DEVELOPMENT AND TESTING OF A ROTARY TYPE BLACK PEPPER CLEANER

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

Department of Farm Power Machinery and Energy

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573

MALAPPURAM

1995

DECLARATION

*I hereby declare that this thesis entitled **"DEVELOPMENT AND TESTING OF A ROTARY TYPE BLACK PEPPER CLEANER"** 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.*

Place : Tavanur

Date : 16 12 95

ABDUL WAHAB, V.S.

CERTIFICATE

Certified that this thesis entitled ***"DEVELOPMENT AND TESTING OF A ROTARY TYPE BLACK PEPPER CLEANER"*** *is a record of research work done independently by Sri.* ***ABDUL WAHAB, V.S.*** *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.*

Place : Tavanur

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ACKNOWLEDGEMENT

My sincere sense of gratitude and indebtedness is extended to **Er. JIPPU JACOB**, Associate Professor, Department of Farm Power Machinery and Energy, KCAET, Chairman of Advisory Committee for his efficacious advices, perpetual and prolific encouragement and creative criticism at all stages of the work. Comments and suggestions made by him were extremely helpful in the preparation of thesis.

Heartfelt thanks are due to **DR. M. SIVASWAMI**, Assistant Professor, Department of Farm Power Machinery and Energy, **DR. JOBY V. PAUL**, Associate Professor, Department of Land Water Resources and Conservation Engineering, KCAET, Tavanur and **Er. M.R. SANKARANARAYANAN**, Assistant Professor (Agrl. Engg.), College of Horticulture, Vellanikkara, members of the Advisory Committee for their timely guidance and support during this course of work.

I express my utmost indebtedness and high sense of loyalty to **DR. K. JOHN THOMAS**, Dean, KCAET, Tavanur, for the indefatigable concern and consideration he has shown all through my studies at KCAET.

Sincere thanks to **DR. K.I. KOSHY**, Professor and Head, Department of SAC for rendering me computer facility.

I am immensely thankful to all the staff members 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 and near ones at KCAET especially to **MUNEER, VINOD, SUSHELANDRA, SIVAJI, JITHESH, JACINTHA** and **AJAYAMBIKA** during this arduous toil 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 for their unfailing support and supervision all through my studies.

A word of gratitude to **Mr. NOEL**, Ambika Computers, Vellanikkara for the prompt service rendered.

Above all I bow my head before **GOD THE ALMIGHTY**, who made everything possible and enabled me to complete this work successfully.

ABDUL WAHAB, V.S.

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SYMBOLS AND ABBREVIATIONS

Agric	:	Agricultural
ASAE	:	American Society of Agricultural Engineers
cc	:	cubic centimetre(s)
Engng.	:	Engineering
deg	:	degree
et al.	:	and others
Fig.	:	Figure
Fmg.	:	Farming
g	:	gram(s)
GI	:	galvanised iron
h	:	hour(s)
ha	:	hectares
HP	:	horse power
J.	:	Journal
kg	:	kilogram(s)
kwh	:	kilowatt hour
m	:	metre(s)
mm	:	millimetre(s)
Nos	:	numbers
pp.	:	pages
Res.	:	Research
rpm	:	revolution per minute
Rs	:	Rupees
sci.	:	science
Technol.	:	Technology
Trans.	:	Transactions
viz	:	namely
/	:	per
%	:	per cent
°	:	degree

Introduction

INTRODUCTION

India is known the world over as 'The Home of Spices'. Spices constitute an important group of agricultural commodities which are virtually indispensable in the culinary art. Black pepper (*Piper nigrum*) among them is one of the most sought after spices in the world. Black pepper, often called the 'King of spices' is the dried mature berries of the perennial evergreen vine *Piper nigrum* belonging to the piperaceae family. It has been the most important spice grown in India from time immemorial. It is also one of the most ancient crops cultivated in India and has probably originated in the hills of south western India.

Black pepper is also cultivated in Indonesia, Malaysia, Sri Lanka, Brazil, Thailand and other tropical countries. In 1991, the world production of black pepper was 2,37,000 tonnes. Out of this Indonesia ranks first with a production of 61,000 tonnes. India stands second with a production of 55,000 tonnes. In India black pepper, the branching vine or climbing perennial shrub, is mostly found in the hot and humid part of southern India, notably Kerala. The contribution of Kerala is about 96 per cent of India's total production while that from Karnataka is 3.5 per cent and the rest is from Tamil Nadu and Pondicherry.

Black pepper is prepared from the unripe but fully matured and developed whole berries by drying. Sun drying is the traditional method of preparing this spice and the vast bulk of world production is still dried by this procedure. After harvesting, the initial step is to initiate the browning fermentation by piling the berry clusters in a heap and exposing them to sun for several hours. The next stage involves spreading the berries out on a suitable drying floor in the sun. Sun drying takes around 7-10 days, during which the moisture content is reduced to 10-15 per cent. The yield of dried black pepper is around 36 kg for every 100 kg of fresh berries. In order to accelerate both browning and rate of drying, it is recommended to blanch the berry clusters in boiling water for about 10 minutes prior to sun drying.

Black pepper is used for a variety of purposes. It is most widely used as a condiment due to its flavour and ability to blend with most savoury dishes. Its stimulating action on digestive organs produces an increased flow of saliva and gastric juices. It has extensive culinary uses and is used in meats, soups, fish, pickles, etc. It is considered as a powerful remedy for various disorders of the anatomical systems and is prescribed as an effective cure for dyspepsia, malaria, delirium, hemorrhoids etc.

India, Indonesia, Malaysia, Sri Lanka, Brazil and Madagaskar are among the countries leading in the trade of black pepper. In the international market, around 1,00,000 tonnes of black pepper is traded annually, with U.S.A. leading the list of importing countries, followed by the erstwhile Soviet Union, Germany, Britain, Italy, and France. Commercially black pepper is traded in different forms namely, black pepper, dried green pepper, pepper in brine, black pepper powder, white pepper, frozen pepper, pepper oil and pepper oleoresin.

Spices contribute Rs.250-350 crore per year to India's foreign exchange earnings, of which about 25-75 per cent comes from black pepper alone. The area under black pepper cultivation, production, trade estimate of production, quantity exported and its value from 1986-1992 are shown in Table 1.1.

Many types and grades of black pepper, each with a specific name and quality, are recognized in the international market. The main criteria for black pepper grading are its colour, uniformity in size, density, moisture content, absence of extraneous matter, filth etc. Black pepper with uniform colour and size, low limits of extraneous matter and absence of filth and contaminating organisms including insects and pests are preferred by consumers. Accordingly, standard grades are prescribed by the Agricultural Marketing Advisor to the Government of India under the provisions of agricultural produce (Grading and Marketing) Act 1937. Some of which are given in Table 1.2.

Black pepper that deviates from these quality standards is of low commercial value, and is liable to be detained or rejected by buyers, and if exported tends to harm the reputation of the country.

The quantity of black pepper to be exported to any given market of the world is determined primarily by factors such as price, quality and ready availability. In order to lower the unit cost and to ensure quality and availability of black pepper in large quantities in less time, it becomes important to develop an efficient low-cost high-capacity equipment for cleaning black pepper, which can bring about an enhancement in the volume of trade and thereby enable the country to earn more of valuable foreign exchange.

Cleaning of black pepper admixture to separate different fractions of black pepper and removal of solid contaminants form an important operation in its processing. The traditional methods of winnowing and spreading the material on floor/mat and hand picking the contaminants are time consuming and labour intensive processes. The existing

Table 1.1 Area, production and export of black pepper during 1986-1992

Year	Area	Production	Trade Estimate of production	Export	
				Quantity	Value
	('000 ha)	('000 MT)	('000 MT)	('000 MT)	(in lakhs)
86-87	132.81	31.34	45.00	37.083	20033.00
87-88	149.93	48.09	65.00	41.010	24057.78
88-89	160.74	44.16	45.00	36.910	16451.17
89-90	171.49	55.19	65.00	34.650	15334.53
90-91	173.43	47.95	55.00	29.980	10239.93
91-92	174.87	42.69	60.00	20.530	7431.70

Source: Spices Statistics (1993), Trade Information Service, Spices Board, Cochin.

Table 1.2 Different grades of black pepper

Grade	Size (mm)	Extraneous matter (% weight)	Light berries (% weight)	moisture content (%)
TGSEB	4.75	0.5	3	11.5
TGEB	4.25	0.5	3	11.5
TG	4.25	0.5	3	11.5

mechanized systems such as winnower, specific gravity/ cyclone/spiral separators etc. are expensive and difficult to be maintained by small or medium scale operators. Blowers of high capacity are unfavourable since dust and other finer fractions are discharged into the environment.

Hence, it was proposed to develop and study a rotary type black pepper cleaner for separating bold pepper from the admixture. The present study was undertaken at the Kelappaji College of Agricultural Engineering and Technology, Tavanur with the following objectives :

1. To study the various physical properties of black pepper relevant to cleaning

2. To develop and test a rotary type black pepper cleaner

3. To evaluate the performance of the machine

Review of Literature

REVIEW OF LITERATURE

A brief review of the cultivation, harvesting and yields of black pepper, types of pepper products, standards of pepper producing countries are given. Similarly a review of the earlier studies on cleaning processes of similar agricultural products and properties relevant to cleaning are also included.

2.1 Cultivation

As indicated in the Package of Practices (1993) of the Kerala Agricultural University, black pepper is almost always propagated vegetatively from cuttings. It requires a warm and humid climate. The plant tolerates a minimum temperature of 10°C and maximum of 40°C, the optimum being 20-30° C. It can be grown from sea level upto an altitude of 1200 m, but lower altitudes are preferable. Black pepper prefers a light, porous and well drained soil rich in organic matter. Water stagnation in the soil, even for a very short period is injurious to the plant.

2.2 Harvesting and yields

Krishnamurthi (1969) points out that there are usually two harvests in India, one in August-September and the other in March-April. Yields vary greatly between countries depending upon the method and intensity of cultivation.

Holliday and Mowat (1963) state that the traditional life of the vine in Sarawak is 12-15 years and the maximum annual yield is extremely high: 4.5-6.8 kg of marketable black pepper per vine by the fifth year, that is, 7.5 tonne/hectare.

Krishnamurthy (1969) further affirms that, under less intensive cultivation in India, an adult vine yields annually about 0.5 kg of fruits, although the better cultivars give higher yields in some areas. Production may continue for 25 years or even longer. The average yield of commercial black pepper in India has been found to vary from 110 to 335 kg per hectare.

Harvesting in Kerala takes place from November to February. Towards the end of the harvest period, the vines are stripped off all fruiting spikes and the ripe and unripe fruits produced are converted to black pepper.

2.3 Types of pepper products

2.3.1 Decorticated black pepper

This is a form of white pepper produced by mechanical decortication of outer skin of black pepper and it is usually done by pepper grinders, in Europe and North America, when white pepper is in short supply.

Lewis *et al.*(1969) report on encountering considerable difficulties in producing conventional decorticated black pepper from the Indian spice owing to the toughness of its outer skin and the shortcomings in the available machines.

2.3.2 Green pepper

Whole green pepper products originating mainly from India, Madagaskar and Brazil, appeared for the first time in the market during the 1970's.

Lewis *et al.* (1976) briefly describe a process for the preparation of dehydrated green pepper in which the enzymes for normal browning reaction are first deactivated by blanching and sulphur dioxide treatment and then the berries are dehydrated.

Pruthi *et al.* (1976) also report of studies on preserving green pepper of the 'Panniyur' and 'Karimunda' varieties. Better colour retention is obtained with berries preserved in brine and citric acid without blanching, than those blanched before bottling.

2.3.3 Pepper oleoresin

Extraction of black pepper with organic solvents provides an oleoresin possessing the odour, flavour and pungent principles of the spice.

Nambudiri *et al.* (1970) describe the extraction process. For processing, the black pepper is to be comminuted into flakes of 0.05 mm thickness or ground into coarse powder measuring 0.1 to 0.3 mm in diameter and is extracted with a suitably purified solvent, usually acetone, ethanol or dichloroethane.

2.3.4 Black pepper oil

Black pepper oil is used in perfumery and in flavouring. But its latter application is decreasing, being replaced by the use of pepper oleoresin.

According to Gildemaster and Hoffman (1956) the black pepper is crushed into a coarse powder and on steam distillation, in which ammonia is evolved, it yields from 1 to 2.6 per cent of a colourless to a pale green essential oil with a mild non-pungent flavour.

2.4 Standards of the black pepper producing countries

Of the major black pepper producing countries, viz., India, Indonesia and Malaysia, India has the most advanced systems of grading and standards. The Indian Government, through the Ministry of Food and Agriculture (Department of Agriculture) has prescribed obligatory grading and standardisation of a large number of agricultural products, under the label, 'Agmark' in the interest of the consumers, both at home and abroad (Anon, 1971). These include black pepper among other spices.

The quality requirements of some of the countries are furnished in Table 2.1, 2.2 and 2.3.

Table 2.1 Quality parameters of International Standard Organization

Moisture (%)	=	12.0
Total ash (%)	=	5.0
Non- volatile ether extract(%)	=	6.0 (minimum)
Volatile oil (ml/100 g)	=	2.0
Piperine (%)	=	4.0

Table 2.2 Quality Parameters of American Spices Trade Association

Number of pests	=	2
Mammalian excreta	=	1 mg/pound
Other excreta	=	5 mg/ pound
Fungus infested	=	1%
Pest infested	=	1%
Extraneous matter	=	1%

Table 2.3 Quality Parameters of British Standard Institute

Extraneous matter	=	1.5 %
Light berry	=	10 %
Pin head	=	4 %
Total ash	=	8 %
Moisture	=	12 %

2.5 Physical properties of black pepper

The physical properties of black pepper admixture play an important role in the design of cleaning machine and handling the material. Density and specific gravity of the food material and agricultural products play an important role in many applications.

Stermer (1965) emphasizes the importance of density or specific gravity of the material in determining the purity of seeds.

According to Kunkal *et al.* (1951) density or specific gravity of the material is an important factor to be considered for the separation and grading processes.

Joshi *et al.* (1993) determined physical properties of pumpkin seed and kernel relevant to the design of the equipment for handling, dehulling and other processes.

Oje and Ugbor (1991) studied the various physical properties of oilbean seed at safe storage moisture content, namely, size, volume, sphericity, density, static coefficient of friction against different materials, angle of repose, hardness, crushing energy and specific heat capacity relevant to dehulling process.

Curray (1951) defines roundness, a measure of shape, as the ratio of the largest projected area of an object in its natural rest position to the area of the smallest circumscribing circle.

$$\text{Roundness} = \frac{A_p}{A_c} \qquad ----(2.1)$$

where,

A_p = Largest projected area of the object in its natural rest position, and

A_c = Area of the smallest circumscribing circle.

Curray (1951) used sphericity to express the shape character of solid material. It is expressed as:

$$\text{Sphericity} = \frac{d_e}{d_c} \qquad ----(2.2)$$

where,

d_e = Diameter of a sphere of the same volume as that of the object, and

d_c = Diameter of the smallest circumscribing sphere

By assuming that the volume of solid is equal to the volume of a triaxial ellipsoid, sphericity is given by:

$$\text{Sphericity} = \frac{\text{Volume of solid}}{\text{Volume of the smallest circumscribing sphere}}$$

$$= \frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

$$= \frac{(abc)^{1/3}}{a} \quad \text{- - - - (2.3)}$$

where,

a = Largest intercept,

b = Largest intercept normal to a, and

c = Largest intercept normal to a and b

2.6 Static and kinetic coefficient of friction

The method used by various investigators to determine the static and kinetic coefficient of friction of agricultural materials are usually designed to suit the particular condition of the material. The usual method includes the tilting of an inclined plane or moving a given surface in contact with the material.

Burbaker and Pos (1960) report on an increase in static coefficient of friction of various grains on various surfaces when moisture content of the grain was increased.

Bickert and Buelow (1966) showed that kinetic coefficient of friction of shelled corn and barley on steel and plywood begins to increase when a certain level of moisture content is exceeded.

One of the numerous techniques which is employed for separating potatoes and stones, is making use of the difference in rolling resistances of these two materials. In determining the rolling resistance, samples of potato or stone are placed on an inclined surface against an adjustable air stream (Maack, 1957).

Various investigators describe the determination of angle of repose using a specially constructed box, with a removable front panel. The box is filled with grains and the front panel is quickly removed. This allows the grains to flow from the bulk and on stabilization it assume its natural slope. This slope is the angle of repose.

Fowler *et al.*(1960) report on using a circular platform apparatus in the determination of angle of repose. They use the expression:

$$f = \frac{\tan^{-1} 2(Hc-Hp)}{Dp} \quad - - - - (2.4)$$

where,

f	=	Angle of repose,
Hc	=	Height of cone,
Hp	=	Height of platform, and
Dp	=	Diameter of platform

2.7 Methods of cleaning

The traditional methods of cleaning black pepper are winnowing and spreading the material on floor/mat and hand picking the contaminants. Mechanized systems such as winnower, cyclone/spiral separator etc. are also used for cleaning black pepper on a large scale. These machines are expensive and difficult to be maintained by small or medium scale operators.

According to Pierce (1985) the rotary type cleaner probably is the most common machine for on-farm application. Rotary grain cleaner separates grain into size fraction by moving it through a trommel. As the trommel rotates, materials cascade over its surface and the fine material passes through the screen. Materials not passing through moves out at the end of the trommel.

Thomas *et al.* (1983) developed a simple method for the separation of stones and sand particles from coriander seeds by using the principle of fluidization with air as medium. When a mixture of coriander seeds and stones is fluidized at minimum fluidizing conditions, the particle with minimum fluidization velocity higher than those of coriander seeds do not fluidize and settle at the bottom of the fluidization column. In contrast, those particles (finer) with minimum fluidization velocity less than or equal to those of coriander seeds get mixed up with coriander seeds. These fine particles are smaller than those of coriander seeds and can be removed by sieving.

Berlage (1984) emphasizes on the frequent use of indent cylinder for the separation of grains.

According to Wolfe (1980) rolling resistance seems promising as a basis for blue berry separation from trash. He utilized inclined belt separator in this.

Teckchandani (1988) used horizontal belt separator to separate pigeon pea from pearled grain by taking advantage of the gummy layer on pearled grain. Such a gummy layer is absent in black pepper.

Kacheru and Sahay (1990) developed a medium capacity pedal-cum-power operated air screen cleaner for the separation of foreign matter from agricultural grains. Separation with two sieves is achieved by difference in size. Larger impurities are retained over the top screen and the under size is separated by a bottom grading sieve.

Gorial and Callagon (1991) studied the separation of particles in a horizontal air stream based on the suspension velocity of particles.

Shinohara (1986) reports that multi-component particles with different shape can be separated continuously in an inclined plate. The path traces of the particles are computed on the basis of the combined motion of rotation, jump and slide.

Sheriff (1986) observed that when both the components are nearly spherical it is difficult to separate them in a compartmental type separator.

Carpenter and Deitz (1951) separated spherical particles from a batch of glass beads which contained some slightly elliptical particles using a rotary disc at a slight angle to the horizontal.

Riley (1968) separated spherical particles from a mixture of particles which contained irregular or cylindrical particles or flakes on an inclined rotary disc. The separation method depends on the fact that spheres will roll in a straight line, whereas non-spheres roll either in a circular path or not at all.

Viswanathan *et al.* (1984), after investigating the use of an inclined rotating disc apparatus to separate spherical from non-spherical particles, recommend its further study.

Sugimoto *et al.* (1977) studied continuous separation of spherical and non-spherical particles on an inclined rotating disc. They used an inclined rotating disc with a spiral scraper to study the efficiency of separation.

From the literature analysed it is seen that, only a few studies are reported in the case of cleaning of black pepper from admixture and that too with limited success. Further it is also seen from the various studies conducted that the use of rotating inclined disc offers better result in the separation of spherical from non-spherical particles. This is relevant in the case of black pepper. Hence an attempt is made to develop a rotary type black pepper cleaner for separating bold pepper from the admixture.

Materials and Methods

MATERIALS AND METHODS

The various methods involved in the determination of the properties of black pepper relevant to cleaning process, the development of a rotary type black pepper cleaner and experimental procedure are discussed in this chapter.

3.1 Properties of black pepper

The properties such as shape, size, weight, moisture content, bulk density, true density, volume, specific gravity, coefficient of sliding friction and coefficient of rolling friction were determined for black pepper. Relevant literature was studied to select appropriate method for the determination of each property. Black pepper purchased from local market irrespective of variety were used for the experiment.

3.1.1 Shape and size

The pepper grains were spread over a clean surface and roughly divided into a number of sectors. From each sector, pepper grains were randomly selected. The shape of the selected pepper grains was observed. Similarly the sizes of the pepper grains were determined using a dial caliper with a least count of 0.05 mm. Measurements on three mutually perpendicular axes, viz. major, intermediate and minor diameters were made.

3.1.2 Sphericity

Sphericity was determined using the formula

$$\text{Sphericity} = \frac{\text{Volume of solid}}{\text{Volume of the smallest circumscribing sphere}}$$

$$= \frac{\text{Geometric mean diameter}}{\text{Major diameter}}$$

$$= \frac{(abc)^{1/3}}{a} \quad \text{- - - - (3.1)}$$

where,

a = Largest intercept,

b = Largest intercept normal to a, and

c = Largest intercept normal to a and b

3.1.3 Weight

Weight of black pepper grains were determined using a common balance. Different groups of ten number of grains were selected randomly and weighed using a common balance. The average weight of each grain was then determined.

3.1.4 Volume

Pepper grains were filled in a jar of 20 cc volume. Number of pepper grains used to fill 20 cc volume was noted. The air trapped in the pore space was replaced by water and the volume of water needed to fill the jar (Vw) was measured. The procedure was repeated for different groups of samples. Then average volume of pepper grain was calculated as follows. During the period of observation, moisture content was not found to vary.

Volume of jar	=	20 cc
Volume of water in the jar	=	Vw cc
Volume of pepper grains in the jar	=	(20-Vw) cc
Number of pepper grains used to fill the jar	=	N

$$\text{Average volume of a pepper grain} = \frac{20-Vw}{N} \text{ cc} \quad \text{- - - - (3.2)}$$

3.1.5 True density

Pepper grains were filled in a jar of 50 cc volume. The air trapped in the pore space was replaced by pouring water into the jar. The volume of water needed to fill the jar was found out.

The procedure was repeated for different groups of samples and true density was calculated as follows :

Weight of pepper grain in the jar	=	Wc g
Volume of jar	=	50 cc
Volume of water in the jar	=	Vw cc
Volume of pepper grain in the jar	=	(50-Vw) cc = Vc

$$\text{True density of pepper grain} = \frac{Wc}{Vc} \text{ g/cc} \quad \text{- - - - (3.3)}$$

3.1.6 Bulk density

Black pepper was filled in a vessel of 50 cc volume. The weight of the pepper used to fill the vessel was measured and the bulk density was calculated using the following equation :

$$\text{Bulk density} = \frac{Wa}{Vv} \text{ g/cc} \quad \text{- - - - (3.4)}$$

where,

Wa = Weight of pepper used to fill the vessel (g) and

Vv = Volume of the vessel (cc)

3.1.7 Moisture content

Moisture content of the black pepper was determined by oven dry method. The wet weight of the grain was measured using a common balance and it was kept in the oven for 24 hours at 105°C . Then the dry weight was measured and the moisture content was determined using the formula:

$$\text{Moisture content (\%)} = \frac{\text{wet weight of grain} - \text{dry weight of grain}}{\text{dry weight of the grain}} \times 100 \quad \text{- - - - (3.5)}$$

3.1.8 Specific gravity

The weight of black pepper in air was determined. It was then submerged in a bottle containing water. Weight of displaced water was then measured. Specific gravity was calculated using the formula:

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight of displaced water}} \times \text{Specific gravity of water} \quad \text{- - - - (3.6)}$$

3.1.9 Coefficient of sliding friction and rolling friction

Coefficient of sliding friction and coefficient of rolling friction of black pepper were determined for the surfaces of mica and cotton. A circular disc was used for this purpose. Black pepper was placed over the disc and the disc was tilted gradually. The angle at which black pepper just began to slide was noted. Similarly, the angle at which the pepper started rolling was also noted. Then the coefficient of sliding and rolling friction, over the surfaces of mica and cotton, were determined.

3.2 Development of a black pepper cleaner

Based on the preliminary studies and trials, a rotary type black pepper cleaner was developed and its performance evaluated.

The principal parts comprising the black pepper cleaner are a circular disc, an involute shaped scraper, a drum sieve, a hopper and a collecting tray. The whole unit is attached to an angle iron frame. Figures 3.1 to 3.3

represent different views of the machine. The functional as well as constructional details are described below.

3.2.1 Functional and constructional details

The functions of each part, the material of construction etc. are discussed in this section.

3.2.1.1 Circular disc

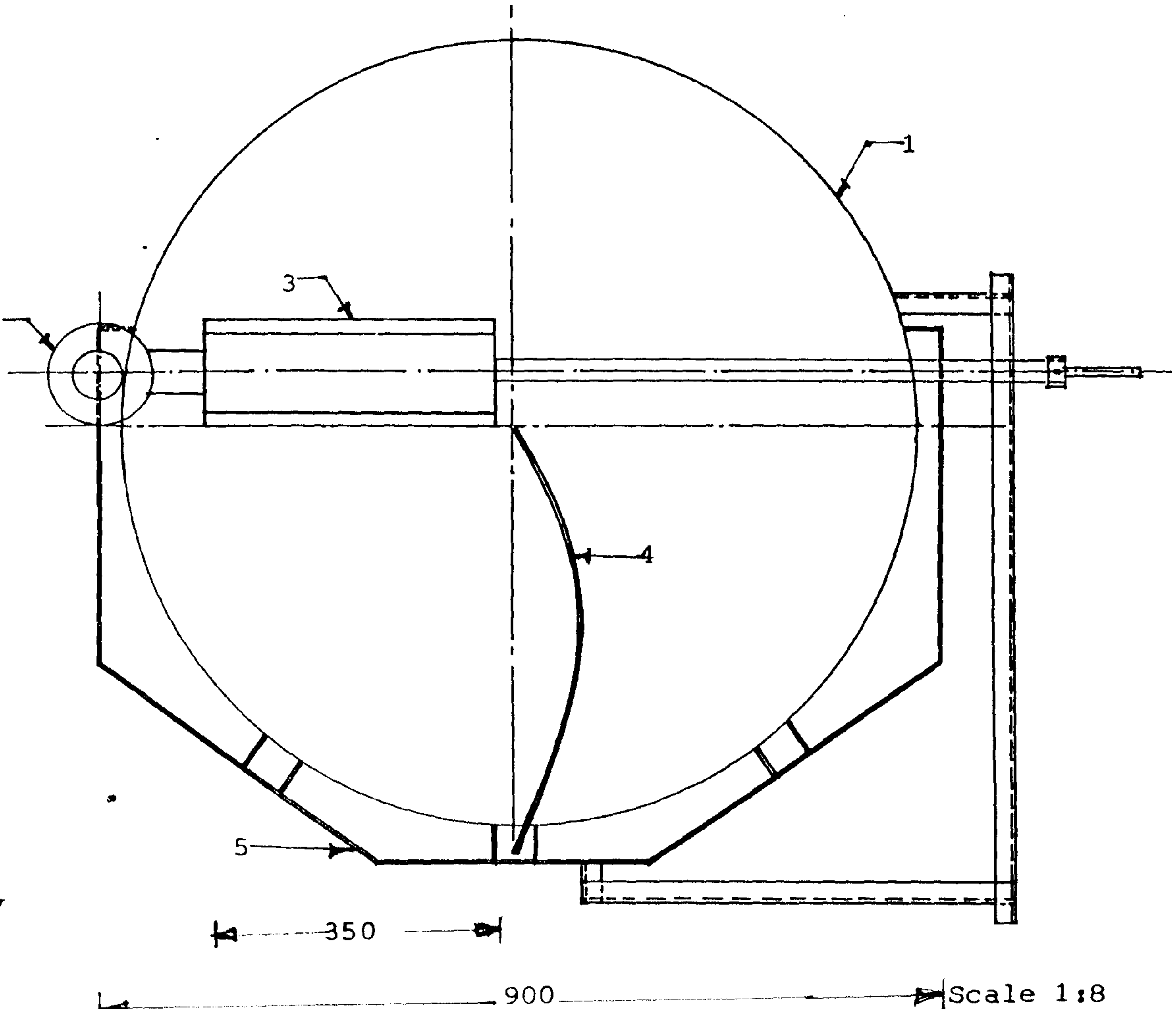
It is the main part of the black pepper cleaning machine. A circular disc of diameter 90 cm is made using a 12 mm plywood. It is pasted with sunmica, a board of laminated sheet.

3.2.1.2 Scraper

An involute type scraper is made using a 22 gauge GI sheet. In order to avoid the scraper from making indelible marks on the rotating smooth disc , a spongy material is applied below the scraper, while doing trials on surface of mica. The main function of the scraper is to scrape out the foreign material from bold pepper.

3.2.1.3 Drum sieve

A drum sieve is made using perforated sheet having 6 mm diameter holes. The outside diameter of the drum sieve is 130 mm and length of the drum sieve is 350 mm. One side of the drum sieve is fixed to a shaft and the other side of

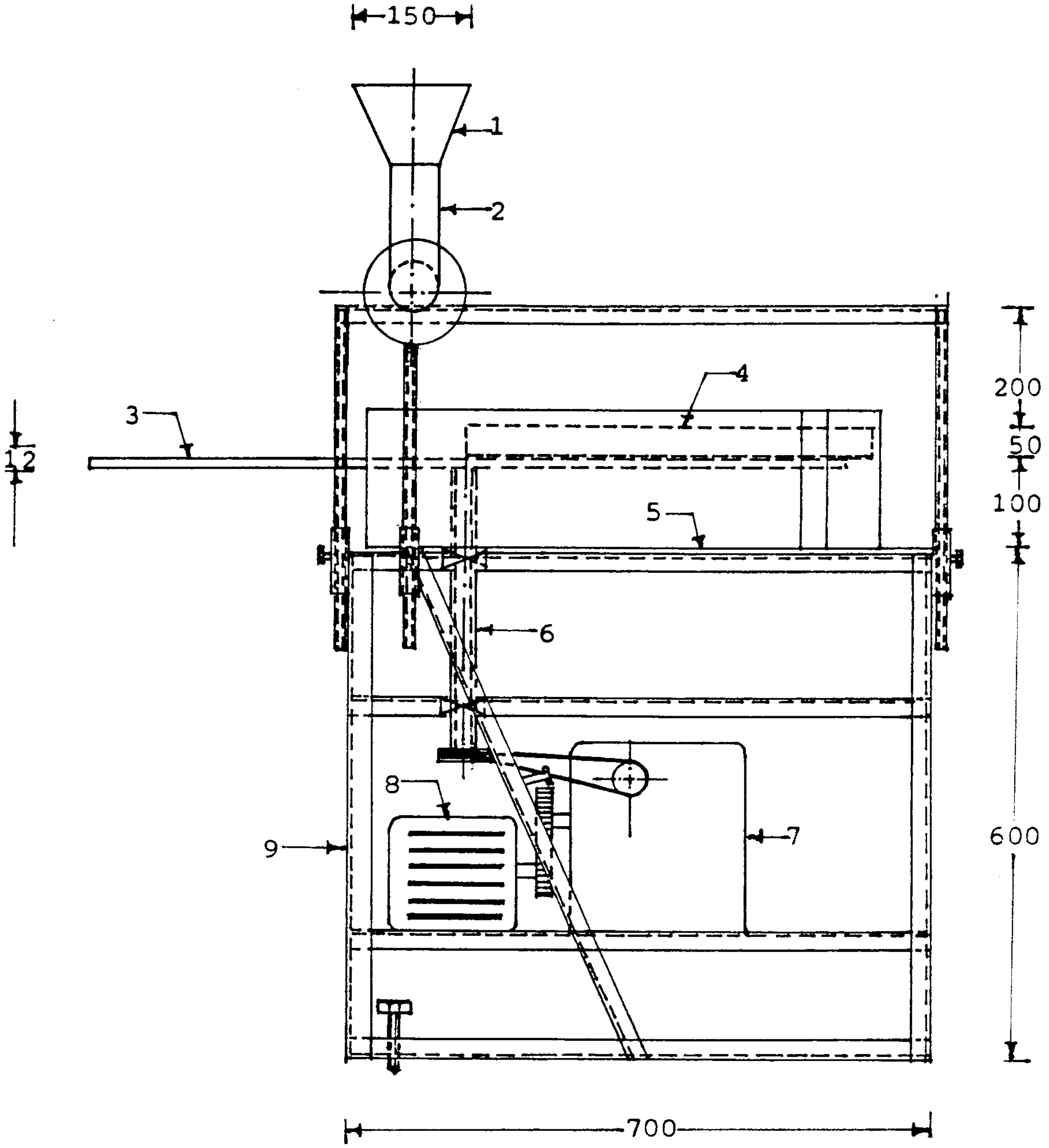


1. Disc
2. Hopper
3. Drum sieve
4. Scraper
5. Collecting tray

Scale 1:8

All dimensions are in mm.

Fig.3.1 Top view of black pepper cleaner

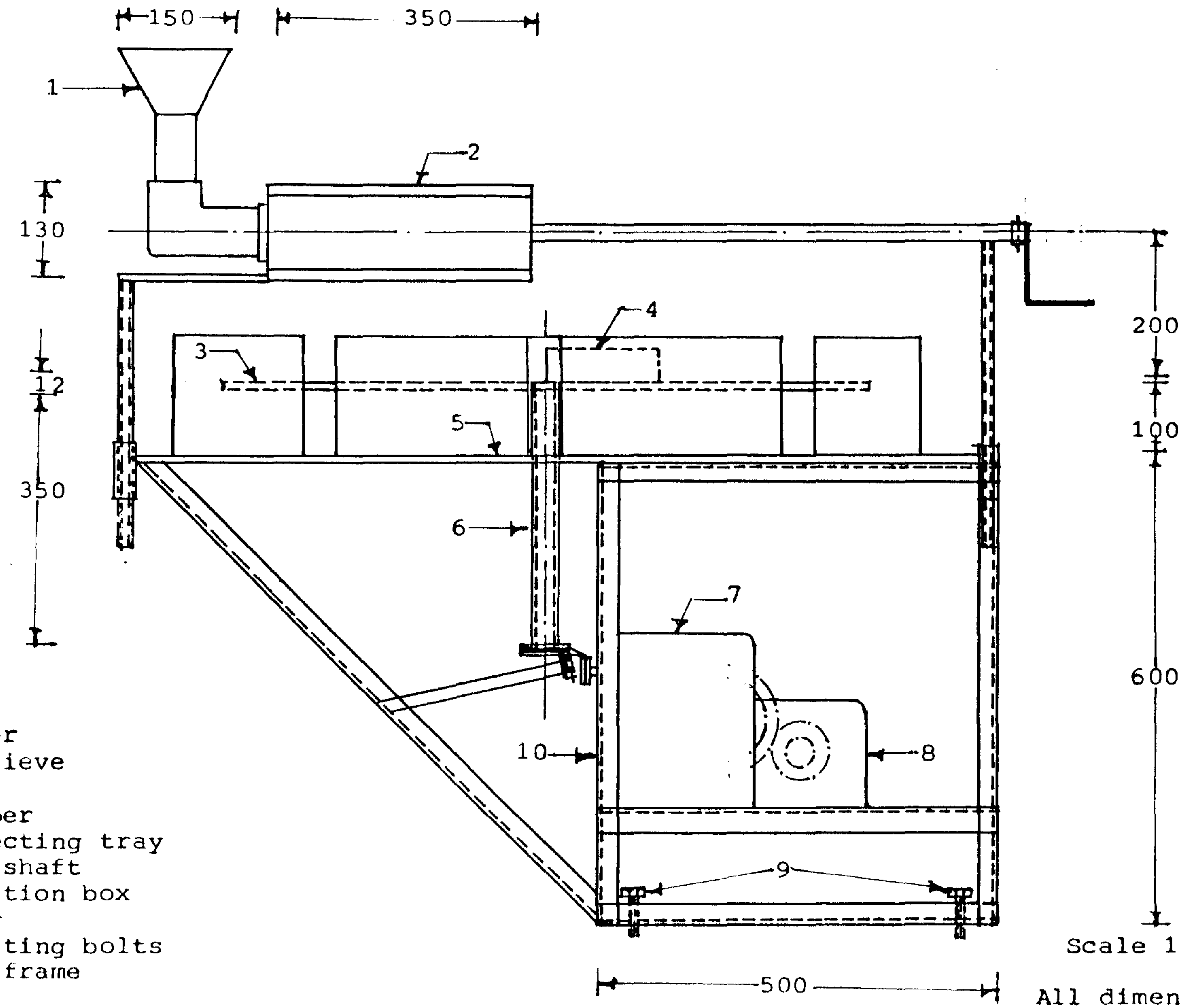


1. Hopper
2. pvc bend
3. Disc
4. Scraper
5. Collecting tray
6. Main shaft
7. Reduction box
8. Motor
9. Main frame

Scale 1:8

All dimensions are in mm.

Fig.3.2 Front view of black pepper cleaner



1. Hopper
2. Drumsieve
3. Disc
4. Scraper
5. Collecting tray
6. Main shaft
7. Reduction box
8. Motor
9. Adjusting bolts
10. Main frame

Scale 1:8

All dimensions are in mm.

Fig.3.3 Side view of black pepper cleaner the sieve is placed over a pvc bend which is connected to a hopper. The sieve can be rotated freely by means of a handle provided at the end of the shaft. The sieve is covered with different strips and by adjusting the gap between these strips, different feed rate is obtained.

3.2.1.4 Hopper

A small hopper is provided at the top so that pepper can be fed easily. The pepper is fed through the hopper to the drum sieve via a pvc bend. The hopper is made of 22 gauge GI sheet.

3.2.1.5 Collecting tray

A collecting tray is placed below the rotating disc. The tray is divided into two compartments so that cleaned pepper and foreign matter can be collected separately. It is made of 22 gauge GI sheet.

3.2.1.6 Main shaft

The main shaft rotates the disc in a horizontal direction. The circular disc is fixed to the shaft through a flange. A suitable thrust bearing is provided in the shaft. The shaft rotates with its axis vertical by means of a quarter turn belt drive. It gets drive from a 10:1 gear reduction box, which derives its power from a 3-phase variable speed dynodrive motor. The 350 mm long GI main shaft is 32 mm in diameter.

3.2.1.7 Main frame

The main shaft and the motor along with gear reduction box etc. are fixed to an angle iron (25 x 25 x 3 mm) frame of size 700 x 500 x 600 mm.

3.3 Power source

A 3-phase 0.5 HP variable speed dynodrive motor along with a 10:1 gear reduction box is used as the prime mover. The gear reduction unit derives its power from an electric motor through a gear drive of ratio 4:1. The rpm of the motor is varied between the range 300-1400 by using a variable dynodrive mechanism. Correspondingly, rpm at the reduction gear unit is also varied. Hence, the desired rpm (8 to 15) is obtained at the main shaft. Power is transmitted to the main shaft by quarter turn drive mechanism using belt and pulley arrangement. The details of variable speed motor are given in the Appendix VII.

3.4 Working principle

The black pepper admixture is fed to the drum sieve through a hopper fixed over the top of the sieve. The drum sieve is rotated uniformly with the help of a handle provided at the end of the sieve. The black pepper admixture falls uniformly over the inclined rotating disc. The black pepper being nearly spherical in shape rolls down easily and get collected at one end, whereas foreign

Plate I   Top view black pepper cleaner

Plate II Front view of black pepper cleaner

Plate III   Side view of black pepper clean

Plate IV   Isometric view of black pepper cleaner

materials most of which are not spherical in shape can not roll down as freely as bold pepper and are scraped out at the other end by means of the involute type scraper. Both these particles are received over a collecting tray placed below the rotating disc.

3.5 Experimental procedure

The experiment was conducted for two surface conditions, surface of mica and cotton.

Based on the preliminary studies and trials, the following levels of feed rate, speed and angle of inclination of disc were selected while testing on the surface of mica.

Feed rate	:	20 kg/h, 12 kg/h, 8 kg/h
Speed	:	8, 10, 12, 15 rpm
Angle of inclination	:	8, 9, 10 degrees

Based on the trails, for the testing on cotton surface, the selected levels of treatment were:

Feed rate	:	20 kg/h, 12 kg/h, 8 kg/h
Speed	:	8, 10, 12, 15 rpm
Angle of inclination	:	10, 11, 12 degrees

Cleaned pepper weighing 150 g and 5 g of foreign matter such as sand, stone, chaff, light berry, pin head etc. were mixed together and used for experimental purpose. The drum sieve was covered with a number of strips. By changing the gap between these strips, the feed rate was varied from 8 to 20 kg/h. The angle of inclination of the disc was adjusted by tightening or loosening the bolts provided at the bottom of the frame. Then, the angle of inclination of the disc with respect to the horizontal plane was read from a protractor fixed on the main frame. The speed of the machine was varied by adjusting the knob of the thyristor unit in the variable speed motor. The grain collected at the cleaned grain outlet and foreign matter outlet were weighed separately. The fraction of cleaned grain from cleaned grain outlet and fraction of cleaned grain from foreign matter outlet were then determined. Each trial was repeated three times and the average value is taken for calculating the overall cleaning efficiency. The readings are tabulated in the Appendix (I & II).

The overall cleaning efficiency is calculated using the formula :

$$\text{Overall cleaning efficiency} = \frac{E\,(E-F)\,(F-G)\,(1-G)}{F\,(E-F)^2\,(1-F)} \qquad \text{- - - - (3.7)}$$

where,

E = Fraction of cleaned grain from the cleaned grain outlet,

F = Fraction of cleaned grain in the feed, and

G = Fraction of cleaned grain from the foreign matter outlet

3.6 Energy requirement

Energy requirement at no load condition and with load conditions were determined using an energy meter. The 3-phase energy meter is connected in series with the motor. The energy consumed by running the motor alone is measured (No load condition). Similarly, the energy consumed after engaging speed reduction unit at different operating speed (loaded condition) is also measured. The energy meter specification is given in the Appendix VIII.

3.7 Economic Analysis

The operating cost of machine was analysed and it is furnished in the Appendix IX.

Results and Discussion

RESULTS AND DISCUSSION

This chapter deals with the results of experiments conducted regarding properties of black pepper cleaner relevant to cleaning process and for evaluating the performance of the newly developed rotary type black pepper cleaner. Besides, the effect of three parameters viz., feed rate, angle of inclination and speed of machine on cleaning efficiency are also discussed.

4.1 Physical properties of 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 discussed.

4.1.1 Shape and size

The black pepper on visual observation, are found to be nearly spherical in shape. The size of black pepper along its major axis varies from 4.75 to 5.60 mm as revealed in Table 4.1.

4.1.2 Sphericity

As depicted in Table 4.1. the sphericity of pepper grain is found to vary from 85.90 per cent to 97.90 per cent with a mean value of 93.20 per cent.

Table 4.1 Sphericity and dimensions of black pepper grain

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	5.25	4.95	4.75	94.80
2	5.55	5.40	5.10	96.30
3	5.15	4.65	4.50	92.30
4	4.95	4.30	4.25	90.60
5	5.55	4.45	4.40	85.90
6	5.60	5.50	5.00	95.70
7	5.20	5.10	4.80	96.70
8	4.85	4.35	4.25	92.30
9	5.45	4.95	4.60	91.50
10	5.40	4.85	4.65	91.70
11	4.85	4.80	4.60	97.90
12	4.80	4.05	3.95	88.50
13	4.90	4.60	4.50	95.20
14	5.10	4.90	4.80	96.20
15	4.75	4.35	4.25	93.50
16	5.50	5.25	5.20	96.60
17	5.30	5.00	4.85	95.20
18	5.00	4.15	4.00	87.20
19	4.85	4.20	4.10	90.10
20	4.95	4.65	4.50	94.80
	Mean			93.20

4.1.3 Weight

Average weight of a pepper grain is found to be 0.060 g with a range of values between 0.050 g to 0.070 g as shown in Table 4.2.

4.1.4 Volume

Average volume of a pepper grain is found to vary from 0.053 cc to 0.055 cc with a mean value of 0.054 cc. It is represented in Table 4.3.

4.1.5 True density

From Table 4.4. the mean true density of pepper grain is found to be 0.878 g/cc. The true density is in the range between 0.806 g/cc to 0.952 g/cc.

4.1.6 Bulk density

The mean bulk density of pepper grain is found to be 0.474 g/cc with a range of 0.472 g/cc to 0.476 g/cc. It is presented in Table 4.5.

4.1.7 Moisture content

The average moisture content of black pepper grain is 10.7 per cent with a range of values between 10.5 per cent to 10.9 per cent as given in Table 4.6.

Table 4.2 Average weight of black pepper grain

Sl. No.	Weight of 10 nos grain (g)	Average Weight (g)
1	0.600	0.060
2	0.620	0.062
3	0.700	0.070
4	0.650	0.065
5	0.550	0.055
6	0.500	0.050
Mean		0.060

Table 4.3 Volume of black pepper grain

Replication	1	2	3	4
Volume of jar(cc)	20	20	20	20
Volume of water in the jar(cc)	10	10	10	10
Number of grains in the jar	183	180	185	190
Volume of grains in the jar(20-Vw)	10	10	10	10
Average volume of a grain(cc)	0.055	0.055	0.054	0.053
Mean				0.054

Table 4.4 True density of black pepper grain

Sl No	Weight of pepper grain (g)	Volume of pepper grain (cc)	True density (g/cc)
1	23.80	25.00	0.952
2	23.40	29.00	0.806
3	23.70	27.00	0.876
4	23.60	27.00	0.874
	Mean		0.878

Table 4.5 Bulk density of black pepper grain

Sl No	Weight of pepper grain (g)	Total volume (cc)	Bulk density (g/cc)
1	23.75	50	0.475
2	23.70	50	0.474
3	23.80	50	0.476
4	23.60	50	0.472
	Mean		0.474

Table 4.6 Moisture content of black pepper grain

Sl No	Weight of wet grains (g)	Weight of grains after oven drying (g)	Moisture content (%)
1	35.80	32.29	10.9
2	35.30	31.95	10.5
3	35.00	31.67	10.5
4	35.50	32.05	10.8
	Mean		10.70

4.1.8 Specific gravity

The specific gravity of black pepper is found to vary from 1.11 to 1.17 as depicted in Table 4.7. with a mean value of 1.15.

4.1.9 Coefficient of sliding friction and rolling friction

Mean coefficient of sliding friction and rolling friction are 0.12 and 0.13 respectively for the surface of mica. For the cotton surface it is found to be 0.15 and 0.17 respectively. It is revealed in Table 4.8.

4.2 Performance evaluation of the black pepper cleaner

Performance of the newly developed rotary type black pepper cleaner is evaluated and the results are discussed. The machine was tested on two surfaces, mica and cotton.

4.2.1 Testing on the surface of mica

The black pepper cleaner was tested at different levels of feed rate, angle of inclination of the disc and speed as given below:

Variable	Level
Feed rate	20, 12, 8 kg/h
Angle	8, 9, 10 degrees
Speed	8, 10, 12, 15 rpm

Table 4.7 Specific gravity of black pepper grain

Sl no	Weight of pepper grains in air (g)	Weight of container+ water (g)	Weight of container+ water+ pepper (g)	Weight of displaced water (g)	Specific gravity
1	1.50	154.70	156.05	1.35	1.11
2	1.40	154.70	155.90	1.20	1.17
3	1.45	154.70	155.95	1.25	1.16
4	1.50	154.70	156.00	1.30	1.15
	Mean				1.15

Table 4.8A Coefficient of sliding friction and rolling friction for the mica surface

Sliding angle													Coefficient of sliding friction
1	2	3	4	5	6	7	8	9	10	11	12	Mean	
7.0	5.0	5.0	7.0	6.0	8.0	6.0	7.5	8.0	6.5	7.5	8.0	6.8	0.12
Rolling angle													Coefficient of rolling friction
9.0	5.0	5.0	8.0	9.0	8.0	6.0	8.0	7.0	7.0	9.0	8.5	7.5	0.13

Table 4.8B Coefficient of sliding friction and rolling friction for the cotton surface

Sliding angle													Coefficient of sliding friction
1	2	3	4	5	6	7	8	9	10	11	12	Mean	
7.0	6.0	6.5	10.5	9.5	10.0	10.0	8.0	7.0	9.0	10.0	9.0	8.5	0.15
Rolling angle													Coefficient of rolling friction
8.0	7.0	7.0	11.0	11.0	12.0	11.0	9.0	11.0	10.5	11.5	10.5	9.9	0.17

Some readings were taken for 11° angle of inclination and at a feed rate of 5 kg/h.

The testing was carried out for thirty six set-up of the machine as shown in Table 4.9. and the data analysed (Appendix III).

The cleaning efficiency of the machine is found to vary from 47 to 75 per cent under different set-up of the machine. The values are shown in Table 4.10. The observations are tabulated in Appendix-I.

Figures 4.1. to 4.3. graphically represent cleaning efficiencies under different levels of speed and angle of inclination at feed rates 20 kg/h, 12 kg/h and 8 kg/h, respectively. The maximum cleaning efficiency of 75 per cent is obtained at an angle of 9°. The same obtained at angles 8° and 10° are 65 per cent and 62 per cent respectively (Fig.4.2.).

From these figures, it is evident that for all the experimental set-up, the maximum cleaning efficiencies are found to occur at 9° inclination of the disc. Therefore, it is revealed that the optimum angle for obtaining maximum cleaning efficiency under this condition is 9°.

Table 4.9 Experimental set-up of the machine while testing on the mica surface

Set-up No.	Feed rate (kg/h)	Angle of disc (deg)	speed (rpm)
1	20	8	8
2	20	8	10
3	20	8	12
4	20	8	15
5	20	9	8
6	20	9	10
7	20	9	12
8	20	9	15
9	20	10	8
10	20	10	10
11	20	10	12
12	20	10	15
13	12	8	8
14	12	8	10
15	12	8	12
16	12	8	15
17	12	9	8
18	12	9	10
19	12	9	12
20	12	9	15
21	12	10	8
22	12	10	10
23	12	10	12
24	12	10	15
25	8	8	8
26	8	8	10
27	8	8	12
28	8	8	15
29	8	9	8
30	8	9	10
31	8	9	12
32	8	9	15
33	8	10	8
34	8	10	10
35	8	10	12
36	8	10	15

Table 4.10 Cleaning efficiency at different levels of feed rate, angle of disc and speed of machine for the surface of mica

Angle (deg)	Feed rate (kg/h)											
	20				12				8			
	Speed (rpm)											
	8	10	12	15	8	10	12	15	8	10	12	15
8	53	61	52	52	61	65	60	56	57	61	59	52
9	63	67	62	59	74	75	75	67	68	73	71	63
10	53	58	51	47	55	62	60	50	53	57	52	47

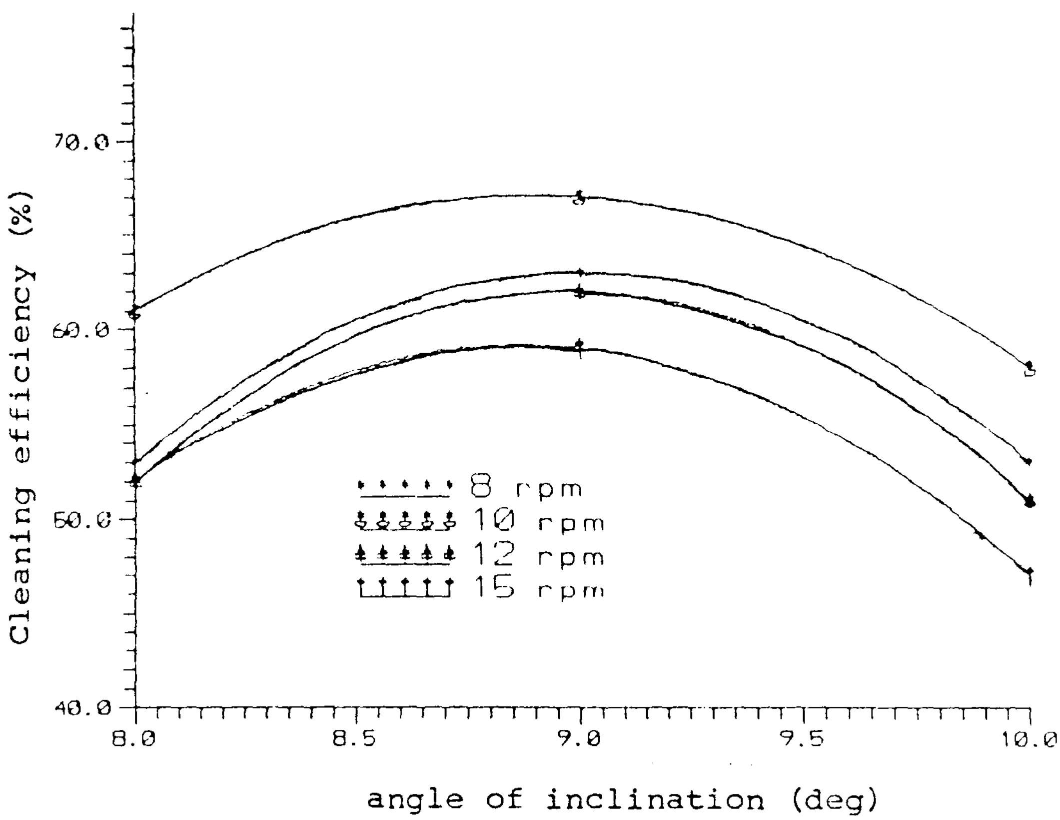


Fig.4.1 Cleaning efficiency at 20 kg/h for different speed and angle of disc for mica surface

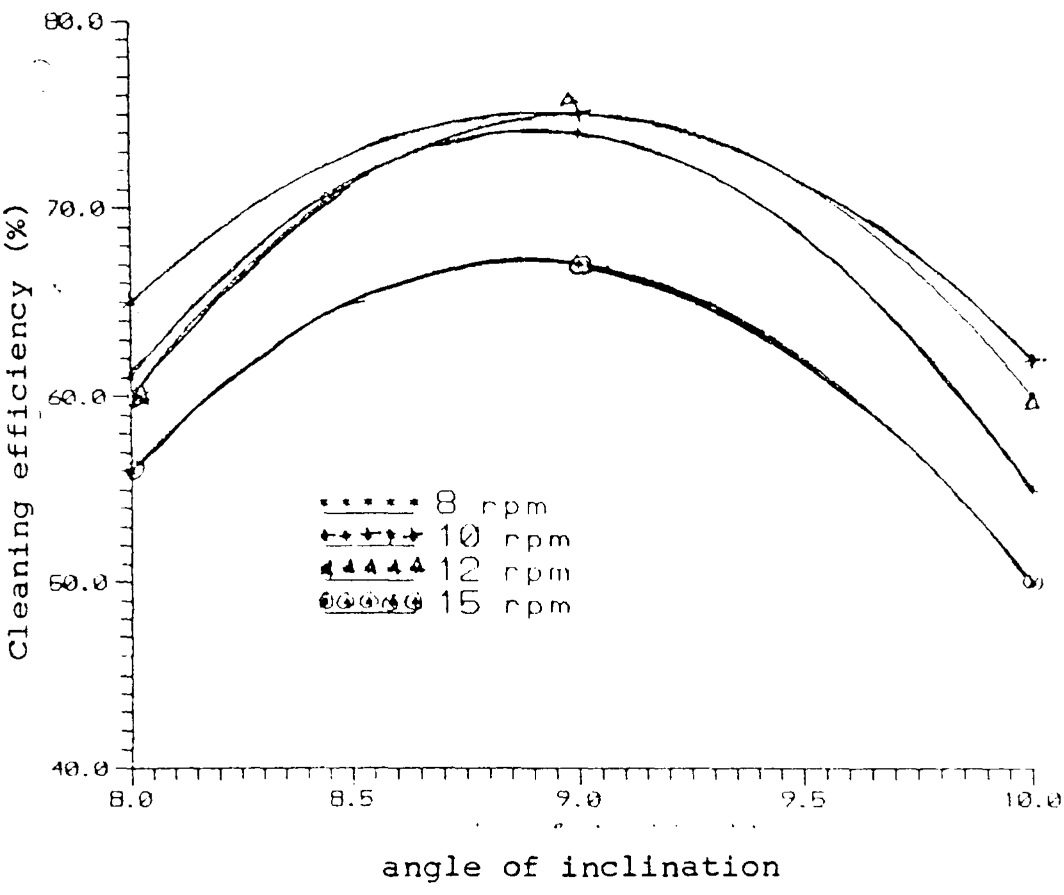


Fig.4.2 Cleaning efficiency at 12 kg/h for different speed and angle of disc for mica surface

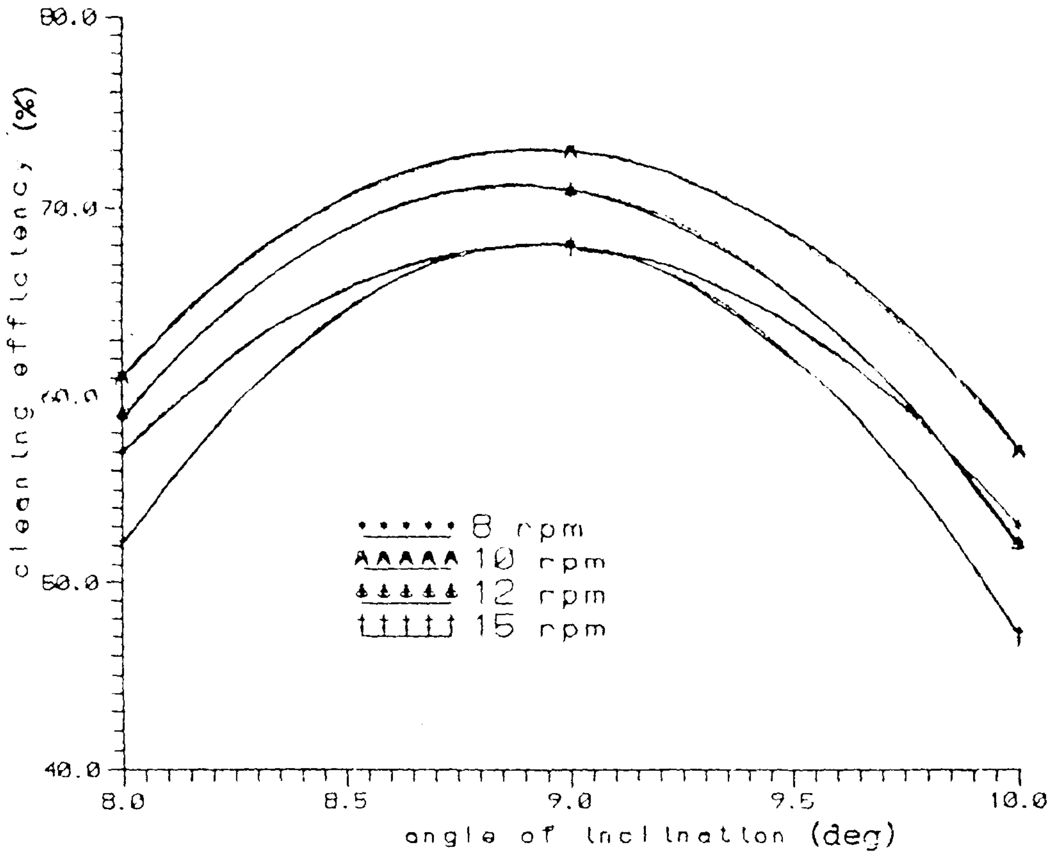


Fig.4.3 Cleaning efficiency at 8 kg/h for different speed and angle of disc for mica surface

It is observed that 8° angle of inclination is not sufficient to roll down all pepper grains towards the collecting position of cleaned grain outlet. As a result, these grains are scraped out at the foreign matter outlet. Consequently, the cleaning efficiency is decreased.

At 10° angle of inclination, it is observed that some of the foreign materials are collected at cleaned grain outlet, the reason being that at 10° inclination, pepper grains rolls down swiftly. During its fast rolling, it collides with foreign particles, and force them to move towards the cleaned grain outlet rather than towards the foreign matter outlet. As a result, these particles are collected at the cleaned grain outlet along with pepper grains. Thus cleaning efficiency is decreased. It is observed that, at 11° angle of disc, the cleaning efficiency is further decreased.

Figures 4.4. to 4.6. represent cleaning efficiencies under different levels of speed and feed rate at the angles of inclination 8, 9 and 10 degrees respectively. The maximum cleaning efficiency of 75 per cent is obtained at a feed rate of 12 kg/h. The maximum efficiency obtained at 20 kg/h is 67 per cent and at 8 kg/h is 73 per cent (Fig.4.5).

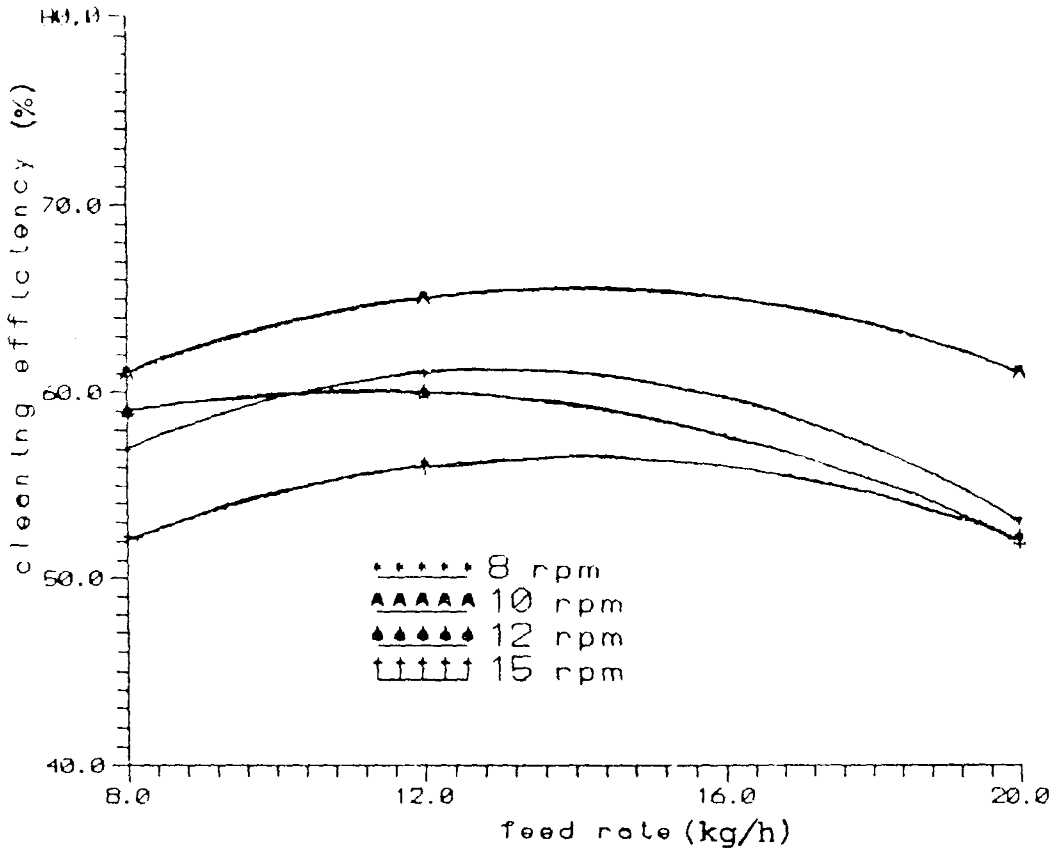


Fig.4.4 Cleaning efficiency at 8° for different speed and feed rate for mica surface

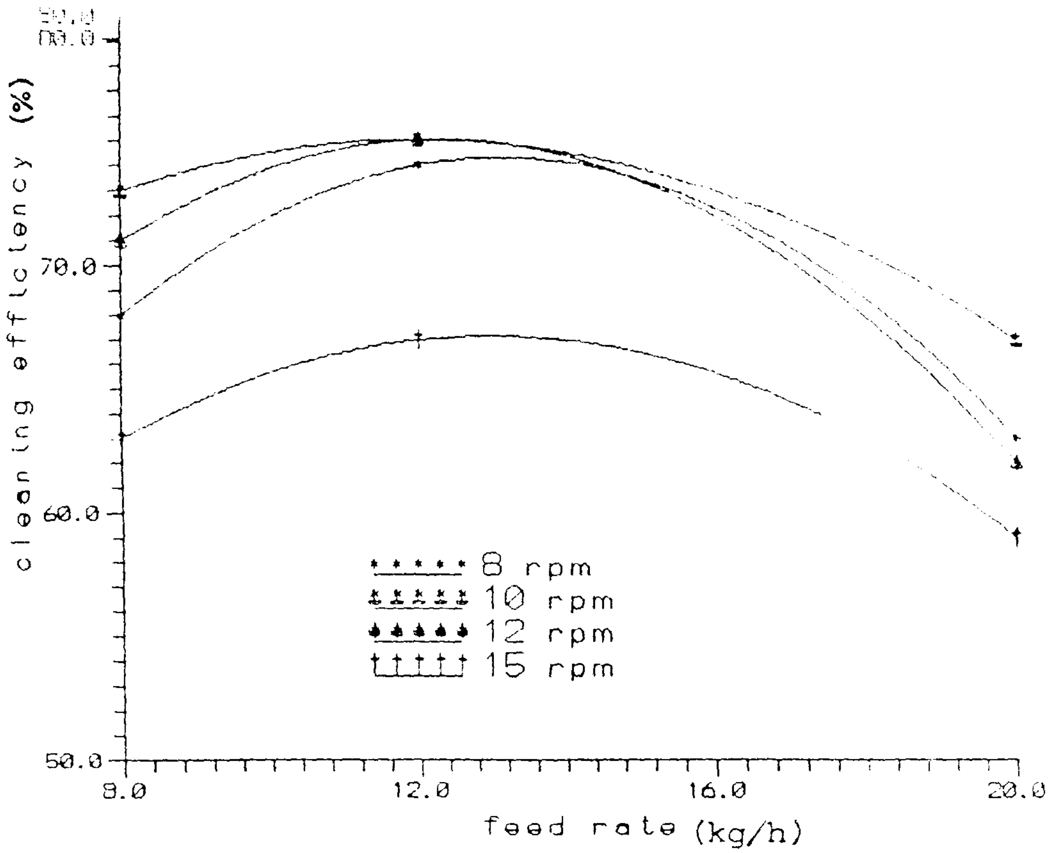


Fig.4.5 Cleaning efficiency at 9° for different speed and feed rate for mica surface

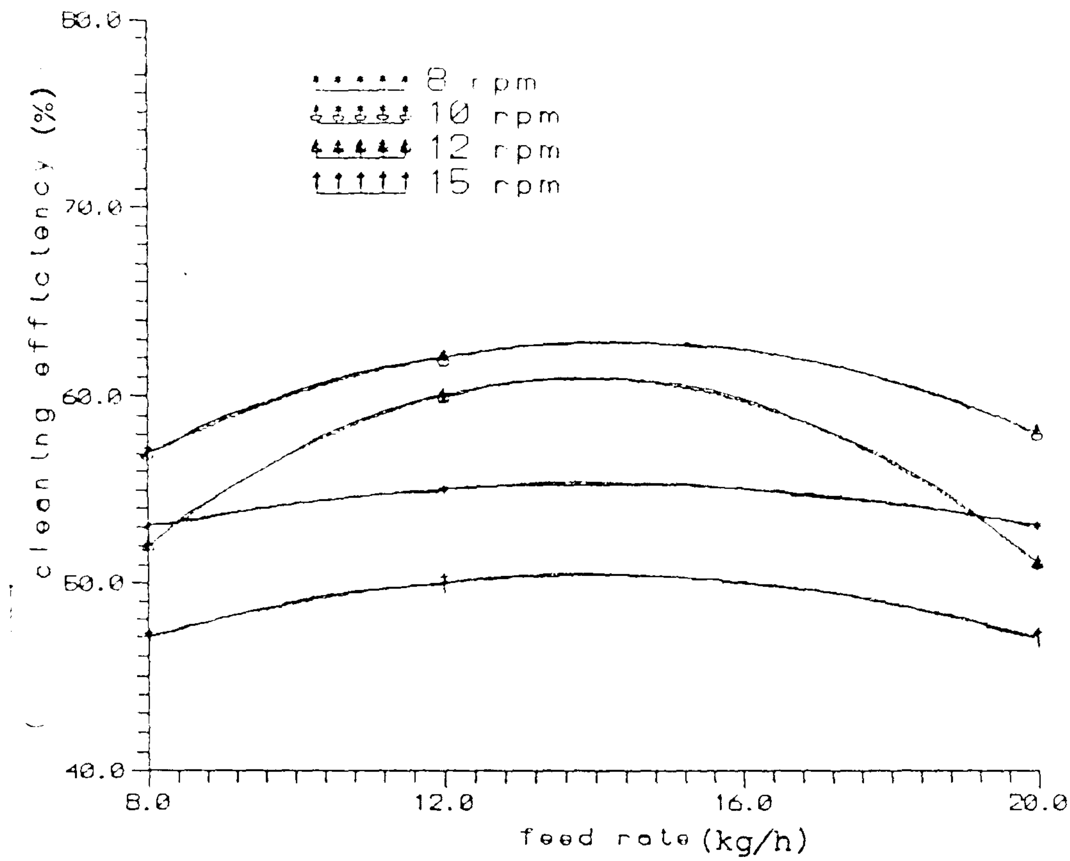


Fig.4.6 Cleaning efficiency at 10° for different speed and feed rate for mica surface

By observing these figures, it is seen that maximum efficiency is obtained at a feed rate of 12 kg/h for most of the machine set-up. It is therefore, inferred that for deriving maximum cleaning efficiency, optimum feed rate is 12 kg/h.

From Figures 4.4. to 4.6. it is apparent that as the feed rate decreases from 20 kg/h to 12 kg/h, the cleaning efficiency increases. But for further decrease in feed rate to 8 kg/h, it shows a decreasing trend. It is also seen that when feed rate is decreased to 5 kg/h, it does not show any pronounced effect on cleaning efficiency.

It is observed that at a feed rate of 20 kg/h, the presence of non-spherical and increased number of pepper grain particles prevent the free rolling of bold pepper, which results in greater time of hold-up of pepper grains in the rotating disc. Because of these, a part of the bold pepper is scraped out at the foreign matter outlet. This results in a lower cleaning efficiency.

Comparison of Figures 4.1. to 4.6. shows that cleaning efficiency presents an increasing trend as the speed increases from 8 to 10 rpm and a reverse trend for further increase to 15 rpm. From Figure 4.5. it is found that the maximum cleaning efficiency of 75 per cent is obtained at a speed of 10 and 12 rpm, corresponding to a feed rate of 12 kg/h and angle of inclination of 9° which are already identified as optimum feed rate and angle of inclination. The maximum cleaning efficiency obtained at a speed of 8 rpm is 74 per cent and that observed at 15 rpm is 67 per cent.

From Figures 4.1. to 4.6. it is also observed that maximum cleaning efficiencies are obtained at a speed of 10 rpm for most of the machine set-up. So, for deriving maximum cleaning efficiency, the machine is to be rotated at 10 rpm.

The lower efficiency at 15 rpm may be because at this speed, effect of the centrifugal force is more and as a result, the pepper grains are thrown away towards the other end of the disc and finally they are collected at the foreign matter outlet.

From the above findings, the optimum set-up of the machine for deriving maximum cleaning efficiency is as follows:

Feed rate	:	12 kg/h
Angle of disc	:	9°
Speed	:	10 rpm

4.2.2 Testing on the cotton surface

The selected level of speed, angle of inclination and feed rate are given below:

Variable	Level of treatment
Feed rate	20, 12 and 8 kg/h
Angle	10, 11 and 12 degrees
Speed	8, 10, 12 and 15 rpm

Some readings are also taken for 13° angle of inclination and 5 kg/h feed rate. Testing is carried out for thirty six set-up of machine as shown in Table 4.11.

The cleaning efficiency of the machine varies from 51 to 88 per cent under different machine set-up as shown in Table 4.12.

Figures 4.7. to 4.9. show cleaning efficiencies under different levels of speed and angle of inclination at feed rates of 20 kg/h, 12 kg/h and 8 kg/h respectively.

The maximum cleaning efficiency of 88 per cent is obtained at an angle of 11° inclination. The corresponding efficiency at 10° inclination is 69 per cent and 12° it is 79 per cent (Fig.4.8).

Table 4.11 Experimental set-up of the machine while testing on the cotton surface

set-up no	Feed rate (kg/h)	Angle of disc (deg)	speed (rpm)
1	20	10	8
2	20	10	10
3	20	10	12
4	20	10	15
5	20	11	8
6	20	11	10
7	20	11	12
8	20	11	15
9	20	12	8
10	20	12	10
11	20	12	12
12	20	12	15
13	12	10	8
14	12	10	10
15	12	10	12
16	12	10	15
17	12	11	8
18	12	11	10
19	12	11	12
20	12	11	15
21	12	12	8
22	12	12	10
23	12	12	12
24	12	12	15
25	8	10	8
26	8	10	10
27	8	10	12
28	8	10	15
29	8	11	8
30	8	11	10
31	8	11	12
32	8	11	15
33	8	12	8
34	8	12	10
35	8	12	12
36	8	12	15

Table 4.12 Cleaning efficiency at different levels of feed rate, angle of disc and speed of machine for the surface of cotton

Angle (deg)	Feed rate (kg/h)											
	20				12				8			
	Speed (rpm)											
	8	10	12	15	8	10	12	15	8	10	12	15
10	52	55	57	51	60	69	68	56	57	66	63	51
11	71	78	73	65	77	88	82	67	75	81	73	66
12	59	60	57	55	74	79	77	68	65	76	71	66

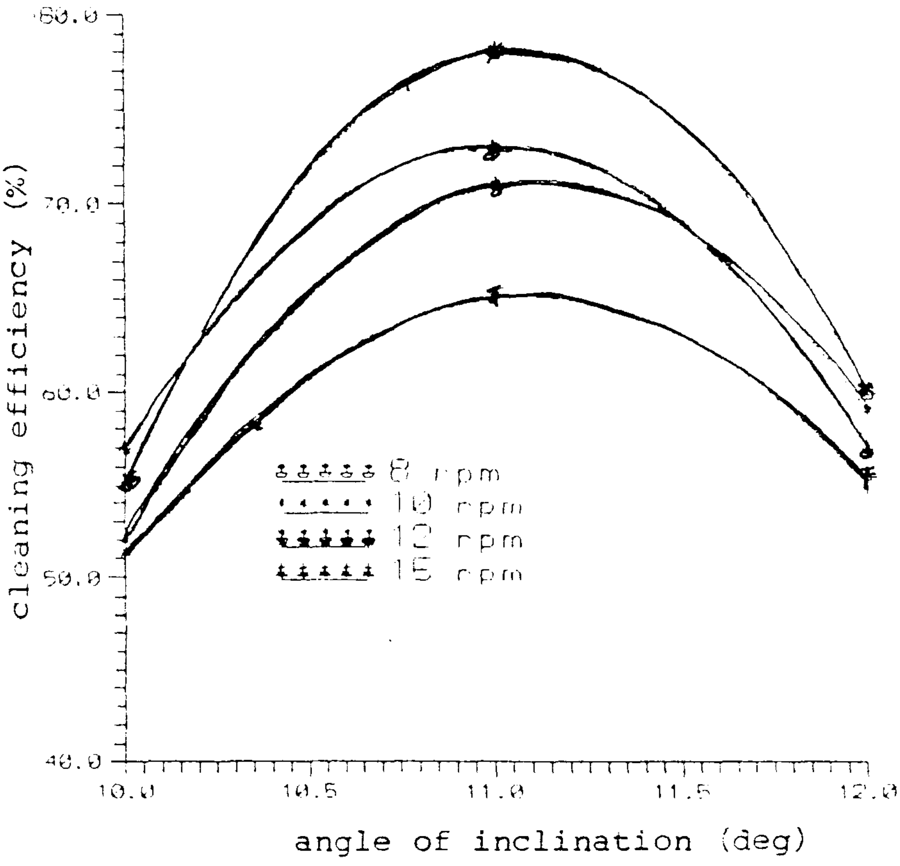


Fig.4.7 Cleaning efficiency at 20 kg/h for different speed and angle of disc for cotton surface

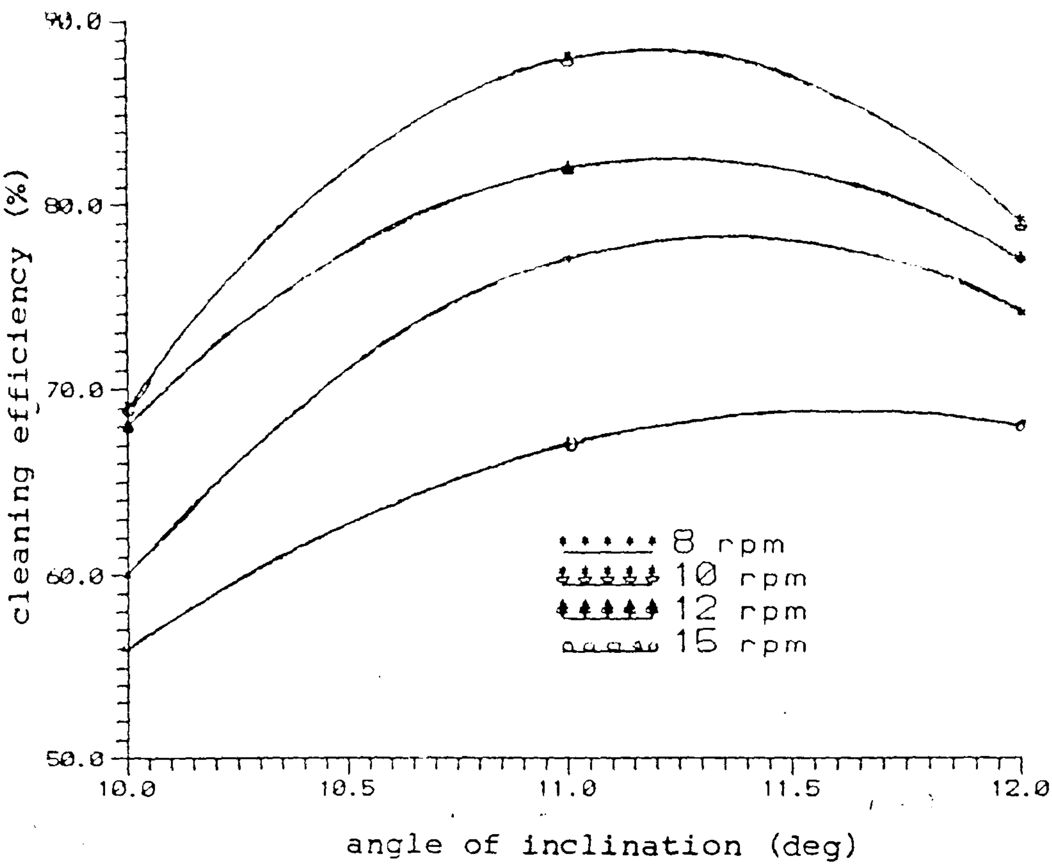


Fig.4.8 Cleaning efficiency at 12 kg/h for different speed and angle of disc for cotton surface

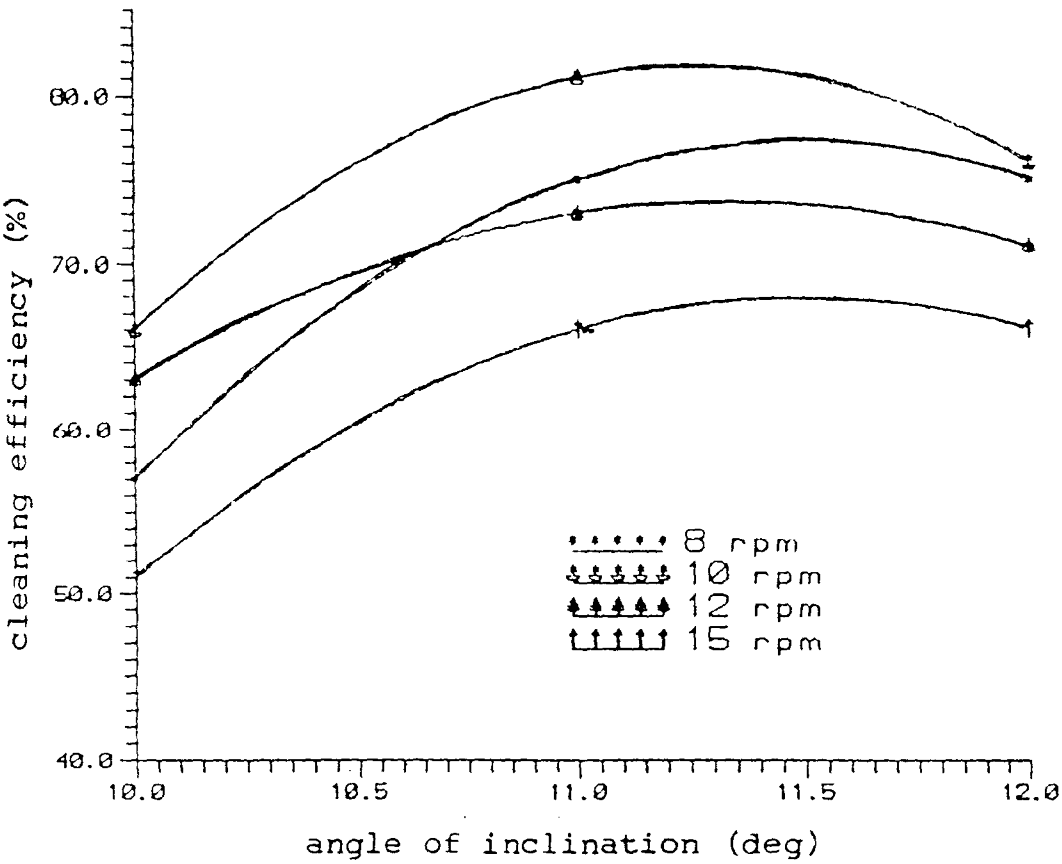


Fig.4.9 Cleaning efficiency at 8 kg/h for different speed and angle of disc for cotton surface

From these results, it is found that for all the experimental set-up, maximum cleaning efficiencies are found to occur at 11° angle of inclination of the disc. This pronounces that the optimum angle is 11° for deriving maximum cleaning efficiency.

From the results, it is revealed that 10° angle of inclination is not sufficient to roll down all the pepper grains towards the collecting position of cleaned grain outlet. Hence, these grains are scraped out at the foreign matter outlet which results in a lower cleaning efficiency.

At 12° angle of inclination, it is seen that some of the foreign materials are collected along with the cleaned pepper at cleaned grain outlet. This is because at 12° inclination causes pepper grains to roll down quickly. During this fast rolling, pepper grains collide with foreign particles and force them to move towards cleaned grain outlet. Hence, these particles are collected at the cleaned grain outlet along with cleaned pepper. Thus, the cleaning efficiency is reduced. It is also found that at 13° angle of disc, cleaning efficiency is further reduced.

Cleaning efficiencies at angle of inclination 10, 11 and 12 degrees under different levels of speed and feed rate are represented in Figures 4.10, 4.11 and 4.12.

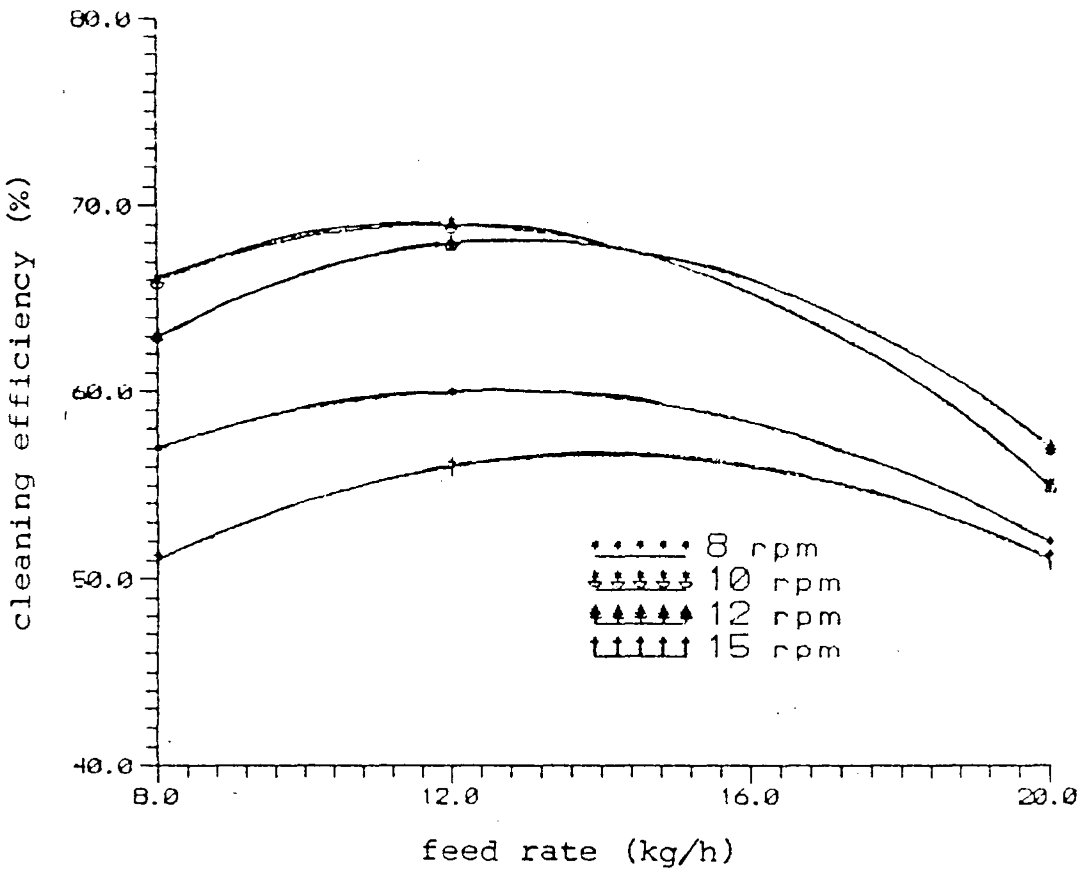


Fig.4.10 Cleaning efficiency at 10° for different speed and feed rate for cotton surface

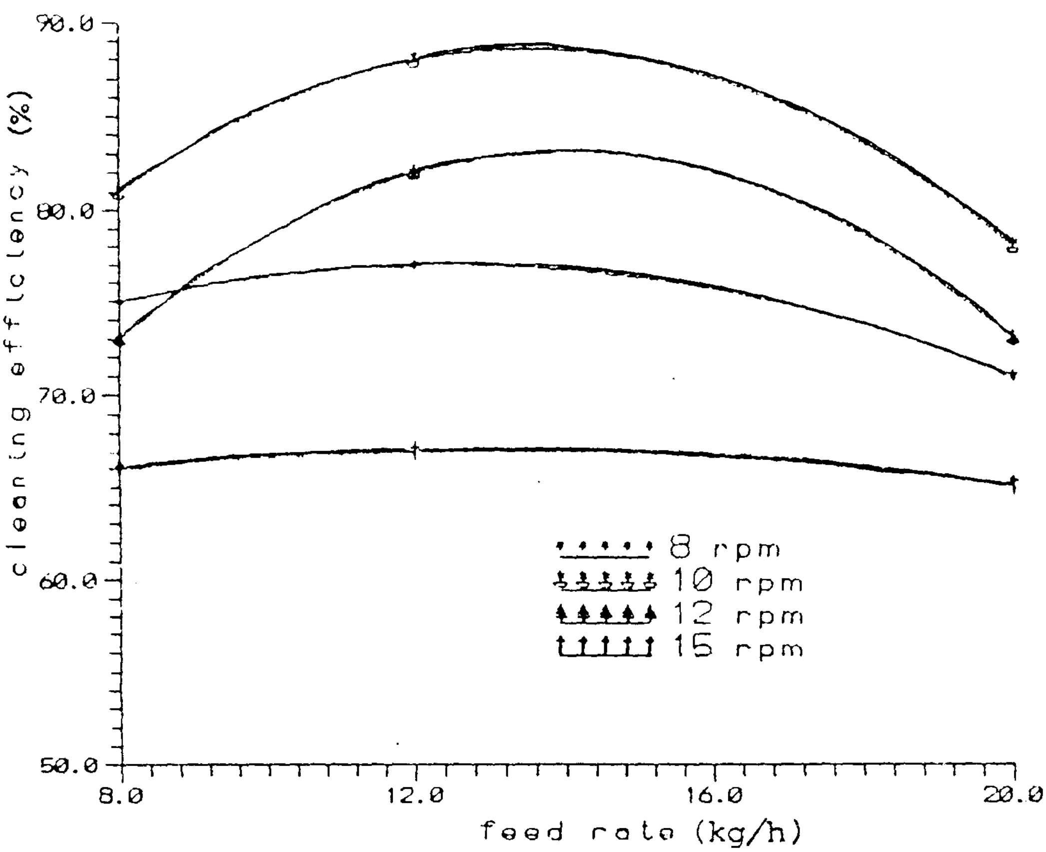


Fig.4.11 Cleaning efficiency at 11° for different speed and feed rate for cotton surface

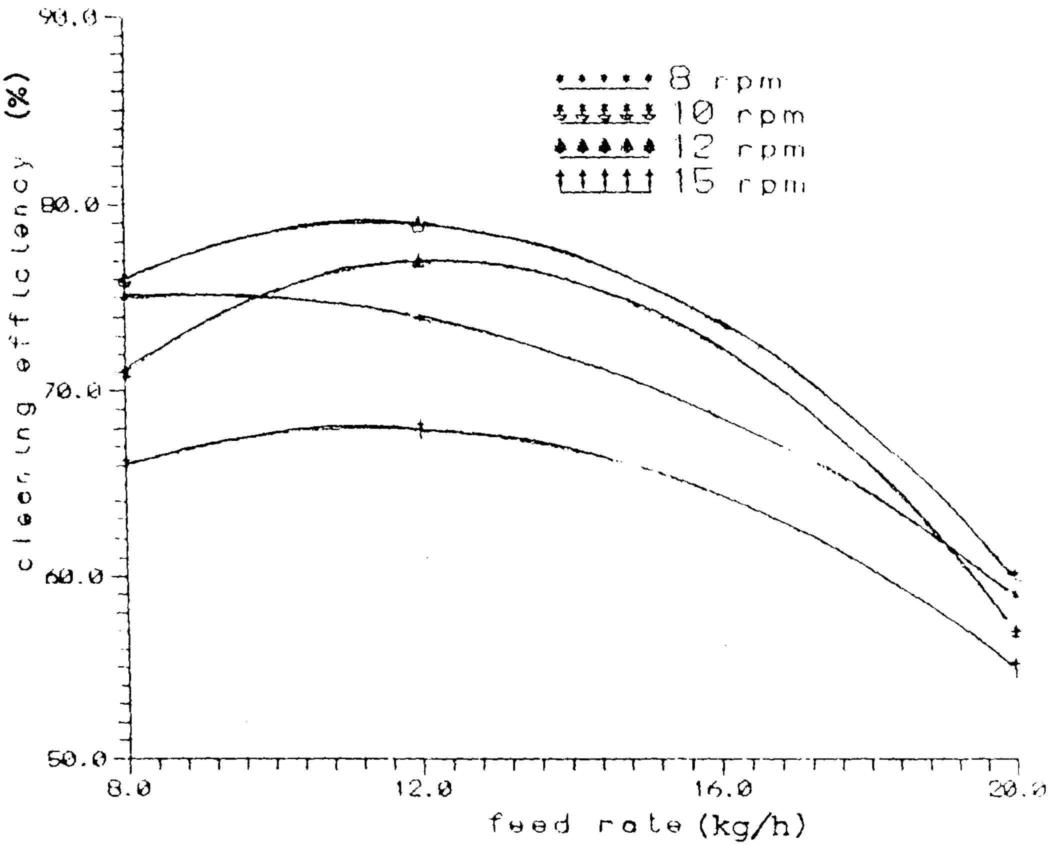


Fig.4.12 Cleaning efficiency at 12° for different speed and feed rate for cotton surface

The maximum cleaning efficiency of 88 per cent is obtained at a feed rate of 12 kg/h. The maximum efficiency at 20 kg/h is 78 per cent while that at 8 kg/h is 81 per cent (Fig.4.11).

It is found that as the feed rate is decreased from 20 kg/h to 12 kg/h, the cleaning efficiency increases. But, further decrease in feed rate to 8 kg/h does not cause any pronounced effect on the cleaning efficiency, rather, it shows a decreasing trend. Further decrease in feed rate to 5 kg/h, is also not causing any effect on cleaning efficiency.

From Figures 4.10. to 4.12. it is observed that the maximum cleaning efficiency is obtained at a feed rate of 12 kg/h, for most of the machine set-up. Hence, 12 kg/h is recommended as the optimum feed rate for deriving maximum cleaning efficiency.

It is observed that at a feed rate of 20 kg/h, the presence of foreign materials and increased number of pepper grains prevent the free rolling of bold pepper, which results in greater time of hold-up of pepper grains in the rotating disc. Hence, a part of bold pepper grain is scraped out at the foreign matter outlet which results in a lower cleaning efficiency.

From Figures 4.7. to 4.12. it is observed that the cleaning efficiency increases as the speed of the machine increases from 8 to 10 rpm. But, further increase to 15 rpm, shows a decreasing trend. It is found that maximum cleaning efficiency of 88 per cent is obtained at a speed of 10 rpm corresponding to the set-up of 11° angle of inclination and feed rate of 12 kg/h, which has been already identified as the optimum angle and feed rate. The corresponding efficiencies at 8 rpm is 77 per cent, at 12 rpm is 82 per cent and at 15 rpm, it is 67 per cent(Fig.4.11). From these results, it is also found that maximum cleaning efficiencies are obtained at a speed of 10 rpm for most of the machine set-up. Hence, for deriving maximum cleaning efficiency, the speed of machine is to be 10 rpm.

At 15 rpm, it is observed that a part of the pepper grains are thrown away towards the other end of the disc due to centrifugal force and these grains are scraped out at the foreign matter outlet, which results in a lower cleaning efficiency.

From the above findings, the optimum set-up of the machine for deriving maximum cleaning efficiency is as follows:

Feed rate	:	12 kg/h
Angle of inclination	:	11°
Speed	:	10 rpm

4.3 Energy requirement

Energy required for operating the machine with different output rpm of motor under no load condition and loaded condition are determined and shown in Table 4.13. Energy requirement varies from 0.099 kwh to 0.102 kwh for an output rpm of 400 to 700. Energy requirement for operating machine by engaging speed reduction unit (Loaded condition) varies from 0.130 to 0.136 kwh for an output rpm of machine from 8 to 15 as revealed in Table 4.13. It is seen that energy requirement for getting maximum cleaning efficiency is 0.132 kwh and this is for a speed of 10 rpm.

4.4 Economic Analysis

The calculation of the operating cost of the machine is given in Appendix IX. The fabrication cost of the machine including the cost of material comes to Rs 1,100/-. The cost of motor and speed reduction unit combined is taken as Rs. 8,000/- and depreciation and other fixed and operating costs are calculated separately. The operating cost is obtained as Rs 16.45/h. Hence, for cleaning 1 kg of black pepper, the cost amounted to Rs 1.37. By improving capacity of machine, cost of operation can be further reduced.

Table 4.13 Energy requirement for operating the machine

A. No load condition

Out put rpm of motor	Energy consumed (kwh)		
	1	2	mean
400	0.099	0.099	0.099
500	0.100	0.100	0.100
600	0.101	0.102	0.1015
700	0.102	0.102	0.102

B. Loaded condition

Output rpm of motor	Speed of machine rpm	Energy consumed(kwh)		
		1	2	Mean
400	8	0.130	0.130	0.130
500	10	0.132	0.132	0.132
600	12	0.134	0.135	0.135
700	15	0.136	0.136	0.136

4.5 Analysis of data

To understand the effect of each parameter on the cleaning efficiency, a 3 x 3 x 4 factorial experiment for completely randomized design is carried out and the results are shown in Appendices IV & VI.

4.5.1 Analysis of data while testing on the surface of mica

From the experimental analysis, it is inferred that all the three parameters, viz., feed rate, angle of inclination and speed of machine significantly affect the overall cleaning efficiency, since F-values for these three parameters falls on the rejection region. Among these parameters 'angle of inclination' of disc (Factor B) has maximum effect on cleaning efficiency, because it has the maximum F-value of 535.81. The F-value for the factor 'feed rate' (Factor A) is 112.67 and for the factor 'speed' (Factor C) is 92.13.

The analysis further reveals that with an F-value of 6.50, the combined effect of feed rate and angle of inclination has more effect on the cleaning efficiency than the combined effect of feed rate and speed which has an F-value of 2.91. The combined effect of angle and speed has no influence on cleaning efficiency.

4.5.2 Analysis of data while testing on the cotton surface

Here also it is inferred that all the three parameters viz., feed rate, angle of inclination and speed of machine significantly affects the overall cleaning efficiency. Among the three parameters, the factor 'angle of inclination' (Factor B) has the maximum effect on cleaning efficiency with an F-value of 693.62. The F-value for the factor 'feed rate' (Factor A) is 342.21 and the F-value for the factor 'speed' (Factor C) is 215.89.

The analysis further reveals that with an F-value of 40.75, the combined effect of feed rate and the angle of inclination has more influence on the cleaning efficiency compared to the combined effect of feed rate and speed and also the angle and speed. With an F-value of 14.76, the combined effect of angle and speed has more influence on the cleaning efficiency as compared to the simultaneous effect of feed rate and speed, which has an F-value of 10.34.

It is observed that for both the surfaces, namely, surfaces of mica and cotton, the maximum cleaning efficiency is obtained at a feed rate of 12 kg/h and at a speed of 10 rpm. In the case of the mica surface, the maximum cleaning efficiency is obtained at a 9° angle of inclination of disc to the horizontal while in the case of cotton surface, the maximum efficiency is obtained at an angle of inclination 11° to the horizontal. Comparing both the testing conditions, a better performance is obtained for the cotton surface.

Summary

SUMMARY

Black pepper is one of the most important spices in the world. Trading in black pepper occupies an important position in the economy of producing countries. Besides giving employment and sustenance to growers, pepper contributes enormously to the foreign exchange earnings of the producing countries.

The processing, primarily involves cleaning of black pepper admixture to separate different fractions of black pepper and removal of solid contaminants. The traditional methods of winnowing, and spreading the material on floor/mat and hand picking the contaminants are time consuming and labour intensive processes. The existing mechanised systems such as winnower, specific gravity/cyclone/spiral separators etc. are expensive and difficult to be maintained by small or medium scale operators.

In an attempt to overcome the above mentioned problems in the process of cleaning, the present work is undertaken. The physical properties of black pepper relevant to the cleaning process are studied.

The black pepper on visual observation is found to be nearly spherical in shape with a mean sphericity of 93.20 per cent. The size of black pepper grain along its major axis varies from 4.75 to 5.60 mm. The average weight of a pepper grain is found to be 0.060 g. The average volume of a pepper grain varies from 0.053 to 0.055 cc with a mean value of 0.054 cc. The average true density of pepper grain is 0.878 g/cc with a range of values between 0.806 to 0.952 g/cc. Mean bulk density of pepper grain is 0.474 g/cc with values between 0.472 to 0.476 g/cc. The mean moisture content of pepper grain is 10.7 per cent. Moisture contents are in the range 10.5 to 10.9 per cent. The specific gravity of black pepper varies in the range of 1.11 to 1.17 with a mean value of 1.15. The mean coefficient of sliding and rolling friction are 0.12 and 0.13 respectively for the mica surface and 0.15 and 0.17 respectively for the cotton surface.

Based on the preliminary studies and trials, a rotary type black pepper cleaner is developed and its performance is evaluated.

The major parts comprising the black pepper cleaner are a circular disc, an involute shaped scraper, a drum sieve, a hopper and a collecting tray.

The black pepper admixture is fed to the drum sieve through a hopper fixed over the top of sieve. The drum sieve is rotated uniformly using a handle provided at the end of sieve. The black pepper admixture falls uniformly over the inclined rotating disc. Good pepper being nearly spherical in shape rolls down easily and is collected at one end, whereas the foreign materials most of which are non-spherical in shape cannot roll down as freely and are scraped out at the other end by means of an involute type scraper. Both these particles are received by a collecting tray placed below the disc.

The machine is tested for two surfaces, the mica surface and the cotton surface under different levels of speed, angle of inclination of disc and feed rate.

For testing on mica surface, following levels of treatments are taken:

Variable	**Level**
Speed	8, 10, 12, 15 rpm
Angle of disc	8, 9, 10 degree
Feed rate	20, 12, 8 kg/h

A total of thirty six set-up with different combination of the aforesaid parameters are obtained and the maximum cleaning efficiency of 75 per cent is obtained at the following machine set-up:

Feed rate	12 kg/h
Angle	9 degree
Speed	10 rpm

Based on trials conducted, the three feed rate selected for cotton surface are 20 kg/h, 12 kg/h and 8 kg/h. The angle of inclination selected for the disc are 10, 11 and 12 degrees. Similarly, the levels of speed are 8, 10, 12 and 15 rpm.

A total of thirty six set-up with different combinations of the aforesaid parameters are obtained and the maximum cleaning efficiency of 88 per cent is obtained at the following machine set up:

Feed rate	12 kg/h
Angle	11 degree
Speed	10 rpm

From the analysis of data carried out for both the surfaces of mica and cotton, it is inferred that all the three parameters viz., feed rate, angle of inclination of disc and speed of machine significantly influence the cleaning efficiency. Among these three parameters, the factor 'Angle of inclination' of disc has more effect on the cleaning efficiency.

It is suggested that the cleaning efficiency can be further improved by incorporating some modifications. Based on the above, the following future lines of work are suggested for further investigations on this machine.

1) The drum sieve is to be given a drive from a mechanical or electrical power source to obtain more uniformity in operation.

2) The effect of position and height of the feeding assembly is to be studied.

3) Trials have to be conducted on disc covered with other materials and surface characteristics.

4) By incorporating more number of units, the capacity and cleaning efficiency is to be increased.

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Appendices

APPENDIX I

OBSERVATIONS MADE UNDER DIFFERENT SET-UP OF THE MACHINE WHILE TESTING ON MICA SURFACE

Total weight of the feed (g) : 155
Weight of cleaned grain in the feed (g) : 150

Machine set-up - ANGLE = 8°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	132.00	130.50	129.00	130.50	112.30	119.30	121.50	117.70	110.85	113.20	116.30	113.45
Weight of foreign matter outlet (g)	23.00	24.50	26.00	24.50	42.70	35.70	33.50	37.30	44.15	41.80	38.70	41.55
Weight of cleaned grain at the cleaned grain outlet (g)	130.10	128.70	127.00	128.60	111.30	118.20	120.40	116.63	109.80	111.90	115.00	112.23
Weight of cleaned grain at the foreign matter outlet (g)	19.90	21.30	23.00	21.40	38.70	31.80	29.60	33.37	40.20	38.10	35.00	37.77
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.985	-	-	-	0.991	-	-	-	0.989
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.873	-	-	-	0.895	-	-	-	0.909
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	53	-	-	-	61	-	-	-	57

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 8°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	135.00	135.00	135.20	135.07	119.60	121.50	120.20	120.43	116.60	117.20	113.80	115.87
Weight of foreign matter outlet (g)	20.00	20.00	19.80	19.93	35.40	33.50	34.80	34.57	38.40	37.80	41.20	39.13
Weight of cleaned grain at the cleaned grain outlet (g)	133.40	133.50	133.70	133.53	118.65	120.60	119.20	119.48	115.50	116.10	112.90	114.83
Weight of cleaned grain at the foreign matter outlet (g)	16.60	16.50	16.40	16.50	31.35	29.40	30.80	30.52	34.50	33.90	37.10	35.17
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.989	-	-	-	0.992	-	-	-	0.991
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.828	-	-	-	0.883	-	-	-	0.899
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	61	-	-	-	65	-	-	-	61

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 8°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	128.00	127.00	126.20	127.07	121.75	121.50	123.00	122.08	119.10	117.20	114.60	116.97
Weight of foreign matter outlet (g)	27.00	28.00	28.80	27.93	33.25	33.50	32.00	32.92	35.90	37.80	40.40	38.03
Weight of cleaned grain at the cleaned grain outlet (g)	126.25	125.00	124.40	125.22	120.50	120.30	121.60	120.80	117.80	116.00	113.60	115.80
Weight of cleaned grain at the foreign matter outlet (g)	23.75	25.00	25.60	24.78	29.50	29.70	28.40	29.20	32.30	34.00	36.40	34.23
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.985	-	-	-	0.989	-	-	-	0.990
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.887	-	-	-	0.887	-	-	-	0.900
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	52	-	-	-	60	-	-	-	59

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 8°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	109.50	120.00	121.00	116.83	106.70	104.20	109.50	106.80	108.65	107.20	105.40	107.08
Weight of foreign matter outlet (g)	45.50	35.00	34.00	38.17	48.30	50.80	45.50	48.20	46.35	47.80	49.60	47.92
Weight of cleaned grain at the cleaned grain outlet (g)	108.00	118.50	119.20	115.23	105.30	103.00	108.00	105.43	107.30	105.80	104.20	105.77
Weight of cleaned grain at the foreign matter outlet (g)	42.00	31.50	30.80	34.77	44.70	47.00	37.00	42.90	42.70	44.20	45.80	44.23
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.986	-	-	-	0.987	-	-	-	0.988
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.911	-	-	-	0.890	-	-	-	0.923
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	52	-	-	-	56	-	-	-	52

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 9°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	147.00	144.00	145.20	145.40	143.95	142.05	141.40	142.47	135.60	131.80	133.60	133.67
Weight of foreign matter outlet (g)	8.00	11.00	9.80	9.60	11.05	12.95	13.60	12.53	19.40	23.20	21.40	21.33
Weight of cleaned grain at the cleaned grain outlet (g)	145.20	142.50	143.40	143.70	142.85	141.05	140.35	141.42	134.50	130.60	132.50	132.53
Weight of cleaned grain at the foreign matter outlet (g)	4.80	7.50	6.60	6.30	7.15	8.95	9.65	8.58	15.50	19.40	17.50	17.47
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.988	-	-	-	0.993	-	-	-	0.992
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.656	-	-	-	0.685	-	-	-	0.819
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	63	-	-	-	74	-	-	-	68

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 9°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	144.10	143.50	142.10	143.23	143.70	143.95	144.20	143.95	140.20	138.70	136.50	138.47
Weight of foreign matter outlet (g)	10.90	11.50	12.90	11.77	11.30	11.05	10.80	11.05	14.80	16.30	18.50	16.53
Weight of cleaned grain at the cleaned grain outlet (g)	142.60	142.00	140.80	141.80	142.60	143.00	143.10	142.90	139.00	137.70	135.60	137.43
Weight of cleaned grain at the foreign matter outlet (g)	7.40	8.00	9.20	8.20	7.40	7.00	6.90	7.10	11.00	12.30	14.40	12.57
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.990	-	-	-	0.993	-	-	-	0.993
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.697	-	-	-	0.643	-	-	-	0.760
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	67	-	-	-	75	-	-	-	73

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 9°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	145.90	144.80	147.50	146.07	143.20	143.80	142.60	143.20	140.80	138.80	137.60	139.07
Weight of foreign matter outlet (g)	9.10	10.20	7.50	8.93	11.80	11.30	12.40	11.83	14.20	16.20	17.40	15.93
Weight of cleaned grain at the cleaned grain outlet (g)	144.25	143.00	145.70	144.32	142.10	142.85	141.50	142.15	139.80	137.60	136.40	137.93
Weight of cleaned grain at the foreign matter outlet (g)	5.75	7.00	4.30	5.68	7.90	7.25	8.50	7.88	10.20	12.40	13.60	12.07
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.988	-	-	-	0.993	-	-	-	0.992
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.636	-	-	-	0.666	-	-	-	0.757
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	62	-	-	-	75	-	-	-	71

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 9°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	146.00	145.20	146.10	145.77	139.80	143.45	141.00	141.42	124.10	125.45	129.10	126.22
Weight of foreign matter outlet (g)	9.00	9.80	8.90	9.23	15.20	11.55	14.00	13.58	30.90	29.55	25.90	28.78
Weight of cleaned grain at the cleaned grain outlet (g)	144.00	143.30	144.30	143.87	138.30	142.10	139.70	140.03	123.10	124.15	127.80	125.02
Weight of cleaned grain at the foreign matter outlet (g)	6.00	6.70	5.70	6.13	11.70	7.90	10.30	9.97	26.90	25.85	22.20	24.98
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.987	-	-	-	0.990	-	-	-	0.990
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.664	-	-	-	0.734	-	-	-	0.868
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	59	-	-	-	67	-	-	-	63

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 10°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	151.60	150.65	150.10	150.78	150.30	150.00	150.10	150.13	149.10	149.70	148.20	149.00
Weight of foreign matter outlet (g)	3.40	4.35	4.90	4.22	4.70	5.00	4.90	4.87	5.90	5.30	6.80	6.00
Weight of cleaned grain at the cleaned grain outlet (g)	149.40	148.30	147.80	148.50	148.05	147.80	148.00	147.95	146.80	147.30	146.10	146.73
Weight of cleaned grain at the foreign matter outlet (g)	0.60	1.70	2.20	1.50	1.95	2.20	2.00	2.05	3.20	2.70	3.90	3.27
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.985	-	-	-	0.985	-	-	-	0.985
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.356	-	-	-	0.421	-	-	-	0.544
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	53	-	-	-	55	-	-	-	53

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 10°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	150.45	151.15	151.00	150.87	150.00	150.50	151.00	150.50	148.75	149.20	148.00	148.65
Weight of foreign matter outlet (g)	4.55	3.85	4.00	4.13	5.00	4.50	4.00	4.50	6.25	5.80	7.00	6.35
Weight of cleaned grain at the cleaned grain outlet (g)	148.15	149.80	148.50	148.82	148.30	148.60	149.10	148.67	146.35	147.00	146.20	146.52
Weight of cleaned grain at the foreign matter outlet (g)	1.85	1.20	1.50	1.52	1.70	1.40	0.90	1.33	3.65	3.00	3.80	3.48
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.986	-	-	-	0.988	-	-	-	0.986
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.367	-	-	-	0.296	-	-	-	0.549
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	58	-	-	-	62	-	-	-	56

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 10°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	150.60	151.60	151.65	151.28	150.10	149.80	150.00	149.97	147.50	146.80	147.10	147.13
Weight of foreign matter outlet (g)	4.40	3.40	3.35	3.72	4.90	5.20	5.00	5.03	7.50	8.20	7.90	7.87
Weight of cleaned grain at the cleaned grain outlet (g)	148.30	149.10	149.25	148.88	148.30	147.80	148.00	148.03	145.10	144.60	144.90	144.87
Weight of cleaned grain at the foreign matter outlet (g)	1.70	0.90	0.75	1.12	1.70	2.20	2.00	1.97	4.90	5.40	5.10	5.13
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.984	-	-	-	0.987	-	-	-	0.985
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.300	-	-	-	0.391	-	-	-	0.653
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	51	-	-	-	60	-	-	-	52

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 10°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	148.30	149.65	148.70	148.88	150.00	150.00	150.50	150.17	144.90	147.80	142.70	145.13
Weight of foreign matter outlet (g)	6.70	5.35	6.30	6.12	5.00	5.00	4.50	4.83	9.50	7.20	12.30	9.67
Weight of cleaned grain at the cleaned grain outlet (g)	145.80	147.00	146.10	146.30	147.65	147.50	148.00	148.72	142.50	145.20	140.20	142.63
Weight of cleaned grain at the foreign matter outlet (g)	4.20	3.00	3.90	3.70	2.35	2.50	2.00	2.28	6.90	4.80	9.80	7.17
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.983	-	-	-	0.984	-	-	-	0.983
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.605	-	-	-	0.472	-	-	-	0.741
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	47	-	-	-	50	-	-	-	47

Contd......

APPENDIX I (Contd...)

Machine set-up - ANGLE = 11°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	151.75	153.20	153.70	152.88	152.00	151.60	152.80	152.13	150.30	151.70	151.10	151.03
Weight of foreign matter outlet (g)	3.25	1.80	1.30	2.12	3.00	3.40	2.20	2.87	4.70	3.30	3.90	3.97
Weight of cleaned grain at the cleaned grain outlet (g)	148.90	149.80	149.80	149.50	149.50	149.40	149.80	149.57	147.90	149.20	148.50	148.53
Weight of cleaned grain at the foreign matter outlet (g)	1.10	0.20	0.20	0.50	0.50	0.60	0.20	0.43	2.10	0.80	1.50	1.47
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.978	-	-	-	0.983	-	-	-	0.983
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.236	-	-	-	0.151	-	-	-	3.70
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	32	-	-	-	48	-	-	-	49

APPENDIX I (Contd....)

Machine set-up - ANGLE = 9°, RPM = 10, Feed rate = 5 kg/h

Description	1	2	3	Mean
Weight of cleaned grain outlet (g)	136.60	141.20	143.70	140.50
Weight of foreign matter outlet (g)	18.40	13.80	11.30	14.50
Weight of cleaned grain at the cleaned grain outlet (g)	135.40	139.80	142.20	139.13
Weight of cleaned grain at the foreign matter outlet (g)	14.60	10.20	7.80	10.87
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.990
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.749
Fraction of cleaned grain in the feed (F)	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	67

APPENDIX II

OBSERVATIONS MADE UNDER DIFFERENT SET-UP OF THE MACHINE WHILE TESTING ON THE COTTON SURFACE

Total weight of the feed (g) : 155
Weight of cleaned grain in the feed (g) : 150

Machine set-up - ANGLE = 10°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	90.50	100.20	98.30	96.33	107.50	109.20	110.30	109.00	104.50	106.20	108.60	106.43
Weight of foreign matter outlet (g)	64.50	54.80	56.70	58.67	47.50	45.80	44.70	46.00	50.50	48.80	46.40	48.57
Weight of cleaned grain at the cleaned grain outlet (g)	89.50	99.40	97.30	95.40	106.60	108.40	109.40	108.13	103.70	105.30	107.50	105.50
Weight of cleaned grain at the foreign matter outlet (g)	60.50	50.60	52.70	54.60	43.40	41.60	40.60	41.87	46.30	44.70	42.50	44.50
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.990	-	-	-	0.992	-	-	-	0.991
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.931	-	-	-	0.910	-	-	-	0.916
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	52	-	-	-	60	-	-	-	57

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 10°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	91.70	94.50	97.30	94.50	125.00	122.30	124.20	123.83	120.20	123.20	120.80	121.40
Weight of foreign matter outlet (g)	63.30	60.50	57.70	60.50	30.00	32.70	30.80	31.17	34.80	31.80	34.20	33.60
Weight of cleaned grain at the cleaned grain outlet (g)	91.00	94.00	96.70	93.90	124.15	121.60	123.40	123.05	119.40	122.20	119.95	120.52
Weight of cleaned grain at the foreign matter outlet (g)	59.00	56.00	53.30	56.10	25.85	28.40	26.60	26.95	30.60	27.80	30.05	29.48
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.994	-	-	-	0.994	-	-	-	0.993
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.927	-	-	-	0.865	-	-	-	0.877
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	55	-	-	-	69	-	-	-	66

Contd......

APPENDIX II (Contd.....)

Machine set-up - ANGLE = 10°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	99.81	98.40	97.60	98.60	123.30	127.00	124.50	124.93	120.80	118.60	117.90	119.10
Weight of foreign matter outlet (g)	55.19	56.60	57.40	56.40	31.70	28.00	30.50	30.07	34.20	36.40	37.10	35.90
Weight of cleaned grain at the cleaned grain outlet (g)	99.17	97.70	97.00	97.96	122.50	126.10	123.60	124.07	119.70	117.50	117.10	118.10
Weight of cleaned grain at the foreign matter outlet (g)	50.81	52.30	53.00	52.04	27.50	23.90	26.40	25.93	30.30	32.50	32.90	31.90
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.993	-	-	-	0.993	-	-	-	0.992
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.923	-	-	-	0.863	-	-	-	0.889
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	57	-	-	-	68	-	-	-	63

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 10°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	89.00	92.40	95.10	92.17	100.50	102.00	104.20	102.23	100.20	98.40	103.60	100.73
Weight of foreign matter outlet (g)	66.00	62.60	59.90	62.83	54.50	53.00	50.80	52.77	54.80	56.60	51.40	54.27
Weight of cleaned grain at the cleaned grain outlet (g)	88.00	93.40	94.00	91.73	99.70	101.10	103.20	101.33	99.20	97.20	102.40	99.60
Weight of cleaned grain at the foreign matter outlet (g)	62.00	58.60	56.00	58.93	50.30	48.90	46.80	48.67	50.80	52.80	47.60	50.40
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.995	-	-	-	0.991	-	-	-	0.989
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.938	-	-	-	0.922	-	-	-	0.929
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	51	-	-	-	56	-	-	-	51

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 11°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	137.55	132.00	135.70	135.08	126.40	122.50	129.50	126.13	126.60	129.40	130.90	128.97
Weight of foreign matter outlet (g)	17.45	23.00	19.30	19.92	28.60	32.50	25.50	28.87	28.40	25.60	24.10	26.03
Weight of cleaned grain at the cleaned grain outlet (g)	136.40	131.00	134.70	134.03	126.00	122.10	129.00	125.70	126.00	128.70	130.30	128.33
Weight of cleaned grain at the foreign matter outlet (g)	13.60	19.00	15.30	15.97	24.00	27.90	21.00	24.30	24.00	21.30	19.70	21.67
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.992	-	-	-	0.997	-	-	-	0.995
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.802	-	-	-	0.842	-	-	-	0.832
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	71	-	-	-	77	-	-	-	75

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 11°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	144.10	143.28	141.60	142.99	137.85	139.20	143.35	140.13	130.60	133.80	135.05	133.48
Weight of foreign matter outlet (g)	10.90	11.72	13.40	12.01	17.15	15.80	11.65	14.87	23.40	21.20	19.95	21.52
Weight of cleaned grain at the cleaned grain outlet (g)	143.10	142.40	140.90	142.13	137.65	138.90	142.95	135.83	131.30	133.30	134.55	133.05
Weight of cleaned grain at the foreign matter outlet (g)	6.90	7.60	9.10	7.87	12.35	11.10	7.05	10.17	18.70	16.70	15.45	16.95
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.994	-	-	-	0.998	-	-	-	0.997
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.655	-	-	-	0.684	-	-	-	0.788
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	78	-	-	-	88	-	-	-	81

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 11°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	137.55	132.00	135.70	135.08	136.80	132.30	134.50	134.53	118.20	122.50	120.60	120.43
Weight of foreign matter outlet (g)	17.45	23.00	19.30	19.92	18.20	22.70	20.50	20.47	36.80	32.50	34.40	34.57
Weight of cleaned grain at the cleaned grain outlet (g)	136.40	131.20	134.85	134.15	136.40	131.95	133.95	134.02	117.90	121.90	120.10	119.97
Weight of cleaned grain at the foreign matter outlet (g)	13.60	18.80	15.15	15.85	13.80	18.05	16.05	16.05	32.10	28.10	29.90	30.03
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.993	-	-	-	0.996	-	-	-	0.996
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.796	-	-	-	0.784	-	-	-	0.869
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	73	-	-	-	82	-	-	-	73

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 11°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	118.70	123.55	121.30	121.18	116.10	120.20	119.80	118.70	120.00	116.60	114.80	117.18
Weight of foreign matter outlet (g)	35.30	31.45	33.70	33.48	38.90	34.80	35.20	36.80	35.00	38.40	40.20	37.87
Weight of cleaned grain at the cleaned grain outlet (g)	117.80	122.55	120.40	120.25	115.50	119.30	119.10	117.97	119.10	115.90	114.10	116.37
Weight of cleaned grain at the foreign matter outlet (g)	31.20	27.45	29.60	29.42	34.50	30.70	30.90	32.03	30.90	34.10	35.90	33.63
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.992	-	-	-	0.994	-	-	-	0.993
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.879	-	-	-	0.882	-	-	-	0.888
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	65	-	-	-	67	-	-	-	66

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 12°, RPM = 8

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	142.60	145.40	144.80	144.27	143.75	146.60	142.50	144.28	140.00	142.80	144.60	142.47
Weight of foreign matter outlet (g)	12.40	9.60	10.20	10.73	11.25	8.40	12.50	10.72	15.00	12.20	10.40	12.53
Weight of cleaned grain at the cleaned grain outlet (g)	140.80	143.50	142.90	142.40	142.65	145.30	141.50	143.22	139.10	141.80	143.40	141.43
Weight of cleaned grain at the foreign matter outlet (g)	9.20	6.50	7.10	7.60	7.35	4.70	8.50	6.78	10.90	8.20	6.60	8.57
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.987	-	-	-	0.993	-	-	-	0.993
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.708	-	-	-	0.633	-	-	-	0.684
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	59	-	-	-	74	-	-	-	75

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 12°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	141.63	142.80	143.00	142.48	147.40	149.20	148.10	148.23	144.80	148.20	145.50	146.17
Weight of foreign matter outlet (g)	13.37	12.20	12.00	12.52	7.60	5.80	6.90	6.77	10.20	6.80	9.50	8.83
Weight of cleaned grain at the cleaned grain outlet (g)	139.93	140.90	141.20	140.68	146.40	148.10	147.30	147.27	143.80	147.10	144.40	145.10
Weight of cleaned grain at the foreign matter outlet (g)	10.07	9.10	8.80	9.32	3.60	1.90	2.70	2.73	6.20	2.90	5.60	4.90
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.987	-	-	-	0.993	-	-	-	0.993
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.744	-	-	-	0.404	-	-	-	0.555
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	60	-	-	-	79	-	-	-	76

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 12°, RPM = 12

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	138.80	139.70	141.20	139.90	145.50	143.75	141.80	143.68	140.60	141.20	143.80	141.87
Weight of foreign matter outlet (g)	16.20	15.30	13.80	15.10	9.50	11.25	13.20	11.32	14.40	13.80	11.20	13.13
Weight of cleaned grain at the cleaned grain outlet (g)	137.00	137.90	139.20	138.03	144.50	142.90	140.80	142.67	139.80	140.10	142.55	140.68
Weight of cleaned grain at the foreign matter outlet (g)	13.00	12.10	10.80	11.97	5.50	7.10	9.20	7.33	10.70	9.90	7.45	9.32
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.987	-	-	-	0.993	-	-	-	0.992
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.792	-	-	-	0.648	-	-	-	0.709
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	57	-	-	-	77	-	-	-	71

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 12°, RPM = 15

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	139.60	140.00	141.50	140.37	140.50	134.68	139.50	138.23	135.60	137.50	131.80	134.97
Weight of foreign matter outlet (g)	15.40	15.00	13.50	14.63	14.50	20.32	15.50	16.77	19.40	17.50	23.20	20.03
Weight of cleaned grain at the cleaned grain outlet (g)	137.70	138.10	139.30	138.37	139.15	133.48	138.30	136.91	134.30	136.20	130.60	133.70
Weight of cleaned grain at the foreign matter outlet (g)	12.30	12.90	10.70	11.63	10.85	16.52	11.70	13.09	15.70	13.80	19.40	16.30
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.986	-	-	-	0.990	-	-	-	0.991
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.795	-	-	-	0.780	-	-	-	0.814
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	55	-	-	-	68	-	-	-	66

Contd......

APPENDIX II (Contd....)

Machine set-up - ANGLE = 13°, RPM = 10

Description	Feed rate (kg/h)											
	20				12				8			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Weight of cleaned grain outlet (g)	141.63	142.80	143.00	142.48	149.88	148.60	151.00	149.83	147.00	146.60	149.10	147.57
Weight of foreign matter outlet (g)	13.37	12.20	12.00	12.52	5.12	6.40	4.00	5.17	8.00	8.40	5.90	7.43
Weight of cleaned grain at the cleaned grain outlet (g)	139.83	140.90	140.90	140.54	147.95	147.00	149.30	148.08	145.20	144.60	147.10	145.63
Weight of cleaned grain at the foreign matter outlet (g)	10.17	9.10	9.10	9.46	2.05	3.00	0.70	1.92	4.80	5.40	2.90	4.37
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.986	-	-	-	0.988	-	-	-	0.987
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.755	-	-	-	0.370	-	-	-	0.587
Fraction of cleaned grain in the feed (F)	-	-	-	0.968	-	-	-	0.968	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	57	-	-	-	64	-	-	-	59

Contd.....

APPENDIX II (Contd....)

Machine set-up - ANGLE = 11°, RPM = 10, Feed rate = 5 kg/h

Description	1	2	3	Mean
Weight of cleaned grain outlet (g)	130.70	129.60	133.50	131.27
Weight of foreign matter outlet (g)	24.30	25.40	21.50	23.73
Weight of cleaned grain at the cleaned grain outlet (g)	130.10	129.00	132.70	130.60
Weight of cleaned grain at the foreign matter outlet (g)	19.90	21.00	17.30	19.40
Fraction of cleaned grain from cleaned grain outlet (E)	-	-	-	0.995
Fraction of cleaned grain from foreign matter outlet (G)	-	-	-	0.817
Fraction of cleaned grain in the feed (F)	-	-	-	0.968
Cleaning efficiency (%)	-	-	-	75

APPENDIX III

SET-UP FOR THE COMPUTERISED STATISTICAL ANALYSIS OF THE DATA FOR THE SURFACE OF MICA

Case No.	Feed Rate (kg/h)	Angle (deg)	Speed (rpm)	Replication	Cleaning efficiency (%)
1	1	1	1	1	54
2	1	1	1	2	55
3	1	1	1	3	51
4	1	1	2	1	60
5	1	1	2	2	62
6	1	1	2	3	60
7	1	1	3	1	55
8	1	1	3	2	50
9	1	1	3	3	53
10	1	1	4	1	50
11	1	1	4	2	55
12	1	1	4	3	51
13	1	2	1	1	62
14	1	2	1	2	66
15	1	2	1	3	61
16	1	2	2	1	66
17	1	2	2	2	66
18	1	2	2	3	69
19	1	2	3	1	65
20	1	2	3	2	61
21	1	2	3	3	62
22	1	2	4	1	57

Appendix III (contd...)

23	1	2	4	2	59
24	1	2	4	3	61
25	1	3	1	1	55
26	1	3	1	2	52
27	1	3	1	3	53
28	1	3	2	1	53
29	1	3	2	2	52
30	1	3	2	3	49
31	1	3	3	1	53
32	1	3	3	2	48
33	1	3	3	3	51
34	1	3	4	1	48
35	1	3	4	2	46
36	1	3	4	3	46
37	2	1	1	1	59
38	2	1	1	2	61
39	2	1	1	3	63
40	2	1	2	1	64
41	2	1	2	2	66
42	2	1	2	3	64
43	2	1	3	1	60
44	2	1	3	2	61
45	2	1	3	3	58
46	2	1	4	1	51
47	2	1	4	2	52
48	2	1	4	3	58

Appendix III (contd...)

49	2	2	1	1	74
50	2	2	1	2	75
51	2	2	1	3	74
52	2	2	2	1	74
53	2	2	2	2	77
54	2	2	2	3	74
55	2	2	3	1	74
56	2	2	3	2	77
57	2	2	3	3	73
58	2	2	4	1	64
59	2	2	4	2	69
60	2	2	4	3	69
61	2	3	1	1	54
62	2	3	1	2	55
63	2	3	1	3	57
64	2	3	2	1	65
65	2	3	2	2	61
66	2	3	2	3	61
67	2	3	3	1	63
68	2	3	3	2	59
69	2	3	3	3	59
70	2	3	4	1	52
71	2	3	4	2	49
72	2	3	4	3	49
73	3	1	1	1	58
74	3	1	1	2	55

Appendix III (contd....)

75	3	1	1	3	57
76	3	1	2	1	60
77	3	1	2	2	60
78	3	1	2	3	62
79	3	1	3	1	58
80	3	1	3	2	59
81	3	1	3	3	61
82	3	1	4	1	52
83	3	1	4	2	51
84	3	1	4	3	53
85	3	2	1	1	70
86	3	2	1	2	66
87	3	2	1	3	69
88	3	2	2	1	70
89	3	2	2	2	73
90	3	2	2	3	74
91	3	2	3	1	74
92	3	2	3	2	70
93	3	2	3	3	69
94	3	2	4	1	66
95	3	2	4	2	61
96	3	2	4	3	63
97	3	3	1	1	52
98	3	3	1	2	51
99	3	3	1	3	56
100	3	3	2	1	58

Appendix III (contd...)

101	3	3	2	2	55
102	3	3	2	3	58
103	3	3	3	1	50
104	3	3	3	2	50
105	3	3	3	3	54
106	3	3	4	1	49
107	3	3	4	2	46
108	3	3	4	3	46

APPENDIX IV

RESULT OF THE COMPUTERISED STATISTICAL ANALYSIS OF DATA FOR MICA SURFACE

Three factor completely randomised design

Case No. 1 to 108

Factorial ANOVA for the factors:

Replication (var 4: replication) with values from 1 to 3

Factor A (var 1: feed rate) with values from 1 to 3

Factor B (var 2: angle) with values from 1 to 3

Factor C (var 3: speed) with values from 1 to 4

Variable 5: Cleaning efficiency

ANALYSIS OF VARIANCE TABLE

Source	Degree of freedom	Sum of squares	Mean square	F value	Prob
Factor A	2	911.722	455.861	112.6613	0.0000
Factor B	2	4336.056	2168.028	535.8055	0.0000
AB	4	105.222	26.306	6.5011	0.0002
Factor C	3	1118.333	372.778	92.1281	0.0000
AC	6	70.72	11.787	2.9130	0.0134
BC	6	23.278	3.88	0.9588	-
ABC	12	138.333	11.528	2.849	0.0030
Error	72	291.333	4.046	-	-
Total	107	6995.000			

APPENDIX V

SET-UP FOR THE COMPUTERISED STATISTICAL ANALYSIS OF THE DATA FOR THE COTTON SURFACE

Case No.	Feed Rate (kg/h)	Angle (deg)	Speed (rpm)	Replication	Cleaning efficiency (%)
1	1	1	1	1	48
2	1	1	1	2	56
3	1	1	1	3	52
4	1	1	2	1	52
5	1	1	2	2	57
6	1	1	2	3	57
7	1	1	3	1	58
8	1	1	3	2	56
9	1	1	3	3	57
10	1	1	4	1	47
11	1	1	4	2	51
12	1	1	4	3	49
13	1	2	1	1	70
14	1	2	1	2	70
15	1	2	1	3	72
16	1	2	2	1	76
17	1	2	2	2	78
18	1	2	2	3	81
19	1	2	3	1	70
20	1	2	3	2	73
21	1	2	3	3	75
22	1	2	4	1	65

Appendix V (contd...)

23	1	2	4	2	65
24	1	2	4	3	66
25	1	3	1	1	60
26	1	3	1	2	59
27	1	3	1	3	59
28	1	3	2	1	61
29	1	3	2	2	58
30	1	3	2	3	60
31	1	3	3	1	58
32	1	3	3	2	59
33	1	3	3	3	55
34	1	3	4	1	57
35	1	3	4	2	57
36	1	3	4	3	52
37	2	1	1	1	58
38	2	1	1	2	61
39	2	1	1	3	61
40	2	1	2	1	69
41	2	1	2	2	70
42	2	1	2	3	69
43	2	1	3	1	69
44	2	1	3	2	69
45	2	1	3	3	68
46	2	1	4	1	56
47	2	1	4	2	55
48	2	1	4	3	55

Appendix V (contd...)

49	2	2	1	1	77
50	2	2	1	2	75
51	2	2	1	3	77
52	2	2	2	1	88
53	2	2	2	2	87
54	2	2	2	3	88
55	2	2	3	1	83
56	2	2	3	2	82
57	2	2	3	3	79
58	2	2	4	1	68
59	2	2	4	2	65
60	2	2	4	3	68
61	2	3	1	1	74
62	2	3	1	2	71
63	2	3	1	3	75
64	2	3	2	1	78
65	2	3	2	2	77
66	2	3	2	3	82
67	2	3	3	1	77
68	2	3	3	2	79
69	2	3	3	3	75
70	2	3	4	1	68
71	2	3	4	2	68
72	2	3	4	3	70
73	3	1	1	1	58
74	3	1	1	2	57

Appendix V (contd....)

75	3	1	1	3	55
76	3	1	2	1	66
77	3	1	2	2	65
78	3	1	2	3	66
79	3	1	3	1	62
80	3	1	3	2	61
81	3	1	3	3	53
82	3	1	4	1	53
83	3	1	4	2	49
84	3	1	4	3	52
85	3	2	1	1	73
86	3	2	1	2	73
87	3	2	1	3	76
88	3	2	2	1	83
89	3	2	2	2	79
90	3	2	2	3	80
91	3	2	3	1	73
92	3	2	3	2	71
93	3	2	3	3	72
94	3	2	4	1	64
95	3	2	4	2	66
96	3	2	4	3	65
97	3	3	1	1	74
98	3	3	1	2	75
99	3	3	1	3	73
100	3	3	2	1	76

Appendix V (contd...)

101	3	3	2	2	75
102	3	3	2	3	74
103	3	3	3	1	69
104	3	3	3	2	73
105	3	3	3	3	70
106	3	3	4	1	65
107	3	3	4	2	65
108	3	3	4	3	66

APPENDIX VI

RESULT OF THE COMPUTERISED STATISTICAL ANALYSIS OF DATA FOR COTTON SURFACE

Three factor completely randomised design

Case No. 1 to 108

Factorial ANOVA for the factors:

Replication (var 4: replication) with values from 1 to 3

Factor A (var 1: feed rate) with values from 1 to 3

Factor B (var 2: angle) with values from 1 to 3

Factor C (var 3: speed) with values from 1 to 4

Variable 5: Cleaning efficiency

ANALYSIS OF VARIANCE TABLE

Source	Degree of freedom	Sum of squares	Mean square	F value	Prob
Factor A	2	2205.352	1102.676	342.2098	0.0000
Factor B	2	4470.019	2235.009	693.6236	0.0000
AB	4	525.204	131.301	40.7486	0.0000
Factor C	3	2087.000	695.667	215.8966	0.0000
AC	6	199.833	33.306	10.336	0.0000
BC	6	285.389	47.565	14.7615	0.0000
ABC	12	38.278	3.190	0.9899	-
Error	72	232.000	3.222	-	-
Total	107	10043.074			

APPENDIX VII

Details of dynodrive variable speed motor

1. Dynodrive

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

2. Motor(Hindutan Brown Boveri) 3 phase Induction motor

Kw	:	0.37
H P	:	0.50
C R	:	50 c/s
r p m	:	1390

3. Rating and specification of electronic regulator

Power supply	: 200/220 V (+10 per cent(-) 15 per cent)
Cycles	: 50/60

Out put circuit

Capacity (w)	:	200
Current (A)	:	2.5
Voltage (Vdc)	:	80

Connection of thyristor	: Single phase, half-wave rectifying connection with free wheel diode
Speed setting input	: 12 Vdc(adjustable within + 20 per cent) input current upto 0.5 m A

Speed setting power supply	:	13 V 150 m A (Short circuiting(built in) at 100 m A transistor series control system)
Dynodrive speed variation	:	Less than 1 or 2 per cent 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 VIII

Specification of energy meter

Ampere	:	3 X 10
Volt	:	3 X 400
Cycles	:	50
1 kwh	:	112.5 revolution of disc
		Made by General Electric Co. of India (Pvt Ltd) Calcutta

APPENDIX IX

Calculation of operating cost

Initial cost(c):

Fabrication cost of cleaning machine including cost of material	=	Rs 1100/-
Initial cost of motor + speed reduction unit	=	Rs 8000/-
Average life of cleaning machine	=	10 years
Average life of motor	=	20 years
working hrs/year	=	1600
Salvage value(s)		
10 per cent of initial cost		
For motor	=	Rs 800/-
For cleaning machine	=	Rs 110/-

Fixed cost

1. Depreciation/h

For cleaning machine

$$= \frac{C - S}{L \times H}$$

$$= \frac{1100 - 110}{10 \times 1600}$$

$$= 0.06$$

For motor

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

$$= \text{Rs } 0.23$$

2. Interest on investment

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

For cleaning machine

$$= \frac{(1100 + 110) \times 15)}{2 \times 1600 \times 100}$$

$$= 0.05$$

For motor = $\frac{(8000 + 800) \times 15)}{2 \times 1600 \times 100}$

= Rs 0.41

Total fixed cost/h = 0.06+0.23+0.05+0.41

= 0.75 Rs/h

Variable cost

Labour = Rs 60/day
= Rs 7.50/ h

For 2 labour = Rs 15/h

Electricity charge = Rs 1/Kwh

= 0.132 X 1

= Rs 0.13

Repair & Maintenance

10 per cent of initial cost per annum

For cleaning machine = $\frac{1100 \times 10 \times 1}{100 \times 1600}$

= Rs 0.07

For motor = $\frac{8000 \times 10 \times 1}{100 \times 1600}$

= Rs 0.50

Total variable cost/h = 15+0.13+0.07+0.5

= 15.70 Rs/h

Total operating cost/h = 15.70 + 0.75

= Rs 16.45

DEVELOPMENT AND TESTING OF
A ROTARY TYPE BLACK PEPPER CLEANER

By

ABDUL WAHAB V. S.

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

1995

ABSTRACT

A power operated rotary type black pepper cleaner is developed, tested and its performance evaluated. The major parts are an inclined circular disc, an involute shaped scraper, a feeding unit and a collecting tray.

The black pepper admixture is fed to the drum sieve through a hopper. By rotating the sieve, feed material fall uniformly over one-half of the area of the inclined rotating disc. Good pepper grains being nearly spherical in shape roll down at one end, whereas foreign materials which cannot roll down as freely, is scraped out at the other end by means of an involute scraper. Both cleaned and uncleaned grains are received in a collecting tray placed below the disc. A 3-phase 0.5 HP variable speed dynodrive motor along with a 10:1 gear reduction unit operates the machine.

The important physical properties of black pepper relevant to cleaning process are also studied. The trials are repeated for the surfaces of mica and cotton under different levels of feed rate, angle of inclination and speed. Better performance is obtained in the case of cotton surface. Under these conditions, a cleaning efficiency of 88 per cent is obtained at a feed rate of 12 kg/h, angle of disc 11° and at a speed of 10 rpm. The cost of the machine excluding the power unit comes to Rs.1,100/-. The operating cost of machine is found to be Rs 16.45/h. It is recommended for further studies and modifications.