DEVELOPMENT OF A POWERED-DECORTICATOR FOR PRODUCING WHITE PEPPER FROM BLACK PEPPER

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DECLARATION

I hereby declare that this thesis entitled **"Development of a Powered–Decorticator for Producing White Pepper from Black Pepper"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **“Development of a Powered–Decorticator for Producing White Pepper from Black Pepper”** is a *bonafide* record of research work done independently by **Miss Chithra, G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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SYMBOLS AND ABBREVIATIONS

Art.	Article
g	gram
mg	milligram
ml	millilitre
°C	degree centigrade
mm	millimetre
cc	cubic centimetre
cm	centimetre
m	metre
MS	Mild Steel
hp	horse power
rpm	revolution per minute
h	hour
min	minute
UV	Ultra Violet
nm	nanometre
µl	microlitre
kg	kilogram
d.b.	dry basis

%	per cent
NaOH	Sodium Hydroxide
α	alpha
β	beta
$^{\circ}$	degree
Fig.	figure
viz.	namely
et al.	and others
r	regression coefficient
Eqn.	Equation

CHAPTER I

INTRODUCTION

Spices play an important role in the day to day diet of people. From time immemorial, people in many parts of the world have been using spices and herbs extensively to improve the flavour and aroma of food materials. Besides flavouring, they are used also as food preservatives. India is considered the ‘Home of Spices’ owing to its favourable climatic and soil conditions. About 90 per cent of the spices produced in the country is used to meet the domestic demand and only the 10 per cent exported helps in earning substantial amount of foreign exchange. India’s share in the world spice market is estimated as 46 per cent by volume and 26 per cent by value (Peter *et al.*, 2006). The reasons for this lower performance are that the country does not produce high quality spices that fetch good price and that the spices are exported without value addition. So, the country is required to concentrate on quality of spices and value addition.

Black pepper (*Piper nigrum* L.) known as the ‘King of Spices’, is the most important and most widely-used spice in the world. Pepper is used for its characteristic aroma and pungent taste. Pepper is a large genus of over 1000 species in the family, *piperacea*. The origin of this precious spice was in the forests of the Western Ghats of India (Purseglove, 1981). Pepper is today a foreign exchange earner for India, Indonesia, Malaysia, and Brazil. Of late, Vietnam has also emerged as a major pepper producing country. Black pepper continues to be one of the major items of international spice trade. Of the total spices traded internationally, pepper accounts for about 34 per cent.

About 85 per cent of the global trade in pepper is covered by the International Pepper Community Countries (IPC). India, Brazil, Indonesia, Malaysia, Sri Lanka, and Thailand are the members of IPC. India plays a significant role on the pepper market both as supplier and consumer (Menon, 1998). Black pepper is grown in about 1.9 lakh hectares in India and the productivity works out to 294 kg/ha (Sadanandan, 2000). Pepper contributed 6.5

per cent in quantity and 7.5 per cent in value of the total spice export from India during 2003-'04 (http://commerce.nic.in/adjin_sun_tmbachina.htm). Kerala shares the foremost portion, contributing about 95 per cent in area and production in the country (Peter *et al.*, 2006).

Spices and spice products entering today's sophisticated and highly competitive markets have to strictly conform to the requirements stipulated by the sales contract; and also have to comply with the legislative requirements of the importing country.

The value added products of black pepper like pepper powder, white pepper, dehydrated green pepper, freeze dried green pepper and pepper in brine are of great demand in export area. The export of white pepper from India has increased from 82.26 tonnes in 2000-'01 to 219.87 tonnes in 2002-'03 (Spices Statistics, Spices Board, 2004).

White pepper is the most appreciated form of decorticated green or black pepper. White pepper is the white inner core obtained after removing the outer skin of pericarp of ripe pepper berries. The white pepper berries are light yellow grayish in colour, which is obtained by removing the upper pericarp either by retting, bacterial fermentation, steaming or by the mechanical decortication. White pepper is liked for its mellow flavour, mild pungency, low fibre and high starch content (Pruthi, 1993). White pepper is preferred over black pepper by the people of certain countries as its colour matches with light coloured food preparations, sauces and soups on which black specks are undesirable and only a mild flavour is required (Lewis and Krishnamurthy, 1980).

Generally, the white pepper is prepared by retting method in which the matured green or black berries are loosely packed in gunny bags and soaked in running water for 10 to 15 days followed by rubbing action. Due to long retting period of 10 to 15 days, the development of the characteristic foul smell, fading of colour, loss of piperine and retention of microorganisms are reported (Natarajan *et al.*, 1967 and Lewis, 1982). In the case of steaming method, harvested berries are cooked in boiling water for 10 to 15 minutes and the pericarp is removed by using a pulping machine. In this process, gelatinization of starch in pepper and loss of volatile principles will affect the quality of the white pepper (Gopinathan and Manilal, 2005).

As white pepper is having export potential, the quality of the product is required to be upgraded for high earning. Even though white pepper is superior to black pepper in terms of profit, Indian farmers are reluctant to resort to white pepper production. The main reason behind this is the absence of a convenient and easy method for the production of white pepper. Keeping in view the above facts, the present study on development of a powered-decorticator for producing white pepper from black pepper was conducted with the following objectives.

1. Study of existing methods (mechanical, fermentation and chemical methods) for the production of white pepper.
2. Study of the physical properties of black pepper as a function of moisture content.
3. Development of a black pepper decorticator.
4. Performance evaluation of the developed machine.
5. Quality analyses of the white pepper on the basis of volatile oil, oleoresin, volatile components, and piperine.

CHAPTER II

REVIEW OF LITERATURE

This chapter deals with a brief review of the crop, its characteristics and the research work carried out by various investigators on the production of white pepper. Also, different methods and technologies adopted for peeling or pulping of spices are discussed. Structure and composition of pepper and physical properties of spices have also been reviewed and discussed briefly.

2.0 Pepper

2.1 Origin

Pepper is a large genus, with over 1000 species, in the family *Piperaceae*, which is a perennial climbing vine or shrub with a smooth woody stem mostly found in hot and moist region of Southern India (Govindarajan, 1977). It is a perennial herbaceous woody climber of 5 m or more in height with a bushy columnar appearance. The spikes are borne on the piagiotropic branches opposite to the leaves and are 3 to 15 cm long. The fruits or berries are 4 to 7 mm in diameter and have a pulpy pericarp and a hard endocarp (Purseglove *et al.*, 1981). Fruits are botanically called drupes but generally called berries. The unripe is green with exocarp turning red when ripe and black on drying.

2.2 Varieties

The varieties under cultivation have been evolved by unconscious selection from natural hybridization and vegetative propagations; thus, they show considerable variation in habitat, size and shape of fruit, and fruiting behavior. More than 75 named-varieties are known to be cultivated in India. They are distinguished by the names of the areas of cultivation. Introductions from one area to another have also taken place, resulting in the same variety being known by different names at different places. The common varieties of pepper grown in India are shown in Table 2.1.

Table 2.1 Some common varieties of pepper grown in India.

Region	Name of cultivars	Green-berry-yield (kg per vine)	Remarks
North Kerala	Kalluvalli	1.0-5.6	Hardy; drought and wilt resistant; regular bearer
North Kerala	Balamcotta	3.0-4.5	Dominantly bisexual; regular and heavy yielder
South Kerala	Karimunda	-	Early bearer but short lived
South Kerala	Kuthiravally	-	High yielder in alternate years
Hybrids in Kerala	Uthriancotta X Kottanadan	3.5	Experimental; degenerates in yield
	Uthriancotta X Thalliparamba	4.5-5.5	Experimental; degenerates in yield
	Uthriancotta X Cheriakaniakadan (panniyur-1)	5.3-10.5	Hardy, adaptable to different soil and climate conditions; respond to nutrients; early bearing and heavy yielder
Karnataka	Malligesara	-	Regular and heavy yielder

2.3 Harvesting and yield

First harvest of pepper is done during the third year after planting. Pepper starts flowering even one year after planting. After flowering, it takes about 8 to 9 months for maturity. Generally, harvesting is done when one or two berries in a few spikes turn orange or red. Harvesting in Kerala is usually done from November to February. The maturity desired at harvest for production of various end products is given in Table 2.2.

Table 2.2 The maturity of pepper desired at harvest for production of various end products

End-Product	Maturity at harvest
White pepper	Fully ripe
Black pepper	Fully mature and nearly ripe
Canned pepper	4 – 5 months after fruit set
Dehydrated green pepper	10-15 days before maturity
Oleoresin	15-20 days before maturity
Oil	15-20 days before maturity
Pepper powder	Fully mature with maximum starch

Source: Govindarajan (1977)

2.4 Structure and composition of pepper berry

A longitudinal section of the corn shows a thin pericarp and spermoderm enclosing single seed. The greater part of the seed consists of a starchy mass around a hollow centre. The embryo is embedded in a small endosperm at the apex of the seed.

Structural details of skin layers and perisperm of black pepper is shown in Fig. 2.1. Seven layers as detailed below are differentiated in the pericarp of pepper (Winton and Winton, 1939).

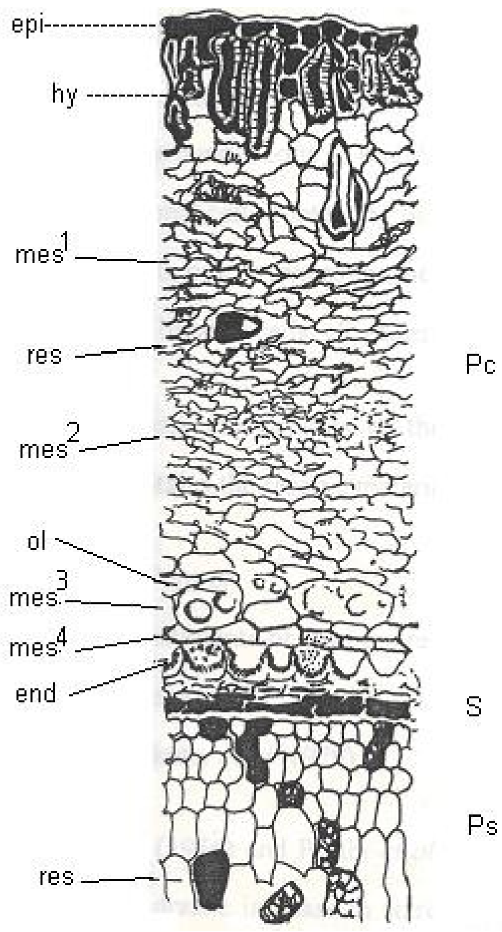

Fig. 2.1 STRUCTURAL DETAILS OF SKIN LAYERS AND PERISPERM OF BLACK PEPPER.

1. Epicarp of polygonal cells, dark contents, and stomata (epi)
2. Hypoderm of polygonal cells and a group of radially elongated stone cells (hy.)
3. Outer mesocarp (mes^1) of polygonal cells interspersed with a few oleoresin cells (res.)
4. Fibovascular bundle zone or middle mesocarp (mes^2)
5. Large polygonal cells containing oil (ol) or inner mesocarp (mes^3)
6. Porous cells in one or two rows (mes^4)
7. Endocarp of breaker cells, characteristics of pepper (end).

The pericarp (Pc) contains the epicarp and hypoderm. The spermoderm (S) consists of three layers and the perisperm (Ps), which is peculiar in pepper, and contains the reserve material starch embedded in a cuticular layer.

2.5 Constituents of pepper

The major constituents of pepper are starch, fibre and protein but more significant ones are the piperine and the volatile oil, which contribute the pungency and aroma respectively (Sumathikutty *et al.*, 1979). The white pepper has a higher starch content but lower fibre content compared to black pepper. The major constituents of black pepper and white pepper are given in Table 2.3.

Table 2.3 Constituents of white- and black-pepper

Chemical constituents (%)	Black pepper	White pepper
Moisture	13.0	14.0
Volatile oil (v/w)	4.1	3.8
Piperine	2.3	3.2
Nonvolatile ether extract	12.0	8.2
Oleoresin	9.6	7.2
Starch	40.5	48.0
Crude fibre	14.0	4.0
Ash	7.0	2.0
Acid insoluble ash	1.5	0.6

Source: Thomas *et al.* (1987)

2.6 Physical properties of pepper

The study of the physical properties of pepper is essential for the design of the equipments for handling and processing. To select an appropriate method for the determination of various properties of pepper, literature on other similar agricultural materials was reviewed since not much work was done for pepper.

2.6.1 Moisture content

Moisture content was determined by toluene distillation method using Dean Stark apparatus as per Associates of Official Analytical Chemists (AOAC, 1975) method. The method was explained in Art. 3.2.1.

2.6.2 Size and shape

The size and shape of the grain was determined by the three principal dimensions of grain namely major, minor and short axes (Mohsenin, 1970).

2.6.3 Sphericity

Sphericity was determined by using the Eqn. 3.2. (Mohsenin, 1970). The method used for finding out the spericity was explained in Art. 3.2.3.

2.6.4 True Density

Santhi (1998) reported that the true density of pepper varied from 1022 to 1104 kg/m^3 when the moisture level increased from 8.2 to 19.7 per cent (d.b).

Verma and Prasad (2000) reported that the true density of Kisan maize variety varied from 1281 to 1187 kg/m^3 and in the case of Hi-starch variety the same varied from 1228 to 1171 kg/m^3 in the moisture range of 12 to 43 per cent (d.b). The same method was adopted in the present study and is explained in Art. 3.2.4.

2.6.5 Bulk density

Singh and Goswamy (1996) reported that the bulk density of cumin seeds varied from 410 to 502 kg/m^3 for an increase in moisture content of 7 per cent to 22 per cent (d.b).

Verma and Prasad (2000) reported that the bulk density of Kisan maize variety varied from 756 to 651 kg/m^3 and in the case of Hi-starch variety the same varied from 729 to 605 kg/m^3 in the moisture range of 12 to 43 per cent (d.b). The same method was adopted in the present study and is explained in Art. 3.2.5.

2.6.6 Porosity

Singh and Goswamy (1996) reported that the porosity of cumin seeds increases from 54 to 64 per cent when the moisture content varied from 7 per cent to 22 per cent.

According to Verma and Prasad (2000), the porosity of Hi-starch and Kisan maize variety increased linearly from 0.4062 to 0.4835 and from 0.4093 to 0.4517 in the moisture range of 12 to 43 per cent (d.b).

Santhi (1998) reported that the porosity of pepper showed an increase in trend of 32 to 47 per cent when the moisture content increases from 8.2 to 19.7 per cent (d.b). The same method was adopted in the present study and is explained in Art. 3.2.6.

2.6.7 Coefficient of friction

Shepherd and Bharadwaj (1986) obtained an increasing trend in the case of static coefficient of friction against galvanized steel surface for pigeon pea from 0.26 to 0.37 with an increase in moisture content from 6.3 to 28.2 per cent (d.b). The static coefficient of friction of pepper increased linearly with respect to moisture content from 8.2 to 19.7 per cent (d.b.) in various surfaces like stainless steel, mild steel, galvanized iron and aluminum (Santhi, 1998). The same method was adopted in the present study and is explained in Art. 3.2.7.

2.6.8 Angle of repose

Angle of repose of pigeon pea was reported to have increased from 21.8 to 25.2 ^{0}in the moisture content range of 6.3 to 28.2 per cent (d.b) (Shepherd and Bharadwaj, 1986) of gram from 25.5 to 30.4^0 in the moisture content range of 8.6 to 17.6 per cent (d.b) (Dutta *et al.*, 1988) and in pumpkin seed from 30 to 52^0 in the moisture content range of 4 to 40 per cent (d.b) (Joshi *et al.*, 1993).

Singh and Goswamy (1996) observed that the angle of repose increased linearly from 36.5 to 51.3 degree for cumin seeds with respect to increase in moisture content from 7 to 22 per cent (d.b).

The angle of repose increased from 24 to 33.87 degrees for black pepper for an increase in moisture content from 8.2 to 19.7 per cent (d.b) (Santhi, 1998).

Verma and Prasad (2000) reported the angle of repose of Hi-starch and Kisan maize was found to increase from 29 to 42 degrees and 29.8 to 42.4 degrees with increase in moisture content from 12 to 43 per cent (d.b). The same method was adopted in the present study and is explained in Art. 3.2.8.

2.7 Production of white pepper

White pepper is prepared from ripe fruits by removing the outer pericarp either before or after drying. White pepper is manufactured in India by one of the following techniques.

2.7.1 White pepper from green berries

White pepper is traditionally prepared by retting method, in which the matured green pepper berries are filled loosely in gunny bags or knitted nylon bags and soaked in flowing water stream or rivers for two to three weeks. After retting the skin is removed mechanically or manually-by trampling. After thorough washing the skin is sun dried to the moisture content of 8-12 per cent (Natarajan *et al*., 1967).

Lewis *et al*. (1969a) developed a technique for the production of white pepper from matured green berries or black berries by steaming or boiling in water for 10 to 25 minutes to soften the skin. The treated material is passed through a fruit pulping machine and the softened outer layer is separated. After drying, the core material will have satisfactory colour and aroma. The yield of white pepper by this method is 20 per cent. Due to gelatinization of starch during the steaming process, the colour of the ground pepper is not as white as that obtained by traditional retting process. Advantage of this method is shortening the processing time and minimizing the microbial load.

In a study on production of white pepper from green berries, Lewis *et al.* (1976) inactivated the enzyme in the green pepper by adequate heat treatment. The resulting product wrinkled in appearance which resembled black pepper, except for colour. The aroma was superior with minimum microbial load.

In the traditional method of preparation of white pepper, the ripe berries are tightly packed in gunny bags and then allowed to soak in slow-running water for one to two weeks. After retting, the skin is removed manually by trampling followed by thorough washing. The pepper is then sun dried to a moisture content of 10 to 15 per cent (Purseglove, 1981).

Madhusoodanan *et al*. (1990) conducted a study for optimization of retting duration of ripened berries in the conventional process. They observed that 100 per cent of white pepper was recovered in15 days retting.

Mathew (1993) reported a faster method of making white pepper by boiling the fresh corns or black pepper in water. Removal of pericarp is done in fruit pulper with appropriate sieve size and hard nylon brushes. Steaming can be used instead of boiling. Due to heat treatment, the starch in the corn gets gelatinized resulting in slight change in texture.

Another indigenous method of preparing white pepper is by pit burial method (Varghese, 1999). Mature (green), semi-ripe (20 to 40 per cent ripe or yellow) and fully ripe (red) berries were put into woven plastic bags and buried 60 cm below the soil surface. Then the pepper skin is degraded by the rubbing action which is washed off and the corns are dried in the sun. It was found that fully ripe berries were converted into white pepper after 7 days whereas it required 14 days for converting green and yellow berries to white. The advantage with this method is that even mature berries get converted fully into white pepper.

Enzymatic decortication is an effective method for white pepper production. Pectinase was found to be most effective for the degradation of pepper skin. At optimum condition, pectinase can facilitate green pepper decortication in 24 h and black pepper decortication in 40 to 50 h of incubation to provide white pepper. The pectinase activity was maximum on pepper skin in a basic mineral salt medium with pH 3.5 at 37 to 40 ^{0}C. The yield of white pepper by enzymatic decortication was 27 to 32 % from green pepper and 67 to 73 % from black pepper (Gopinathan and Manilal, 2004).

Gopinathan and Manilal (2005) reported that white pepper could be prepared through bacterial fermentation. Pepper Skin Fermenting Bacteria (PSFB) have the ability to degrade pepper skin completely in the tested period of 14 days. There were four potent strains, named PSFB1 as *Xanthomonas sp*., PSFB2 as *Pseudomonas sp*. and PSFB3 and PSFB4 as *Bacillus sps.*

Another chemical method patented by Omanakutty (2006) comprises soaking the berries in a dilute solution of alkali, followed by blanching, decortication in a pulper, bleaching and drying. Here, the advantage is that the decortication is made possible within 12 to 14 hours in the case of fresh green pepper.

2.7.2 White pepper from black berries

A chemical process for making white pepper from black pepper was patented by Joshy (1962). The whole dried pepper is steeped in five times its weight of water for four days, treated with four per cent sodium hydroxide solution and boiling the mixture. The skin is removed by agitation, followed by washing the product with water, bleaching with 2.5 per cent hydrogen peroxide solution and drying the berries at 52 ^{0}C. This process is not tried commercially.

Pruthi (1993) reported on an improved process of National Research Development Corporation (NRDC) in which the processing was done in a dry state so that black skin could be separated and which could be used for oil and oleoresin extraction. Dry black pepper was cleaned and conditioned to get an optimum product with acceptable colour, yield, etc. and then ground pepper in a specially designed mill. Size separation was carried out by sieving till satisfactory white pepper powder of requisite micron size was obtained.

2.7.3 White pepper by decortication technique

Selective grinding of black pepper to remove the outer coat has been tried to produce white pepper. In this new approach, the skin of black pepper is mechanically removed (Thomas *et al.*, 1987). This process is seldom practiced because of the requirement of relative grading to collect uniform sized berries, and while grinding significant loss of aromatic compound from the upper layer of the mesocarp is another disadvantage.

Anandabose (1996) had developed a pepper skinner for obtaining white pepper from green pepper berries. It mainly consists of two cylinder-concave assemblies, a hopper, a feed roll and an inclined belt separator assembly. The decortication took place as a result of the compressive and the shearing forces acting upon the pepper berries fed between the rotating drum and the stationary concave. The maximum overall decorticating efficiency was observed at the feed rate of 12 kg/h and drum speed of 20 rpm for both the surfaces. The maximum decorticating efficiency observed for coir-mat was 91.5 and that for rubber surface was 94.2.

Ginu *et al.* (2000) developed a power operated black pepper decorticator. The major parts were a cylinder with a rough inside surface, rotating shaft with vane arrangement, a hopper and a collecting tray. The decortication took place as a result of the compressive and shearing forces acting upon the pepper berries fed between the rotating vane and stationary cylinder. At optimum condition, overall decorticating efficiency obtained was 86 per cent.

According to Thirupathi (2004), white pepper was obtained from black pepper by polishing in a laboratory model pepper polisher. Evaluation was conducted for pre-treated black pepper (untreated, boiling and steaming) by varying peripheral speeds (from 170 to 280 rpm) and clearance (6 to 12 mm) for different grades of abrasive stones (A 24, A 46, and A 60). The peripheral speed was varied by changing the size of driven pulley and the clearance was varied by replacing the abrasive stone of varying diameter. Black pepper was fed at the centre of the abrasive stone. By the centrifugal force, the samples were thrown to the periphery of the stone. By abrasion between the feed and the abrasive stone and friction between the feed and the perforated screen, the black skin was removed. The optimum values of polishing efficiency (89.8 %), recovery (66.7 %) and broken (20.3 %) were achieved at 283 rpm and 6 mm clearance for steamed sample by using A 46 grade stone in the pepper polisher.

A power-operated pepper peeler was developed by Thirupathi (2004), which consists of a blade and brush assembly to peel the skin and water distribution system to wash the peeled pepper. Peeling efficiency and per cent of broken were determined at different parameters (retting, blanching and untreated), rotational speed (141, 189, 236 and 283 rpm) and clearance between the blade and outer perforated screen (4, 6, 8 and 10 mm). The peeler was also manually operated by gear wheel mechanism and evaluated by varying the clearance. Peeling efficiency of 90.9 per cent and broken of 7.2 per cent for untreated ripe berries were found to be optimum values at rotational speed of 189 rpm and 8 mm clearance in the power-operated pepper peeler.

2.8 Peeling methods used for spices

An abrasive brush-type ginger peeling machine was developed by Agarwal *et al*. (1987). The machine consisted of two continuous brush belts, which move in opposite direction with a variable-speed motor. The movement of the two brush belts in opposite directions provided the abrasive action on the ginger passing in between them while the downward relative velocity provided the downward flow of ginger. The machine had a capacity of 20 kg/h and a peeling efficiency of 71 per cent. The meat loss at full capacity is 1.6 per cent.

Pimento pepper lye-peeling process by using response surface methodology was conducted by Floros and Chinman (1987). It was analyzed for different lye concentration (4 to 12 %) at different process temperatures (80 to 100 ^{0}C) and time (1.5 to 6.5 minutes). The result shows that, at a relatively high temperature of around 90^{0}C with lye concentration of 12 per cent sodium hydroxide, and processing durations of 1.6 to 2 minutes, the method removed practically all skin and the peeling loss was as low as 20 per cent.

Ali *et al.* (1991) developed a brush-type ginger peeling machine. The machine essentially consists of two continuous vertical abrasive belts with a brush of 32 gauge steel wires, 2 cm long and spacing of 1.90 cm. The peeling zone has a length of 135 cm and width of 30 cm. The peeling efficiency was 85 per cent.

Emmanuel *et al.* (1994) developed a hand operated brush type ginger peeling machine which consisted of a stationary abrasive unit and a moving abrasive unit. The stationary and moving abrasive units are made of canvas belts. The brush was made with nylon threads of 1.5 cm long pieces mounted on the canvas belt. The brushing action from the movement of moving belt over the stationary belt causes the peeling.

John *et al.* (1996) developed a semi mechanical abrasive roller type ginger peeling machine. The machine consists of an abrasive unit, collection unit and frame. The abrasion unit was a wooden roller of 15 cm diameter on which a 0.6 cm coir rope was wound. A coir rope belt was used to remove the peels that are remaining between the branches of the ginger. Abrasion unit does the work of peeling when ginger rhizome is pressed manually on to the rotating roller. The peeling efficiency and capacity of the machine under optimum conditions were in the range of 75 to 85 per cent and 1.3 to 1.6 kg/h respectively.

2.9 Quality requirement of pepper

Pepper is exploited industrially for its pungency and aroma. It is evaluated for its appearance, pungency and its aroma or flavour properties. The aroma is contributed by its essential oil, which consists of a wide variety of chemical constituent's viz., terpenes, hydrocarbons and oxygenated compounds. The oleoresin or the solvent extract represents the total pungency and flavour of pepper.

2.9.1 Pepper oil

Lewis *et al.* (1969b) reported that the yield of pepper oil varies from 2 to 3.5 per cent and it consists of major monoterpene hydrocarbon (70 to 80 per cent), sesquiterpenes (22 to 30 per cent) and oxygenated compounds. In general, the chief monoterpene hydrocarbon constituents are α-pinene and β-pinene, limonene and sabinene. Sesquiterpene hydrocarbon present is mainly β-caryophyllene. The oxygenated derivatives, which are the chief contributors to aroma, represent only 3 per cent of the total oil.

Richard *et al*. (1971) studied the volatile components of black pepper varieties by Gas Chromatograph (GC) methods. Panniyoor-1 and Narayakodi exhibited low monoterpene hydrocarbon concentrations (55 and 51.5 %, respectively).

Pruthi (1980) has shown that starch content increases during maturation whereas volatile oil decreases and little change was observed in non-volatile ether extract and piperine.

According to Balakrishnan (1992), essential oil represents the total aroma of the parent spice. It does not impart colour to the end product; has uniform flavour quality and is free from enzymes and tannins.

Essential Oil Association of America (E.O.A) specification of black pepper oil is given in Appendix A.

2.9.2 Piperine and oleoresin

Extraction of black pepper with organic solvents provides an oleoresin with exact odour, flavour and pungent principles of the spice. The organoleptic properties of the oleoresin were determined by its volatile oil and piperine content.

Pruthi (1970) reported that ultra violet spectroscopy and calorimetric analysis were more accurate methods for piperine estimation. Maximum absorption value was observed at 345 nm in benzene or chloroform solution.

According to Sumathikutty *et al*. (1979), the major constituents of pepper are starch, fibre, and protein; but the significant ones are the piperine and volatile oil, which contribute the pungency and aroma respectively.

Mathai (1981) studied different methods for the estimation of oleoresin and piperine in black pepper. Of the three methods studied, the modified cold percolation method was found to be the most efficient for oleoresin estimation; this was followed by soxhlet distillation. The least efficient was (conventional) cold percolation method. Inspite of the use of a very efficient solvent (ethyl alcohol), the conventional method gave a poor oleoresin yield. The piperine content in the oleoresin of modified cold percolation was very much higher compared to other two methods. This could be due to the complete extraction and also the prevention of loss of the alkaloids during the process of extraction and estimation.

Soubhagya *et al*. (1990) conducted a study on piperine estimation in different solvents by spectrophotometric method. From that study, they concluded that pepper oleoresin samples meant for piperine estimation have to be protected from light immediately after dilution. Since ethylene dichloride and benzene are carcinogenic in nature, other solvents like alcohol, acetone and ethyl acetate can be used for the estimation of piperine. The absorption maxima for different solvents used are 337 nm for acetone, cyclohexane and ethyl acetate; 342 for ethanol, ethylene dichloride, and chloroform, and 343 nm for benzene.

Freshly prepared oleoresin is a dark green, viscous, heavy liquid with a strong aroma. Indian standard specification of black pepper oleoresin is given in Appendix B.

CHAPTER III
MATERIALS AND METHODS

The various methods adopted in the determination of physical properties of black pepper and different methods of producing white pepper are discussed in this chapter. It also describes the fabrication and evaluation of a powered black pepper decorticator; and quality analyses of the white pepper in detail.

3.1 Test sample

Pepper (*Piper nigrum* L.) Panniyur-1 variety harvested in December-January, 2005 procured from a local trade centre was used for the study. The seeds were cleaned manually for removing brokens, immature seeds, and foreign matter.

3.2 Physical properties of black pepper

The properties such as shape, size, moisture content, bulk density, true density coefficient of friction, and angle of repose were determined for black pepper at different moisture content.

3.2.1 Determination of moisture content of pepper

Moisture content was determined by toluene distillation method using Dean Stark apparatus as per Associates of Official Analytical Chemists (AOAC, 1975) method (Plate 3.1). Toluene, measuring 100 ml, was taken in a distillation flask containing 5 g of ground black pepper sample. The flask was attached to the Dean Stark apparatus with the condenser. On boiling, the water vapour along with toluene got distilled from the flask, condensed, and was trapped in the receiver of the apparatus, which contained toluene. Distillation was continued till the volume of moisture collected remained constant. The apparatus was cooled at room temperature and weight of moisture collected was noted. The moisture content was calculated by,

$$\text{M.C. (w.b), \%} = \frac{W_w}{W} \times 100 \qquad \text{---- (3.1)}$$

where,

W_w = Weight of water collected, g

W = Intial weight of sample, g

M.C (w.b) = Moisture content, % wet basis

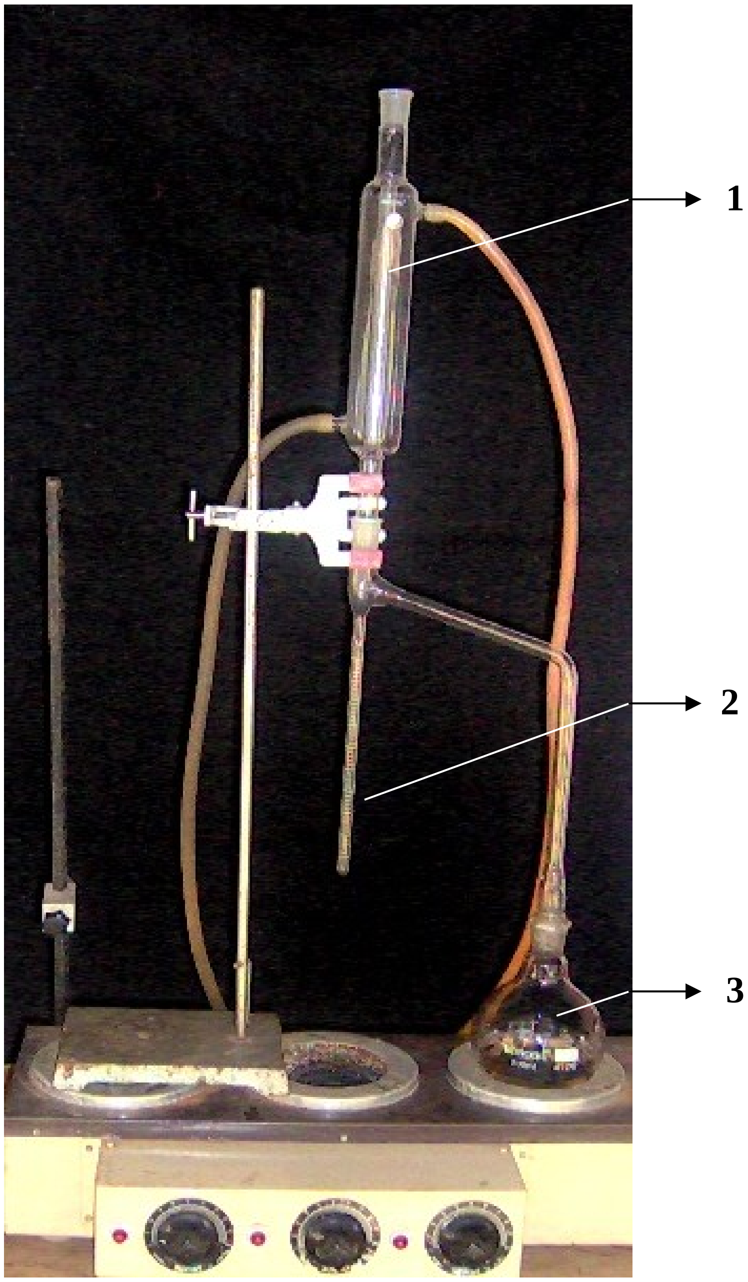

Plate 3.1 Dean Stark Apparatus

1. **Condenser**
2. **Dean Stark Apparatus (moisture collected)**
3. **Round Bottom Flask (Sample + Toluene)**

3.2.1.1 Preparation of samples of desired moisture content

Pepper at different moisture levels were obtained by adding 100 ml and 200 ml distilled water about 500 g of samples and sealed in polyethylene bag and stored in refrigerator at 5 ^{0}C for two weeks with frequent agitation to ensure uniform moisture distribution. Before starting the experiments, the pepper was taken out of the refrigerator and allowed to warm up to room temperature.

Lower moisture levels were obtained by drying the samples in an oven at 55 to 60 ºC for two to six hours depending upon the final moisture content required.

3.2.2 Shape and size

The pepper berries 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 berries was observed. Similarly, the size of the pepper berries were determined using a travelling microscope. Measurements on three mutually perpendicular principal axes viz; major, intermediate and minor diameters were determined.

3.2.3 Sphericity

Sphericity was determined using the following expression (Mohsenin, 1970). Length of the intercepts taken were those obtained under Art. 3.2.2 above as major, intermediate, at minor diameters respectively.

$$\text{Spericity} = \frac{(lbt)^{1/3}}{l} \qquad \text{---- (3.2)}$$

where,

l = Largest intercept, mm

b = Largest intercept normal to l, mm

t = Largest intercept normal to l and b, mm

3.2.4 True density

A jar of 100 cc volume was filled with approximately 50 g of pepper. Similarly toluene was taken in another measuring jar of 100 cc. Then the toluene was poured into the jar containing pepper berries such that it displaces the entire quantity of air in the jar containing pepper. The volume of toluene transferred to the first jar from the second jar was noted. The true density was determined based on these observations from the formula given below.

$$\text{True density} = \frac{Wp}{V_j - Vt}$$

$$= \frac{Wp}{Vp} \qquad \text{---- (3.3)}$$

where,

Wp = Weight of pepper, g

Vt = Volume of toluene in the jar containing black pepper, cc

Vj = Volume of jar

Vp = Volume of pepper

= Vj – Vt

3.2.5 Bulk Density

The bulk density of pepper berries was determined by filling black pepper in a circular container of known volume of 100 cc and weighing the content. The measurements were replicated. Bulk density was calculated as the ratio between the mass of pepper and the volume of the container.

3.2.6 Porosity

Porosity is the per cent of volume of voids in the test sample at a given moisture content. It was computed from the value of true density and bulk density using relationship given by Mohsenin (1970) as follows.

$$\text{Porosity} = 1 - \frac{\text{Bulk density}}{\text{True density}} \quad \text{---- (3.4)}$$

3.2.7 Coefficient of friction

The experimental apparatus used in the friction studies consisted of a frictionless pulley fitted on a frame, a bottomless cylindrical grain container, a loading pan and test surfaces. The grain container placed on the test surface was filled with a known quantity of pepper of 100 g and weights were added to the loading pan until the container began to slide. The weight of the pepper and the added weights comprised the normal force (N) and frictional force (F) respectively.

From the normal force and frictional force exerted by the material on different surfaces, the coefficient of friction was calculated by using the formula;

$$\text{Coefficient of friction} = \frac{\text{Force of friction}}{\text{Normal reaction}} \quad \text{---- (3.5)}$$

$$\mu = \frac{F}{N}$$

where, μ = coefficient of friction

F = force of friction, g

N = force normal to the surface of contact, g

3.2.8 Angle of repose

The angle of repose was determined by filling method. A funnel fitted with a gate was filled with the sample. The gate was then opened allowing the pepper berries to flow to a circular plate. When a heap was formed on the plate, the valve was closed and the height and diameter of the heap were measured. The angle of repose was calculated by using the equation.

$$\phi = \tan^{-1}\left(\frac{h}{[D/2]}\right) \qquad \text{---- (3.6)}$$

where,

ϕ = angle of repose, degrees

h = height of the heap, cm

D = diameter of the heap, cm

3.3 Studies on existing methods on production of white pepper

To have more information on the various methods of producing white pepper, various trials were conducted with the existing methods.

3.3.1 Mechanical method

A prototype of the mechanical decorticator for black pepper developed in this college was tested for its performance. The machine consisted of a cylinder with vane arrangement, feeding and discharge mechanisms, frame assembly, and power transmission system. The decortication was done by the rubbing of pepper berries by the vanes against the rough inside surface of the cylinder.

Experiments were conducted using black pepper soaked in water for 16, 17, 18 and 19 hours. The quality of white pepper was evaluated in terms of volatile oil, piperine, oleoresin, and oil constituents. Decorticating efficiency, wholeness of kernels, and overall decorticating efficiency were also observed.

3.3.2 Fermentation / Retting method

As described in Art.2.7.1, white pepper was prepared by the retting method in which the matured black pepper berries were packed in gunny bags and steeped as such in water for 9, 10 and 11 days. Water was changed everyday. After retting, the skin was removed manually by trampling, washed, and sun-dried to a moisture content of 8 to 12 per cent (d.b).

3.3.3 Chemical method.

In the chemical process for the preparation of white pepper, the whole dried black pepper was steeped with about five times of water for four days. Then, the sample was boiled with four per cent sodium hydroxide solution. The skin of berries was removed by rubbing. This white pepper is bleached with 2.5 per cent hydrogen peroxide to get good attractive colour.

3.4 Development of a black pepper decorticator

Based on the preliminary studies, a cylinder with different grinding surfaces was developed and its performance evaluated. The underlying principle of the machine was to subject the berries to compression and shearing between two abrading surfaces. The treated black pepper berries were fed between the two abrading surfaces from a hopper. The compressive forces crushed the skin of the berries and the shear forces separated the skin. The centrifugal and gravitational forces threw the berries to the periphery of the rotating grinding surface. The nylon brushes fixed along the periphery of the upper grinding surface gave a brushing action. A water jet enhanced the separation of berries. The berries and the skin moved out to the discharge outlet through the opening provided on the collecting tray. The developed machine has the following components.

1. Grinding/Abrading surfaces
    a. Stationary grinding disc
    b. Rotating grinding disc
2. Feed hopper
3. Cylindrical collecting tray & Discharge chute
4. Water supply system
5. Main shaft
6. Main frame
7. Power transmission system
8. Power source

3.4.1 Grinding surfaces

The machine consists of two circular grinding surfaces of 300 mm diameter and 16 mm thickness, which are the main functional parts of the machine. The two grinding surfaces; are arranged on two discs; the top disc and the bottom disc. The top disc carries on its bottom the top-grinding surface and the bottom disc has on its top the bottom-grinding surface. The bottom disc is coupled to the main shaft and hence rotated by it. The top disc is mounted directly above the bottom disc so that the two grinding surfaces face each other. The top disc, though inserted over the main shaft, is restrained from having rotating motion. The top disc is spring loaded vertically and hence free to move up and down along the main shaft. This small up and down motion of the top disc facilitates the adjustment off the clearance between the two grinding surfaces according to the varying sizes of the berries. The different combinations of surfaces required for abrading the surface of black pepper were prepared by changing the surface characteristics of the two grinding surfaces as given below.

Treatments	**Top grinding surface**	**Bottom grinding surface**
I	Knurled MS surface	Knurled MS surface
II	Rexin lined MS plate	Rexin lined MS plate
III	Teflon lined MS plate	Teflon lined MS plate
IV	Polyurathene lined MS plate	Emery surface

The top and bottom discs had a thickness of 6 mm. The knurled lines in both the directions were apart by 1 mm. The thickness of the materials used for lining were as given below.

Rexin sheet:	0.6 mm
Teflon sheet:	3.0 mm
Polyurethane sheet:	3.0 mm

The emery stone used in the fourth treatment was of BA (coarse) grade. Around the circular surface, nylon brushes are provided in series with alternate two and three bunches. Two views of the grinding surfaces are shown in Plate 3.2 and 3.3**.** Fig. 3.1 shows the grinding surface. The bottom surface is connected to a shaft of 3.16 cm diameter and 33.5 cm length through a tapered roller bearing.

3.4.2 Feed hopper

A hopper of size 12 x 10 x 5 cm is provided at the top so that pepper can be fed easily. The hopper is made out of 16 gauge MS sheet.

3.4.3 Cylindrical collecting tray and outlet arrangement

The grinding surfaces are surrounded by a cylindrical collecting tray at an angle of 9 degree to the horizontal plane and has a diameter of 44 cm. It is made of 16 gauge MS sheet. The pepper berries get discharged from the grinding surfaces through an outlet due to centrifugal and gravitational forces. At the bottom of the frame, outlet is provided by means of a bent pipe of 3.81 cm diameter.

3.4.4 Water supply system

A ball valve of 1.27 cm diameter is welded on the side of the rectangular frame to control the flow of water. A hose is connected from the ball valve to supply water in the entire decorticating area.

3.4.5 Main shaft

A vertical main shaft of 3.16 cm diameter and length 33.5 cm is connected to the output shaft of a reduction gear unit through a flanged coupling. The reduction gear unit is coupled to a single-phase 0.5-hp motor through a belt and pulley system. The vertical main shaft, at its top end carries the revolving grinding surface, through a tapered roller thrust bearing. The reduction gearbox has a gear ratio of 5:1.

3.4.6 Main frame

The entire decorticating assembly, main shaft, and motor, along with gear reduction box, are fixed to an angle iron frame of overall size 96 x 85.5 x 51.5 cm as shown in Plate 3.4. The front and top views of the pepper decorticator are shown in Fig. 3.2 and 3.3.

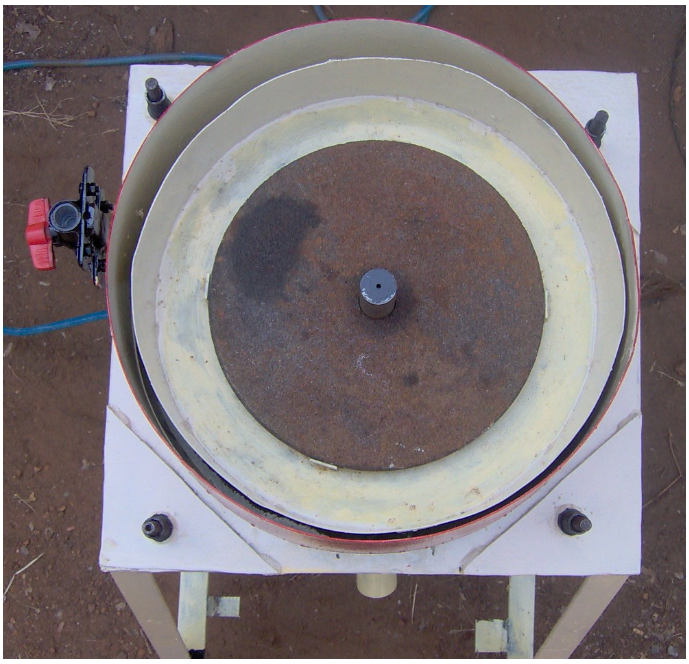

Plate 3.2 Grinding stone

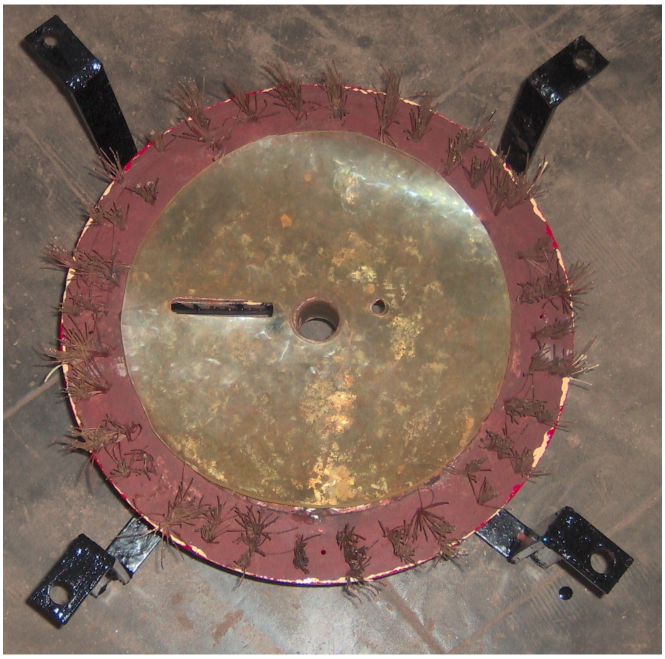

Plate 3.3 Polyurethane (Grinding surface)

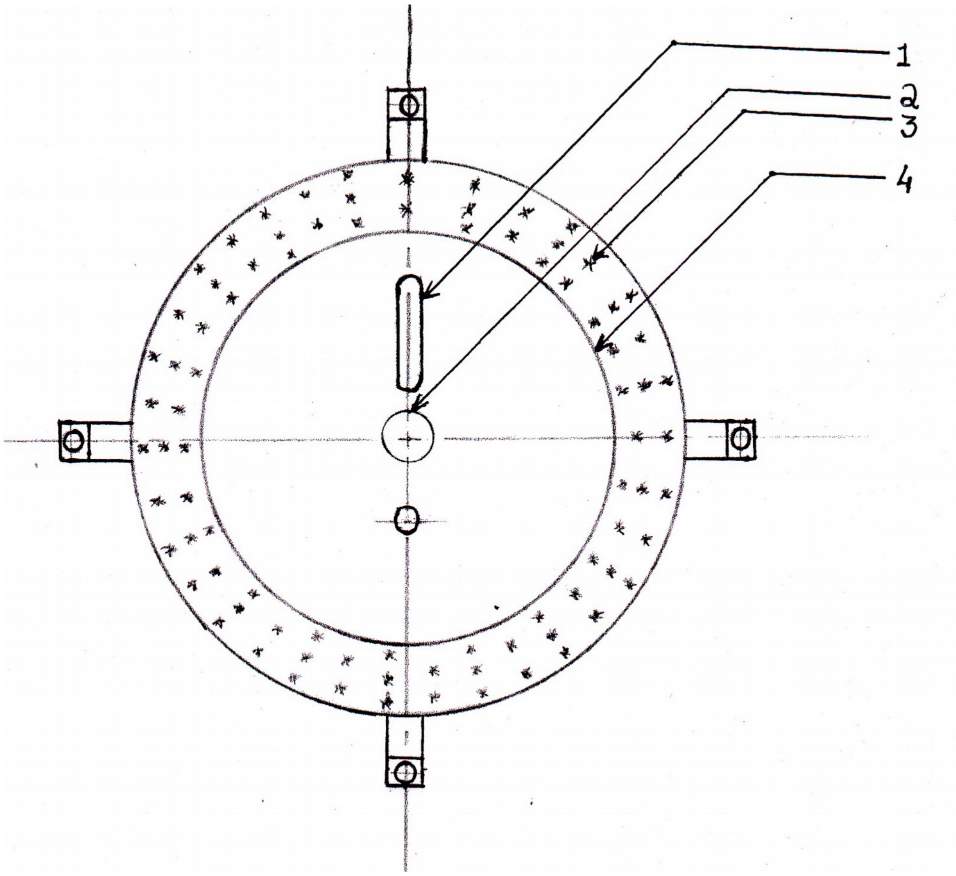

Fig. 3.1 Grinding surface- Top view

SI. No.	Particulars
1	Hopper dimensions: (Top -12 x 5, Bottom - 9 x 2, Height – 10)
2	Shaft (3.16 ϕ)
3	Brushes (length – 4 cm, raw to raw spacing – 4 cm)
4	Grinding surface (30 ϕ)

All dimensions in cm

Scale 1:5

3.4.7 Power source

A single-phase electric motor of 0.5 hp and rated speed of 1440 rpm is used to drive the main shaft. Power is transmitted from the motor to the reduction gear box by means of a ‘V’ belt and pulley system as shown in Plate 3.5. The gear reduction unit derives its power from the electric motor through a gear ratio of 5:1. The speed of the machine is varied in the range 47 to 81 rpm by using belt and pulley arrangement. Correspondingly, rpm at the reduction gear unit is also provided. Hence, the desired speed of 47 to 81 rpm is obtained at the main shaft.

3.4.8 Power transmission system

The power was transmitted for the rotation of the grinding surface. The rated speed of motor was 1440 rpm and the various speeds obtained based on various pulley diameters 5, 17, 20, 22, 25 and 30 cm and the speed reduction ratio of 5:1 for the gear reduction unit are presented below.

Table 3.1 Main shaft speed for a rated speed of 1425 rpm for motor

Diameter of Pulley		Reduction Gear Ratio	Main Shaft Speed (rpm)
Driver Pulley (cm)	Driven Pulley (cm)		
5	17	5:1	81
-do-	20	-do-	71
-do-	22	-do-	63
-do-	25	-do-	57
-do-	30	-do-	47

Plate 3.4 Pepper decorticator-Front view

Plate 3.5 Power transmission system-Front view

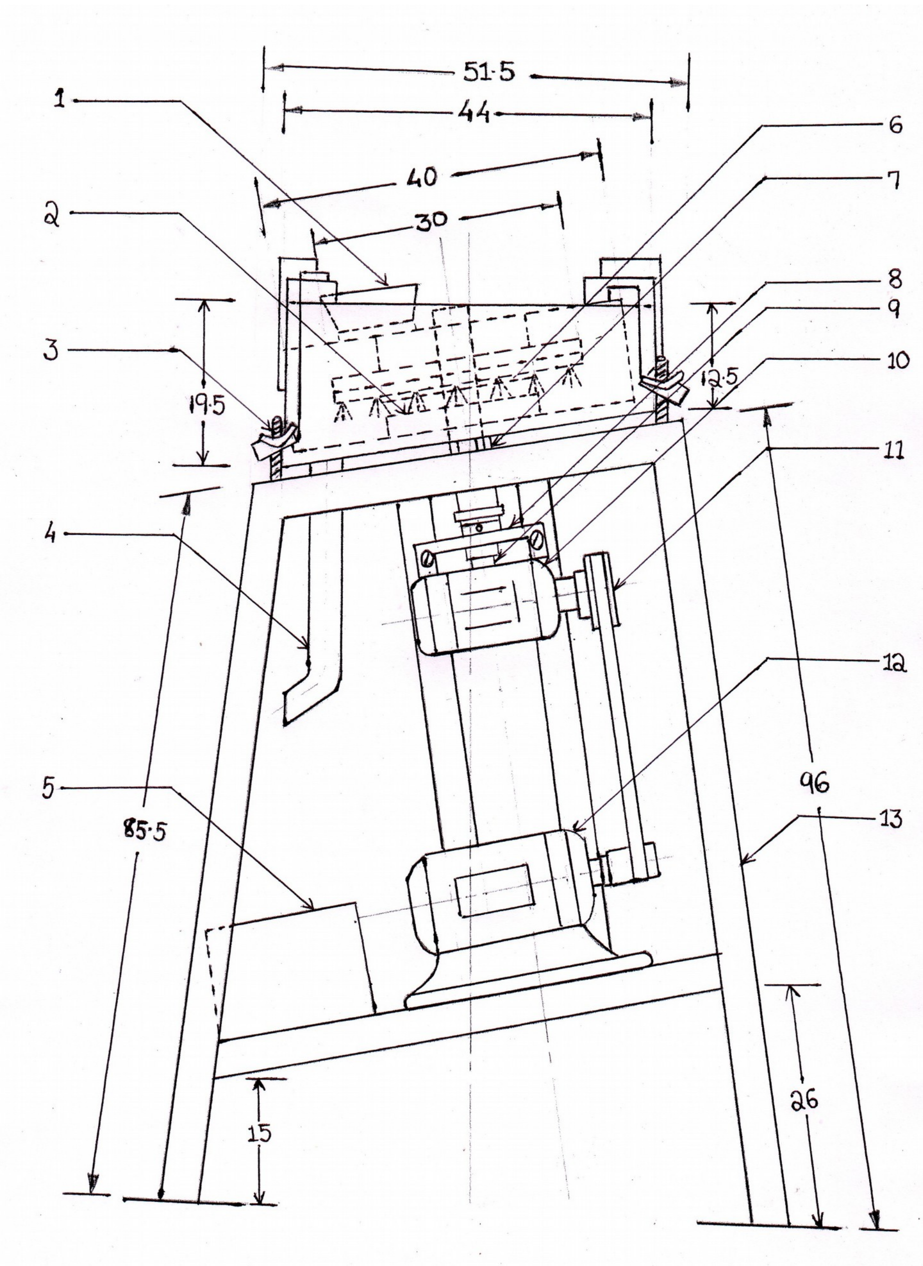

Fig. 3.2 Pepper decorticator-Front view

All dimensions in cm

Scale 1:6

SI. No.	Particulars
1	Feed hopper dimensions: (Top - 12 x 5, Bottom – 9 x 2, Height – 10)
2	Rotating grinding surface (30 ϕ)
3	Screw arrangement
4	Outlet arrangement (3.81 ϕ)
5	Water storage system (17 x 4.35 x 2.55)
6	Stationary grinding surface (30 ϕ)
7	Tapered roller bearing
8	Shaft (33.5 cm length)
9	Flanged coupling
10	Reduction gear Box (5:1 gear ratio)
11	Belt and pulley arrangement
12	Motor (0.5 hp)
13	Main frame

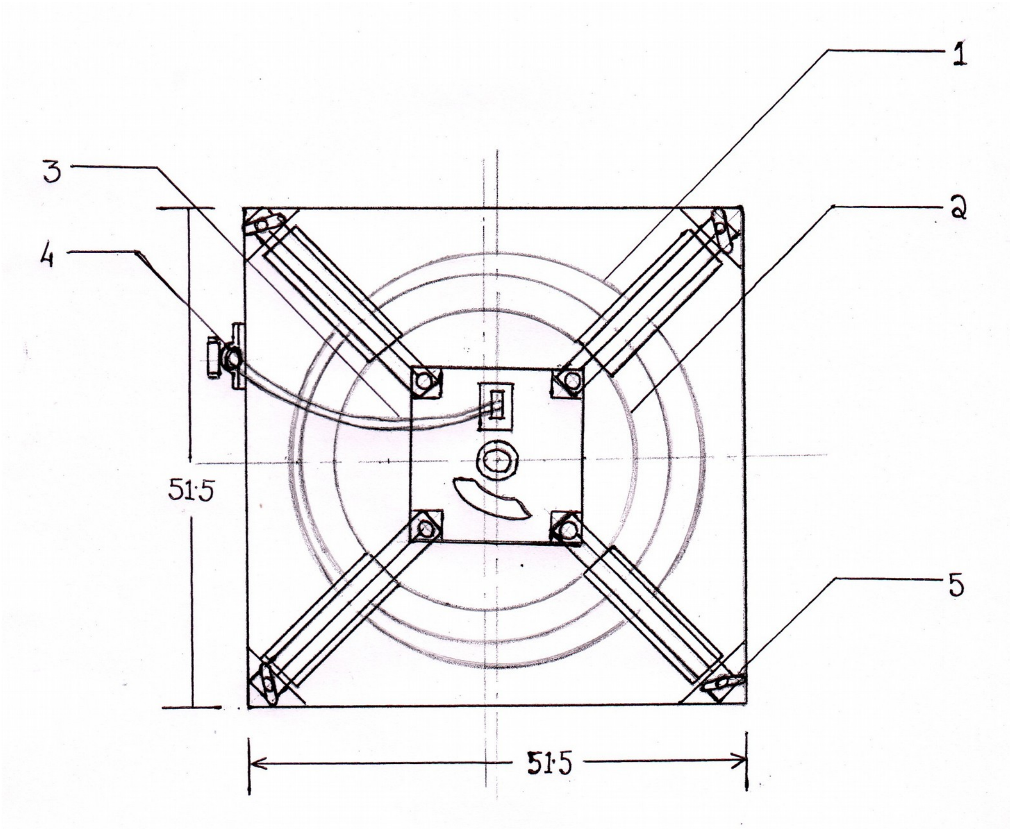

Fig. 3.3 Pepper decorticator-Top view

SI. No.	Particulars
1	Cylindrical collecting tray (44 ϕ)
2	Grinding surface (30 ϕ)
3	Hose for water supply (1.25 ϕ)
4	Ball valve (1.27 ϕ)
5	Wing type bolt

All dimensions in cm

Scale 1:4

3.5 Experimental Design

The effect of soaking water temperature on yield of white pepper was studied. From the preliminary studies, it was found that as the temperature of water increases the decorticating efficiency decreases. Also the quality of white pepper with respect to volatile oil and its constituents shows a decreasing trend. Hence, no further studies were made along this line.

The experiment was conducted as a 2-factor experiment in Completely Randomized Design (CRD). Corresponding to the nature of the surface type, three soaking times and three speeds of cylinders were chosen, so that for each surface type the experiment was conducted as factorial CRD with soaking time at three levels and speed of cylinder at three levels. The details of soaking time and speed of cylinder for each grinding surface are given below. For each CRD, the number of replications was three.

I Independent Variables	**Levels of treatment**		
MS knurled plate, Rexin sheet, Grinding stone			
Soaking time (h)	16,	17,	18,
Speed of cylinder (rpm)	63,	71,	81
Teflon			
Soaking time (h)	17,	18,	19
Speed of cylinder (rpm)	47,	57,	63

II Dependent Variables

Decorticating efficiency (%)

Wholeness of kernel

Mechanical damage (%)

Overall decorticating efficiency (%)

Accordingly, the total number of treatments was 9 for each surface with three replications.

3.5.1 Selection of various parameter levels

From the preliminary studies it was found that the pepper soaked in water for more than 16 hours give better results for decortication. Hence the study was focused on a soaking time of more than 16 hours. From the preliminary studies, it was found that materials like MS plate, lining sheet, teflon and grinding stone give better results in decorticating the pepper to satisfactory levels. Hence, these surfaces were selected for the studies. Depending on the nature of the surface, the rotational speed give varied results for decortication. The ideal rotational speeds observed were (63 to 81) for MS knurled plate, (63 to 81) for lining sheet, (47 to 63) for teflon and (63 to 81) for grinding stone.

3.6 Performance evaluation of pepper decorticator

Pepper decorticator was evaluated at various speed, soaking time and grinding surface. The speed was varied by varying the belt and pulley arrangement. The clearance was changed by adjusting the spring arrangement provided on the top of the platform. By turning the screw; the upper plate (stationary plate) moves to the top and thus the clearance get changed. A measured quantity of pretreated black berries were fed through the hopper into the decorticator, due to the compression and shear forces the outer skin of the berries get decorticated and by the centrifugal force the berries thrown out in radial direction. The bristles provide a brushing action to the pepper berries for complete discharge. Water distribution assembly fixed on the top gives an easy washing and removal of the treated berries. The whole pepper was carried along with water and is discharged out.

3.6.1 Decorticating efficiency

Decorticating efficiency is defined as the ratio of the weight of decorticated berries to that of the total whole berries fed to the system. It was calculated by the following equation,

$$\eta_d = \frac{W_0 - W_1}{W_0} \times 100 \qquad \text{---- (3.7)}$$

where,

W_0 = Weight of berries fed to the machine, g; and

W_1 = Weight of undecorticated berries after decortication, g

3.6.2 Mechanical damage

Mechanical damage is defined as the ratio of the weight of the broken to the total berries fed to the machine.

$$\text{Mechanical damage (\%)} = \frac{\text{Weight of brokens}}{\text{Weight of feed}} \times 100 \qquad \text{---- (3.8)}$$

3.6.3 Wholeness of kernels

The wholeness of kernels, (W_k) is defined as the proportion of whole kernels extracted to the total quantity of kernels fed to the system.

It was determined by the following equation

$$W_k = \frac{K_2 - K_1}{(K_2 - K_1) + (d_2 - d_1) + (m_2 - m_1)} \qquad \text{---- (3.9)}$$

where,

K_2 = weight of whole kernels after decortication

K_1 = weight of whole kernels before decortication

d_2 = weight of crushed kernels after decortication

d_1 = weight of crushed kernels before decortication

m_2 = weight of mealy waste in the product after decortication

m_1 = weight of the mealy waste in the product before decortication

(Chakraverty, 1981)

3.6.4 Overall Decorticating Efficiency

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

$$\eta_{od} = \eta_d \times W_k \qquad \text{-----(3.10)}$$

where,

η_d = decorticating efficiency, %

W_k = Wholeness of kernels

3.7 Quality analyses of white pepper

The dried white pepper is subjected to subsequent quality analyses. The important factors affecting quality are volatile oil, oleoresin, piperine, colour, size and volatile oil constituents.

3.7.1 Volatile oil

The volatile oil content was estimated by distillation method using Clevenger apparatus as shown in Plate 3.6. About 50 g powder and 500 ml distilled water were taken in a round bottom flask and attached to the Clevenger apparatus with a condenser. On boiling, the oil was collected in the receiver of the apparatus which contained distilled water. The distillation was carried out for 2 hours. Volume of oil collected after cooling was expressed as,

$$\text{Volatile oil, \% (v/w)} = \frac{V}{W} \times 100 \qquad \text{---- (3.11)}$$

where,

V = volume of oil collected ml, assumed g

W = Total weight of the sample, g

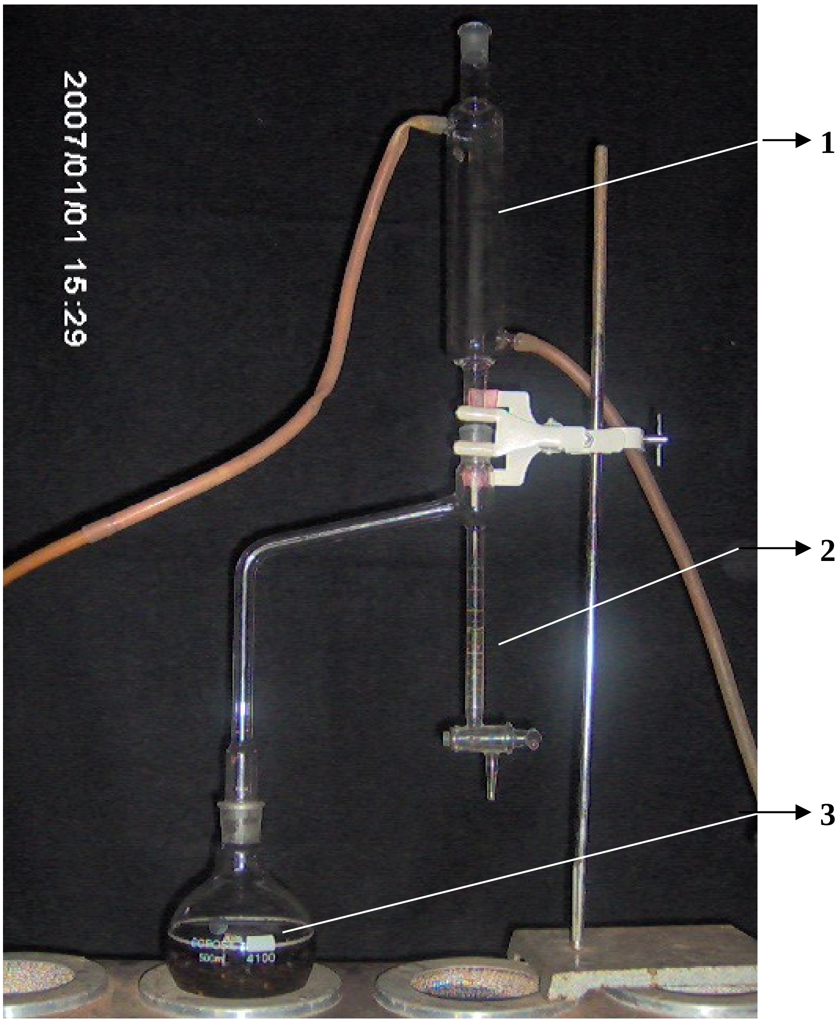

Plate 3.6 Clevenger apparatus

1. **Condenser**
2. **Clevenger Apparatus (oil collected)**
3. **Round Bottom Flask (Sample + Distilled water)**

3.7.2 Oleoresin

The oleoresin was extracted with n-hexane by using a solvent extraction method using a Soxhlet extraction apparatus (Plate 3.7).

Pepper powder of 20 gram was packed in a thimble and kept in the extraction tube of the Soxhlet apparatus. About 75 ml of n-hexane was taken in the Soxhlet flask and attached to the extraction tube along with a condenser. The extraction was continued for four hours (six cycles) on water bath. At the end of the extraction period, the pepper powder packet was removed from the apparatus and distilled further for the removal of the solvent. The last traces of the solvent were removed at room temperature using a vacuum pump.

$$\text{Oleoresin, \%} = \frac{\text{Weight of extracted oleoresin}}{\text{Initial weight of pepper powder}} \times 100 \qquad \text{---- (3.12)}$$

3.7.3 Piperine

Piperine, the main pungent principle in the black pepper, was estimated by UV-spectrophotometric method (Plate 3.8) at a wavelength of 337 nm using acetone. Weighed accurately 0.1 g of pepper powder and transferred it into a 100 ml volumetric flask made up to 100 ml with acetone. Pipetted out 1 ml of this solution into a 10 ml volumetric flask and made up the volume with acetone. Read the absorbance at 337 nm in the UV-Spectrophotometer. The per cent of piperine was calculated using the equation as given in 3.13.

A standard graph (Fig. 3.4) was plotted for the piperine estimation for different values of optical density and concentration for which the same absorbance, 337 nm was used.

$$\text{Piperine, \%} = \frac{A_{sa}}{A_{st}} \times \frac{C_{st}}{S_a} \times \frac{V_{sa}}{T_{sa}} \times 100 \qquad \text{---- (3.13)}$$

Where,

A_{sa}	=	Absorbance of sample
A_{st}	=	Absorbance of standard
C_{st}	=	Concentration of standard, in µg
V_{sa}	=	Total volume of sample, in ml
S_a	=	Sample taken, in ml
T_{sa}	=	Total sample taken, in mg

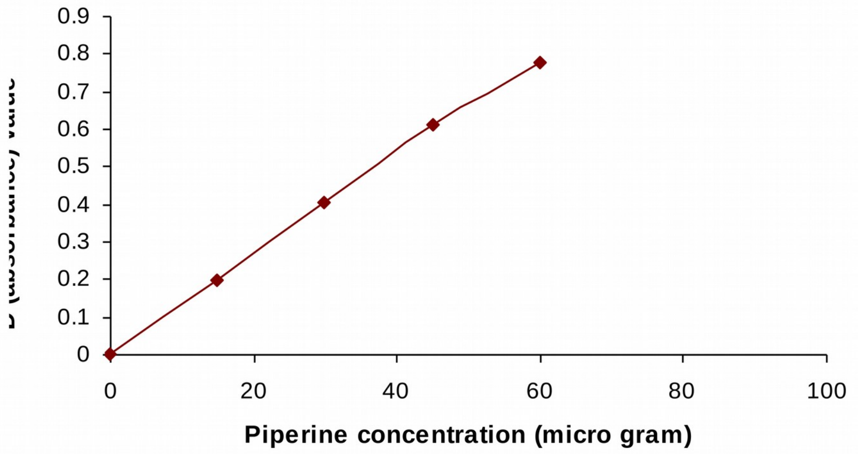

Fig. 3.4 Standard graph for piperine estimation

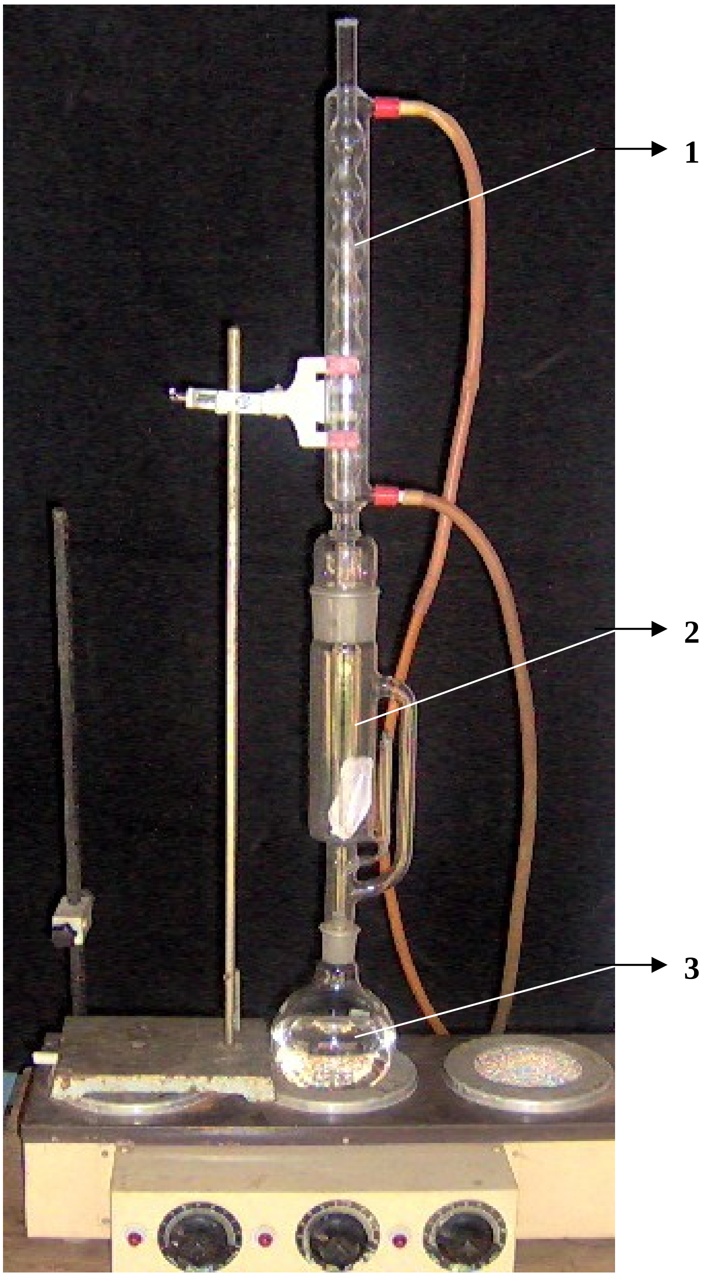

Plate 3.7 Soxhlet apparatus

1. **Condenser**
2. **Soxhlet Apparatus (Sample)**
3. **Round Bottom Flask (n-hexane)**

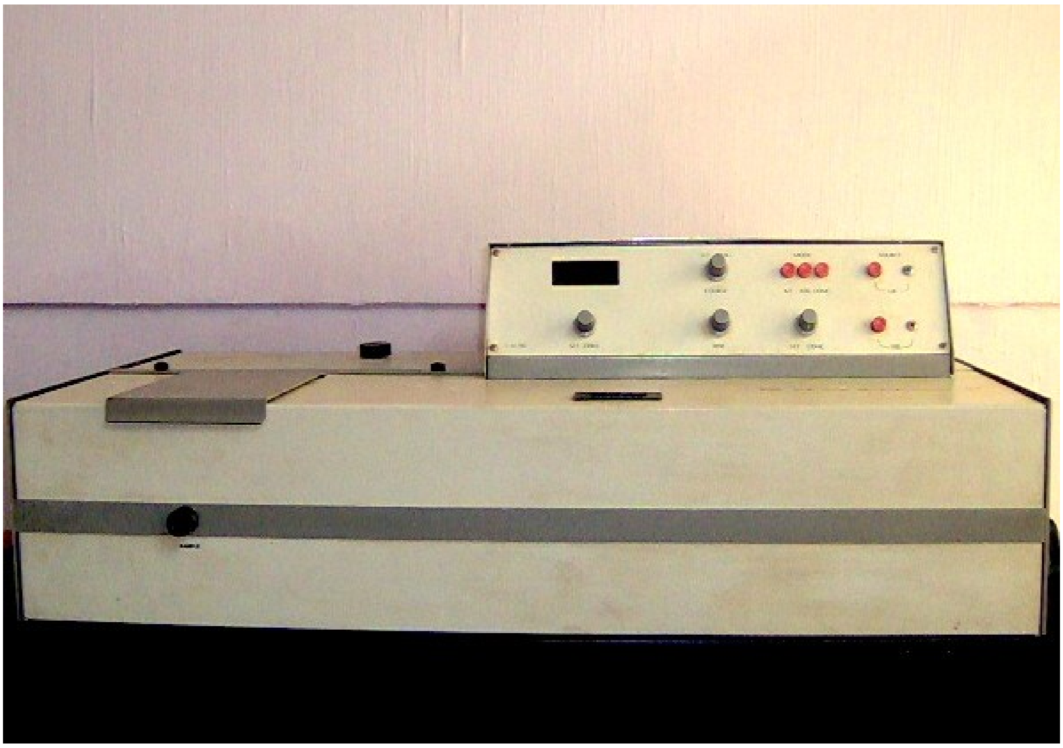

Plate.3.8 Spectrophotometer

3.7.4 Colour

The colour of white pepper was observed by naked eye.

3.7.5 Gas chromatographic analysis of volatile components

The volatile components of pepper were extracted and analyzed by Gas chromatograph (Plate 3.9). The model GC–Shimadzu-17A equipped with Flame Ionisation Detector (FID) was used. The pepper oil of 0.5 μl was injected under the following conditions.

Column	: DB-1
Type of column	: Capillary
Column temperature	: 70 to 225^{0}C at the rate of 5^{0}C/ min
Detector temperature	: 275^{0}C
Injector temperature	: 250^{0}C
Nitrogen flow	: 11ml/min.

Concentration and quantification of major constituents of pepper oil were carried out using the reference standards obtained from Sigma Chemical Company, Unite States of America (U.S.A.).

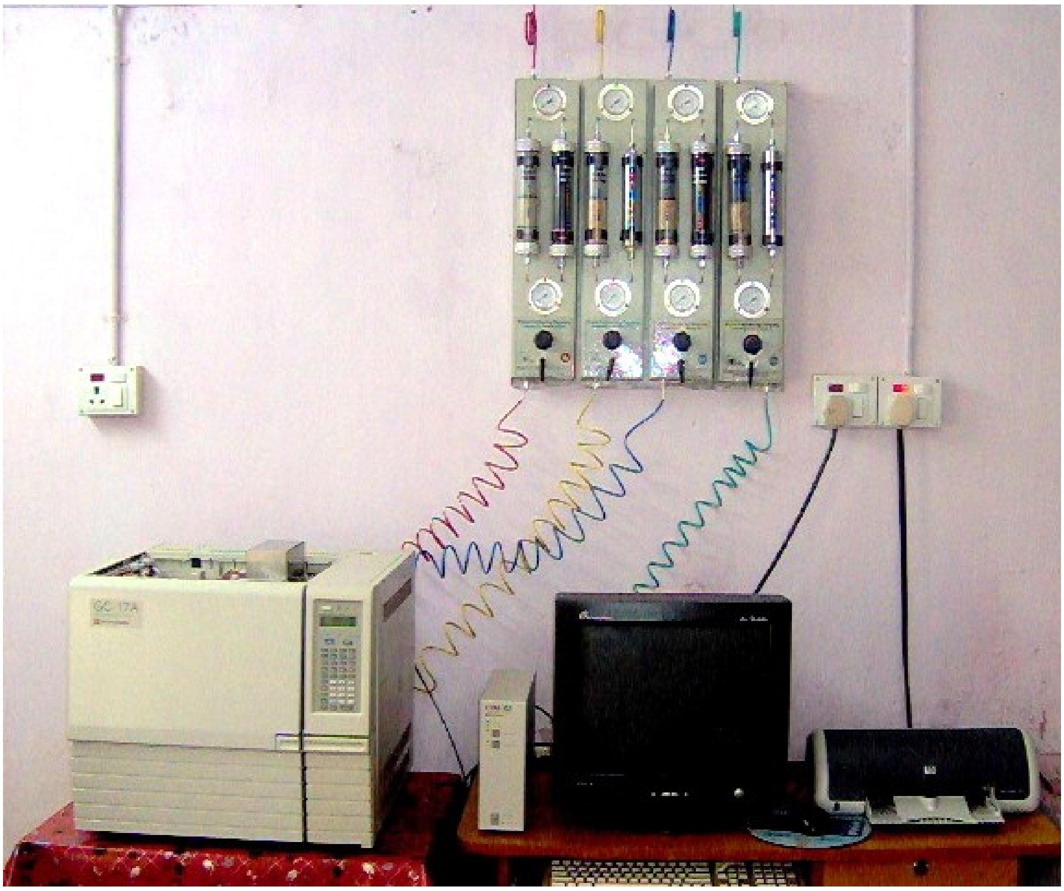

Plate 3.9 Gas chromatograph

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, results of the experiments on the physical properties of black pepper relevant to decortication and the effect of various methods on the production of white pepper are discussed. Also, the results of the evaluation of white pepper decorticator are presented and discussed.

4.1 Physical properties of black pepper

The results of the relevant physical properties are presented in this section.

4.1.1 Size and shape

The measured tri-axial dimensions and sphericity of black pepper with respect to different moisture content are reported in Table 4.1. All the dimensions were found to increase with increase in moisture level. The size of the pepper berries varies from 4.4 to 4.8 mm. The shape of the pepper berries was determined in terms of sphericity using Eqn. 3.2. The sphericity increased from 0.95 to 0.97 with increase in moisture content. The clearance between the grinding surfaces were adjusted based on size of black pepper.

Table 4.1 Dimensions and Sphericity of pepper berries at various moisture contents

SI No.	Moisture Content (%)	Length/ Major Axis (mm)	Breadth/ Intermediate Axis (mm)	Thickness/ Minor Axis (mm)	Sphericity
1	9.2	5.05	4.80	4.60	0.95
2	19.4	5.20	4.95	4.80	0.95
3	26.7	5.35	5.15	5.05	0.96
4	38.1	5.50	5.35	5.25	0.97

4.1.2 Coefficient of friction

The coefficients of friction for pepper berries with respect to different moisture contents on three metal surfaces namely, galvanized iron, stainless steel and aluminium is given in Fig. 4.1. The friction coefficient increased linearly with moisture content for all contact surfaces. The maximum coefficient of friction of 0.45 was observed by galvanized iron at 38.1 per cent moisture content, followed by aluminium and stainless steel. The reason for the increased friction coefficient at higher moisture content may be owing to the water present in the berries offering an adhesive force on the surface of contact. The stainless steel offered the least friction of 0.24 at 9.2 per cent moisture content. This may be due to the smoother and polished surface of the stainless steel compared with other sheets used. The relationships between moisture content and coefficient of friction can be correlated by the following equations;

For Black pepper and Galvanized iron,

$$f_{gi} = 0.2738 + 0.0048\ M \qquad (r^2 = 0.9746) \qquad \text{---- (4.2)}$$

where,

f_{gi} = Coefficient of friction between black pepper and galvanized iron

M = Moisture content, % (d.b)

For Black pepper and Aluminum,

$$f_{al} = 0.2397 + 0.0046\ M \qquad (r^2 = 0.9879) \qquad \text{---- (4.3)}$$

where,

f_{al} = Coefficient of friction between black pepper and aluminum

M = Moisture content, % (d.b)

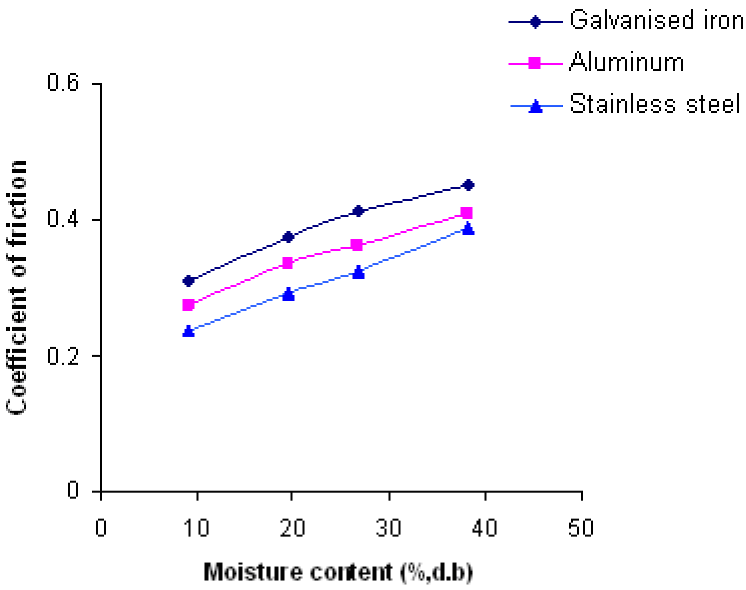

Fig. 4.1 Effect of moisture content on coefficient of friction

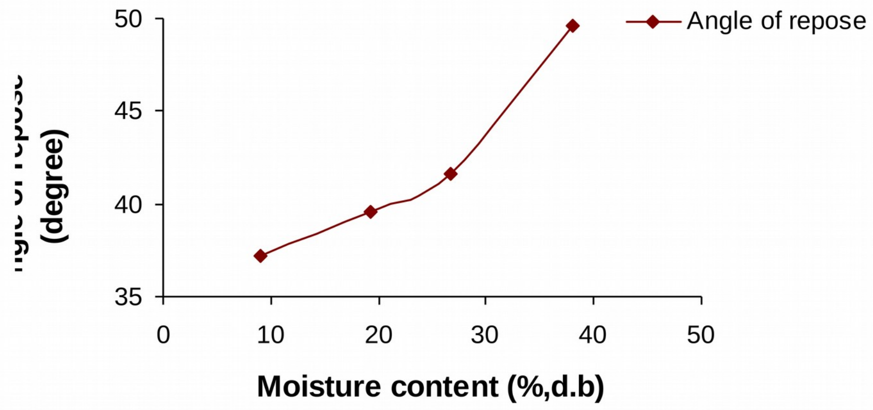

Fig. 4.2 Angle of repose at different moisture content of pepper

For Black pepper and Stainless steel,

$$f_{ss} = 0.1887 + 0.0052\ M \qquad (r^2 = 0.9984) \qquad \text{---- (4.4)}$$

where,

f_{ss} = Coefficient of friction between black pepper and stainless steel

M = Moisture content (d.b), %

The increase of coefficient of friction with respect to moisture content may be that at higher moisture contents, the berries became more rough and sliding characteristics are decreased so that the static coefficient of friction increased.

4.1.3 Angle of repose

The experimental results for angle of repose with respect to different moisture contents are shown in Fig. 4.2. The angle of repose is found to increase with moisture content linearly from 37.2 to 49.5 ^{0}for the moisture range from 9.2 to 38.1 per cent (d.b). The relationship between moisture content and angle of repose can be represented by the following equation.

$$\Phi = 32.099 + 0.4219\ M \qquad (r^2 = 0.9174) \qquad \text{---- (4.1)}$$

where,

Φ = angle of repose, ^{0}

M = Moisture content (d.b), %

All biological materials appear to exhibit an increase in angle of repose with moisture content (Mohsenin, 1970) and the present study also follows the similar pattern.

4.1.4 Bulk density and true density

The variation in bulk density, true density and porosity with moisture content is shown in Fig. 4.3. The bulk density of pepper respond to decrease whereas the true density increases with increase in moisture content. The volumetric expansion of the seed and pore space become proportionally greater which resulted in the decreasing trend on bulk density. The bulk density of seed bears the following relationship with moisture content.

$$P_b = 498.62 + 4.0546\ M \qquad (r^2 = 0.9581) \qquad \text{---- (4.5)}$$

where,

P_b = bulk density (kg/m^3)

M = moisture content (d.b), %

The true density of pepper berries was found to increase from 1041.67 to 1333 kg/m^3 with increase in moisture content from 9.2 to 38.1 per cent.

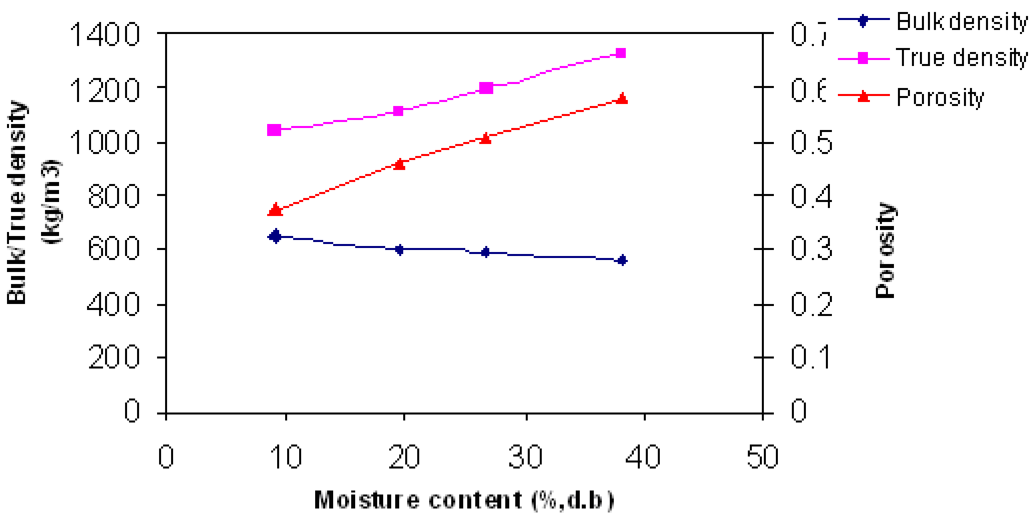

Fig. 4.3 Bulk/True density and Porosity of pepper berries at different moisture content

The variation in true density with moisture content of pepper berries can be represented by the equation.

$$P = 935.97 + 10.619\ M \qquad (r^2 = 0.9614) \qquad \text{---- (4.6)}$$

where,

P = true density (kg/m^3)

M = moisture content (d.b), %

The porosity was determined using the Eqn. 3.4. The porosity increased from 37.50 to 57.95 per cent when the moisture content varied from 9.2 to 38.1 per cent (d.b).

4.2 Study of existing methods

Existing methods such as fermentation, mechanical and chemical methods for the production of white pepper were conducted and the quality was analyzed.

4.2.1 Test sample

The black pepper procured from a local trade centre was used for the experiments. The initial moisture content, volatile oil, oleoresin yield and piperine content of the original sample were estimated by the standard methods explained in chapter III. The gas chromatographic analysis of volatile oil was also estimated and the results are tabulated in Table 4.2 and 4.3.

Table 4.2 Quality of test sample

Composition	Per cent
Moisture content (d.b)	10.0
Volatile oil	2.2
Oleoresin	12.5
Piperine	6.8

Table 4.3 Volatile oil constituent's determination using Gas chromatography

Constituents	Per cent
α-pinene	7.03
limonene	15.65
β-caryophyllene	23.00

4.2.2 Evaluation of existing mechanical decorticator

Experiments were conducted for four different soaking times and at a particular speed, the white pepper obtained and the performance of the decorticator are shown in Table 4.4.

Table 4.4 Performance of mechanical decorticator

SI No.	Soaking Time (days)	Decorticating Efficiency (%)	Wholeness of Kernels	Overall Decorticating Efficiency (%)
1	3	78.60	0.87	68.38
2	4	80.20	0.91	72.98
3	5	84.30	0.88	74.18
4	6	77.30	0.82	63.39

The increase in overall decorticating efficiency with soaking time is attributed to the progressive softening of skin due to increased soaking time. But, from the fifth day onwards the overall decorticating efficiency started decreasing. This is because of increase in the amount of broken due to the softening of inner core of the black pepper by excessive soaking. The quality of white pepper was estimated by the standard methods explained in Chapter III.

Table 4.5 Quality of white pepper produced by existing mechanical decorticator

SI No.	Soaking time (days)	Volatile oil (%)	Piperine (%)	Oleoresin (%)	Oil constituents (%)		
					α-pinene	limonene	β-caryophyllene
1	3	1.57	6.33	11.98	4.63	9.63	22.65
2	4	1.66	6.43	12.25	5.27	10.54	22.98
3	5	1.70	6.68	12.39	6.83	11.76	23.00
4	6	1.57	6.54	12.19	5.98	11.98	22.58

An increasing trend in volatile oil was observed with respect to the increase in soaking time. This may be due to the prolonged soaking of pepper sample (Table 4.5). The gas chromatographic analysis of volatile oil was also conducted and it is seen that there is an increase in α-pinene and limonene, the low boiling constituents of the oil.

4.2.3 Fermentation method

The results of the white pepper obtained by fermentation method and their quality analyses are shown in Table 4.6. The maximum white pepper of 41.79 per cent was obtained at 10 days' soaking period. During the decortication process there is a slight decrease of volatile oil content in the pepper. This may be due to the loss of oil in the soaking water. Similar results were also obtained by Gopinathan and Manilal (2005) for bacterial fermented white pepper. From Table 4.6 it was observed that there is no loss of piperine content. It may be due to the concentration of piperine in the endosperm (Mathew and Sankarikutty, 1978). An increase in oleoresin content was observed compared to the test sample and it might be due to the fact that the product might have absorbed moisture during soaking. The average size of the white pepper obtained for 9, 10 and 11 days soaking period were 4.30, 4.44, and 4.77 mm. Among the three samples of white pepper obtained, 10 days' soaked sample have a good attractive colour compared to the other two (Plates 4.1, 4.2, 4.3 and 4.4).

Table 4.6 Quality analyses and yield of white pepper from fermentative decortication

SI No.	Weight of Black Pepper (g)	Soaking Time (days)	White Pepper (%)	Volatile Oil (%)	Oleoresin (%)	Piperine (%)	Spericity	Moisture Content (%)
1	150	9	39.75	2.1	12.2	6.25	0.90	36.2
2	150	10	41.79	2.1	13.0	6.13	0.92	38.4
3	150	11	39.33	1.8	13.2	6.19	0.90	42.7

The volatile oil components were analyzed as discussed in Art. 3.7.5 and are tabulated in Table 4.7. It is observed that there is no change in the percentage of low boiling constituents like α-pinene and limonene. But, there is a change in the value of β-caryophyllene and it may be due to the incomplete distillation of pepper.

Table 4.7 Gas chromatographic analyses of white pepper

Components (%)	Soaking Time (days)		
	9	10	11
α-pinene	7.0	6.9	6.9
limonene	15.5	15.4	15.4
β-caryophyllene	21.3	20.9	20.8

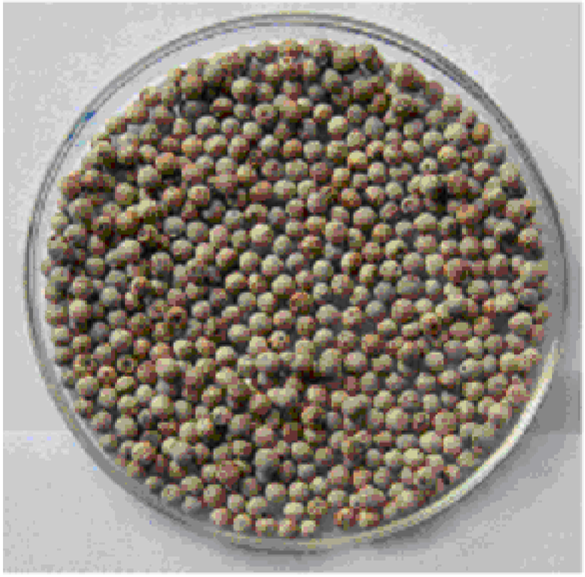

Plate 4.1 White pepper from fermentation method [9 days' soaking]

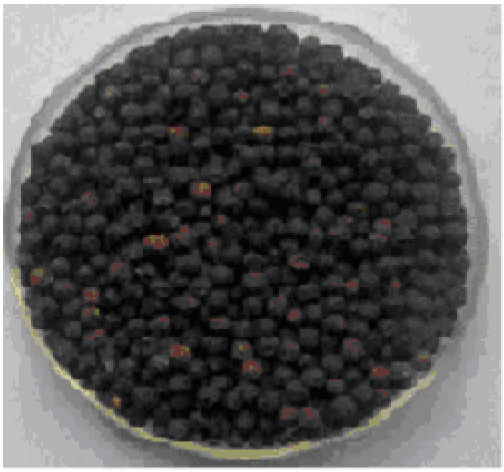

Plate 4.2 Black Pepper

Plate 4.3 White pepper from fermentation method [10 days' soaking]

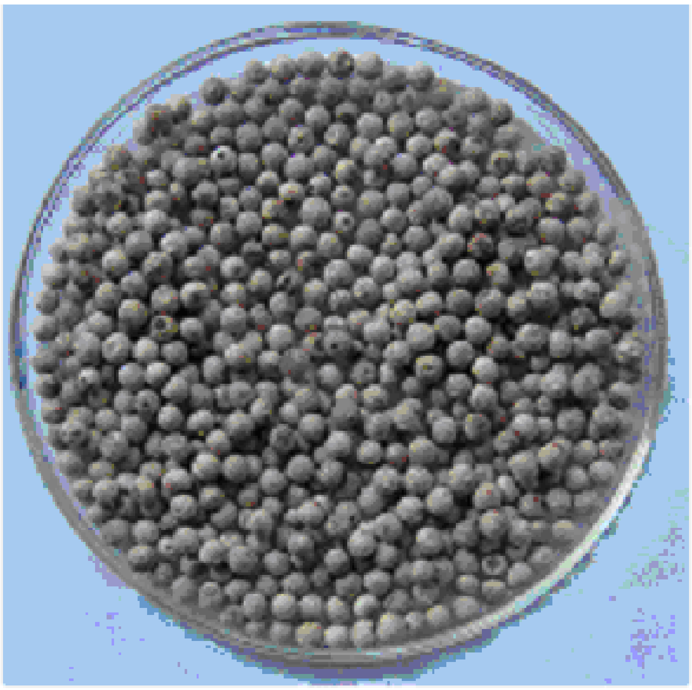

Plate 4.4 White pepper from fermentation method [11 days soaking]

4.2.4 Chemical method

The maximum per cent of white pepper obtained by chemical method was 65.69 %. The white pepper obtained by chemical method is shown in Plate 4.5.

The yield of white pepper was more compared to the fermentation method, but the colour was inferior. The quality of the white pepper obtained by the chemical method was analyzed and is presented in Table 4.8. The quality analyses of the test sample is given in Table 4.2. Comparing these two tables the results obtained were as follows. The loss of volatile oil is due to the heating of black pepper along with the chemical NaOH. There is no loss of piperine content. It may be due to the concentration of piperine in the endosperm (Mathew and Sankarikutty, 1978). Also, there is no change in oleoresin and oil constituents. Size of the white pepper obtained varied from 4.41 to 4.49 mm. This process involves usage of high concentration of alkali resulting in wrinkled appearance of white pepper.

Table 4.8 Quality of white pepper obtained by chemical method

SI. No	Components	Components (%)
1	White pepper	65.69
2	Volatile oil	1.60
3	Oleoresin	8.63
4	Piperine	5.87
5	Spericity	92.15
6	Moisture content	19.50
7	α-pinene	6.98
8	limonene	13.46
9	β-caryophyllene	22.43

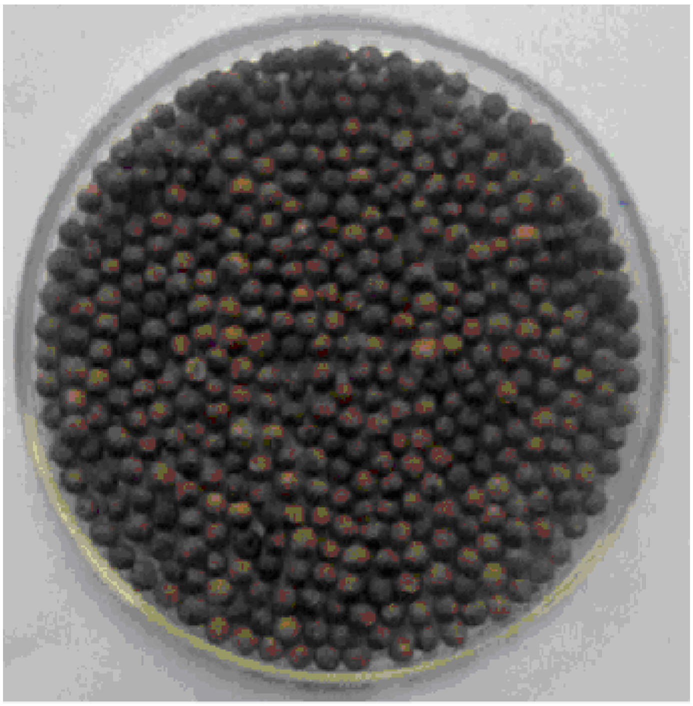

Plate 4.5 White pepper from chemical method

4.3 Performance evaluation of the mechanical decorticator

Performance of the newly developed power operated black pepper decorticator was evaluated. The machine was tested for different grinding surfaces like MS knurled plate, rexin sheet, teflon and grinding stone and the results of the experiments are presented.

For all the four grinding surfaces of the black pepper decorticator; decorticating efficiency, effectiveness of wholeness of kernel, mechanical damage and overall decorticating efficiency were computed for different cylinder speed and soaking time. All these four parameters were analyzed as a 2-factor experiment in Completely Randomized Design (CRD) and the results are presented in Appendix D.

4.3.1 Performance evaluation of mechanical decorticator for MS plate

Effect of soaking time, speed and the combination of soaking time and speed on decorticating efficiency, effectiveness of wholeness of kernel, mechanical damage and overall decorticating efficiency were determined for MS plate and their statistical analysis was done.

4.3.1.1 Decorticating efficiency

The decorticating efficiency was found to be significantly different as far as the soaking time was concerned. The same parameter was found to be not significantly different with respect to the speed. The maximum decorticating efficiency of 46.1 was observed at 17-hour soaking time and at a speed of 71 rpm. Fig. 4.4 shows that as soaking time increases up to 17 h, decorticating efficiency too increases, up to 17 hour soaking time and after which it decreases. The increase in decorticating efficiency with soaking time is attributed to the softening of skin due to soaking. The decrease in decorticating efficiency is due to the softening of inner core of black pepper by excessive soaking leading to increase in the number of broken (Ginu *et al*., 2000). The differential response of the speeds in combination with different soaking time was also found to be not significant.

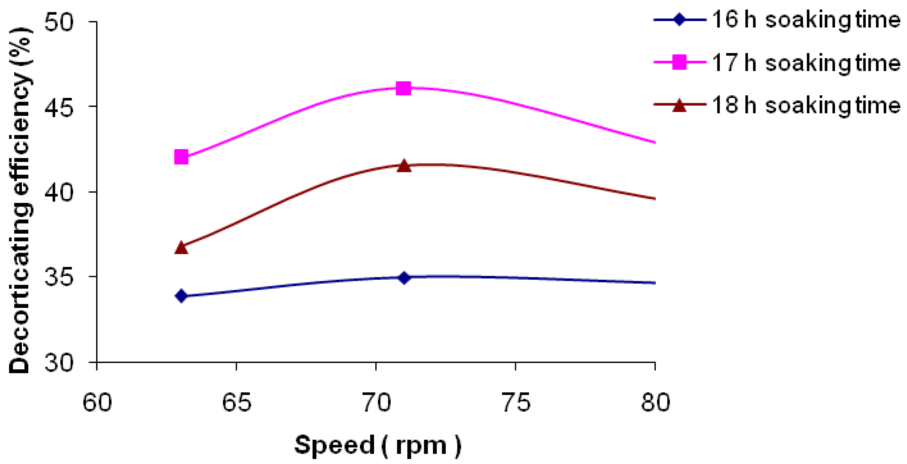

Fig. 4.4 Decorticating efficiency Vs Speed for MS plate at different soaking time

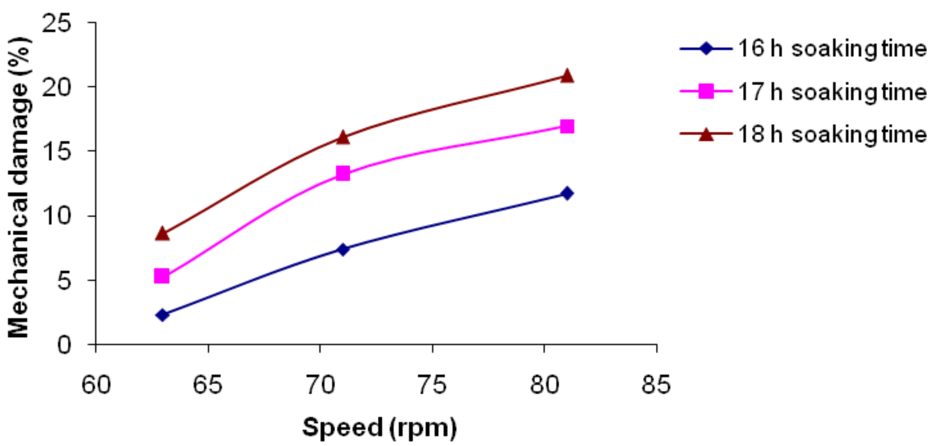

Fig. 4.5 Mechanical damage Vs Speed for MS plate at different soaking time

4.3.1.2 Wholeness of kernel

The wholeness of kernels was found to be not significantly different with regard to speed, soaking time and also the different combinations of speed and soaking time. Table 4.9 shows that at all the three speeds of 63, 71 and 81 rpm the wholeness of kernels observed showed a decreasing trend with respect to soaking time. At 81 rpm the wholeness of kernels value was the lowest only 0.65, which indicates of highest berry damage. At higher speeds, the increase in compressive and shearing forces led to crushing of berries giving lower values for wholeness of kernels (Anandabose, 1996).

Table 4.9 Wholeness of kernel from MS plate

Soaking time (h)	Speed (rpm)		
	63	71	81
16	0.94	0.78	0.75
17	0.86	0.81	0.71
18	0.75	0.72	0.65

4.3.1.3 Mechanical damage

The mechanical damage was found to be significantly different with respect to soaking time, speed and also different combinations of soaking time and speed. Fig. 4.5 shows that with increase in speed, the damage of berries increases. As speed of cylinder increases, the damage of berries increases. At higher speed the compressive and shearing forces acting on the pepper berries increases, leading to a increase in mechanical damage (Anandabose, 1996). But for 18 hour soaking time at 81 rpm it shows a maximum damage of 20.91 per cent. Here, as soaking time increases damage also increases. This is due to the softening of inner core of the black pepper by excessive soaking (Ginu *et al.*, 2000).

4.3.1.4 Overall decorticating efficiency

The overall decorticating efficiency was found to be significantly different with respect to soaking time, speed and was found to be not significantly different based on the different combinations of speed and soaking time. The maximum overall decorticating efficiency of 37.38 was observed for 17-hour soaking time at 71-rpm speed as shown in Fig. 4.6. The increase in overall decorticating efficiency with the increase in soaking time was observed only up to 17 hour which is attributed to the softening of the skin of pepper berries (Ginu *et al*., 2000). The increase in overall decorticating efficiency was observed only up to 71 rpm due to the action of compressive and shearing forces on the berries. The ideal soaking time speed combination for MS knurled plate was found to be 17 hour and 71 rpm. The capacity of the developed machine at the optimum condition was 1.04 kg/h.

4.3.2 Performance evaluation of mechanical decorticator for rexin sheet

Effect of soaking time, speed and the combination of soaking time and speed on decorticating efficiency, effectiveness of wholeness of kernel, mechanical damage and overall decorticating efficiency were determined for rexin sheet and their statistical analysis was done.

4.3.2.1 Decorticating efficiency

The decorticating efficiency was found to be significantly different with regard to soaking time, speed, and was found to be not significantly different based on the different combinations of speed and soaking time. The maximum decorticating efficiency of 51.30 was observed at 17 hour soaking time and 71 rpm speed. Fig. 4.7 shows that as speed increases, decorticating efficiency also increases up to 71 rpm and after that it decreases. The increase in efficiency with soaking time is due to softening of skin by moisture absorption, which gives better decortication. The decorticating efficiency increases with increase in soaking time up to 17 hour soaking and at 18 hour the parameter shows a decrease in trend.

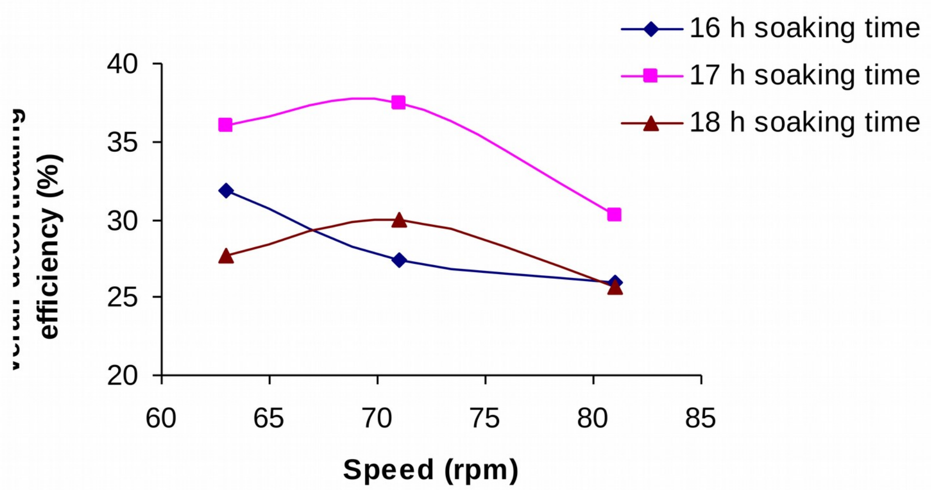

Fig. 4.6 Overall decorticating efficiency Vs Speed for MS plate at different soaking time

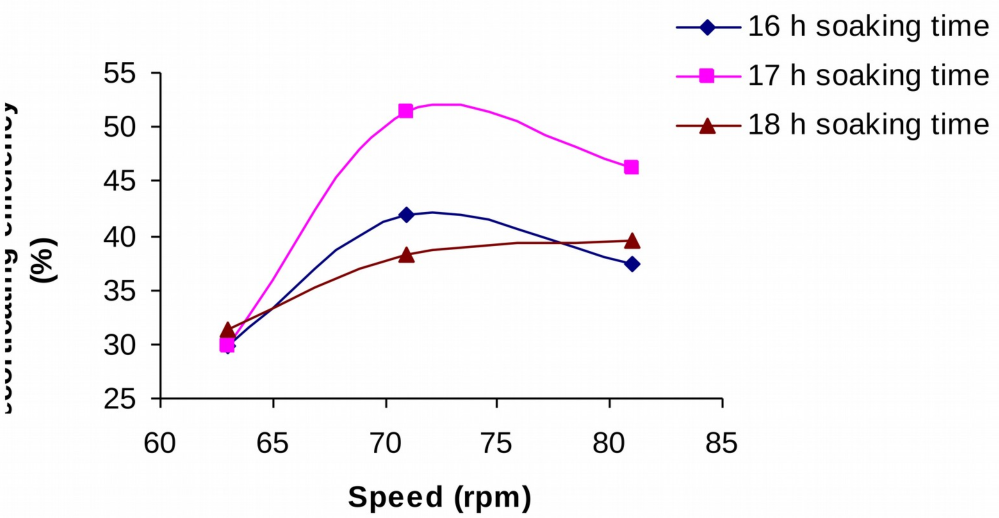

Fig. 4.7 Decorticating efficiency Vs Speed for rexin sheet at different soaking time

4.3.2.2 Wholeness of kernel

The wholeness of kernel was found to be not significantly different with respect to soaking time, speed and also the different combinations of soaking time and speed. Table 4.10 shows that the wholeness of kernels decresaes with increase in speed, which implies greater damage of pepper berries. Since at higher rpm, the increase in compressive and shearing forces led to crushing of berries giving lower values for wholeness of kernels (Anandabose, 1996). The lower damage of 0.60 was found to be at 18 hour soaking time; 81 rpm speed.

Table 4.10 Wholeness of kernel from rexin sheet

Soaking time (h)	Speed (rpm)		
	63	71	81
16	0.75	0.73	0.66
17	0.70	0.76	0.68
18	0.66	0.68	0.60

4.3.2.3 Mechanical damage

The mechanical damage was found to be significantly different with respect to soaking time, speed and also the different combinations of soaking time and speed. Fig. 4.8 shows an increase in trend in damage with cylinder speed. Since at higher speed, due to increase in compressive and shearing forces, crushing of berries occurred which resulted in increase in damage (Anandabose, 1996). The figure also shows an increasing trend of mechanical damage with soaking time. This is due to the softening of inner core of black pepper by excessive soaking leading to increase in the number of broken (Ginu *et al.*, 2000).

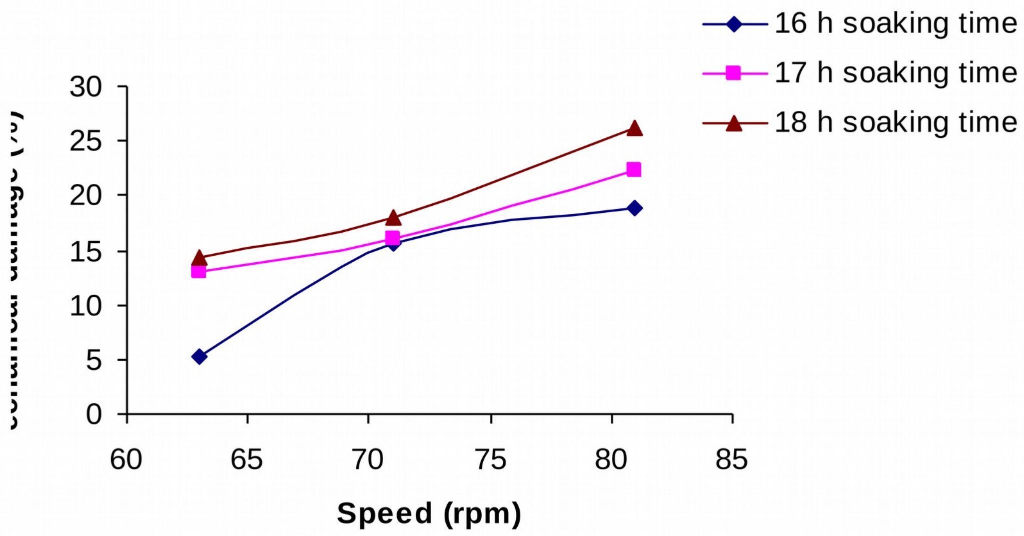

Fig. 4.8 Mechanical damage Vs Speed for rexin sheet at different soaking time

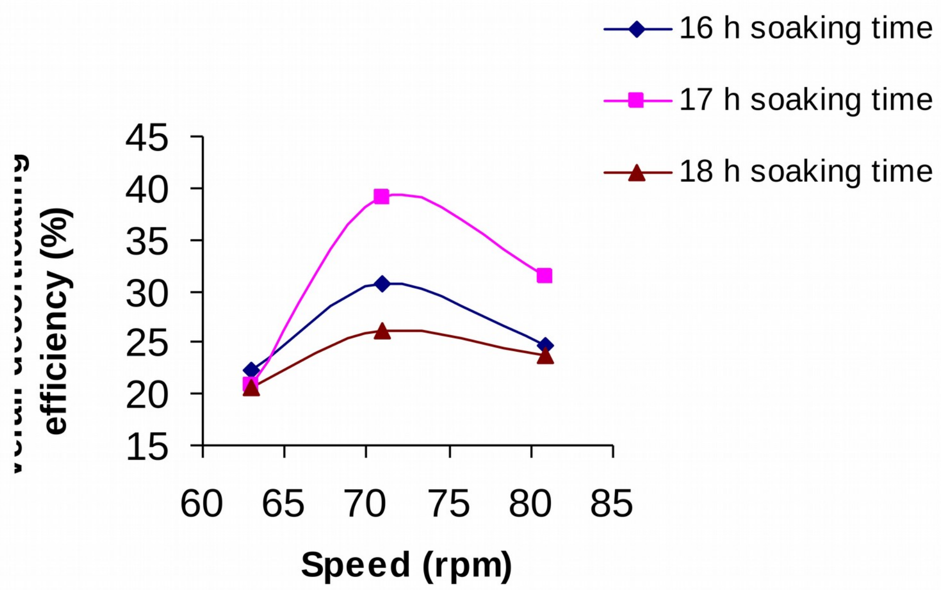

Fig. 4.9 Overall decorticating efficiency Vs Speed for rexin sheet at different soaking time

4.3.2.4 Overall decorticating efficiency

The overall decorticating efficiency was found to be significantly different with respect to soaking time, speed and was found to be not significantly different based on the different combinations of speed and soaking time. The maximum overall decorticating efficiency of 38.99 was observed at the 17 hour soaking time with 71 rpm speed combination. Fig. 4.9 shows an increasing trend of overall decorticating efficiency with speed upto 71 rpm and after that decreases. Since at higher speeds, due to increase in compressive and shearing forces, crushing of berries occurred which resulted in increase in damage (Anandabose, 1996). The most suitable soaking time, speed combination of 17 hour, 71 rpm gave best efficiency. The capacity of the developed machine at optimum condition was 1.16 kg/h.

4.3.3 Performance evaluation of mechanical decorticator for teflon

Effect of soaking time, speed and the combination of soaking time and speed on decorticating efficiency, effectiveness of wholeness of kernel, mechanical damage and overall decorticating efficiency were determined for teflon and their statistical analysis was done.

4.3.3.1 Decorticating efficiency

The decorticating efficiency was found to be significantly different with respect to soaking time, speed and also the different combinations of speed and soaking time. The maximum decorticating efficiency of 47.50 was observed for a soaking time of 18 hour at 57 rpm speed. Fig.4.10 shows an increase in trend of decorticating efficiency up to 57 rpm, and after which it decreases. Similarly an increase in trend was observed for soaking time up to 18 hour.

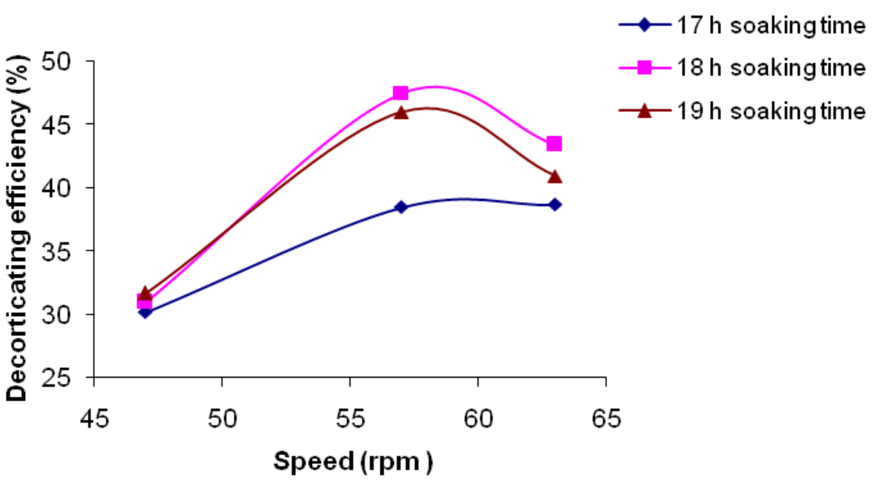

Fig. 4.10 Decorticating efficiency Vs Speed for teflon at different soaking time

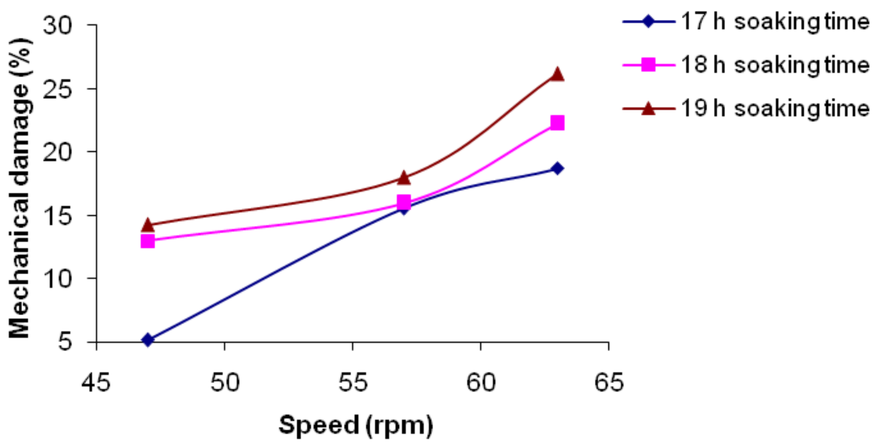

Fig. 4.11 Mechanical damage Vs Speed for teflon at different soaking time

4.3.3.2 Wholeness of kernel

The wholeness of kernel was found to be not significantly different with respect to soaking time, speed and also the different combinations of soaking time and speed. Table 4.11 shows that the wholeness of kernels increases as speed increases, which imply lesser damage of pepper berries. Since at higher rpm, some of the pepper berries might have roll down from the grinding surface leading to decrease in damage (Anandabose, 1996).

Table 4.11 Wholeness of kernel from teflon

Soaking time (h)	Speed (rpm)		
	47	57	63
17	0.72	0.71	0.75
18	0.54	0.75	0.74
19	0.59	0.75	0.89

4.3.3.3 Mechanical damage

The mechanical damage was found to be significantly different with respect to soaking time, speed and also the different combinations of soaking time and speed. From Fig. 4.11 it was observed that maximum mechanical damage occurs at higher rpm of 63. At higher speeds, the increase in compressive and shearing forces led to crushing of berries giving lower values for effectiveness of wholeness of kernels (Anandabose, 1996). Thus it leads to increase in damage. As soaking time increases the damage also increases, this may be due to the softening of inner core of black pepper by excessive soaking leading to increase in the number of broken (Ginu *et al.*, 2000).

4.3.3.4 Overall decorticating efficiency

The Overall decorticating efficiency was found to be significantly different with respect to soaking time, speeds and also the different combinations of soaking time and speed. The maximum overall decorticating efficiency of 35.63 was observed for the 18 hour soaking time with 57 rpm speed combinations. Fig. 4.12 shows an increasing trend of overall decorticating efficiency up to 57 rpm. Similarly soaking time also shows an increase in trend of overall decorticating efficiency up to 18 hour and then showed a decrease in trend. So it is concluded that the combination of 18 hour soaking time with 57 rpm speed was the best for Teflon surface. The capacity of the developed machine at optimum condition was 1.09 kg/h.

4.3.4 Performance evaluation of mechanical decorticator for grinding stone

Effect of soaking time, speed and the combination of soaking time and speed on decorticating efficiency, effectiveness of wholeness of kernel, mechanical damage and overall decorticating efficiency were determined for grinding stone and their statistical analysis was done.

4.3.4.1 Decorticating efficiency

The decorticating efficiency was found to be significantly different with respect to soaking time, speed and also the different combinations of speed and soaking time. Fig.4.13 shows that increase in speed gave an increase in trend of decorticating efficiency up to 71 rpm and after which it decreases. The maximum decorticating efficiency of 61.52 was observed for soaking time of 17 hour at a speed of 71 rpm. As soaking time increases the same also showed an increase in trend up to 17 hour. Since at higher soaking time the softening of inner core of pepper berries increases, which led to lower decorticating efficiency.

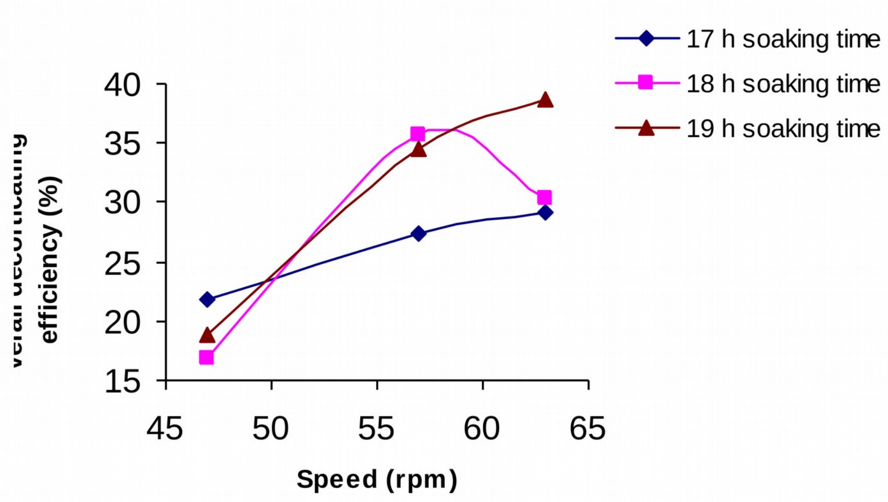

Fig. 4.12 Overall decorticating efficiency Vs Speed for teflon at different soaking time

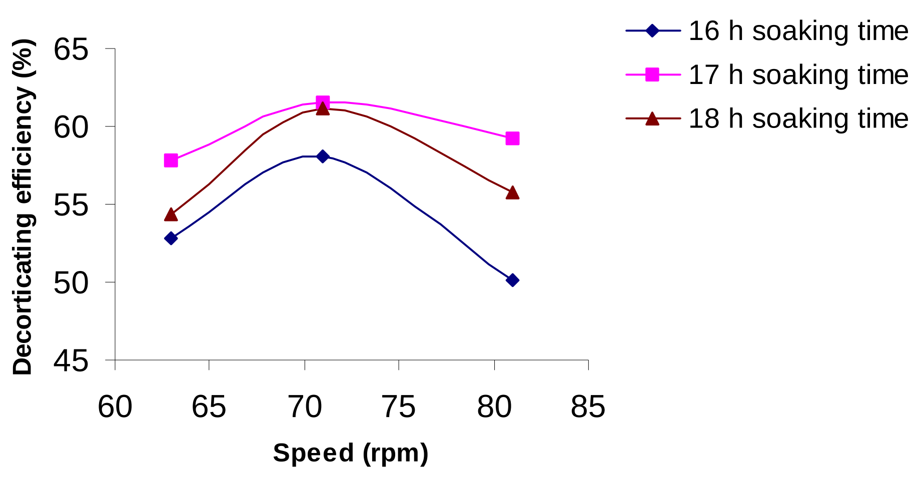

Fig. 4.13 Decorticating efficiency Vs Speed for grinding stone at different soaking time

4.3.4.2 Wholeness of kernel

The wholeness of kernels was found to be not significantly different with respect to soaking time, speed and also the different combinations of speed and soaking time. Table 4.12 shows a decrease in trend of wholeness of kernels with soaking time and speed. Since at higher soaking time the softening of inner core of pepper berries increases which led to lower decorticating efficiency. At higher speeds, the increase in compressive and shearing forces led to crushing of berries giving lower values for wholeness of kernels.

Table 4.12 Wholeness of kernel from grinding stone

Soaking time (h)	Speed (rpm)		
	63	71	81
16	0.83	0.82	0.76
17	0.84	0.83	0.74
18	0.79	0.80	0.84

4.3.4.3 Mechanical damage

The mechanical damage was found to be significantly different with respect to speed and also with different combinations of soaking time and speed. The same parameter was found to be not significantly different with regard to the soaking time. Fig. 4.14 shows an increasing trend of mechanical damage with respect to soaking time and speed.

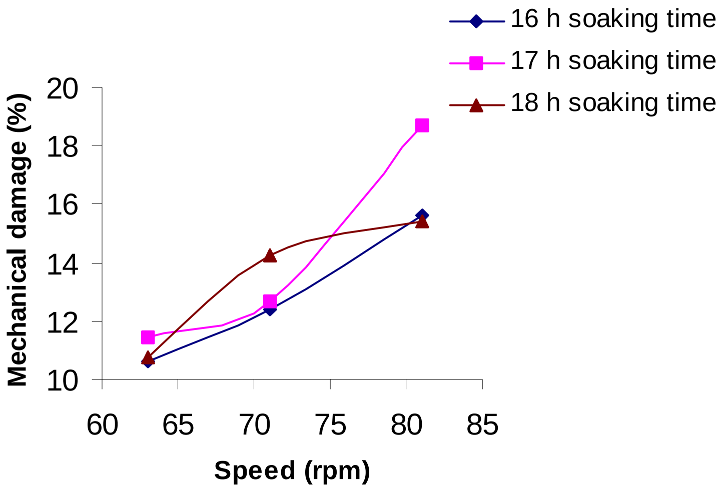

Fig. 4.14 Mechanical damage Vs Speed for grinding stone at different soaking time

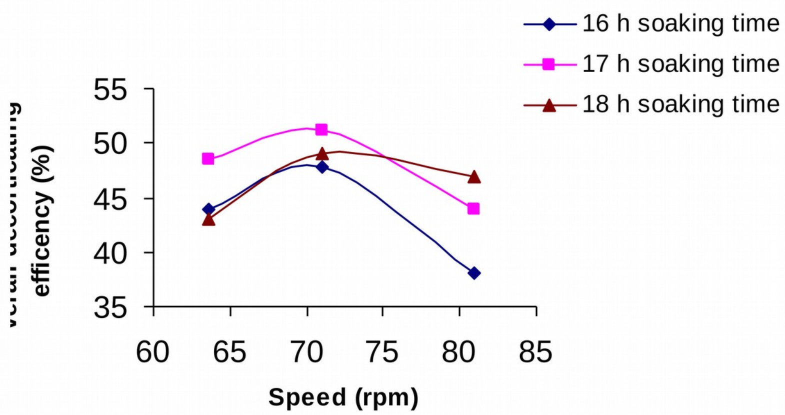

Fig. 4.15 Overall decorticating efficiency Vs Speed for Grinding stone at different soaking time

4.3.4.4 Overall decorticating efficiency

According to statistical analysis the maximum overall decorticating efficiency of 51.06 % was observed at 17 hour soaking time and 71 rpm speed. From the Fig. 4.15, as soaking time increases the overall decorticating efficiency shows an increasing trend up to 17 hour and after which it decreases. The increase in decorticating efficiency with soaking time is attributed to the softening of skin due to soaking. The increase in overall decorticating efficiency was observed only up to 71 rpm due to the action of compressive and shearing forces on the berries. The overall decorticating efficiency was found to be significantly different with regard to soaking time, speed and also the different combination of speed and soaking time. The ideal soaking time speed combination of 17 hour soaking time with 71 rpm speed was found to be the best for grinding stone. The capacity of the developed machine was 1.23 kg/h. Hence comparing the four surfaces, better performance is provided by the grinding stone coupled with polyurethane.

4.4 Quality of white pepper

The quality of the white pepper for the four grinding surfaces with the suitable soaking time and speed are given in Table 4.13. As a vector of parameters of qualitative trades has to be considered simultaneously for the end product namely white pepper, a relative retention efficiency index of the all the set parameters was worked out as follows.

For the eight parameters under consideration namely, volatile oil, oleoresin, piperine, sphericity,α-pinene, limonene, and β-caryophyllene;moisture content should be a minimum; all the seven parameters should be as close to the test sample parametric values except the moisture content. So at the first step, the ratio of the individual parametric values of the produce to the corresponding parametric values of the test sample was computed. The optimum value for this seven ratio will be of one. Therefore the product of all this ratios should also lead to a value close to unity. Even at this stage as the moisture content is of extreme importance, the product of the ratio of seven parametric so obtained were divided by the respective moisture content values. The concept is that lesser the moisture content, the better the product. So a lower moisture content value will definitely boost the product value. Since in all these cases a fraction is obtained for a better comparison between the four computed values; the values were converted to per cent by multiplying by hundred.

The relative retention efficiency index values are given for the four grinding surfaces at their best soaking time- speed combinations. From Table 4.14, it is evident that the grinding stone is the best of all the four grinding media followed by teflon, rexin sheet and MS plate. These findings are further justified by the fact that the order of mechanical damage for the four surfaces was also the same.

Table 4.13 Quality analyses of white pepper from different grinding surfaces

Components	Grinding surfaces			
	MS Plate (17 h, 71 rpm)	Rexin sheet (17 h, 71 rpm)	Teflon (18 h, 57 rpm)	Grinding stone (17 h, 71 rpm)
Volatile oil	1.3	1.3	1.2	1.3
Oleoresin	10.43	10.1	11.7	12.34
Piperine	5.59	5.12	5.36	6.25
Spericity	0.94	0.93	0.96	0.97
α-pinene	5.17	5.26	5.68	5.91
Limonene	10.38	9.54	11.25	12.28
β-caryophyllene	21.25	20.95	21.68	22.13
Moisture content	21.07	20.85	21.85	21.19

Table 4.14 Relative retention efficiency index for quality analyses

MS Plate	Rexin sheet	Teflon	Grinding stone
0.4	0.67	0.99	1.61

Plates 4.6 to 4.8 depict the white pepper prepared by decortication using different grinding surfaces like MS Plate, rexin sheet, teflon and grinding stone. From these plates it is evident that the colour is not so good as compared to fermentation, chemical and mechanical method. The cream coloured outer skin of white pepper has the characteristic striations fractured due to mechanical decortications. Consequently the brownish oil zone and inner starch layer got exposed. This gave a slight brownish appearance to the product. The results of volatile oil, oleoresin, piperine, sphericity, α-pinene, limonene, β-caryophyllene and moisture content are presented in Table 4.13. The gas chromatogram of black pepper and white pepper are shown in Fig. 4.16 and Fig.4.17. The volatile oil and oleoresin content for various surfaces follow a range of 1.2 to 1.3 and 10.1 to 12.43 respectively. Compared to the test sample, there is a loss of volatile oil content, this may be due to the loss of oil in the soaking water and removal of the creamy outer layer and the oil zone during decortications. There is no change for oleoresin content compared with test sample.

The piperine content of white pepper by using different grinding surfaces follow a range of 5.12 to 6.25, which is similar to that of test sample. Thus it was observed that there is no loss of piperine content and it may be due to the concentration of piperine in the endosperm. From the Table 4.13 it was found that the sphericity also shows a similar trend. Sphericity ranges from 93.52 to 97.52, which is 97.56 per cent for test sample.

Fig. 4.16 and 4.17 shows the gas chromatographic analysis of white pepper and black pepper oil. From the gas chromatographic analysis of volatile oil it is seen that there is a decrease in α-pinene and limonene, the low boiling

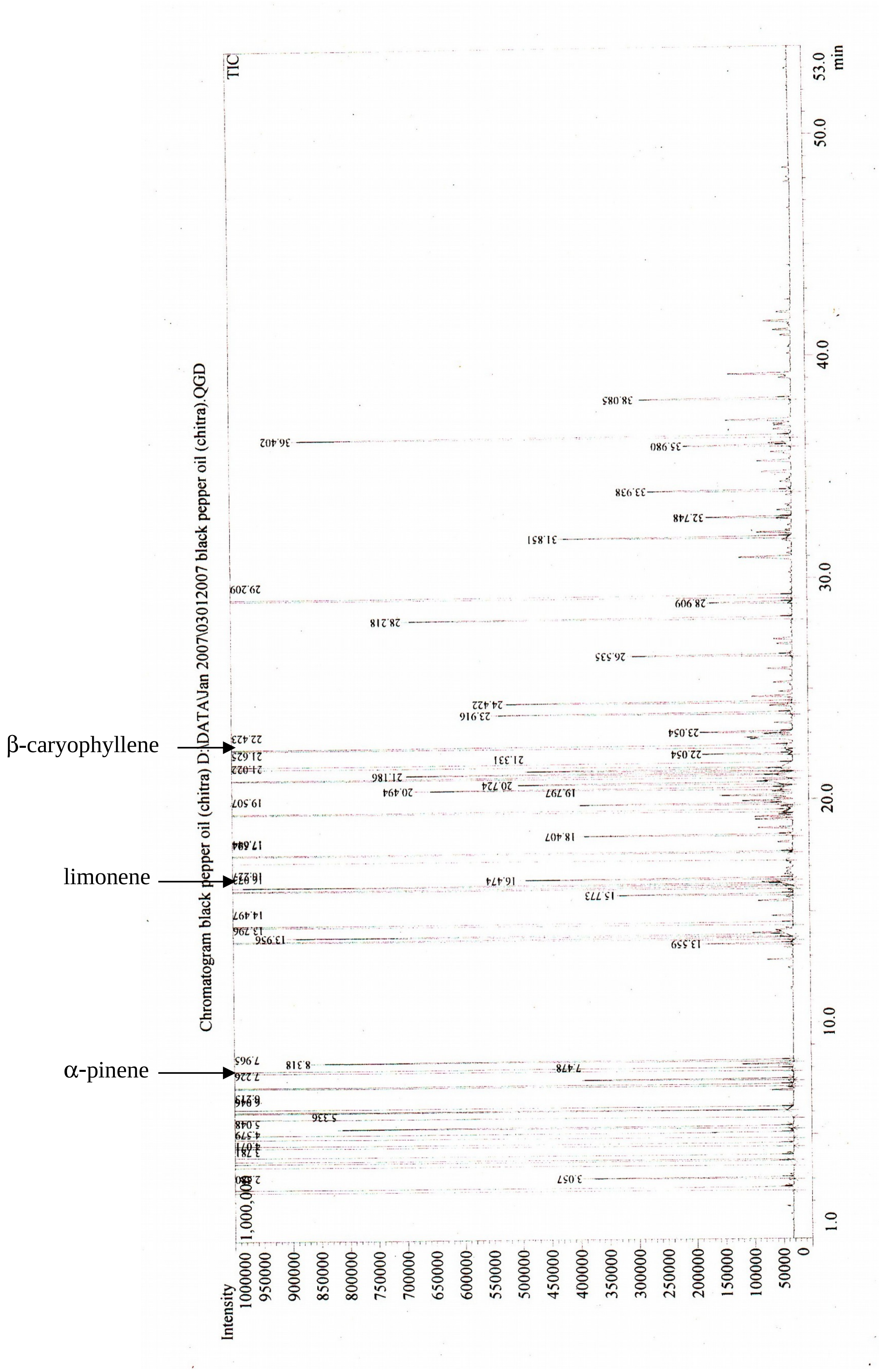

Fig. 4.16 Gas Chromatogram of Black Pepper oil

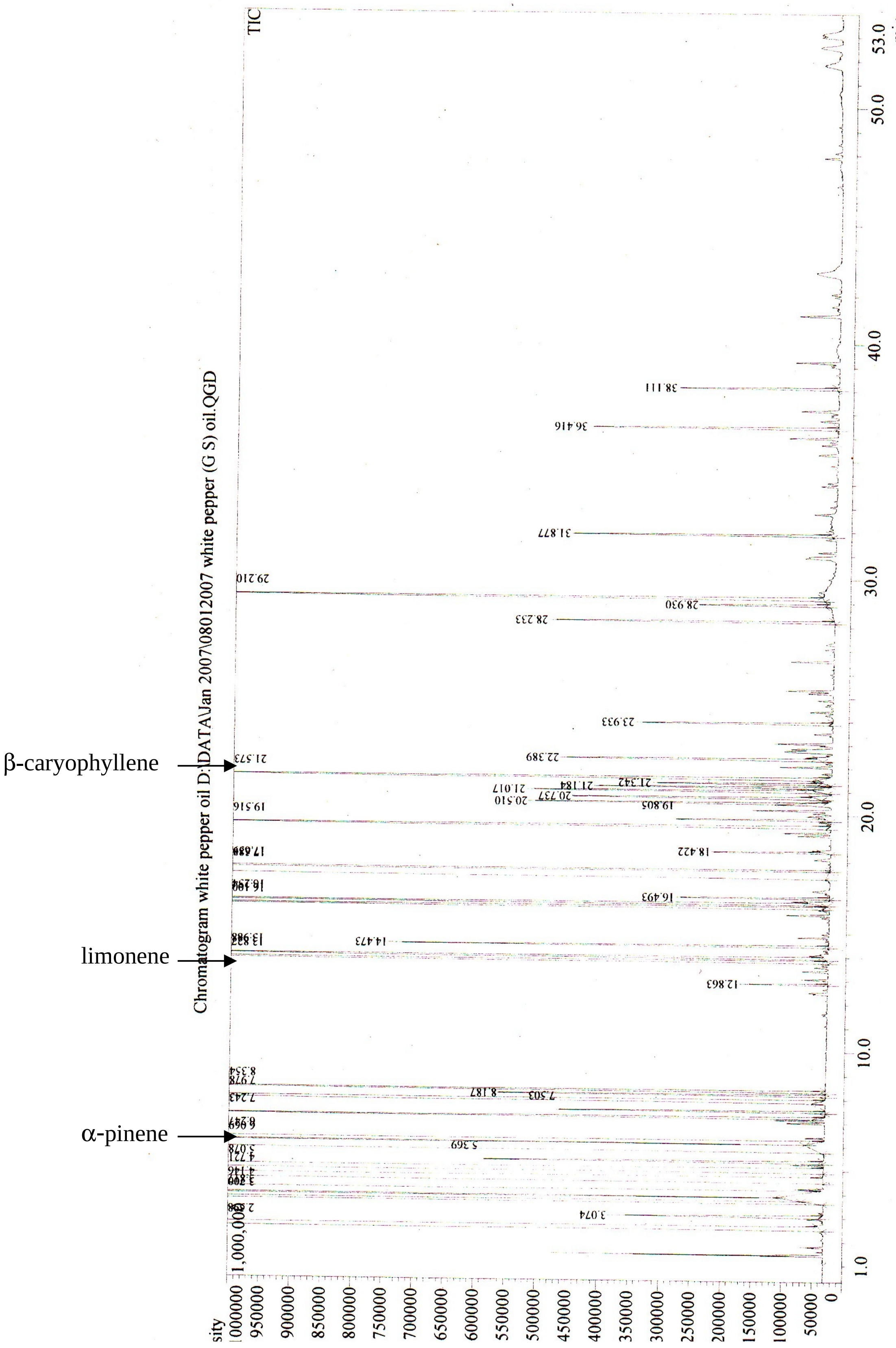

Fig. 4.17 Gas Chromatogram of white pepper oil
[Grinding Stone Surface]

Plate 4.6 White pepper from MS Plate

Plate 4.7 White pepper from Lining sheet

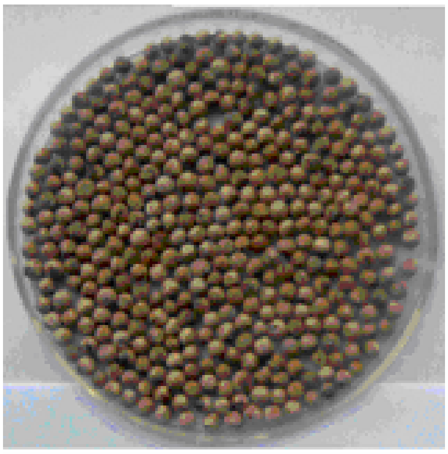

Plate 4.8 White pepper from Teflon

Plate 4.9 White pepper from Grinding stone

constituents of the oil. It may be due to the heat generated in the grinding zone during decortication process. There is no loss for the major constituent of pepper, β-caryophyllene. The pepper sample after soaking shows moisture range of 21.07 to 21.85 per cent, which is only 10 per cent for black pepper.

From the results it is observed that for four surfaces tested the grinding stone coupled with polyurethane shows the best result. The maximum overall decorticating efficiency of 51.06 was obtained at a soaking period of 17 hour and at a speed of 71 rpm. In the case of teflon, the maximum overall decorticating efficiency of 35.63 is obtained at a soaking period of 18 hour and at a speed of 57 rpm. For rexin sheet, the maximum overall decorticating efficiency of 38.99 is obtained at a soaking period of 17 hour and at a speed of 71 rpm. The MS knurled plate obtained a maximum overall decorticating efficiency of 37.38 are obtained at a soaking period of 17 hour and at a speed of 71 rpm. Comparing the four surfaces, better performance is provided by the grinding stone coupled with polyurethane.

The appearance of white pepper prepared by black pepper decorticator developed in this study is slightly affected due to the damage caused to the outer skin. This gave a slightly brownish appearance to the product. Little losses in the case of volatile oil and oil constituents of α-pinene and limonene were observed for the white pepper prepared by this machine when compared with that made by fermentation and chemical method. This may be due to the excessive abrasion caused to the surface of kernels.

SUMMARY AND CONCLUSION

White pepper is the most appreciated form of decorticated green or black pepper. White pepper is the white inner core obtained after removing the outer skin of pericarp of ripe pepper berries. The white pepper berries are light yellow grayish in colour, which is obtained by removing the upper pericarp either by retting, bacterial fermentation, steaming or by the mechanical decortication. White pepper is liked for its mellow flavour, mild pungency, low fibre and high starch content. White pepper is preferred over black pepper by the people of certain countries as its colour matches with light coloured food preparations, sauces and soups on which black specks are undesirable and only a mild flavour is required.

As white pepper is having export potential, the quality of the product is required to be upgraded for high earning. Even though white pepper is superior to black pepper in terms of profit, Indian farmers are reluctant to resort to white pepper production. The main reason behind this is the absence of a convenient and easy method for the production of white pepper. The present study was undertaken to develop a powered black pepper decorticator.

To get the first hand information a trial was conducted with the existing methods for the production of white pepper. Various methods like fermentation, mechanical and chemical methods for the production of white pepper were conducted and the quality was analyzed. In fermentation method, 10 days soaking performs the best result of 41.79 per cent white pepper yield.

In chemical method, the product was faded in colour with wrinkled appearance and the yield of white pepper was 65.69 per cent.

The existing black pepper decorticator was evaluated and the results are summarized below. At optimum soaking condition of 5 days an overall decorticating efficiency obtained was 86 per cent. The quality analyses show a lower result for volatile oil and oil constituents due to the prolonged soaking of pepper for 5 days. Hence considering these factors a new model of black pepper decorticator was developed.

The physical properties of black pepper were studied at various moisture content. The sphericity increased from 0.95 to 0.97 with increase in moisture content. The angle of repose is found to increase with moisture content linearly from 37.2 to 49.5^0 for the moisture range of 9.2 to 38.1 per cent (d.b). The coefficient of friction were tried on three metal surfaces, namely, galvanized iron, stainless steel and aluminium. The friction coefficient increased linearly with moisture content for all contact surfaces. The maximum friction of 0.45 was offered by galvanized iron at 38.1 per cent moisture content, followed by aluminium and stainless steel. The stainless steel offered the least friction of 0.24 at 9.2 per cent moisture content.

The bulk density of pepper responds to decrease whereas the true density increases with increase in moisture content. The true density of pepper berries was found to increase from 1041.67 to 1333 kg/m^3 with increase in moisture content from 9.2 to 38.1 per cent. The porosity increased from 37.50 to 57.95 per cent when the moisture content varied from 9.2 to 38.1 per cent (d.b).

The newly developed powered black pepper decorticator is evaluated and the results are discussed below. The machine was tested by using various grinding surfaces like the MS knurled plate, rexin sheet, teflon and grinding stone and the result was evaluated. The developed machine consists of grinding surfaces, feed hopper, cylindrical collecting tray, water distribution assembly, main shaft, main frame and power source.

A measured quantity of pretreated black berries were fed through the hopper into the decorticator, due to the compression and shear forces the outer skin of the berries get decorticated and by the centrifugal force the berries get thrown out. The bristles provide a brushing action to the pepper berries for complete discharge. Water distribution assembly fixed on the top gives an easy washing and removal of the treated berries. The whole pepper was carried along with water and is discharged out.

The experiment was conducted as a 2-factor experiment in Completely Randomized Design (CRD). Corresponding to the nature of the surface type, three soaking times and three speeds of cylinders were chosen that for each surface type the experiment was conducted as factorial CRD with soaking time at three levels and speed of cylinder at three levels.

From the results it is observed that for four surfaces tested the grinding stone coupled with polyurethane shows the best result. The maximum overall decorticating efficiency of 93.40 is obtained at a soaking period of 17 hour and at a speed of 71 rpm. In the case of teflon, the maximum overall decorticating efficiency of 67.45 is obtained at a soaking period of 18 hour and at a speed of 57 rpm. For rexin sheet, the maximum overall decorticating efficiency of 77.00 is obtained at a soaking period of 16 hour and at a speed of 81 rpm. The MS knurled plate obtained a maximum overall decorticating efficiency of 67.31 are obtained at a soaking period of 17 hour and at a speed of 71 rpm. Comparing the four surfaces, better performance is provided by the grinding stone coupled with polyurethane.

For the statistical analysis on quality parameters, a relative retention efficiency index values are given for the four grinding surfaces at their best soaking time- speed combinations. According to statistical analysis, the values of grinding stone, Teflon, MS Plate and rexin sheet were 1.61, 0.99, 0.67 and 0.4. Thus it is evident that the grinding stone is the best of all the four grinding media followed by teflon, MS Plate and rexin sheet. These findings are further, justified by the fact that the order of mechanical damage for the four surfaces was also the same.

The performance of this machine can be improved further by incorporating the modifications suggested below.

1. Incorporate a size-classifier for grading the berries prior to feeding operation

2. Separated skin get mixed with the white pepper produced. Therefore provision of a mechanism for separation of the white pepper produced and the skin could contribute to the increase in the efficiency of the process.

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APPENDIX A

EOA Specifications for pepper oil

Botanical nomenclature: *Piper nigrum* L. Preparation: By steam distillation of berries		
Physical and chemical characteristics	Appearance and odour	Almost colourless to slightly greenish Characteristic odour of pepper, taste of oil mild, lacking the pungency of pepper
	Specific Gravity	0.864 to 0.884 at 25°C
	Optical rotation	1 to 23°
	Refractive index	1.4795 to 1.4480 at 20°C
	Solubility in alcohol	In 3 volume 95% alcohol
Descriptive characteristics	Solubility	Benzyl benzoate, soluble in all proportions
		Diethylphthalate,in all proportions
		Fixed oil, in all proportions
		Glycerine,sparingly
		Mineral oil, in all proportions
		Propylene glycol, in all proportions
	stability	Alkali - stable
		Acid - unstable
Containers		Preferably shipped in glass containers
Storage		Store in tight, full containers protected from light

APPENDIX B

Standard and specification for black pepper oleoresin

Ref: Indian standard specification 5832, 1970

Description Preparation	Oleoresin black pepper shall be obtained by extraction of the ground dried berries of the vine *Piper nigrum*. L. fam.Pipereace with chlorinated solvents, methanol, isopropanol or acetone and subsequent removal of the solvents from the extract.
Physical and chemical constituents	
Appearance and colour	The material shall be either a viscous dark green to light brown dispersion or shall consists of an upper oily layer and a lower crystalline mass, free from adulterants
Volatile oil content	16 to 20 per cent (V/w)
Optical rotators of oil	-1 to 23°
Refractive index of oil at 20°C	1.439 to 1.449
Total nitrogen	Piperine per cent by weight (By Kjeldahl's method or by spectrophotometric method)
Residual solvent in oleoresin	Acetone, ethylene dichloride or tricholoromethylene- 30 ppm,isoproponol and methanol 50 ppm
Descriptive characteristics Aroma and flavour	Typical of lack pepper; number of flavours or off odours due to residual solvent or other causes
Containers Storage	Preferably shipped in glass containers Store in tight, full containers protected from light

APPENDIX C

Table C.1 Physical properties of pepper at different moisture content

Moisture content, d.b (%)	True density (kg/m^3)	Bulk density (kg/m^3)	Porosity (%)	Angle of repose (degree)	Coefficient of friction		
					G.I	Al	S.S
9.2	1041.67	651.00	37.50	37.20	0.3100	0.2762	0.2358
19.4	1111.00	602.10	45.81	39.48	0.2930	0.3370	0.3502
26.7	1200.00	589.45	50.88	41.59	0.4280	0.3850	0.3600
38.1	1333.00	560.50	57.95	49.53	0.4530	0.4500	0.4110

APPENDIX D

Performance Evaluation of Decorticator for MS Plate

Table D.1 Decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of decorticating efficiency with respect to soaking time
16	33.90	35.0	34.63	34.51
17	42.0	46.10	42.50	43.53
18	36.80	41.60	39.40	39.27
Mean of decorticating efficiency with respect to speed	37.57	40.90	38.84	

CD ($P<0.05$) for Soaking time : 3.31

Speed : NS

Soaking time x Speed : NS

Table D.2 Wholeness of kernel

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of wholeness of kernel with respect to soaking time
16	0.94	0.78	0.75	0.82
17	0.86	0.81	0.71	0.79
18	0.75	0.72	0.65	0.71
Mean of wholeness of kernel with respect to speed	0.85	0.77	0.70	

CD (P<0.05) for Soaking time : NS

Speed : NS

Soaking time x Speed : NS

Table D.3 Mechanical damage

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of mechanical damage with respect to soaking time
16	2.30	7.37	11.74	7.14
17	5.22	13.23	16.97	11.78
18	8.64	16.12	20.91	15.22
Mean of mechanical damage with respect to speed	5.39	12.24	16.54	

CD (P<0.05) for Soaking time : 2.61

Speed : 2.61

Soaking time x Speed : 4.53

Table D.4 Overall decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of overall decorticating efficiency with respect to soaking time
16	31.87	27.30	25.97	28.38
17	35.96	37.38	30.18	34.51

18	27.60	29.95	25.61	27.72
Mean of overall decorticating efficiency with respect to speed	31.81	31.54	27.25	

CD (P<0.05) for Soaking time : 4.193

Speed : 4.193

Soaking time x Speed : NS

Performance Evaluation of Decorticator for Rexin Sheet

Table D.5 Decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of decorticating efficiency with respect to soaking time
16	29.70	41.80	37.20	36.23
17	29.80	51.30	46.20	42.43
18	31.20	38.20	39.50	36.30
Mean of decorticating efficiency with respect to speed	30.23	43.77	40.97	

CD (P<0.05) for Soaking time : 3.77

Speed : 3.77

Soaking time x Speed : NS

Table D.6 Wholeness of kernel

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of wholeness of kernel with respect to soaking time
16	0.75	0.73	0.66	0.71
17	0.70	0.76	0.68	0.71
18	0.66	0.68	0.60	0.65
Mean of wholeness of kernel with respect to speed	0.70	0.72	0.65	

CD (P<0.05) for Soaking time : NS

Speed : NS

Soaking time x Speed : NS

Table D.7 Mechanical damage

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of mechanical damage with respect to soaking time
16	5.14	15.57	18.71	14.44
17	12.99	15.95	22.24	17.06
18	14.24	17.99	26.16	19.46
Mean of mechanical damage with respect to speed	10.79	16.50	22.37	

CD (P<0.05) for Soaking time : 1.64

Speed : 1.64

Soaking time x Speed : 2.85

Table D.8 Overall decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of overall decorticating efficiency with respect to soaking time
16	22.25	30.51	24.55	25.77
17	20.86	38.99	31.42	30.42
18	20.53	25.98	23.70	23.40
Mean of overall decorticating efficiency with respect to speed	21.21	31.83	26.56	

CD (P<0.05) for Soaking time : 4.193

Speed : 4.193

Soaking time x Speed : NS

Performance Evaluation of Decorticator for Teflon

Table D.9 Decorticating efficiency

Soaking time (h)	Speed (rpm)			
	47	57	63	Mean of decorticating efficiency with respect to soaking time
17	30.20	38.50	38.70	35.80
18	31.00	47.50	40.95	39.82
19	31.70	46.00	43.45	40.38
Mean of decorticating efficiency with respect to speed	30.97	44.00	41.03	

CD (P<0.05) for Soaking time : 2.06

Speed : 2.06

Soaking time x Speed : 3.57

Table D.10 Wholeness of kernel

Soaking time (h)	Speed (rpm)			
	47	57	63	Mean of wholeness of kernel with respect to soaking time
17	0.72	0.71	0.75	0.73
18	0.54	0.75	0.74	0.68
19	0.59	0.75	0.89	0.74
Mean of wholeness of kernel with respect to speed	0.62	0.74	0.79	

CD (P<0.05) for Soaking time : NS

Speed : NS

Soaking time x Speed : NS

Table D.11 Mechanical damage

Soaking time (h)	Speed (rpm)			
	47	57	63	Mean of mechanical damage with respect to soaking time
17	5.14	15.57	18.71	13.14
18	12.99	15.95	22.24	17.06

19	14.24	15.43	26.16	18.61
Mean of mechanical damage with respect to speed	10.79	15.65	26.16	

CD (P<0.05) for Soaking time : 1.26

Speed : 1.26

Soaking time x Speed : 2.18

Table D.12 Overall decorticating efficiency

Soaking time (h)	Speed (rpm)			
	47	57	63	Mean of overall decorticating efficiency with respect to soaking time
17	21.72	27.34	29.03	26.03
18	16.74	35.63	30.30	27.56
19	18.70	34.50	38.67	30.62
Mean of overall decorticating efficiency with respect to speed	19.05	32.49	32.67	

CD (P<0.05) for Soaking time : 4.358

Speed : 4.358

Soaking time x Speed : 7.548

Performance Evaluation of Decorticator for Grinding stone

Table D.13 Decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of decorticating efficiency with respect to soaking time
16	52.86	58.12	50.09	53.69
17	61.18	61.52	52.77	58.49
18	55.71	54.32	61.15	57.06
Mean of decorticating efficiency with respect to speed	56.58	57.99	54.67	

CD (P<0.05) for Soaking time : 1.72

Speed : 1.72

Soaking time x Speed : 2.98

Table D.14 Wholeness of kernel

Soaking time (h)	Speed (rpm) 63	71	81	Mean of wholeness of kernel with respect to soaking time
16	0.83	0.82	0.76	0.80
17	0.84	0.83	0.74	0.80
18	0.79	0.80	0.84	0.81
Mean of wholeness of kernel with respect to speed	0.82	0.81	0.78	

CD (P<0.05) for Soaking time : NS

Speed : NS

Soaking time x Speed : NS

Table D.15 Mechanical damage

Soaking time (h)	Speed (rpm) 63	71	81	Mean of mechanical damage with respect to soaking time
16	10.63	12.41	15.63	12.89
17	11.42	12.67	18.71	14.27
18	10.74	14.28	15.41	13.48
Mean of mechanical damage with respect to speed	10.93	13.12	16.58	

CD (P<0.05) for Soaking time : NS

Speed : 1.25

Soaking time x Speed : 2.96

Table D.16 Overall decorticating efficiency

Soaking time (h)	Speed (rpm)			
	63	71	81	Mean of overall decorticating efficiency with respect to soaking time
16	43.87	47.66	38.07	43.20
17	48.53	51.06	43.79	47.79
18	42.91	48.92	46.80	46.21
Mean of overall decorticating efficiency with respect to speed	45.10	49.21	42.89	

CD (P<0.05) for Soaking time : 4.451

Speed : 4.451

Soaking time x Speed : 7.709

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DEVELOPMENT OF A POWERED-DECORTICATOR FOR PRODUCING WHITE PEPPER FROM BLACK PEPPER

CHITHRA, G.

ABSTRACT OF THE THESIS REPORT

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ABSTRACT

A powered black pepper decorticator for producing white pepper from black pepper was developed, tested and its performance evaluated. The major parts are grinding surfaces, feed hopper, cylindrical collecting tray, water distribution assembly, 0.5 hp motor and reduction gear of 5:1 gear ratio. The decortication of the pepper berries was performed by compressive and shearing forces between the grinding surfaces. The experiment was conducted at different soaking time, speed and grinding surfaces. A 2- factor, experiment in Completely Randomized Design (CRD) with speed and soaking time as factors were adopted. The maximum decorticating efficiency observed for MS Plate, rexin sheet, teflon and grinding stone were 46.10, 51.30, 47.50 and 61.52 at 17 h -71 rpm, 17 h -71 rpm, 18 h -57 rpm and 17 h- 71 rpm soaking time - speed combinations. The wholeness of kernels show a decreasing trend at higher speeds that is crushing of berries increases. Generally, the mechanical damage also shows the similar trend. The maximum overall decorticating efficiency for various surfaces were 37.38 of 17 h -71 rpm, 38.99 17h- 71rpm, 35.63 of 18h- 57rpm and 51.06 of 17h -71rpm.

The study shows that the parameters of speed and soaking time have significant influence on decorticating efficiency, wholeness of kernels, mechanical damage and overall decorticating efficiency. The quality of white pepper obtained from grinding stone coupled with polyurethane was superior to those obtained by other surfaces. The overall decorticating efficiency of powered decorticator was found maximum (51.06 %) at 71 rpm and 17 hour soaking period. The capacity of the developed machine was 1.23 kg/h.