DEVELOPMENT AND TESTING OF A CLEANER CUM GRADER FOR BLACK PEPPER

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PROJECT REPORT

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DECLARATION

We here by declare that this project report entitled **"DEVELOPMENT AND TESTING OF A CLEANER CUM GRADER FOR BLACK PEPPER"** is a bonafide record of project work done by us and that the report has not previously formed on the basis for the award any degree, diploma, associateship, fellowship or other similar title to us, of any other University or Society.

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CERTIFICATE

Certified that this project report, entitled, **"DEVELOPMENT AND TESTING OF A CLEANER CUM GRADER FOR BLACK PEPPER"** is a record of project work done jointly by James P. George , Muneer K and Sharmila Mathew under my guidance and supervision and that it has not previously formed on the basis for the award of any degree, diploma, fellowship or associateship to them.

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James P George

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SYMBOLS AND ABBREVIATIONS

A	-	Ampere
Agric	-	Agricultural
ASAE	-	American Society of Agricultural Engineers
APS	-	Agricultural Processing
cm	-	Centi meters
cm^2	-	square centimetre
Dept.	-	Department
Engng	-	Engineering
Engrs	-	Engineers
et. al	-	And others
Fig.	-	Figure(s)
Govt.	-	Government
G.I	-	Galvanised Iron
h	-	hour (s)
H.P	-	Horse Power
Inc.	-	Incorporated
Inst.	-	Institution
J	-	Journal
KAU	-	Kerala Agricultural University
K.C.A.E.T	-	Kelappaji College of Agricultural Engineering and Technology
Kg	-	Kilogram
Kwh	-	Kilo Watt Hour
Ltd	-	Limited
Max	-	Maximum
Min	-	Minimum
MT	-	Metric Tonnes
M S	-	Mild steel
m	-	meters
m/minute	-	meters per minute
mm	-	milli meter (s)

m^2	-	square meter
min	-	minute (s)
No	-	Number
%	-	per cent
pp	-	page
Pvt	-	Private
P	-	Provisional
Proc	-	Proceedings
rpm	-	Rotations per minute
Rs	-	Rupees
Res	-	Research
Sec	-	Seconds
TG	-	Tellissery Garbled
TGEB	-	Tellissery Garbled Extra Bold
TGSEB	-	Tellissery Garbled Special Extra Bold
Trans	-	Transactions
V	-	Volts
viz.	-	namely
o	-	degree

INTRODUCTION

India is well known the world over as the "Home of spices". Spices constitute an important group of agricultural commodities, which since antiquity have been considered indispensable in the culinery art for flavouring of foods. They are also used in pharmaceutical, perfumery, cosmetics and several other industries. Since antiquity, India has been a leading spice-producing and exporting country of the world and therefore spice business play a very important role in national economy. In 1996-1997, India earned foreign exchange worth 11800 million rupees through the export of 219,400 tonnes of spice. Besides, huge quantities of spices are also consumed within our country for seasoning of foods and several other purposes.

Among the spices "Black pepper", the dried and matured berries of the perennial evergreen vine belonging to the piperaceae family is the most important one and is called the 'King of spices'. Out of the total export of spices from India, 80% is accounted by pepper alone and 90% of the countries black pepper production is from Kerala. This shows that pepper holds a vital role in the rural economy of Kerala and therefore is called the "Black Gold" of the state.

India which is the major player in the international pepper trade exported about 47770 tonnes of black pepper during 1996-'97 worth Rs.417 crores. This constitutes about 35% of export of spices by value. But the situation in the international market is fast changing and India though produces pepper in large quantities is now only the third biggest player in the international market. This has been mainly due the fact that Indian pepper is not standing up to the international quality standards. With India becoming a member of the GATT agreement and as a result of liberalisation of the economy, removal of trade barriers and opening up of market, both Indian and international markets are flooded with quality products. With increased purchasing power, consumers are becoming more quality conscious. This is true in the domestic market also. Therefore it is necessary to produce high quality pepper in large quantities at minimum production costs to become internationally competitive.

The quality of black pepper is largely determined by the berry size, colour, damaged berries, moisture content, foreign matter, insect infestation, animal excreta and microbial load. Because of the poor processing and storage practices adopted at farm level, the product supplied are generally poor. A survey conducted under the ICAR scheme titled "Design and Development of Equipments for threshing, cleaning and grading of black pepper" at Kelappaji College of Agricultural Engineering and Technology revealed that the pepper farmers of the spice growing districts of Kerala are not using any improved methods or machineries for pre-processing of pepper. Most of the operations like threshing, cleaning, grading and drying are carried out employing traditional methods. It was also revealed that the farmers do no grading and cleaning at farm level and sell the product in the dried form to the trader or exporter. Only about 3% of the traders surveyed, do grading and rest of the cleaning and grading is done by exporter. This is mainly due to the fact that in spite of the progress made in the research on agronomical aspects there had been little effort to design and develop appropriate equipments suitable for farm level and small scale level operations for pre-processing of pepper.

Due to the lack of proper cleaning equipment the product brought by farmers contain much of damaged berries, foreign matter, animal excreta and microbes. In order to effectively improve the quality of black pepper. Export grade specifications were introduced by the Directorate of marketing and inspection after a detailed study of geographical, botanical and morphological conditions under which the spice was cultivated, processed and cured. Compulsory grading for black pepper was enforced with the aim to ensure a high reputation for Indian produce at international markets. Also cleaning standards such as amount of filth, excreta and their tolerance limits have also been specified.

Bold pepper above 4.25 mm size referred as Wynadan/Tellissery bold command a premium in the wholesale market. Though Wynadan refers to the traditional bold varieties cultivated in Kerala, bold berries present in the pepper lots, whether they belong to Wynad or other districts is separated out by sieving and sold as Wynadan/Tellissery bold etc. Lured by high premium obtained for bold berries, an unhealthy trading operation is active now. The farmers are indirectly discouraged to process and market the traditional bold varieties separately. The traders separates the bold berries and sell it at high premium in the national and international markets. The farmers lots containing large proportion of bold pepper above the size 4.25 mm is sold at normal price of non-bold varieties. Studies in Idukki and Wynad have revealed that an average lot contains 52.75% extra bold pepper (of sizes 4.75 mm and above) and 77% bold pepper (of size 4.25 mm and above including extra bold). The benefit of the bold pepper thus present in the lot is entirely cornered by the traders.

Considering the above facts, the needs for introducing cleaning and grading at producers level in black pepper can be summarised as follows.

1. To introduce quality consciousness among the producers and to highlight the importance of quality in the marketing.
2. To enlist the participation of farmers in marketing process and to integrate production and marketing.
3. To produce better quality at lesser cost at farmers level and to ensure fair return that commensurate with quality to the farmer.
4. To ensure supply of dependable quality produce to the exporters and there by reducing the cost and burden of multiple processing at exporters level.

5. To develop a common language for quality and there by improving the communication between the farmer and the exporter bringing the consumer nearer to the producer.

The cleaning and grading operations are now concentrated on the wholesalers and exporters only. These operations in bulk are carried out through highly sophisticated vibrators and separators and are very costly.

There is a wide gap between the quality of pepper available to the exporters and the quality of pepper required in international market. It is well recognised fact that quality control operations at the end of the line cannot produce quality product. It can only advice further processing which escalate the cost of production and incompetence in the market.

Therefore it is essential that processing should start at farmers level. Also from the above discussion it is evident that no value addition takes place at the farm level where as the benefits of value addition and the accompanied profit is being bagged by the trader or the exporter. So the immediate requirement is to shift the primary quality upgradation operation of black pepper such as cleaning and grading to the farm level for which appropriate equipments are to be indigenously developed.

With this in view an attempt was undertaken at Kelappaji college of Agricultural Engineering and Technology, Tavanur with the following objectives.

1. To develop a simple and low cost cleaner cum grader for black pepper.
2. To evaluate the performance of the fabricated machine.

REVIEW OF LITERATURE

A brief review of the cultivation, harvesting, yield of black pepper, quality standards of black pepper, earlier studies on grading and cleaning processes of pepper and similar agricultural products and engineering properties relevant to cleaning and grading are included in this chapter.

2.1 Origin and agronomical aspects

As indicated in the handbook of agriculture(1980) pepper (*Piper Nigrum Linn*) is one of the most important and earliest known spice crops of India. It is a perennial climbing vine belonging to the family piperaceae and is indigenous to the west cost of southern India. Pepper is propagated, best from cutting of runner shoots which originate from the base of the vines. Cuttings from lateral fruiting branches can also be used for planting.

The stem and branches bear alternate dark green leaves. Hanging spikes or catkin's which originate from the nodes bear the sessile, small and which flowers without perianth, Mature spike vary from 5.30 cm in length and support 30-50 flowers. Flowers develop into fruits upon fertigation and aided by light showers received during the flowering period from May to June. The fruit is small, sessile, indehiscent berry, dark green when unmature which turns yellowish and finally red as it ripens. It takes nearly 6-8 months from flowering to harvesting. Harvesting is done by plucking the spikes. The spikes are spread on the floor or on mats and the berries are separated by trampling.

2.2 Black pepper

Black pepper is obtained by drying the mature ripe or unripe berries in the sun for 4-7 days until the outer skin become black and shrink.

Table 2.1 Chemical Composition of Black Pepper

Component	Percentage contained
Volatile oil	2.00
Non volatile oil	7.67
Starch	48.2
Crude fibre	12.2

2.3 Standards of black pepper producing countries

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

Table 2.2 Grade standards for Black Pepper

Grade	Size mm	Extraneous matter (% in weight)	Light berries (% weight)	M.C (% weight)
TGSE	4.75	0.5	3.0	11.5
TGEB	4.25	0.5	3.0	11.5
TG	4.25 (50%min) 4.00 (50% max)	0.5	3.0	11.5

As per the official statistics, production of pepper in India during 1996-'97 was 55000 tonnes from an area of 186000 ha. which in only 36% of the total world production.

Table 2.3 Statistics of the World Production and India's Share.

YEAR	WORLD PRODN. (in Thousand M.T.)	SHARE OF INDIA (in Thousand M.T.)	SHARE OF INDIA (in %)
1982	141.7	38	27
1983	147.0	45	31
1984	143.4	38	26
1985	128.0	27	21
1986	162.0	65	40
1987	142.0	45	32
1988	186.0	65	35
1989	182.0	45	25
1990	214.0	65	30
1991	233.6	55	23
1992	212.7	60	28
1993	175.0	55	34
1994	-------	55	---
1995	-------	55	---
1996	-------	55	---
1997	-------	55	---

Source : Spices Board

2.4 Physical properties of black pepper

The physical properties of black pepper admixture play an important role in the design of a cleaner cum grader.

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 Uglor (1991) studied the various physical properties of oil bean seed at safe storage m.c. viz size, volume, sphericity, density, state coefficient of friction against different materials angle of repose, hardness, crushing energy.

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.

$$\text{Roundness} = \frac{Ap}{Ac} \quad \ldots\ldots\ldots\ldots 2.1$$

where,

Ap= largest projected area of the object in its natural rest position

and

Ac= area of the smallest circumscribing circle

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

$$\text{Sphericity} = \frac{de}{dc} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

where de = diameter of the sphere of the same volume as that of the object and

dc = diameter of the smallest circumscribing sphere

By assuming that the volume of solid = the volume of a triaxial ellipsoid, sphericity is given by

$$\text{sphericity} = \frac{\text{volume of solid}}{\text{volume of smallest circumscribing sphere}}$$

$$= \frac{\text{geometric mean diameter}}{\text{major diameter}}$$

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

where,

a = largest intercept

b = largest intercept normal to a

c = largest intercept normal to a and b

2.4.1 Static and Kinetic Co-efficient of Friction

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

Brekert and Beulow (1966) showed that kinetic coefficient of friction of shelled coin and barley on sheet 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 (Maacle, 1957).

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

2.5 Cleaning cum grading

According to Vishwanathan *et al* (1994) a rotary sieve type cleaner cum grader is effective in removing large and small impurities from sesame seeds and in grading the seeds.

Bisht *et al* (1985) observes that an air screen seed cleaner-cum-grader is performing well with maximum seed purity and power requirement when it is operating at 7-10 quartels/h and air velocity of 15-16 mm/sec at feed section.

Morghan *et al* (1976) suggests that two divergent rollers in place of screens are best suited for sorting cereal grains, pear and soyabeans.

Manfredi, E (1989) suggests the importance of using computers, electronic and image processing techniques in harvesting, separation and grading of a wider range of crops including cereals pear, beans, tomatoes, sugar beet, cotton, coffee and groundnut.

2.6 Cleaning

The traditional methods of cleaning of black pepper are winnowing and spreading the material on floor or on mat and hand picking the contaminates. Mechanised 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) rotary type cleaner probably is the most common machine for on farm application, rotary grain cleaner separate grains in to size fraction by moving it through a trommel. As the trommel rotates materials cascade over its surface and the fine materials passes through the screen. Material not passing through moves out at the end of the trommel.

Abdul Wahab (1995) developed a rotary type black pepper cleaner. In this, shape of the grain is the property utilized and he finds cleaning efficiency is 88% on a cotton surface.

2.7 Grading

Harrison *et al* (1983) reported that a widely used process for sizing is screen sizing -the separation of under and over sized particles on an oscillation screen - and is affected by the size of particles- and apertures, the relative particle to screen velocity, the mean particle velocity and orientation of oblong particles. They suggest to incorporate a quick return movement with a spatial mechanism.

Feller and Foux (1975) indicate that the frequency and amplitude of oscillations affect the passage of particles through the screen.

Garvie (1966) suggests that continuous sliding is the most useful motion in screen sizing. He concludes that there is a velocity limit which if exceeded reduces the opportunities for undersized particles to pass through the sieve.

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

Sherif (1986) observes that clogging decreases sizing accuracy, Fellor (1980) developed a screening rate function as a sum of the passage and clogging rate factors versus relative particle size to characterise screen performance.

Balachandran Pillai *et al* (1992) observes that the optimum angle of inclination of the sieve to get maximum discharge is between three and four degrees and finds that grading is effective at lower speed compared to the higher speed. Clogging of the sieve found to be less at higher speed.

MATERIALS AND METHODS

Details of the materials and methods adopted in the determination of various properties of black pepper relevant to cleaning and grading, the development of black pepper cleaner cum grader and the experimental procedure to evaluate the performance of the machine are discussed in this chapter.

3.1 Properties of black pepper

The engineering properties such as shape, size, weight, moisture content, bulk density, true density, volume, sphericity, angle of internal friction and the angle of external friction were identified as the properties to be determined based on the initial studies. Relevant literature was studied for selecting appropriate methods. Black pepper purchased from local farmers of Tavanur village irrespective of the variety was used for the experiments.

3.1.1 Shape and size

The pepper grains were spread over a clean surface and roughly devided into a number of sectors. From each sector berries were randomly selected. The shape of selected pepper grains was observed. Similarly size of the pepper berries was determined using a vernier dial caliper with least count of 0.05 mm. measurements of length along three perpendicular axes Viz: major, medium and minor were determined.

3.1.2 Sphericity

Sphericity was determined by the formula

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

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

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

where,

a = largest intercept

b = largest intercept normal to a

c = largest intercept normal to a and b

3.1.3 Weight

Weight of the mature berries was determined using an electronic balance with a sensitivity of 0.01/0.1g, different groups of ten number of berries were selected randomly and weighed. The average weight of berries was then determined.

3.1.4 Volume

Black pepper berries were filled in a jar of 20 cm^3 volume. Number of pepper berries (N) used to fill a volume of 20 cm^3 was counted. The air trapped in the pore spaces was replaced by water and water required to fill the jar (Vw) was measured. The process was repeated for different groups of samples. As the duration of the experiment was very short the moisture content of the pepper berries was found to be not varying. The volume was determined as follows.

$$\text{Average volume of the pepper berry} = \frac{20 - V_w}{N} cm^3$$

3.1.5 True density

Pepper berries were filled in a jar of 20 cm^3 volume. The air trapped in the pore spaces replaced by pouring water in to the jar. The volume of water needed to fill the jar was found out (Vw). Absorption of moisture by berries was reduced by keeping the duration of experiment short. The procedure was repeated for different samples and true density was calculated by the formula

$$\text{True density} = \frac{W_c}{V_c} g/cm^3$$

where,

Wc	=	weight of pepper sample
Vc	=	volume of pepper berries in the jar
	=	25-Vw

3.1.6 Bulk density

Pepper berries were filled in a jar of volume 50 cm^3. The weight of pepper used to fill the vessel was determined. The bulk density was determined using the formula

$$\text{Bulk density} = \frac{W_a}{V_v} g/cm^3$$

where,

Wa	=	weight of pepper used to fill the vessel
Vv	=	volume of the vessel

3.1.7 Moisture content (dry basis)

Moisture content of the mature pepper berries was determined by the oven dry method. *The weight of the pepper berries* was measured using an electronic balance having a sensitivity of 0.01/0.1g. and it was kept in the oven for 24 hrs under 378 K. Then the dry weight was measured and moisture content on dry basis was determined using the formula

$$\text{Moisture content} = \frac{(\text{wet weight of berries - dry weight of berries}) \times 100}{\text{dry weight of berries}}$$

3.1.8 Angle of external friction

A cylindrical bottomless bin was filled with pepper and placed over different surfaces (G.I, Aluminium and M.S). The cylindrical bin was attached to different weights using a thread running over a frictionless pulley. The weight when bin just start sliding was found. The friction between the surfaces and the wall of the bin was neglected.

The angle of external friction was found using the formula

$$\tan \phi^{1} = \frac{F}{N}$$

where,

ϕ^1	=	angle of external friction
F	=	weight added
N	=	normal reaction (weight of pepper)

3.1.9 Angle of internal friction

Angle of internal friction was determined using a transparent box with the provision for lifting one vertical side for the material to slide out. The pepper was filled ¾th full and the vertical side was lifted. The angle formed at the base was noted and mean angle of ten observations was taken as the angle of internal friction of black pepper.

3.2 Fabrication of the cleaner cum grader

3.2.1 General layout and details of the machine

The main parts of the cleaner cum grader are the sieve unit with cleaning mechanism, the feeding and discharge mechanism, the power transmission system and the frame assembly.

3.2.1.1 The sieve unit with cleaning mechanism

This unit which formed the heart of the machine consists of three concentric cylindrical sieves with one end welded on to a circular mild steel plate of thickness 3 mm having a hole of 4.8 cm. dia. made at the centre to accommodate the inlet chute. The other end was open to accommodate the discharge unit. The mild steel sieves were of length 0.95 m. and thickness 1 mm which were bend on a standard bending machine to cylindrical shape. The diameter of the cylindrical sieve and the sieve opening for the inner, intermediate and outer sieves were 10 cm and 6.24 mm, 20 cm and 4.8 mm and 30 cm and 3 mm respectively are shown in Fig. no. 3.2.

In order that the cylinders are fastened to the disc strongly and without tearing off the circular m s plate mild steel flat (3 cm x 3 mm) was welded on to the plate concentrically after drilling holes it at a centre to centre distance of 10 cm on it. The diameters of these round m s flats were same as that of the cylindrical sieves. The cylindrical sieves were then screwed on to these flats which provided additional tearing and shearing strength while the loaded sieves were rotated.

On to the inlet end circular plate opening at the centre of the sieve unit was welded a GI pipe of 4.25 cm internal diameter which formed the inlet chute

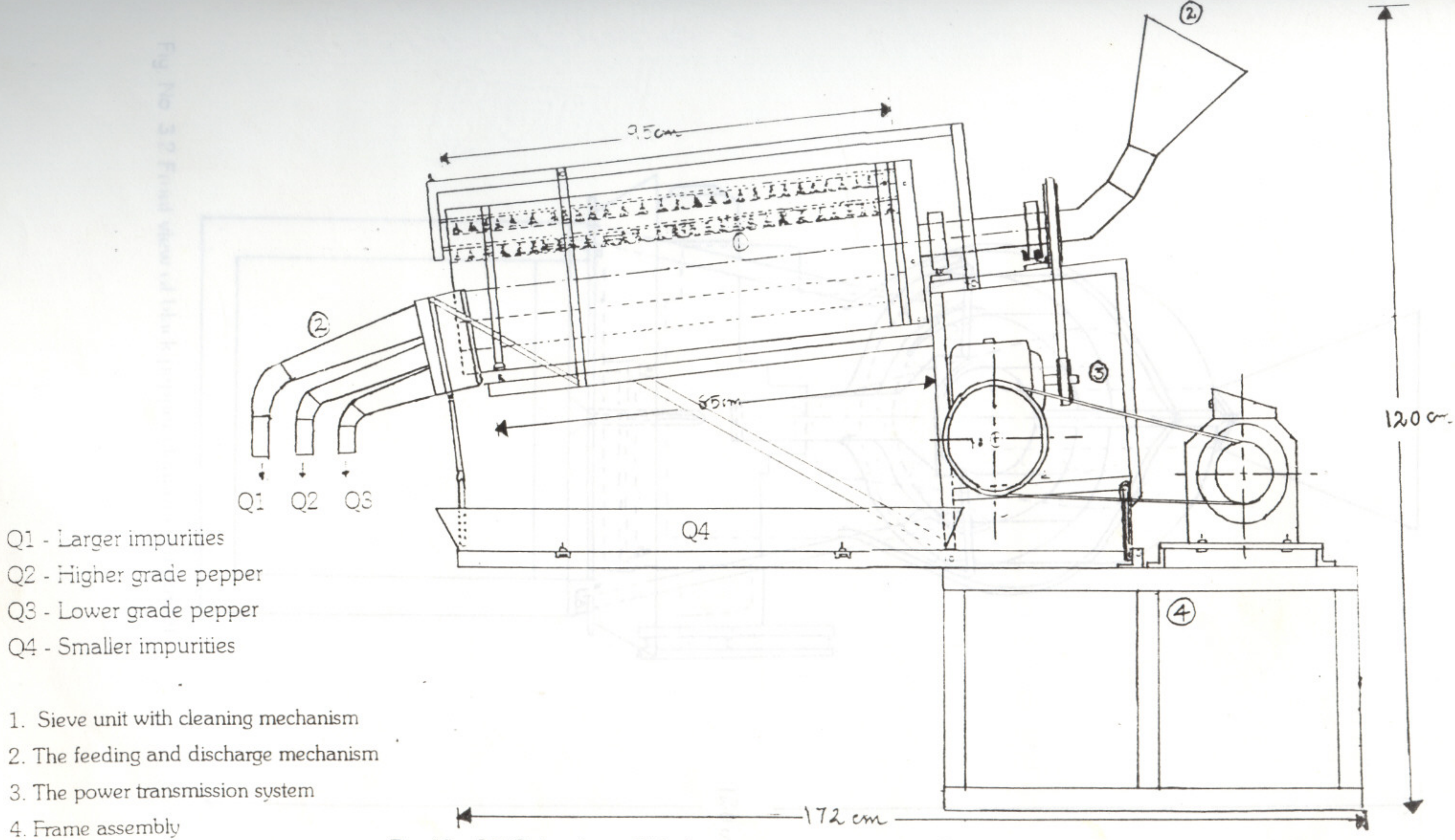


Fig. No. 3.1 Side view of black pepper cleaner cum grader

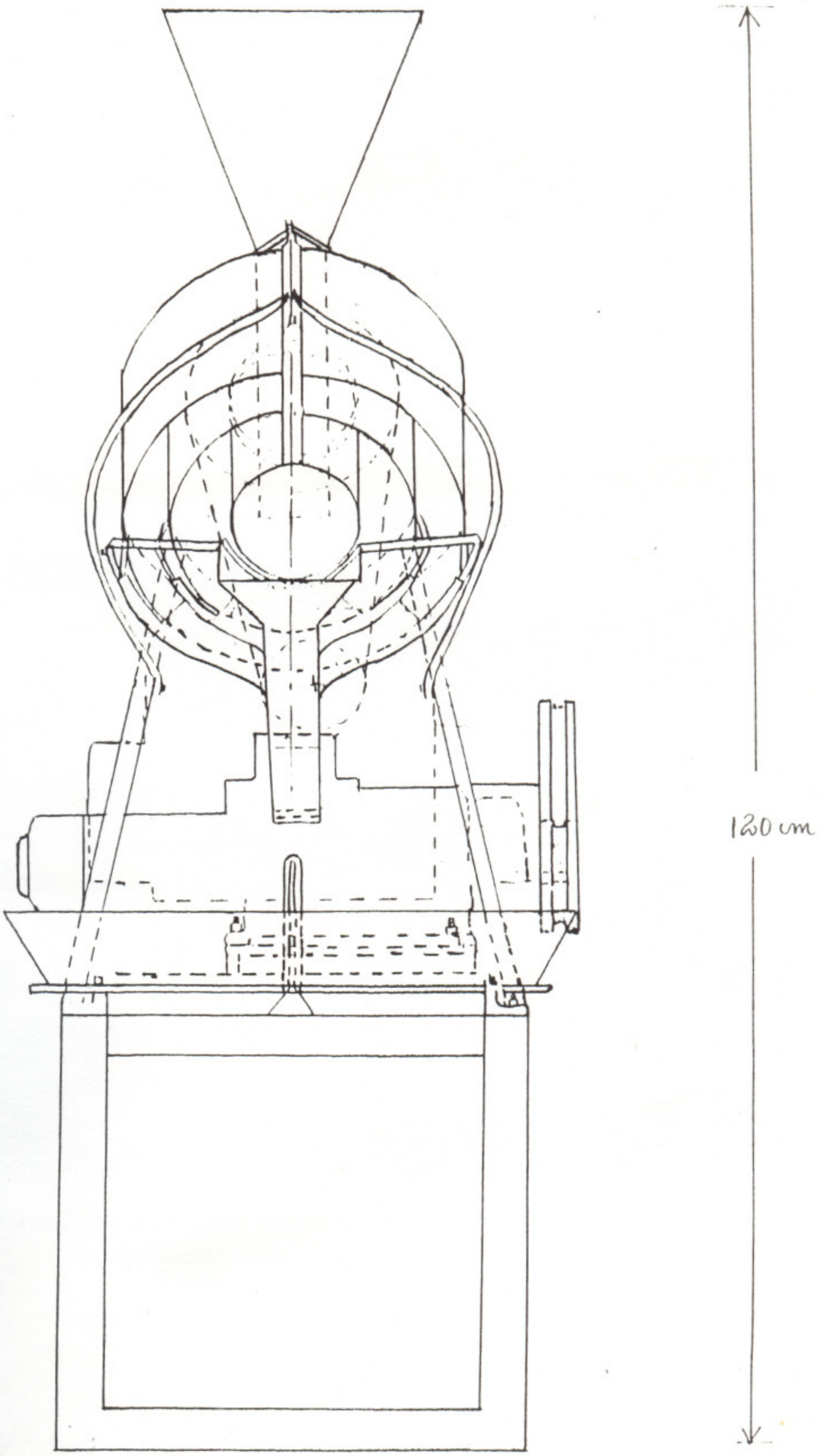


Fig. No. 3.2 Front view of black pepper cleaner cum grader and also the shaft of the unit. The shaft was mounted on to the frame assembly using two ball bearings (SKF 6210) of internal diameter 50 mm as shown in Plate no. 3.1. The power was transmitted to the rotating cylindrical sieve unit through V- belt pulley of 17 cm diameter mounted on the shaft at distance of 26 cm from the inlet end of the cylindrical unit as shown in Fig. 3.1. The outlet end of the cylindrical sieve unit was supported by two cantilever angle iron section (ISA 2525 M S section) of length 85 cm on both sides of the machine with one end of each fixed on the frame assembly at the inlet end. The other ends of the two angle iron sections on to which M S roller bushes were provided support the rotating cylindrical sieve unit. Roller bearings in contact with the rotating sieve unit thus rotates in the opposite direction. Two brushes of length 95 cm made by inserting nylone fibres of size 0.5 mm through the drilled holes on a C.channel (20x5 mm) was used to dislodge the berries that clog the sieve openings. The channel was then filled in with wax and top rounded off to prevent the berries accumulating in it as shown in plate no 3.3 . One end of both the brushes were welded to the frame assembly at the top of the inlet end. The brush was fixed in such a way that the end of brush always slides over the top surface of the intermediate and top of the rotating sieve unit so that berries that clog the opening was detached and was allowed to fall down to be carried again by the sieve. The angle of the rotating unit with horizontal can be varied from 1 degree to a maximum of a 8 degree by using screw and slot mechanism. Among the sieves the innermost sieve acted as a scalper sieve.

3.2.1.2. Feeding and discharge mechanism

An aluminium hopper with hopper angle of 40 degree was fabricated and was provided at a height of 1.2m. from the ground so that pepper can be fed easily. The bottom of the hopper was connected to a bent GI pipe as shown in plate no. 3.1 . This unit was mounted on to the main frame assembly so that the pepper fed in the hopper got accelerated due to the bend and was let into inlet pipe which also acted as the shaft of the sieve unit. The feeding unit was mounted with its outlet very close to the shaft pipe but not touching it leaving a gap of only 1 mm so that berries will not fall down on its way to the sieve unit.

The discharge unit of the black pepper grader cum cleaner consisted of three collecting tubes made up of aluminium sheet. The overflow of the innermost scalper sieve, overflow of intermediate and outer sieves were collected in three collecting boxes made up of 22 gauge GI sheet. The boxes were placed on a platform of a telescopic stand whose height could be raised or lowered according to the angle of sieve. The dirt and other powdery matter (underflow of the outer sieve) was collected in collecting tray made up of 22 gauge GI sheet fitted below the cylindrical sieve unit.

3.2.1.3 Power transmission system

A three phase 0.5 HP variable speed dynodrive motor was used as the prime mover. The speed of the motor could be varied between the range of 120 to 1200 rpm using a variable dynodrive electronic mechanism. Drive from variable speed motor was given to a speed reduction gearbox having a reduction ratio of 10:1 and from the reduction unit to the sieve unit through a V-belt and pulley (B,17 cm) mounted on the shaft. An overall variable speed reduction of 40:1 was obtained.

3.2.1.4 Frame assembly

The main frame assembly was fabricated of ISA 3535 M S section. The rotating sieve unit, the power transmission system, bearings, cleaning brush, inlet and discharge mechanism were mounted on this assembly.

3.3 Performance Evaluation

Samples of dried, matured black pepper collected from four local farmers of Tavanur village was used for the experiment. The machine was put on and when it attained the set running speed, black pepper was fed uniformly through the hopper into the rotating cylinder. The overflow of the rotating innermost sieve and the underflow of the outer sieve were considered as the impurity outlets. The overflow of the intermediate and outer sieves were considered clean pepper outlets.

Preliminary investigation showed that between slopes of 1^0 and 8^0 degrees and rotational speeds of 13 and 28 rpm for the sieve unit, the machine showed maximum cleaning efficiency and grading efficiency. Therefore speeds of 13, 18, 23 and 28 rpm and slope of 1^0, 2^0, 4^0, 6^0 and 8^0 for the sieve unit was taken as independent variables to evaluate the performance. The peripheral speeds of the sieves are shown in Table 4.12.

3.3.1 Cleaning Efficiency

Known mass of feed sample was mixed with known mass of impurities of different kind. This mix was then fed into running machine. The impurities in the two cleaned grades of the pepper was manually separated and the weights of the impurities and clean pepper were found out. Similarly the weights of the clean pepper and impurities were found for the impurities outlets. The cleaning efficiency was then determined using the equation

$$\text{Overall Cleaning Efficiency} = \frac{(m_f - m_u)(m_o - m_f)(1 - m_u)m_o}{(m_o - m_u)^2(1 - m_f)m_f}$$

where,

m_f = mass fraction of pepper in the feed

m_u = mass fraction of clean pepper in the impurity outlet

m_o = mass fraction of clean pepper in the cleaned pepper outlet

3.3.2 Grading Efficiency

Two grades of cleaned black pepper with sizes less than the size of the grading screen(4.8 mm) and grater than 4.8 mm were prepared by manually sieving the pepper mix in a horizontal sieve of size 4.8 mm. The separated grades were sieved again to ensure that there was no pepper of size less than desired size (4.8 mm) in the overflow of sieve. Known quantities of the two grades were mixed and fed into the running machine at a uniform rate. The overflow of the grading screen (intermediate screen) was taken as the higher grade (size>4.8mm) and the overflow of the outer sieve was taken as the lower grade. The overflow of the grading screen which may contain under sized pepper grains was taken and sieved manually and the weight of the under sized pepper grains was found out. The grading efficiency of the intermediate sieve was taken as the grading efficiency of the machine and was calculated using the equation

$$\text{Grading efficiency} = \frac{m_o(m_f - m_u)(m_o - m_f)(1 - m_u)}{(m_o - m_u)^2(1 - m_f)m_f}$$

where,

m_f = mass fraction of higher grade pepper in the feed

m_o = mass fraction of higher grade pepper in the overflow of the intermediate sieve

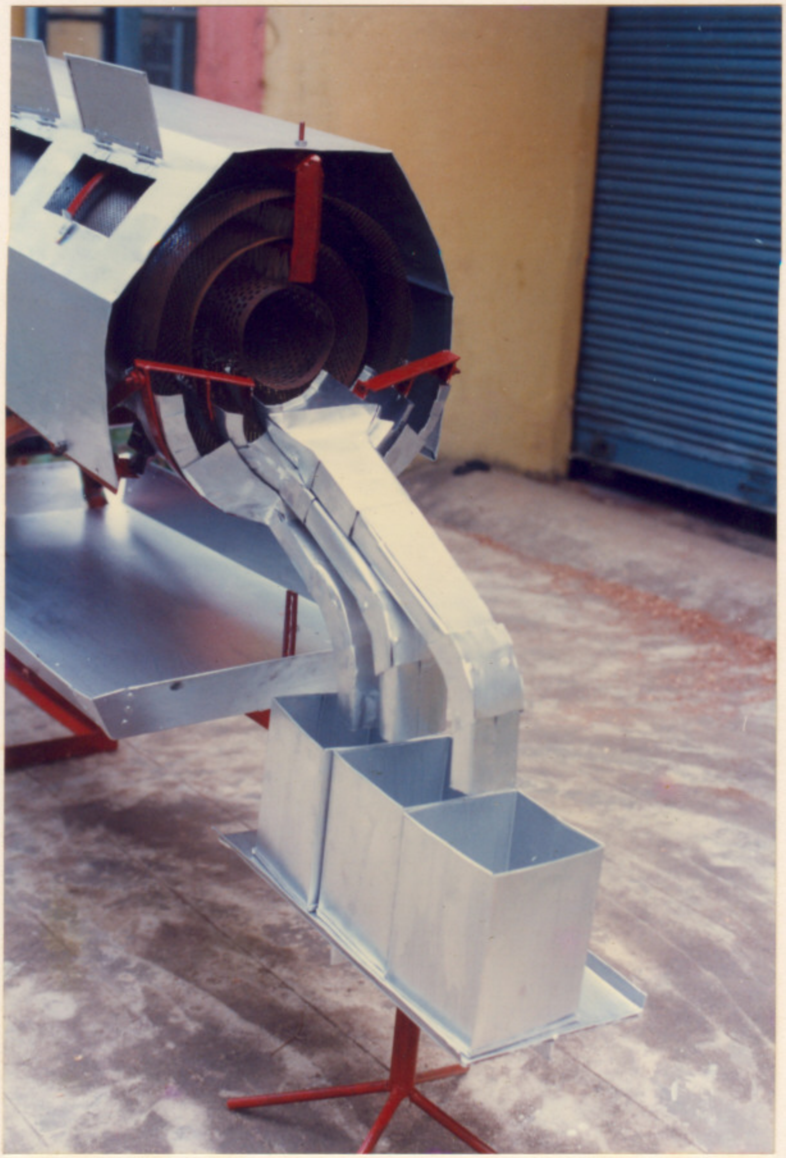
m_u = mass fraction of higher grade pepper in the overflow of the outer sieve

3.3.3 Capacity

The capacity of the machine at different angles and speeds set up were determined by noting total weight of the two grades of pepper and impurities collected at different outlets for a known time.

3.3.4 Energy requirement

Energy requirement at no load condition and load condition were determined using an energy under the 3-phase energy under was connected in series with the motor. The energy consumed by running the unit without load and with load were noted and recorded.



RESULTS AND DISCUSSION

This chapter deals with the results of experiments conducted regarding engineering properties of black pepper relevant to cleaning and grading process and also the performance evaluation of the developed cleaner cum grader.

4.1 Physical Properties of black pepper

The physical properties such as shape, size, weight, volume, moisture content, true density, bulk density, angle of internal friction and angle of repose were determined and discussed.

4.1.1 Shape and size

The black pepper on visual observation, was found to be nearly spherical in shape. The size of black pepper along its major axis varied from 4.45 mm to 5.6 mm as revealed in table 4.1.

4.1.2 Sphericity

The sphericity of pepper grain is found to vary from 85.9 percent to 97.9 percent with mean value of 93.2 percent as depicted in table 4.1.

4.1.3 Weight

Average weight of a pepper grain was found to be 0.06 with a range of values between 0.04g to 0.07g from table 4.2.

Table 4.1 Sphericity and dimension of black pepper

Sl No.	Largest Intercept	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	49.8
2	5.55	5.4	5.10	96.3
3	5.15	4.65	4.5	93.3
4	4.95	4.3	4.25	90.6
5	5.55	4.45	4.4	85.9
6	5.6	5.5	5	95.7
7	5.2	5.10	4.8	96.7
8	4.85	4.35	4.25	92.3
9	5.45	4.95	4.6	97.7
10	5.4	4.85	4.65	91.7
11	4.85	4.8	4.6	97.9
12	4.80	4.05	3.95	88.5
13	4.90	4.6	4.5	95.2
14	5.10	4.9	4.8	96.2
15	4.75	4.35	4.25	95.2
16	5.5	5.25	5.2	93.5
17	5.3	5.0	4.85	96.60
18	5.0	4.15	4.0	87.2
19	4.85	4.2	4.1	90.1
20	4.95	4.65	4.5	94.8
	Mean			93.2

4.1.4 Volume

Average volume of a pepper grain was found to vary from 0.053 cc to 0.059 cc with a mean value of 0.056. It is represented in table 4.3.

4.1.5 True density

From Table 4.4 it is found that the mean true density of pepper grain is 0.87 g/cc. The true density is varied between the range 0.80 g/cc to 0.93 g/cc.

4.1.6 Bulk density

The mean bulk density of pepper grain was found to be 0.475 g/cc with in the range of 0.464 to 0.482 g/cc. It is presented in Table 4.5.

4.1.7 Moisture content

The average moisture content of black pepper grain was 9.25 per cent (db). It was found that the values were ranging from 8.7% and 9.8% and is given in Table 4.6.

4.1.8 Angle of repose

The angle of repose for the black pepper grain was found to be $41^{0}3'$ from Table 4.7.

4.1.9 Angle of external friction

The angle of external friction of black pepper on surfaces such as Galvanised Iron, Mild Steel and Aluminium were found out.

Table 4.2 Average weight of black pepper grain

Sl. No	Wt. of 10 Nos. grain(g)	Average Wt. (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 grain in the jar	183	180	185	190
Volume of grains in the jar($20-V_w$)	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	23.8	25.00	0.952
2	23.4	29.00	0.806
3	23.7	27.00	0.876
4	23.6	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	0.482
2	23.7	50	0.478
3	23.8	50	0.464
4	23.6	50	0.476
	Mean		0.475

Table 4.6 Moisture content of black pepper grain

Sl No.	Weight of Wet grain	Weight of grain after oven drying	Moisture content (% db)
1	35.7	32.52	9.7
2	34.8	31.98	8.8
3	34.60	31.5	9.8
4	34.9	32.105	8.7
	Mean		9.25

Table 4.7 Angle of repose of black pepper

Sl.No.	Height of grains of in the bin(h) cm	depth of the base of bin (b) cm	$\theta = \tan^{-1}(h/b)$
1	11.1	12.5	41°36'
2	10.8	12.5	40°8'
3	11.0	12.5	41°34'
Mean			

Table 4.8 Angle of external friction

Sl No	Surfaces taken	Wt. of pepper (g)	Wt. added (g)	Coefficient of friction
1	Galvanised iron surface	321.2	165	0.573
2	Mild steel surface	321.2	210	0.6537
3	Aluminium surface	317.3	134.9	0.425

galvanised iron, mild steel and Aluminium were found out . The coefficient of friction for the various surfaces were obtained as 0.513 for galvanised iron sheet 0.6537 for mild steel and 0.425 for aluminium as shown in table 4.8.

4.2 Performance evaluation of the black pepper cleaner cum grader

Performance of the newly developed cleaner cum grader was evaluated and the results are discussed . The machine was tested for 5 different angles of inclination of the sieves and for different speeds of rotation. Each experiment was repeated 3 times and mean value was taken.

The cleaning and grading efficiency and the possible capacity is indicated in Table 4.9 and 4.10.

Fig. 4.1 and 4.2 shows the graphical representation of the variation of cleaning and grading efficiency. At different speeds and angles of inclination the cleaning efficiency was found to vary between 42% to 65.3% under different test conditions. A maximum cleaning efficiency of 65% was obtained at a angle of inclination of 1 degree and at a speed of 13 rpm. The maximum grading efficiency of 99.63% was also obtained at the same set up of the system . The capacity of the machine shifted from 3.1 kg/h at a slope of 1 degree and an rpm of 13, to 19.43 kg/h at a slope of 8 degree and 28 rpm.

The machine could give only an average cleaning efficiency. This is due to fact that impurities having size or shape lesser than the scalper sieve opening and greater than the outer most sieve were not removed. Further, the impurities having a diameter same as that of cleaned pepper but different specific gravity may also come through the clean grain outlet.

Also it was observed that increasing the angle of inclination of the system developed a tendency for the product to flow quickly towards the scalper

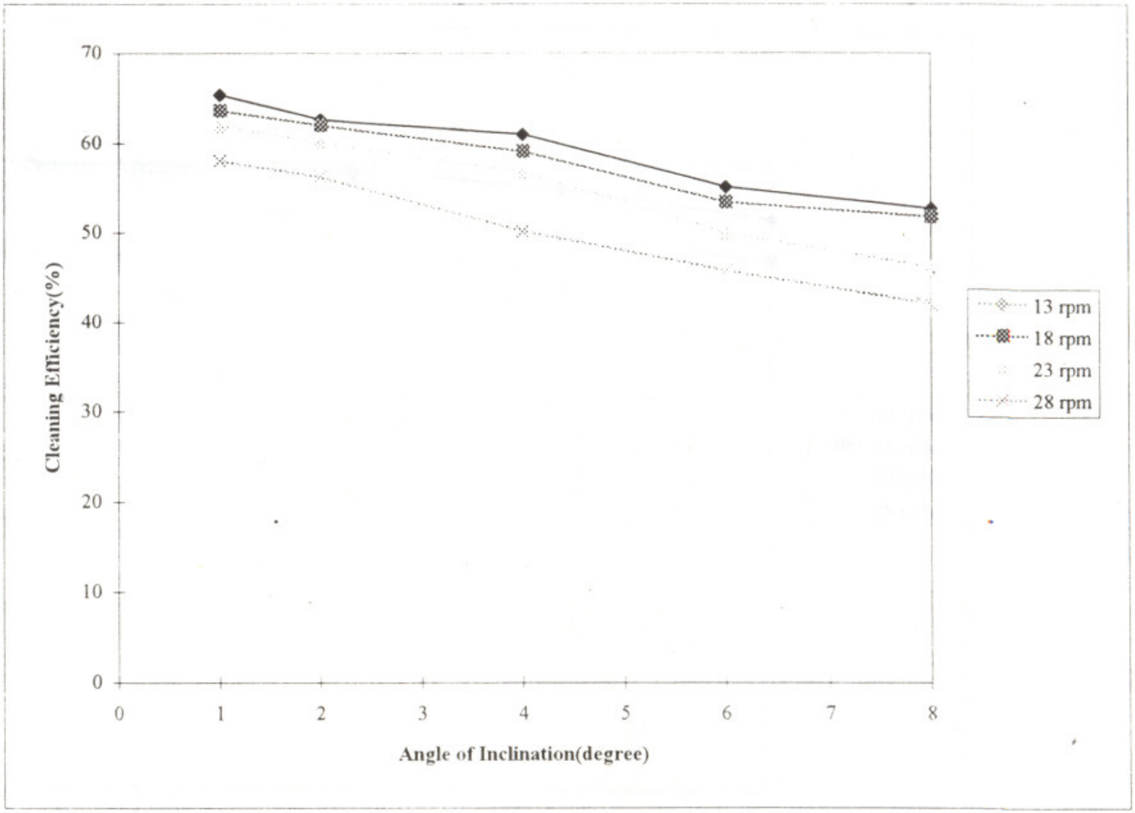


Fig. No. 4.1 Cleaning efficiency of black pepper cleaner cum grader for different speeds at different angles of inclination

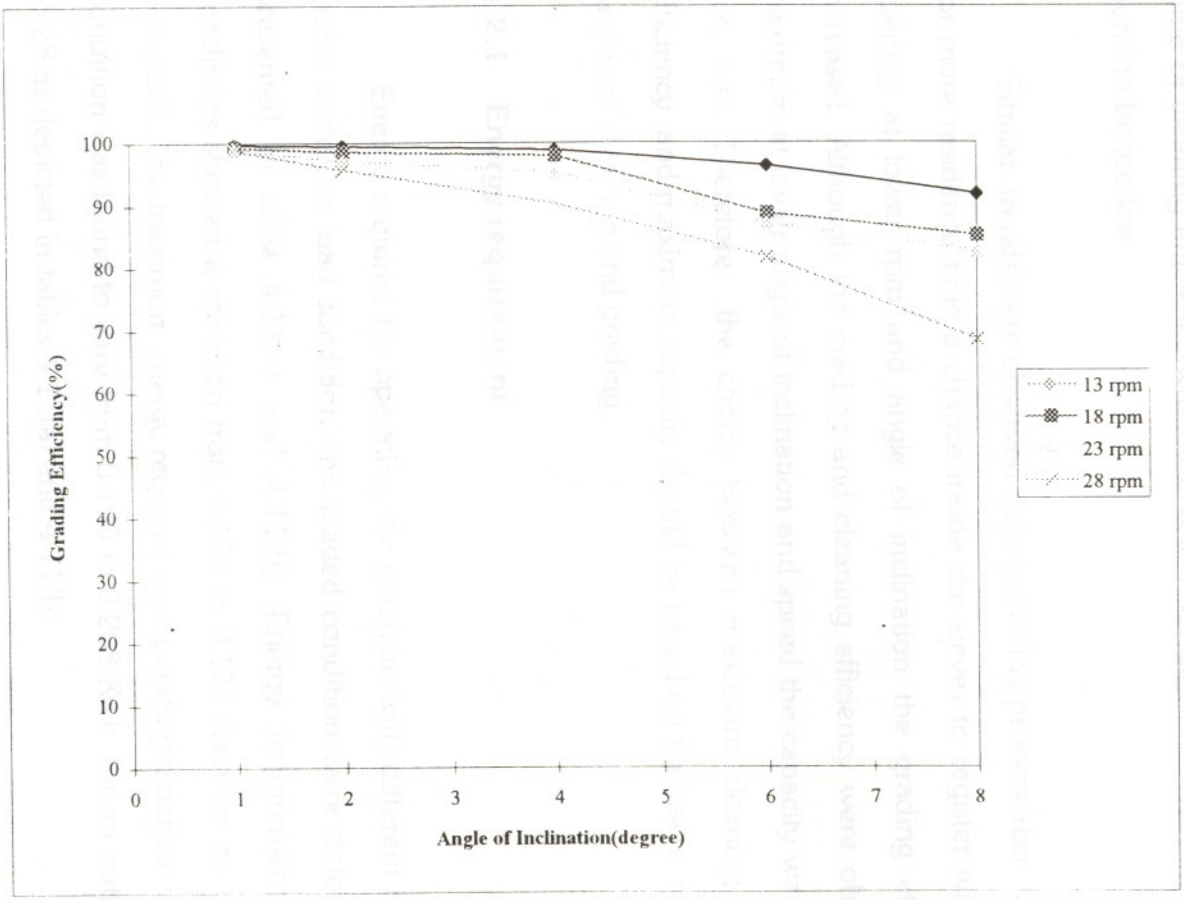


Fig. No. 4.2 Grading efficiency of black pepper cleaner cum grader for different speeds at different angles of inclination screen outlet without effective cleaning. This in turn reduced the cleaning efficiency. Therefore it was recommended that the machine should be used for cleaning purpose in tandem with a specific gravity separator to achieve maximum cleaning. It was also observed that at lower angles of inclination and at lower speeds pepper berries got more residence time and chance in the sieve to register with sieve openings and probability of product getting sieved depending on the size was more. Consequently a corresponding increase in value of cleaning efficiency was observed. But at this set-up the capacity was found to be too low.

Similar trends were observed during grading process also . When pepper got more residence time a chance inside the sieves to register with the sieve opening at lower rpm and angle of inclination the grading efficiency also increased. Although the grading and cleaning efficiency were observed to be maximum at lower angle of inclination and speed the capacity was found to be very less. Therefore the choice between maximum cleaning and grading efficiency and maximum capacity should be based on the users requirement of degree of cleaning and grading.

4.2.1 Energy requirement

Energy required for operating the machine with different output rpm of motor under no load condition and loaded condition were determined and is presented in table 4.11(a) and 4.11(b). Energy requirement at no load conditions showed a variation from 0.170 to 0.178 Kwh for an output rpm of 600-1200. The maximum energy required for operating machine under full load condition was found to vary from 0.190 to 0.208 Kwh. for an output rpm of 13 to 28 as depicted in tables 4.11(a) and 4.11(b).

It can be concluded that the energy requirement for getting maximum cleaning and grading efficiency was 0.16 Kwh at a machine speed of 13 rpm.

Table 4.9 Cleaning efficiency of the cleaner cum grader

angle	speed (rpm)	cleaning efficiency (%)	capacity (kg/h)
1^0	13	65.3	3.10
	18	63.50	4.45
	23	61.85	5.75
	28	57.90	7.2
2^0	13	62.5	3.69
	18	61.90	5.3
	23	59.98	6.4
	28	56.10	9.4
4^0	13	60.90	5.47
	18	59.00	7.98
	23	56.70	9.10
	28	50.21	11.94
6^0	13	55.00	5.75
	18	53.25	9.63
	23	49.85	13.15
	28	45.65	16.13
8^0	13	52.65	7.2
	18	51.75	12.16
	23	46.10	15.29
	28	42.00	19.43

Table 4.10 Grading efficiency of the cleaner cum grader

angle	speed (rpm)	grading efficiency (%)	capacity (kg/h)
1^0	13	99.63	3.10
	18	99.19	4.45
	23	98.90	5.75
	28	98.75	7.20
2^0	13	99.34	3.69
	18	98.50	5.3
	23	97.00	6.40
	28	95.62	9.40
4^0	13	98.76	5.47
	18	97.8	7.98
	23	95.20	9.10
	28	90.20	11.94
6^0	13	96.17	5.75
	18	88.55	9.63
	23	86.90	13.15
	28	81.58	16.13
8^0	13	91.68	7.2
	18	85.00	12.16
	23	82.46	15.29
	28	68.35	19.43

Energy requirement for operating the machine

Table 4.11 (a). No load condition

Output rpm of motor	Energy consumed (kwh)
600	0.174
750	0.175
950	0.176
1200	0.178

Table 4.11 (b). Full load condition

Output rpm of the motor	Speed of the machine	Energy consumed (kwh)
600	13	0.190
750	18	0.194
950	23	0.201
1200	28	0.208

4.12 Paripheral speeds of sieves.

Sieves	Speed (rpm)	Peripheral Speed (m/sec)
	13	0.068
Scalper sieve	18	0.094
	23	0.120
	28	0.147
	13	0.136
Intermediate sieve	18	0.188
	23	0.240
	28	0.294
	13	0.204
Outer sieve	18	0.282
	23	0.360
	28	0.440

SUMMARY

The cleaning and grading operations of black pepper are now concentrated at the wholesalers and the exporters level and are carried out through highly sophisticated vibrators and separators. These machines are very costly. To reduce the processing cost and to minimise the gap between the quality of pepper available to the exporters and quality of pepper required in the international market, processing should start at farmers level. But at farm level no indigenously developed appropriate equipment is available for the purpose and so no grading and cleaning takes place. Therefore to shift this tendency and to ensure a remunerative price to the farmer for his product, a power operated cleaner cum grader for black pepper was developed.

The machine essentially consisted of a rotating cylindrical sieve unit with cleaning mechanism, feeding and discharge mechanism, frame assembly and power transmission system. In operation power from a variable speed motor was given to a reduction gear unit and then to rotating sieve unit through a V-belt pulley. Materiel fed in the hopper comes through an inlet pipe which also acts as the shaft of the unit, to the inner scalper sieve of the concentric sieve unit and from there to the intermediate and then to the outer sieves each having different sieve opening size.

In the process of its rolling movements, through the scalper big impurities such as trash, spikes, leaves etc. were separated. In the subsequent sieves pepper was graded into different fractions depending upon the size of the sieve opening and these were collected in the collecting boxes through the outlet chutes provided at the outer end of the machine. The fine dust, powder etc. coming out of the outer sieve was collected in the tray mounted below the unit. Arrangement was provided on the unit to change the angle of the inclination of the sieve unit.

The machine was evaluated for its performance with four speeds namely 13, 8, 23 and 28 rpm and five angles of inclination 1^0, 2^0, 4^0, 6^0 and 8^0. It was observed that a maximum cleaning efficiency of 65% and grading efficiency of 99.63% was obtained at 1^0 inclination and 13 rpm. It was also observed that the cleaning and grading efficiencies of the machine showed a decreasing trend with higher speed and inclinations. But capacity of the machine showed an increasing trend. A maximum capacity of 19 kg/h was observed at an inclination of 8^0 and at a speed of 28 rpm.

From the experimental results it is obvious that the newly developed machine is technically and economically suitable for farm level and small scale level operations.

Suggestions

1. The cleaning efficiency of the machine may be increased by incorporating a blower in to the system.

2. To get maximum cleaning the machine should be used in tandem with a specific gravity separator.

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APPENDIX I

Details of dynodrive variable speed motor.

Dynodrive

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

APPENDIX II

Specifications of energy meter

Three phase energy meter

Voltage	-	3x400
Current	-	3x104
Frequency	-	50 Hz
Energy meter constant	-	112.5 revolutions/Kwh

APPENDIX III

Power requirement

Load condition

From energy meter specification,

112.5 revolutions of energy meter disc	=	1 Kwh
Time taken for one revolution of the energy meter disc	=	154 Sec
No. of revolution in an hour	=	3,600 / 154
	=	23.38
Energy requirement to operate the machine in an hour	=	23.38 / 112.5
	=	0.208 kwh
Power requirement	=	0.208 / 1
	=	0.208 kw
	=	0.208 / 0.746
	=	0.28 HP

APPENDIX IV

Calculation of operating cost

Initial cost (C)

Fabrication cost of cleaner cum grader including cost of mateial

= Rs. 2000/-

Initial cost of motor and speed reduction unit = Rs. 8000/-

Average life of cleaner cum grader = 10 yrs

Average life of motor = 20 yrs

Working hours per year = 600

Salvage value (s)

10% of initial cost

For motor = Rs. 800/-

For machine = Rs. 200/-

Fixed cost

1. Depreciation per hour

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

$= \frac{2000-200}{10 \times 600}$

= Rs. 0.3/-

For motor $= \frac{8000-800}{20 \times 600}$

= Rs. 0.6/-

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

For machine $= \frac{(2000+200) \times 15}{2 \times 600 \times 100}$

= Rs. 0.275/-

For motor $= \frac{(8000+800) \times 15}{2 \times 600 \times 100}$

= Rs. 1.1/-

Total fixed cost per hour = 0.3+0.6+0.275+1.1

= 2.275 Rs./hr

Variable cost

Labour charge	=	Rs. 120/Day
	=	Rs. 15/hr
Electricity charge	=	Rs. 1.1/Kwh
	=	0.208x1.1
	=	Rs. 0.229
Repair and maintenance		
10% of initial cost per annum		
For machine	=	$\frac{2000 \times 10}{600 \times 100}$
	=	Rs. 0.33/-
For motor	=	$\frac{8000 \times 10}{100 \times 600}$
	=	Rs. 1.33/-
Total variable cost per hour	=	15+0.229+ 0.33+1.33
	=	16.889 Rs./hr
Total operating cost per hour	=	16.889+2.275
	=	19.16 Rs./hr

DEVELOPMENT AND TESTING OF A CLEANER CUM GRADER FOR BLACK PEPPER

By

JAMES P. GEORGE
MUNEER. K.
SHARMILA MATHEW

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering and Technology
Kerala Agricultural University

Department of Post Harvest Technology and Agricultural Processing

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA

1998

ABSTRACT

A power operated cleaner cum grader for black pepper using concentric sieves was developed at K.C.A.E.T. Tavanur. The machine consists of a rotating concentric sieve unit with a cleaning mechanism, feeding and discharging mechanism, frame assembly and power transmission system. The machine was tested for cleaning and grading efficiencies at different speeds and angles of inclinations of the sieves. Maximum cleaning efficiency of 65% and grading efficiency of 99.63% was obtained at a speed of 13 rpm and at an angle of 1^0. The machine was found to be technically and economically suitable for farm level and small scale level operations.