticating efficiency,

E_{wk} = effectiveness of wholeness of kernels.

3.6 ENERGY REQUIREMENTS

The energy requirements for loaded and no-load conditions were determined using an energy meter. A three phase energy meter was connected in series with the motor. The energy consumed by running the unit without load and with load were noted and recorded. The energy meter specifications are given in the Appendix F.

3.7 ECONOMIC ANALYSIS

The operating cost of the machine was calculated. Operating cost includes 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 the rate of Rs. 100/- per day. The cost of electric power was at the rate of Re 1.00 / kWh. Ten per cent of the initial investment per annum was utilised for repair and maintenance.

Results and Discussion

RESULTS AND DISCUSSION

This chapter deals with the results of experiments on the properties of black pepper relevant to decortication, and the performance of the newly developed black pepper skinner.

4.1 PHYSICAL PROPERTIES OF RIPE BLACK PEPPER

The properties such as shape, size, weight, volume, moisture content, true density, bulk density, coefficient of sliding friction and rolling friction were determined and are presented and discussed as follows.

4.1.1 Shape and Size

Based on visual observation it was found that 97 per cent of the berries were nearly spherical and the remaining were non-spherical. Dimensions of the berries along the three axes are given in Table 4.1. Dimensions of fully matured berries along its major axis and minor axis range 5.75 to 6.55 and 5.15 to 6.3 mm respectively. Clearance between the concave and the cylinder were adjusted based on these measurements.

4.1.2 Sphericity

The sphericity of fully matured ripe pepper berries was found to vary from 99 to 97 per cent with a mean value of 98 per cent (Table 4.1). It showed that the most of the berries were almost spherical. This was advantageous in the

Table 4.1

Sphericity and dimensions of ripe pepper berries

Sl. No.	Largest intercept (a) (mm)	Largest intercept normal to a (b) (mm)	Largest intercept normal to a+b(c) (mm)	Sphericity $\frac{(abc)^{1/3}}{a}$ (%)
1.	5.75	5.70	5.40	98
2.	5.80	5.75	5.40	97
3.	6.05	6.15	5.80	99
4.	6.55	6.45	6.45	99
5.	5.45	5.15	5.20	97
6.	5.80	5.80	5.60	99
7.	5.90	5.80	5.60	98
8.	6.20	5.85	5.85	97
9.	6.50	6.45	6.30	98
10.	5.50	5.55	5.30	99
11.	6.05	5.85	5.75	99
12.	6.25	5.95	5.85	96
			Mean	98
			S.D.	0.96

flow of the material till crushing occured.

4.1.3 Weight

Average weight of a single fully ripe pepper berry was found to be 0.115 g with the values ranging from 0.107 g to 0.115 g (Table 4.2). The higher moisture content laden in the mesocarp of fresh berry was responsible for the heaviness of the berries. In the skinning operations it was this mesocarp which was removed.

4.1.4 Volume

Average volume of a ripe pepper berry was found to be 0.0894 cm^3 with value ranging from 0.0873 cm^3 to 0.0909 cm^3 (Table 4.3). As the berries were nearly spherical, increase in volume was associated with increase in diameter. This affected skinning and damage because the material was subjected to compressive stress while it was in the clearance in the cylinder-concave assembly.

4.1.5 True density

From Table 4.4. the mean true density of fully ripe pepper was found to be 1.088 g/cm^3. The true density was in the range between 1.05 to 1.189 g/cm^3.

4.1.6 Bulk Density

The mean bulk density of fully ripe pepper berries was found to be 0.56 g/cm^3. The bulk density ranged from 0.54 to 0.6 g/cm^3 (Table 4.5)

Table 4.2

Average weight of ripe pepper berry

Sl.No.	Weight of 10 Nos.grain (g)		Average weight (g)
1.	1.152		0.1152
2.	1.152		0.1152
3.	1.150		0.115
4.	1.110		0.111
5.	1.07		0.107
6.	1.12		0.112
		Mean	0.113
		S.D.	0.003

Table 4.3

Volume of pepper berries

Replication	1	2	3	4
Volume of jar (cm^3)	25	25	25	25
Volume of water in the jar (cm^3)	15	15	15	15
Number of pepper grains in the jar	110	112	115	118
Volume of grains in the jar (20-Vw)	10	10	10	10
Average volume of a single pepper grain	0.0909	0.09	0.0813	0.0813
Mean				0.0894
S.D.				0.005

Tble 4.4

True density of pepper berries

Sl. No.	Weight of pepper grains (g)	Volume of pepper grains (cm^3)	True density (g/cm^3)
1.	23.9	20.10	1.189
2.	23.4	21.00	1.114
3.	22.8	24.00	0.95
4.	24.2	22.00	1.1
		Mean	1.088
		S.D.	0.087

Table 4.5

Bulk density of pepper berries

Sl. No.	Weight of pepper grains (g)	Total Volume (cm^3	Bulk density (g/cm^3)
1.	14.89	25	0.5956
2.	13.80	25	0.552
3.	14.50	25	0.58
4.	13.40	25	0.536
		Mean	0.5659
		S.D.	0.023

4.1.7 Moisture Content (d.b.)

The moisture content of fully ripe pepper berries was found to have a mean value of 60.75 per cent with values ranging from 59.2 to 62.4 per cent (Table 4.6). It was seen that only 25 per cent by weight of the berries was removed while skinning. Therefore, the actual loss of solid matter was only about 10 per cent since bulk of the weight of skin was moisture.

4.1.8 Specific Gravity

The specific gravity of fully ripe pepper berries was found varying from 1.11 to 1.17 with a mean value of 1.14 (Table 4.7). Therefore, it is heavier than water. It was seen that berries sunk to the bottom in water.

4.1.9 Coefficient of Rolling Friction and Sliding Friction

Coefficient of sliding friction and rolling friction was found to be 0.29 and 0.41 respectively for the coir mat. For the rubber surface corresponding values were 0.187 and 0.21 respectively(Table 4.8). Therefore, the movement of material on the rubber surface was easier than that on the coir mat for both rolling and sliding.

4.2 PERFORMANCE EVALUATION OF THE BLACK PEPPER SKINNER

Performance of the newly developed black pepper skinner is evaluated and the results are discussed below. The machine was tested using separately the coir-mat and the

Table 4.6

Moisture content of pepper berries

Sl. No.	Weight of wet grains (g)	Weight of grains after over drying (g)	Moisture content (%)
1.	15.6	6.98	59.2
2.	18.2	7.04	61.3
3.	15.6	5.86	62.4
4.	12.4	4.95	60.1
		Mean	60.1
		S.D.	

Table 4.7

Specific gravity of ripe pepper berries

Sl. No.	Weight of pepper berries in air (g)	Weight of container + water (g)	Weight of container + water + pepper (g)	Weight of displaced water (g)	Specific gravity
1.	10.85	71.35	80.59	9.24	1.17
2.	9.85	71.35	79.92	8.57	1.15
3.	12.80	71.35	82.58	11.23	1.11
4.	14.1	71.35	83.83	12.48	1.13
				Mean	1.14
				S.D.	0.022

Table 4.8

Co-efficient of sliding friction and rolling friction for the rubber surface and coir-mat

Sample No.	Rubber surface		Coir-mat surface	
	Sliding angle (°)	Rolling angle (°)	Sliding angle (°)	Rolling angle (°)
1	11.8	12.4	15.4	16.8
2	9.5	11.4	15.2	20.5
3	8.6	11.5	13.2	17.8
4	11.2	13.3	18.1	22.8
5	10.1	11.3	17.1	23.1
6	12.9	10.4	14.8	19.8
7	9.4	11.4	16.0	18.7
8	11.0	12.1	18.2	20.4
Mean	10.615	11.71	16.15	22.46
S.D.	1.25	0.77		
Coefficient	0.187	0.21	0.29	0.41

rubber sheet pasted on the concave and the cylinder.

Effect of drum speed, feed rate, and surface type on decorticating efficiency, effectiveness of wholeness of cores, and overall decorticating efficiency were determined for different machine set-ups (Table 4.9). By conducting a 3-factor Factorial Experiment in Completely Randomized Design (CRD), the effect of the three parameters, feed rate, drum speed and surface type were analysed. Results of the experiments (Appendix A and B) are presented as follows.

4.2.1 Effect of Various Parameters on Decorticating Efficiency

From the Analysis of Variance (ANOVA), it is evident that all the three parameters has significant influence on decorticating efficiency since the computed F-value for each variable is in the critical region at 5% significance level (Appendix-C). Among the three parameters, drum speed shows maximum influence, since the F-value (145.4) is greater than that observed for the feed rate (19.1581), and surface type (3.87). It is also observed that the joint effect of drum speed and surface type have significant influence on decorticating efficiency, since the F-value (4.08) lies in the critical region at 5% significance level.

4.2.1.1 Feed rate

Tables 4.10 and 4.11 show that maximum decorticating efficiencies of 91.4 for coir-mat, and 94.99

Table 4.9

Experimental set-up of the machine while testing with coir-mat and rubber sheet

Set-up No.	Feed rate (kg/h)	Speed of cylinder (rpm)
1	8	10
2	8	15
3	8	20
4	8	25
5	12	10
6	12	15
7	12	20
8	12	25
9	16	10
10	16	15
11	16	20
12	16	25

for rubber surface are observed at the feed rate of 12 kg/h. The maximum decorticating efficiencies observed at the feed rate of 8 kg/h are 85.5 and 89.01 for coir-mat and rubber surface respectively and that observed at the feed rate of 10 kg/h are 89.92 and 92.34 respectively. Figures 4.1 and 4.2 show that as the feed rate increases from 8 to 16 kg/h, the decorticating efficiency shows an increasing trend upto 12 kg/h and a reverse trend thereafter. It is observed that at the feed rate of 16 kg/h, when more pepper berries come in contact with the cylinder-concave assembly, the berries which are slighly smaller in size are found simply rolling down without being decorticated which results in the low decorticating efficiency. The irregularities and asperities on the coir-mat also result in low decorticating efficiency. From the experiments it is observed that the optimum feed rate is 12 kg/h.

4.2.1.2. Drum speed

From, Tables 4.10 and 4.11 it is observed that maximum decorticating efficiency of 91.54 for coir-mat and 94.19 for rubber surface are observed for the higher speed selected, that is 25 rpm. Figures 4.1. and 4.2 reveal that the decorticating efficiency shows an increasing trend as the speed of drum is increased from 10 rpm to 25 rpm. The increase in drum speed results in corresponding increase in pheripheral velocity of the drum. So the shearing and compressive forces acting on the pepper corns in the clearance increase which lead to more efficient

Table 4.10

Decorticating efficiency observed at various machine set-ups for coir-mat

rpm	Feed rate * (kg/h)		
	8	12	16
10	73.67	78.30	79.03
15	84.02	85.01	82.14
20	84.44	89.81	91.62
25	85.5	91.54	89.92

* Mean of three replications

Table 4.11

Decorticating efficiency observed at various machine set-ups for rubber surface

rpm	Feed rate * (kg/h)		
	8	12	16
10	74.86	77.32	74.66
15	82.97	83.34	84.64
20	87.38	92.93	92.68
25	89.93	94.19	92.74

* Mean of three replications

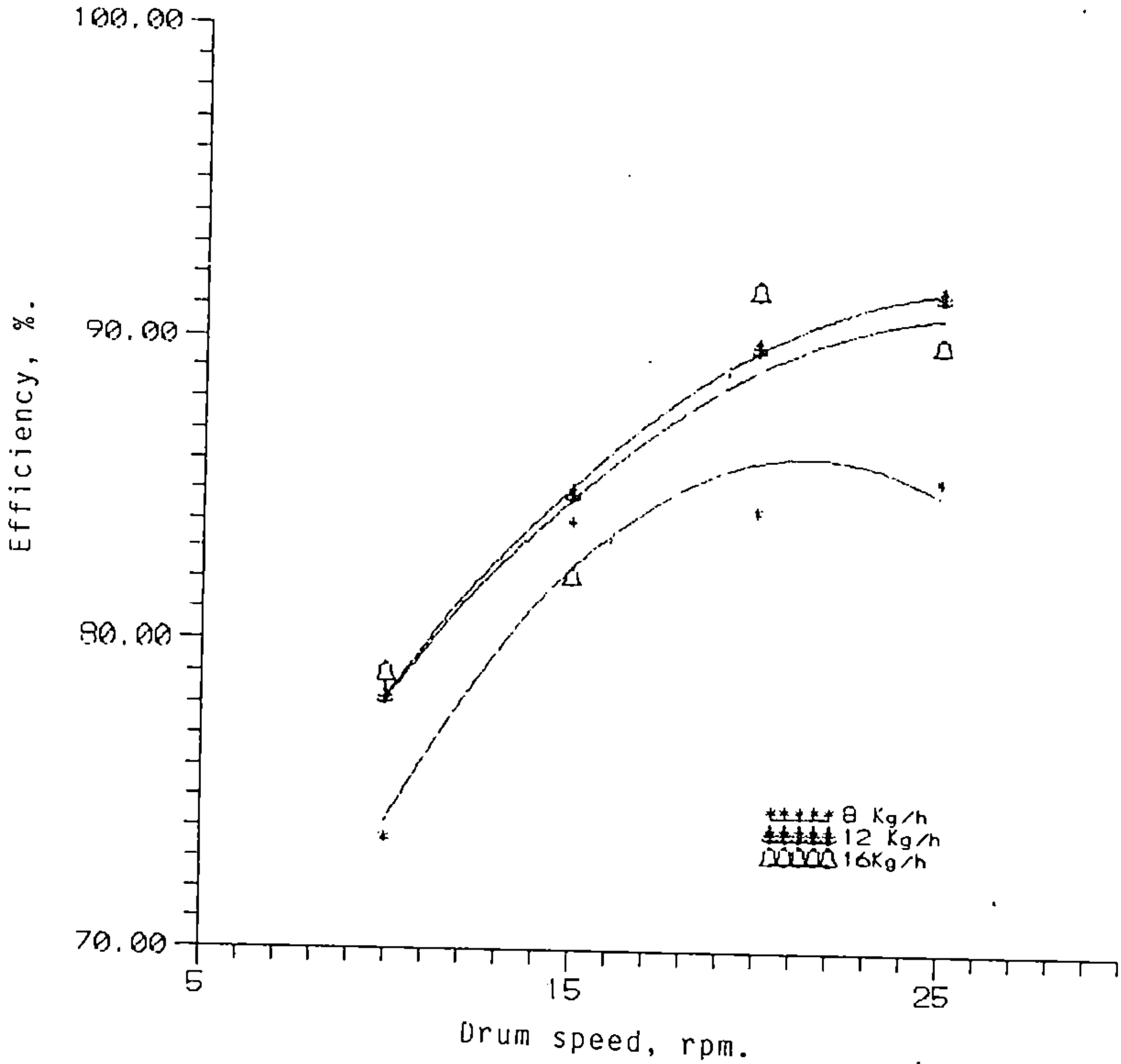


Fig. 4.1. Decorticating efficiency Vs speed of drum for coir-mat at different feed rates.

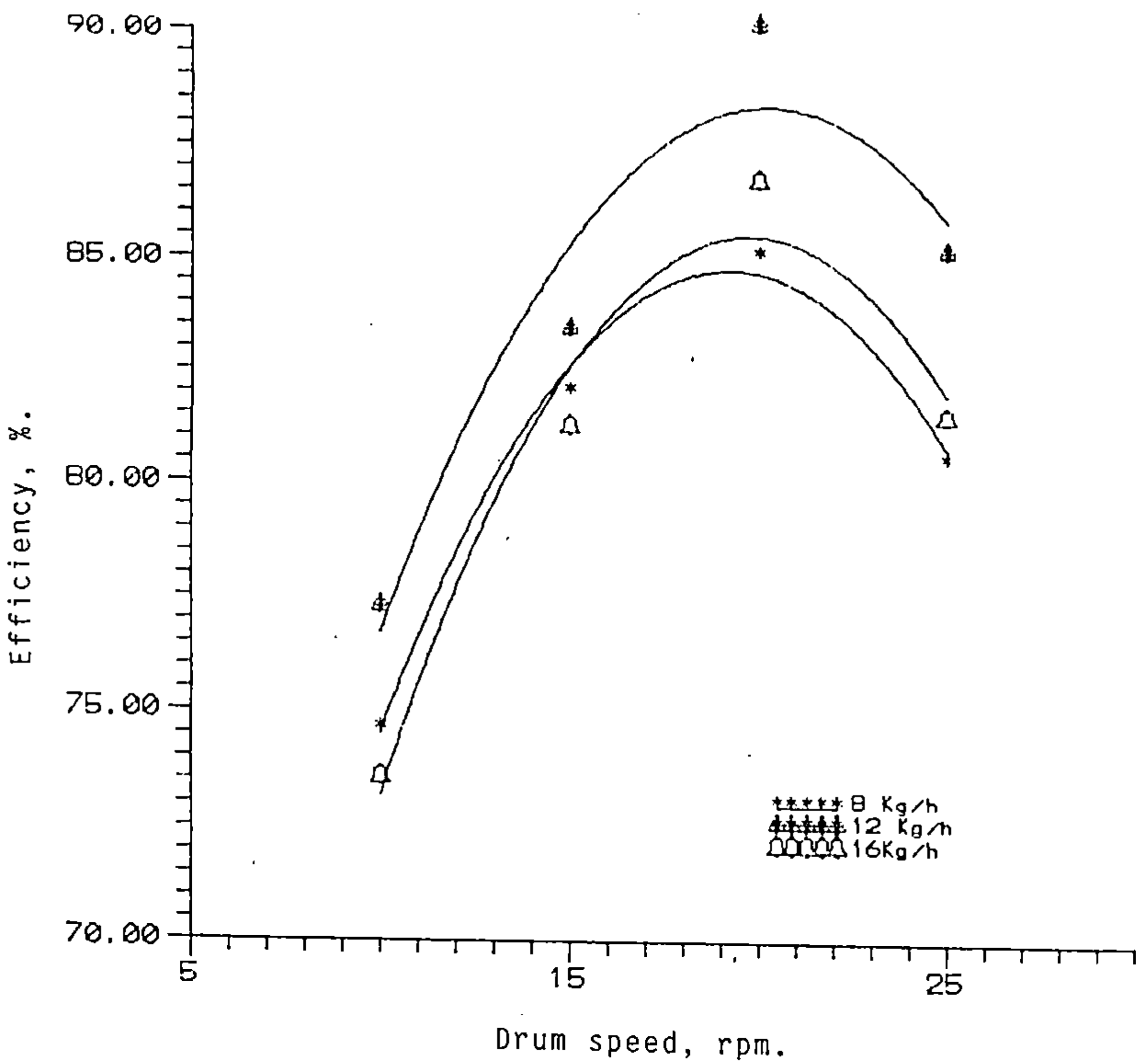


Fig. 4.4. Overall decorticating efficiency Vs speed of drum for rubber mat at different feed rates.

decortication.

4.2.1.3. Surface type

Tables 4.10 and 4.11 reveal that for the various machine set-ups more decorticating efficiencies are observed for the rubber surface. The maximum decorticating efficiency of 94.19 is observed for the rubber surface type and for the machine set-up with feed rate, 12 kg/h, and drum speed, 25 rpm. The same observed for coir-mat surface type was 91.54 for the machine set-up with feed rate 12 kg/h and drum speed 25 rpm. The coir-mat has more asperities and irregularities on its surface than on the rubber surface. It was observed at the time of experiment that some berries were found sticking to these irregularities and asperities over the coir-mat resulting in partial or no-decortication. So it is concluded that the rubber surface gives better decorticating performance.

4.2.2 Effect of Various Parameters on Effectiveness of Wholeness of Kernels

From the Analysis of Variance, it is observed that all the three parameters, viz. speed of drum, feed rate, and surface type, exert significant influence on the effectiveness of wholeness of kernels (Appendix-C). The effect of drum speed is more pronounced with an F-value of 69.21 followed by feed rate with 17.25 and surface type with 8.34. The combined effect of different combinations of parameters is found to have no significant influence on the effectiveness of wholeness of kernels since the corresponding F-value falls in the acceptance region at 5% significance level.

4.2.2.1 Feed rate

As observed from the Tables 4.12 and 4.13 the effectiveness of wholeness of kernals at lower feed rates is found to be unity or near unity. This shows that there is no crushing of berries at low feed rates. As the feed rate is increased, the value of the effectiveness of wholeness of kernels begins to show a downward trend from unity and going upto 0.85. This downward trend from unity is due to the crushing of berries occuring in the cylinder-concave assembly.

4.2.2.2 Drum speed

Tables 4.12 and 4.13 show that at lower speeds of 10 rpm and 15 rpm the effectiveness of wholeness of kernels observed are unity or near unity. As the speed increases to 20 rpm and 25 rpm, the same observed are less than unity going upto 0.85. At higher speeds, due to increase in compressive and shearing forces, crushing of berries occurred which resulted in lower values for effectiveness of wholeness of kernels.

4.2.2.3. Surface type

On a comparison of values presented in Table 4.12 and 4.13, no significant differences are reported for

Table 4.12

Effectiveness of wholeness of kernels at various machine set-ups for coir-mat

	Feed rate *		
rpm	8	12	16
10	1	0.99	0.98
15	0.98	0.99	0.98
20	0.98	0.96	0.91
25	0.95	0.90	0.89

* Mean of three replications

Table 4.13

Effectiveness of wholeness of kernels at various machine set-ups for rubber surface

	Feed rate * (kg/h)		
rpm	8	12	16
10	1	1	0.99
15	0.99	0.99	0.96
20	0.97	0.97	0.94
25	0.91	0.90	0.87

* Mean of three replications

effectiveness of wholeness of kernels, no significant differences are seen between coir-mat and rubber sheet.

4.2.3 Effects of various parameters on the overall decorticating efficiency

From the Analysis of Variance, it is inferred that the parameters, feed rate and drum speed, have significant influence on the overall decorticating efficiency since the corresponding F-values 9.02 and 50.06 fall in the critical region at 5% significance level. The parameter, surface type, is found to have no significant influence, since the F-value 1.59 lies in the acceptable region at 5% significance level. The combined effect of various combinations of parameters are also found to have no significant influence since the corresponding F-values fall in the acceptance region at 5% significance level.

4.2.3.1 Feed rate

The overall decorticating efficiency is found to vary from 66.00 to 90.22 as shown in Tables 4.14 and 4.15 for the machine set-ups with feed rates 8,12 and 16 kg/h. The values are shown in the Appendices- A and B. The maximum value of overall decorticating efficiency is observed at the feed rate, 12 kg/h, which is 86.71 for coir-mat and 90.22 for rubber surface. Values of the same at the feed rates of 8 kg/h are lower than those observed at 12 kg/h due to the lower values of decorticating efficiency because of reasons explained earlier. At the feed rate of

Table 4.14

Overall decorticating efficiency observed at different levels of feed rate and speed for coir-mat.

	Feed rate * (kg/h)		
rpm	8	12	16
10	72.35	78.04	77.44
15	82.92	83.88	81.35
20	82.42	86.71	83.74
25	81.22	83.29	79.73

* Mean of three replications

Table 4.15

Overalldecorticating efficiency observed at different levels of feed rate and speed for rubber surface

	Feed rate* (kg/h)		
rpm	8	12	16
10	74.67	77.32	13.59
15	82.12	83.47	81.28
20	85.19	90.22	86.79
25	80.60	85.25	81.54

* Mean of three replications

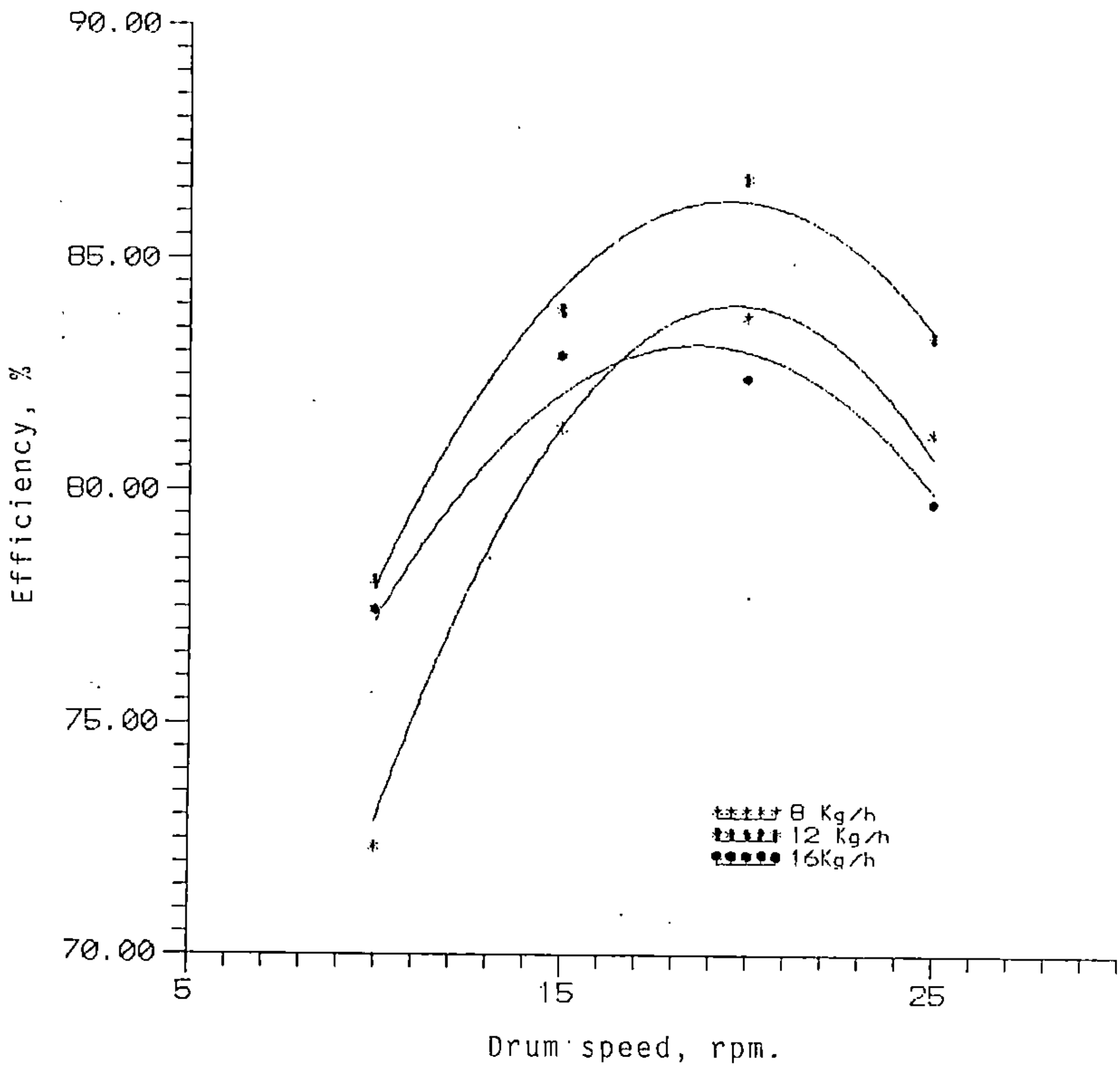


Fig. 4.3. Overall decorticating efficiency Vs speed of drum for coir-mat at different feed rates.

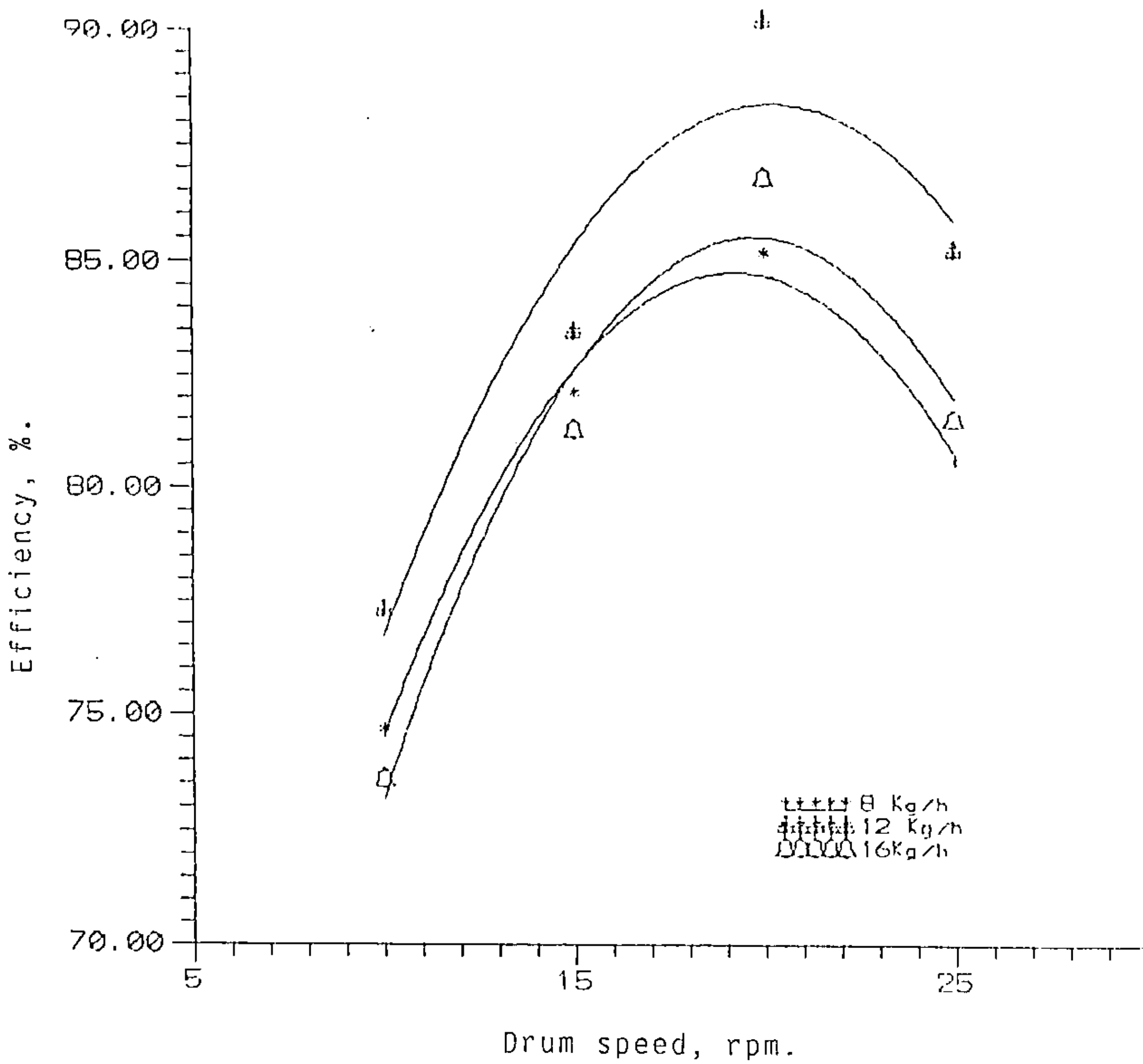


Fig. 4.4. Overall decorticating efficiency Vs speed of drum for rubber mat at different feed rates.

16 kg/h the lower values of overall decorticating efficiencies are due to the lower values obtained for both the decorticating efficiency and the effectiveness of wholeness of kernels. Therefore, the optimum feed rate identified for obtaining maximum overall decorticating efficiency is 12 kg/h.

4.2.3.2 Drum speed

As the Tables 4.14 and 4.15 reveal, the overall decorticating efficiency is found to vary from 66.0 to 90.2 for various machine set-ups. The maximum value of overall decorticating efficiency is observed at the drum speed of 20 rpm which is 86.11 for coir-mat and 90.22 for rubber surface. Figures 4.3 and 4.4 show that as the speed increases from 10 rpm to 25 rpm, the overall decorticating efficiency also shows an increasing trend. It reaches a maximum value at the drum speed of 20 rpm and thereafter the trend is reversed. At the drum speed of 25 rpm, the lower values of effectiveness of wholeness of kernels observed are due to crushing of cores; consequently the overall efficiency becomes lower than that observed at 20 rpm. At lower speeds overall decorticating efficiencies observed are lower due to the lower decorticating efficiencies recorded at the corresponding speeds. Therefore, the optimum speed of drum identified for obtained maximum overall decorticating efficiency is 20 rpm.

4.2.3.3 Surface type

As depicted in Tables 4.14 and 4.15 the maximum overall decorticating efficiency observed for coir-mat and rubber surface are 86.71 and 90.22 respectively. An analysis of the above Tables reveals that comparatively higher values for overall decorticating efficiency are observed for rubber surface type under various machine set-ups. The reason might be that the rubber sheet has a more even surface than the coir-mat whose surface has irregularities and asperities. Hence, the rubber surface is found to give comparatively higher overall decorticating efficiency.

4.3. ENERGY REQUIREMENT

The energy required for operating the machine at different speeds under loaded and no-load conditions vary from 0.089 to 0.19 kWh (Tables 4.15 and 4.16). Energy required for operating the machine under load ranged from 0.125 to 0.255 kWh for machine speeds in the range of 10 to 25 rpm. It is also observed that the energy consumption corresponding to maximum decorticating efficiency is 0.255 kWh and that observed for maximum overall decorticating efficiency is 0.205 kWh.

A regression curve was plotted between speed and energy requirement (Fig 4.5). An equation of the form $Y = mx + C$ was derived. The derived equation is,

Table 4.16

Energy requirements at no-load conditions

Output rpm of motor	Energy consumed (kWh)		
	1	2	mean
400	0.087	0.095	0.092
600	0.098	0.099	0.095
800	0.15	0.145	0.1475
1000	0.185	0.19	0.1875

Table 4.17

Energy requirements at load conditions

Output rpm of motor	Speed of machine	Energy consumed (kWh)		
		1	2	Mean
400	10	0.125	0.131	0.128
600	15	0.135	0.138	0.1365
800	20	0.205	0.205	0.205
1000	25	0.252	0.255	0.233

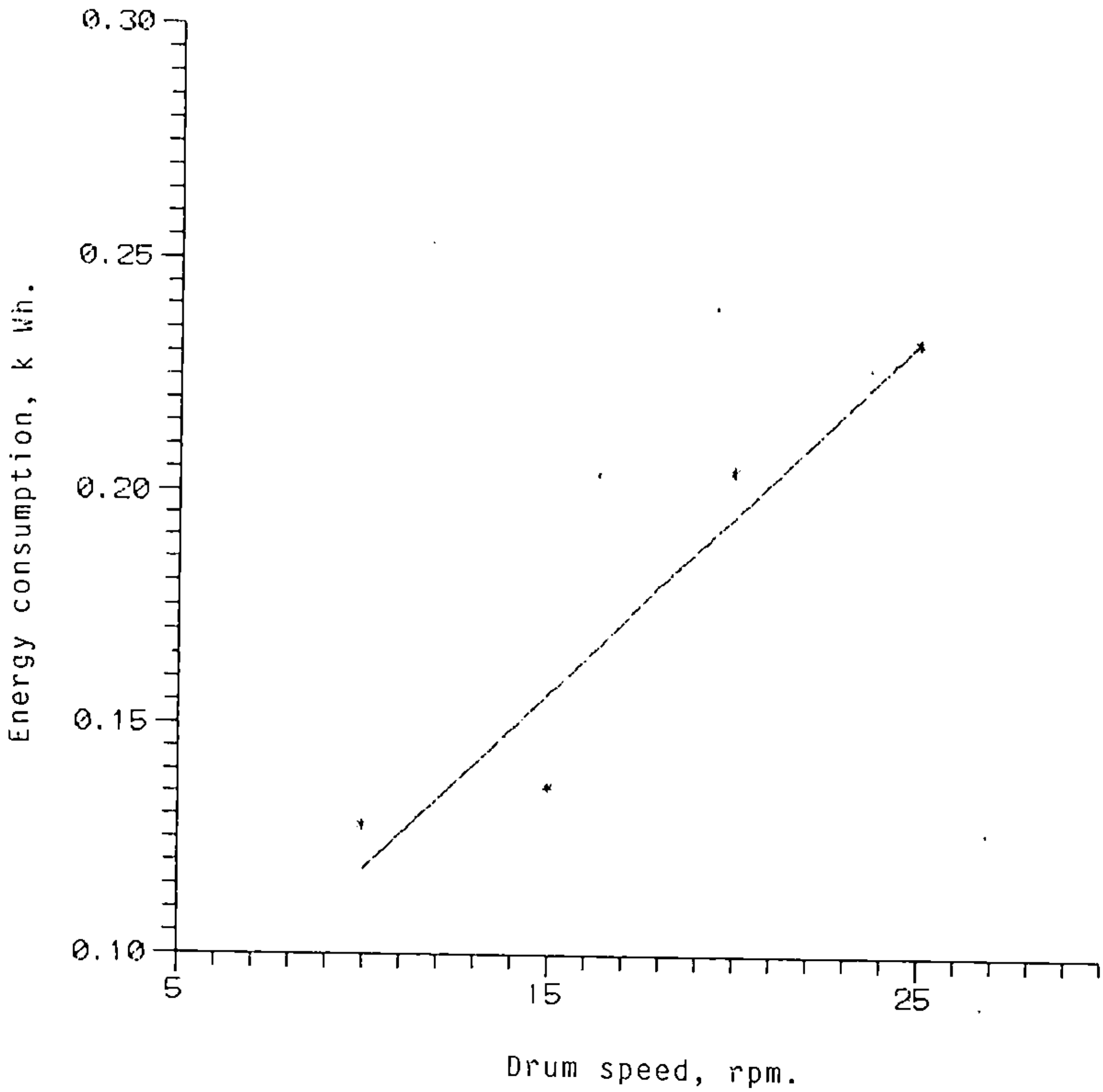


Fig. 4.5. Energy consumption Vs drum speed.

$$Y = 0.0077X + 0.04$$

Where, Y = energy requirement, kWh

X = speed, rpm.

4.4. ECONOMIC ANALYSIS

The calculation of operating cost of the machine is described in Appendix - D. The fabrication cost of the machine including the cost of motor and speed reduction unit combined, is taken as Rs.9500/-. Depreciatiion, other fixed costs, and operating costs are calculated separately. The operating cost is obtained as Rs.14.18/h. Hence the cost for decorticating 1 kg of ripe pepper berries is Rs.2.1, at the prevailing rates. This is almost insignificant compared to the price advantage of Rs.80-100/kg, in favour of white pepper over black pepper.

4.5. COMPARISON BETWEEN WHITE PEPPER MADE BY MECHANICAL DECORTICATION AND TRADITIONAL METHOD

Plates 1-3 depict white pepper samples prepared by the three methods of traditional retting, decorticationg using coir-mat and decortication using rubber surface respectively. from these Plates it is evident that traditionally made white pepper has an attractive appearance than the other two. The cream coloured outer skin of white pepper which has the characteristic striations has been fractured due to mechanical decortication. Consequently the brownish oil zone and inner starch layer got exposed. This gave a slight brownish appearance to the product.

The results of test conducted to determine the content of volatile oil, oleoresin and piperine are presented in Table 4.18. The tradionally made white pepper was found to have more of volatile oil and oleoresin at 2.8% and 8.3% respectively. These values for coir-mat and rubber sheet were 2.7 and 7.6, 2.2 and 7.2 respectively. The loss of some quantity of these contents were due to the fracture and removal of the creamy outer layer and the oil zone during decortication.

The piperine content of traditionally made white pepper and that made by using coir-mat is found to be the same at 1.9 per cent. The peperine content of white pepper made by using rubber surface is 1.6 per cent which is slightly lower that that observed for traditionally made white pepper. Piperine is present in the inner core of the berries. So the loss of peperine content might be due to the damage caused to bigger sized berries.

It is observed that for both surfaces of the coir-mat and the rubber surface, the maximum overall decorticating efficiencies are obtained at a feed rate of 12 kg/hr and at a drum speed of 10 rpm. In the case of coimr-mat, the maximum overall decorticating efficiency observed is 86.11 and that observed for rubber surface is 90.22. Comparing both surfaces, better performance is provided by the rubber surface.

The appearance of white pepper prepared by black

Table 4.18

Analysis of white pepper samples for quality evaluation

Sample	Volatile oil % (v/w)	Oleoresin % (w/w)	Piperine %(w/w)
A	2.8	8.5	1.9
B	2.7	7.6	1.9
C	2.2	7.2	1.6

A - traditionally made white pepper

B - white pepper made by using coir-mat

C - white pepper made by using rubber surface

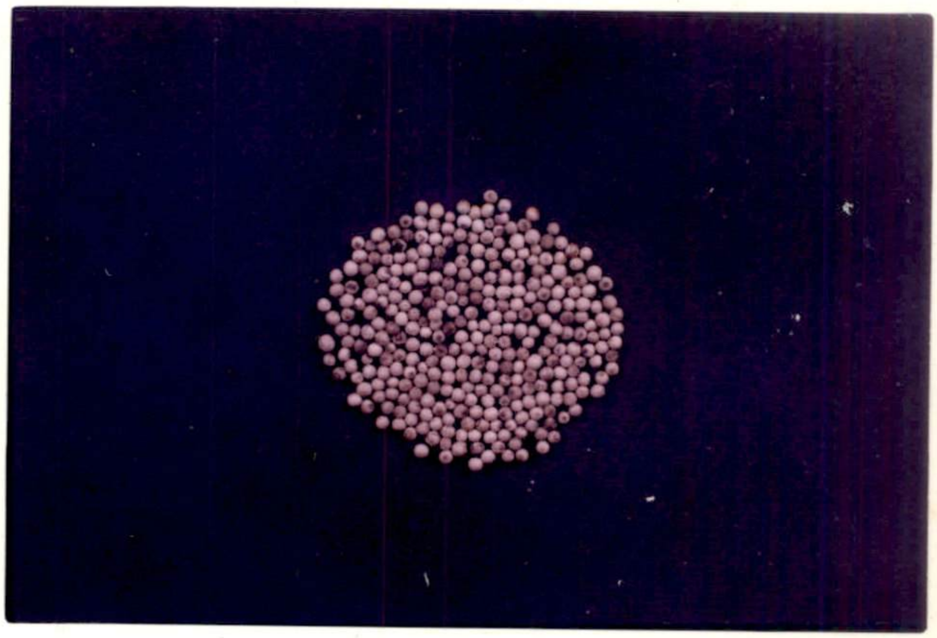


Plate 4.1 White pepper prepared by traditional method

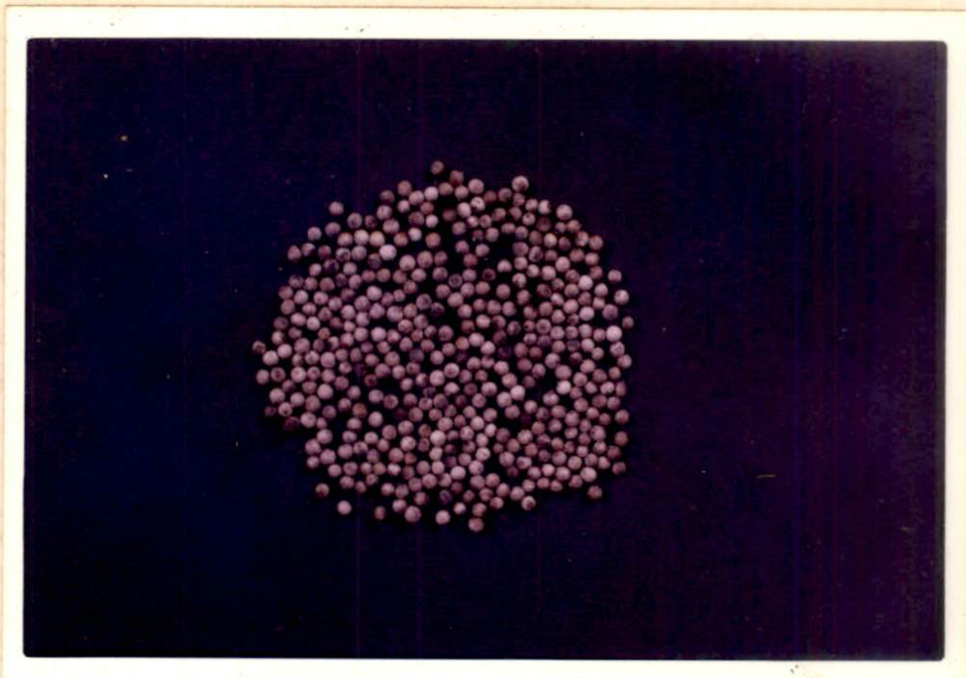


Plate 4.2 White pepper prepared by using coir-mat

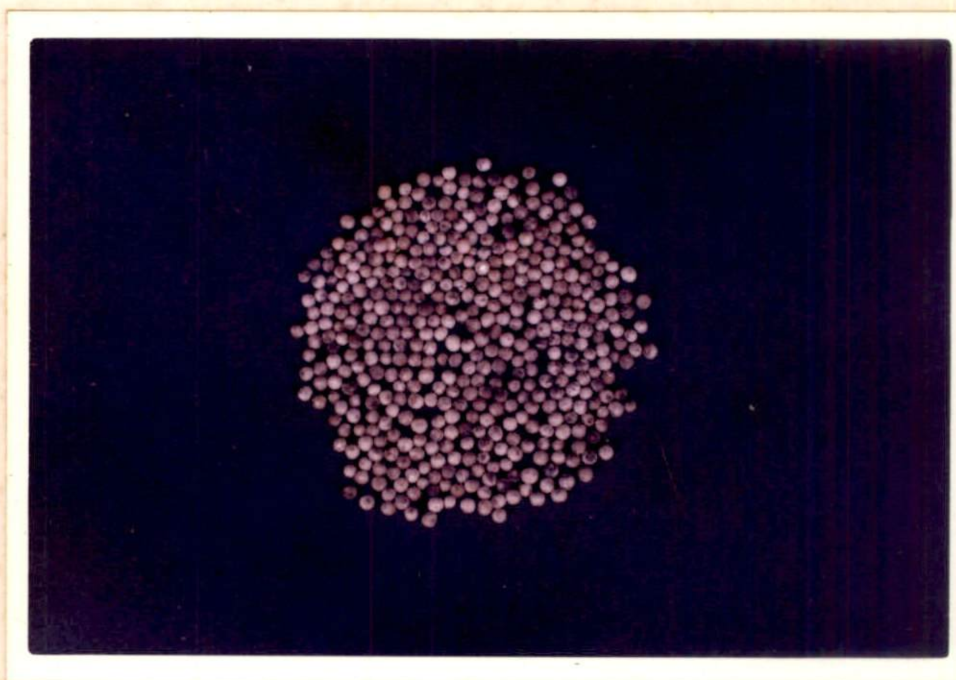


Plate 4.3 White pepper prepared by using rubber surface

pepper skinner developed in the study is slightly affected due to the damage caused to the outer skin. This gave a slightly brownish appearance to the product. Little losses in the case of volatile oil, oleoresin and piperin content were also observed for the white pepper prepared by this machine when compared with that made by traditional retting method. This may be due to the excessive abrasion caused to the surface of the kernels. It may be possible to reduce this damage by making use of better substitute material for both the cylinder and the concave.

Summary

SUMMARY

The creamy white dried inner corns, obtained by removing the outer skin of ripe pepper berries, are called white pepper. White pepper normally commands a premium over black pepper in the international market. It is preferred to black pepper, to make light coloured food preparations, sauces, and soups. White pepper is a value added foreign exchange earner. The present and most widely employed method of preparing white pepper in our country is by retting ripe pepper and kneading it with hand. This method is time consuming and needs extra facilities like running water, water tank, and involves huge amount of labour. The development of a low-cost pepper decorticator would enable the pepper growers and traders, to obtain this value added product in a quicker and better way. The present work was, therefore, undertaken with a view to develop a low-cost black pepper skinner.

Determination of the physical properties relevant to decortication of ripe pepper berries belonging to the specific Karimunda variety was undertaken as the first part of the present study in order to specify the samples more satisfactorily. Results of these are summarised below.

(i)	Sphericity	= 98%
(ii)	Mean weight (single berry)	= 0.113 g
(iii)	Mean volume (single berry)	= 0.087 cm^3

(iv) True density = 1.08 g/cm^3

(v) Bulk density = 0.57 g/cm^3

(vi) Moisture content (d.b.) = 60.75 %

(vii) Specific gravity = 1.14

(viii) Co-efficient of sliding friction

(a) on coir-mat = 0.29

(b) on rubber surface = 0.87

(ix) Co-efficient of rolling friction

(a) coir-mat = 0.41

(b) rubber surface = 0.21

Based on preliminary studies and trials, a black pepper skinner was developed and its performance evaluated in the present study. It comprises of two cylinder-concave assemblies, a hopper, a feed roll, a separator and a main frame.

The ripe pepper berries freshly collected from the vines were fed between the concave and the cylinder assembly. The decortication of ripe pepper berries took place between the cylinder and concave due to compressive and shearing forces. The fragments of mesocarp and the decorticated pepper were separated by an inclined and upward moving separator belt and collected in separate outlets.

The machine was tested for the two surfaces of coir-mat and rubber placed separately on the concave and the cylinder. A Completely Randomized Design (CRD) was selected for the study with three factors viz., feed rate, drum speed and surface type with following levels.

Variable	Level of treatment			
Feed rate (kg/h)	8	12	16	
Speed of drum (rpm)	10	15	20	25
Surface types	coir-mat, rubber sheet.			

For both the surfaces of coir-mat and rubber, the maximum overall efficiency was observed at the feed rate of 12 kg/h and drum speed of 20 rpm. The maximum overall decorticating efficiency observed for coir-mat was 86.71 and that for rubber surface was 90.22.

The maximum value obtained for the decorticating efficiency for coir-mat was 91.5 and that for rubber surface was 94.2. The maximum damage was found to occur at the drum speed of 25 rpm. Consequently the lowest value obtained for effectiveness of wholeness of kernels was 0.87. The energy requirement for obtaining maximum overall decorticating efficiency was found to be 0.205 kWh, whereas that observed for obtaining maximum decorticating efficiency was 0.233 kWh. The cost of operation for decorticating 1 kg of ripe pepper berries is found to be Rs.1.18.

An analysis carried out indicated that white pepper obtained by the newly developed machine suffered some losses with respect to volatile oil and oleoresin. Peperine content did not show any significant loss.

Based on the present study, it is felt that the performance of this machine can be improved further by incorporating the modifications suggested below.

1. Cover the surfaces coming in contact with the pepper in the actual decorting zone, i.e., cylinder-concave assembly - with better substitute materials.
2. Incorporate a size-classifier for grading the berries before being fed into cylinder-concave assembly.
3. Testing of the machine at higher speeds.
4. Incorporate a floating type concave to take care of size variation in berries.

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Appendices

APPENDIX - A

Table A.1

Weight of some fractions of the output, decorticating efficiency, effectiveness of wholeness of kernels and overall decorticating efficiency for the coir surface for different speeds (Feed rate = 8 kg/h, Quantity of feed = 200 g, Duration of Expt. = 90 s

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	78.00	68.20	0	66.59	1	66.59
10	102.03	40.38	0	79.81	1	79.81
10	93.85	50.74	0	74.63	1	74.63
				Mean=73.67	Mean= 1	Mean=73.68
15	126.27	42.48	5.26	82.04	0.96	78.76
15	127.73	27.96	0	86.02	1	86.02
15	120.63	32.06	0	83.99	1	83.99
				Mean=84.02	Mean= 0.98	Mean=82.29
20	115.58	28.23	5.58	85.90	0.95	81.68
20	115.81	24.59	3.10	87.03	0.98	85.29
20	120.45	39.28	0	80.40	1	80.40
				Mean=84.44	Mean= 0.98	Mean=82.42
25	125.68	31.98	8.22	84.01	0.94	78.96
25	126.57	29.04	8.35	85.98	0.97	82.91
25	124.87	27.32	7.60	87.00	0.94	81.78
				Mean=85.50	Mean=0.95	Mean=81.22

Table A.2

Feed rate = 12 kg/h, Quantity of feed = 20 g   Duration of experiment = 60 s

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	96.69	39.21	1.47	80.39	0.99	71.50
10	106.21	49.26	0	75.37	1	75.37
10	115.94	41.70	0	79.15	1	79.15
				Mean=78.30	Mean=0.99	Mean=78.04
15	119.27	29.45	2.78	85.27	0.98	83.56
15	115.86	32.76	2.05	83.62	0.98	81.95
15	118.18	27.72	0	86.14	1	86.14
				Mean=85.01	Mean=0.99	Mean=83.88
20	125.23	26.02	5.00	86.99	0.96	83.52
20	101.55	20.63	4.55	89.68	0.96	86.40
20	101.60	14.80	3.20	92.76	0.97	96.21
				Mean=91.81	Mean=0.96	Mean=89.38
25	109.84	17.68	8.48	91.16	0.92	83.88
25	98.56	15.40	10.52	92.30	0.90	83.01
25	112.04	12.20	10.68	91.17	0.91	83.29
				Mean=91.54	Mean=0.90	Mean=83.29

Table A.3

Feed rate = 16 kg/ha, Quantity of feed = 200 g, Duration of experiment = 45 S

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	110.43	43.62	0	78.19	1	78.19
10	168.28	39.50	1.91	80.41	0.98	78.80
10	124.05	43.03	2.65	78.48	0.96	75.34
				Mean=79.03	Mean=0.98	Mean=81.45
15	91.02	54.21	8.63	82.99	0.99	82.17
15	112.30	52.20	7.86	81.03	0.98	79.36
15	119.85	51.60	9.13	54.20	0.98	8.51
				Mean=82.14	Mean=0.98	Mean=83.74
20	119.48	20.25	9.50	89.87	0.92	82.68
20	127.20	18.90	8.95	90.55	0.93	84.20
20	124.38	14.68	7.85	92.66	0.91	84.32
				Mean=91.62	Mean=0.91	Mean=83.74
25	112.16	20.25	17.30	90.14	0.87	78.42
25	115.34	23.32	14.46	88.34	0.89	78.62
25	122.32	17.45	13.67	91.27	0.90	82.14
				Mean=89.92	Mean=0.89	Mean=79.73

APPENDIX - B

Table B.1

Weight of some fractions of the output, decorticating efficiency, effectiveness of wholeness of kernals and overall decorticating efficiency for rubber surface for different speeds
Feed rate = 8 kg/ha, Quantity of feed = 20 g, Duration of experiment = 90 s

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	109.90	50.26	0	74.86	1	74.86
10	108.36	54.18	0	72.11	1	72.11
10	112.30	47.90	0	76.01	1	76.01
				Mean=89.92	Mean=0.89	Mean=79.73
15	148.40	38.00	2.6	81.00	0.98	79.38
15	125.90	32.04	0	83.98	1	83.98
15	126.25	32.12	0	83.94	1	83.94
				Mean=82.97	Mean=0.99	Mean=82.12
20	120.88	29.32	4.98	85.33	0.96	81.92
20	121.40	23.54	9.27	88.23	0.98	86.24
20	126.86	20.45	2.98	89.77	0.98	88.20
				Mean=82.97	Mean=0.99	Mean=82.12
25	112.91	16.60	18.26	91.69	0.87	78.30
25	124.15	24.83	25.10	87.58	0.92	80.96
25	140.13	21.34	26.53	89.01	0.93	82.77
				Mean=89.43	Mean=0.91	Mean=80.60

Table B.2

Feed rate = 12 kg/ha, Quantity of feed = 200 g, Duration of experiment = 60 S

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	103.03	48.03	0	75.98	1	75.98
10	92.18	50.00	0	75.00	1	75.00
10	108.36	38.05	0	80.97	1	80.97
				Mean=77.32	Mean=1	Mean=77.52
15	139.85	31.96	0	84.01	1	82.99
15	135.86	34.02	0	82.99	1	82.99
15	113.56	27.57	3.90	86.01	0.97	83.42
				Mean=84.34	Mean=0.99	Mean=83.47
20	128.00	13.67	5.90	93.60	0.96	90.24
20	127.90	16.70	3.76	91.65	0.97	89.24
20	132.68	12.04	4.42	93.98	0.97	91.18
				Mean=92.43	Mean=0.97	Mean=90.22
25	119.78	13.96	11.85	93.02	0.90	83.70
25	120.78	8.05	9.35	95.57	0.93	89.28
25	127.27	12.02	15.70	93.99	0.88	87.27
				Mean=94.19	Mean=0.90	Mean=85.23

Table B.3

Feed rate = 16 kg/ha, Quantity of feed = 200 g, Duration of experiment = 45 s

Speed (rpm)	Weight of some fractions			Decorticating efficiency (%)	Effectiveness of wholeness of cores (%)	Overall decorticating efficiency (%)
	Whole core (g)	Undecorticaded berries (g)	Crushed berries(g)			
10	106.42	48.02	1.48	75.99	0.99	75.24
10	110.38	54.02	0	12.98	1.00	72.98
10	97.28	50.0	2.70	75.00	0.98	72.52
				Mean=74.66	Mean=0.99	Mean=73.57
15	112.26	30.00	3.74	84.00	0.97	81.48
15	113.22	25.96	4.82	87.01	0.96	83.52
15	112.25	34.19	6.13	82.90	0.95	78.55
				Mean=84.64	Mean=0.96	Mean=81.18
20	122.14	13.96	7.42	95.02	0.94	87.42
20	116.32	17.90	6.28	91.05	0.94	85.54
20	125.68	12.02	9.72	93.98	0.93	87.42
				Mean=92.68	Mean=0.94	Mean=86.79
25	109.85	11.95	19.10	94.02	0.86	82.72
25	118.44	14.02	12.70	92.18	0.90	83.70
25	116.78	15.95	16.64	92.02	0.85	78.20
				Mean=92.74	Mean=0.87	Mean=81.54

APPENDIX C

Results of 3-factor, Factorial experiment in Completely Randomized Design

Table C.1

ANALYSIS OF VARIANCE TABLE SHOWING EFFECT OF FEED RATE, DRUM SPEED AND SURFACE TYPE ON DECORTICATING EFFICIENCY

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
2	Factor A	2	209.793	104.897	19.1581	0.0000
4	Factor B	3	2388.397	796.132	145.4041	0.0000
6	AB	6	61.861	10.310	1.8830	0.1031
8	Factor C	1	21.201	21.201	3.8721	0.0549
10	AC	2	4.619	2.309	0.4218	
12	BC	3	67.050	22.350	4.0819	0.0116
14	ABC	6	27.530	4.588	0.8380	
-15	Error	48	262.815	5.475		
	Total	71	3043.264			

Factor A - Feed rate

Factor B - Drum speed

Factor C - Surface type

Table C.2

ANALYSIS OF VARIANCE TABLE SHOWING EFFECT OF FEED RATE, DRUM SPEED AND SURFACE TYPE ON EFFECTIVENESS OF WHOLENESS OF KERNELS

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
2	Factor A	2	0.017	0.009	17.2486	0.0000
4	Factor B	3	0.104	0.035	69.2192	0.0000
6	AB	6	0.025	0.004	8.3352	0.0000
8	Factor C	1	0.001	0.001	1.5912	0.2133
10	AC	2	0.001	0.000	0.9282	
12	BC	3	0.002	0.001	1.1565	0.3361
14	ABC	6	0.001	0.000	0.3831	
-15	Error	48	0.024	0.001		
	Total	71	0.176			

Factor A - Feed rate

Factor B - Drum speed

Factor C - Surface type

Table C.3

ANALYSIS OF VARIANCE TABLE SHOWING EFFECT OF FEED RATE, DRUM SPEED AND SURFACE TYPE ON OVERALL DECORTICATING EFFICIENCY

K value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Probability
2	Factor A	2	135.998	67.999	9.0214	0.0005
4	Factor B	3	1131.948	377.316	50.0583	0.0000
6	AB	6	50.007	8.335	1.1057	0.3730
8	Factor C	1	11.345	11.345	1.5051	0.2259
10	AC	2	14.580	7.900	0.9672	
12	BC	3	48.701	16.234	2.1537	0.1057
14	ABC	6	23.551	3.925	0.5207	
-15	Error	48	361.802	7.538		
	Total	71	1777.932			

Factor A - Feed rate

Factor B - Drum speed

Factor C - Surface type

APPENDIX - D

Calculation of operating costs

Initial cost (C)

Fabrication cost of black pepper skinner	= Rs 1500/-
Initial cost of motor and speed reduction unit	= Rs 8000/-
Average life of black pepper skinner	= 10 years
Average life of motor	= 20 years
Working hours/year (H)	= 1600
Salvage value (g)	
For motor	= Rs 800/-
For black pepper skinner	= Rs 150/-

a. **Fixed cost:**

1.. Depreciation

$$= \frac{C-S}{LxH}$$

$$= \frac{1500-150}{10x1600}$$

= Re 0.08/-

For motor

$$= \frac{8000-800}{20 \times 1600}$$

= Re 0.23/-

2. Interest on investment

$$= \frac{C+S}{2xH} \times \frac{15}{100}$$

For machine

$$= \frac{1500+150}{2x1600} \times \frac{15}{100}$$

= Re 0.08/-

For motor $= \dfrac{8000+800}{2 \times 1600} \times \dfrac{15}{100}$

= Re 0.41/-

Total fixed cost/h = 0.08 + 0.23 + 0.08 + 0.41

= Re 0.80/-

b. Variable cost:

Labour = Rs 100/day

= Rs 12.5/h

For two labours = Rs 25/h

Electricity charges = Re 1/kwh

= 0.20 x 1

= Re 0.20/-

c. Repairs and maintenance:

(10 per cent of initial cost per annum)

For skinning machine $= \dfrac{1500 \times 10 \times 1}{100 \times 1000}$

= Re 0.09/-

For motor $= \dfrac{800 \times 10 \times 1}{100 \times 1000}$

= Re 0.05/-

Total variable cost/h = 25 + 0.20 + 0.09 + 0.05

= Rs 24.34 / h.

Total operating cost/h = 24.34 + 0.80

= Rs 25.14 / h

Operating cost per kilogram considering the feed rate of 12 kg/h as optimum $= \dfrac{25.14}{12}$

$= \text{Rs } 2.10 \text{ / kg}$

APPENDIX E

Details of dynodrive variable speed motor

1. Dynodrive

Type	: OBOMN
Hz	: 50
Torque	: 0.26 kg m
Speed range	: 120 - 2000
Maximum existing current	: 1.7A
Exciting voltage	: 80
Weight	: 42 kg
Generator	: Tacho generator

2. Motor (Hindustan Brown Boveri) ·3 phase Induction Motor

kW	: 0.37
HP	: 0.50
CR	: 50c/s
rpm	: 1390

3. Rating and specification of electronic regulator

Power supply	: 200/220 v(± 10%)
Cycles	: 50 / 60
Output circuit	
Capacity (W)	: 200
Current (A)	: 2.5
Voltage (Vdc)	: 80
Connection of thyristor	: Single phase, halfwave rectifying connection with free wheel diode.

Speed setting input	: 12 vdc (adjustable within ± 20%) input current upto 0.5 m A
Speed setting power supply	: 13 v, 150 mA Short circuiting [built in] at 100 mA transistor series control system
Dynodrive speed variation	: Less than 1 or 2 percent of maximum speed (for load change from 100 per cent to 10 per cent)
Dimensions	
Length	: 300 mm
Width	: 180 mm
Depth	: 140 mm

Manufactured in collaboration with Yaskana Electric Manufacturing Co. Ltd., Japan.

Eddy Current Controls (India) Ltd., Eddypuram, Chalakudi - 680 307, Kerala, India.

APPENDIX F

Specifications of energy meter

Ampere	:	3 x 10
Volt	:	3 x 400
Cycles	:	50
1 kWh	:	112.5 revolutions of disc Made by General Electric Corporation of India (Pvt) Ltd., Calcutta.

DEVELOPMENT AND PERFORMANCE EVALUATION OF A BLACK PEPPER SKINNER

By

ANANDABOSE, D.

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

TAVANUR - 679 573

MALAPPURAM

1996

ABSTRACT

A power operated black pepper skinner was developed, tested and its performance evaluated. The major parts were two cylinder-concave assemblies, a hopper, a feed roll, an inclined belt separator assembly and a variable speed electric motor with a speed reduction unit of 10:1 ratio. The decortication took place as a result of the compressive and the shearing forces acting upon the pepper berries fed between the rotating drum and the stationary concave. A 3-factor, Factoral Experiment in Completely Randomized Design (CRD) with feed rate, drum speed and surface condition as factors was adopted. The maximum overall decorticating efficiency was observed at the feed rate of 12 kg/h and drum speed of 20 rpm for both the surface types. The maximum decorticating efficiency observed for coir-mat was 91.5 and that observed for rubber surface was 94.2. The effectiveness of wholeness of kernels was found to show lower values for the highest speed of 25 rpm due to the crushing of berries. The maximum overall decorticating efficiency recorded for coir-mat was 87.7 per cent and that recorded for rubber sheet was 90.3 per cent.

The study showed that the parameters of feed rate, drum speed, and surface type, have significant influenz on decorticating efficiency, effectiveness of wholeness of kernals and overall decorticating efficiency.