STUDIES ON DEMUCILAGING AND WASHING OF COFFEE

Thesis submitted in partial fulfilment of the requirements for the Degree of **MASTER OF ENGINEERING (Agriculture)** in Agricultural Process Engineering to the Tamil Nadu Agricultural University, Coimbatore.

By

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COLLEGE OF AGRICULTURAL ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON DEMUCILAGING AND WASHING OF COFFEE**" submitted in part fulfilment of the requirements for the degree of **MASTER OF ENGINEERING (AGRICULTURE)** in **AGRICULTURAL PROCESS ENGINEERING** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **M.MADASAMY** (I.D.No. 93-625-004) under my Supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific and popular journal or magazine.

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DEDICATED TO MY BELOVED PARENTS .....

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(M.MADASAMY)

ABSTRACT

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STUDIES ON DEMUCILAGING AND WASHING OF COFFEE

By

M.MADASAMY

Degree : **MASTER OF ENGINEERING (AGRICULTURE) IN AGRICULTURAL PROCESS ENGINEERING**

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From the mechanization point of view, to avoid the human drudgery in demucilaging of coffee and unhygenic fermentation process, to minimise the water requirement in this process which needs about 80 m^3 of water per tonne of cleaned parchment this study was proposed. In this study it was attempted to develop suitable coffee washing mechanisms requiring less quantity of water and ease of fabrication.

The physical properties of wet parchment like bulk density, true density, content of mucilage and static co-efficient of friction against various surfaces involved in

the development of coffee washers were determined for the arabica parchments. In this present study two washing mechanisms viz. screw auger type (model-I) and brush type (model-II) were developed. These mechanisms consisted of simple components and operated by 1 hp motor.

These mechanisms were tested for their efficiency in demucilaging and in washing at Horticultural Research Station, TNAU, Yercaud for arabica coffee and at Coffee Demonstration Field, Coffee Board, Yercaud for robusta coffee. The cost of the units and the cost of operation were worked out for these mechanisms.

The average values of the bulk density and true density of the arabica parchment with mucilage were 681.4 and 856.6 kg/m^3 respectively. The content of mucilage in the arabica coffee was found to be 20.1 per cent. The average static co-efficient of friction against coir rope, mild steel and nylon rope were 0.80, 0.42 and 0.32 respectively.

In the screw auger type, the highest washing efficiency of 84.9 per cent was achieved at 40 rpm, 200 kg/hr and 0.44 lps of auger speed, feed rate and water flow rate respectively. The minimum breakage of 10.4% was also found at this combination which is optimum. The washing efficiency of 95.3% with negligible breakage was obtained for robusta parchment at this optimum combination of auger speed, feed rate and water flow rate. The water requirement in this model is 10 times less than the water required for the existing washer.

In the brush type, the optimum brush speed, feed rate and water flow rate are 620 rpm, 25 kg/hr and 0.03 lps respectively for both hard and smooth brushes. The maximum washing efficiency of 100 per cent with negligible breakage was found in this model fitted with both hard brush and smooth brush at this condition for arabica coffee. The maximum washing efficiency of 85.7 per cent with negligible breakage was achieved in this model fitted with hard brush at the same condition for robusta parchment which required two passes of washing. The water requirement in this model is 15 times less than the water required for the existing washer.

The cost of the two models of washers are worked out to be Rs.9930/- and Rs.10655/- for their capacities of 200 kg/hr and 25 kg/hr for the screw auger type and brush type respectively. The cost of operations were around Rs.24/- for these models.

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INTRODUCTION

CHAPTER I

INTRODUCTION

The coffee plant belongs to the family Rubiacease comprises 400 genera and about 5000 species. The genus coffee is an important member of the family Rubiacease and there are 67 species in this genus. The coffee species are divided into different groups namely Eucoffea, Mascaracoffea, Agrocoffea and Paracoffea group. The first three groups are native to Africa and the last group native to India, Indo-China, Srilanka and Malesiya. The group Eucoffea includes the important species such as **Coffea arabica, Coffea canephora, Coffea liberica** and **Coffea congensis**. The important commercial species such as **Coffea arabica** (arabica coffee), **Coffea canephora** (robusta coffee) and **Coffea liberica** (tree coffee) are grown in India. The species native to India are **C.bengalensis, C.Kasiana, C.weightiana** and **C.travancoorensis** and they are not important for commercial cultivation. Arabica is the most largely cultivated coffee in the world. It produces the best quality coffee.

Coffee is grown in 66 countries of the world. It is cultivated between tropic of cancer and tropic of capricorn. Arabica coffee was introduced in India sometime during

1670's by a Muslim pilgrim, Bababudan who brought seven seeds from Yeman and raised seedlings on the hills near the town of Chikmagalur (Bheemaiah, 1992). Robusta was introduced from Indo-China towards the end of the nineteenth century for planting in estates of lower elevation. The commercial coffee producing states are Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Assam, West Bengal, Maharastra, Nagaland, Tripura, Manipur, Himachal Pradesh and Andaman and Nicobar Islands.

The Robusta and arabica coffee grow well at altitudes from 500 to 900 m and 800 to 1500 m above mean sea level (M.S.L.) respectively. The annual rainfall should be about 1750 to 2000 mm. The suitable temperature range for arabica is of $15^{o}C$ to $25^{o}C$ and $20^{o}C$ to $30^{o}C$ for robusta. The relative humidity of 70 per cent to 80 per cent is suitable for arabica and 80 per cent to 90 per cent for robusta.

The yearly production of coffee in the world is about 70 lakhs tonnes. Out of this Brazil produces 13 lakhs tonnes in the year 1992. The contribution of African countries is about 25 per cent. The total annual production in India is around 2 lakhs tonnes. The production of arabica and robusta is in the ratio of approximately 50 : 50 (Anonymous, 1989). The foreign exchange earnings amount to over 585 crores of rupees.

The harvesting stage of the fruit is identified by giving gentle squeezing on the fruit having bright red all over, glossy in appearance (Henderson and Perry, 1955). If it is ripened fully then the bean inside will comeout easily. These fruits are harvested by hand picking and processed either of the two processing methods namely washed method or natural (dry) method (Anonymous, 1985). The ratio of washed arabica to unwashed arabica is 70:30 and for robusta is 6:94 (Menon, 1989). In many of the coffee producing countries like Kenya, Colombia or Costa Rica, the good quality coffee is produced from arabica coffee which is 100 per cent washed.

The harvested fruits of arabica consists of 39 per cent pulp, 17 per cent mucilage, 7 per cent parchment and skin and 37 per cent of beans. The berry harvested in the correct stage contains about 65 to 70 per cent of moisture whereas the green or clean coffee which is eventually exported has only 11 to 12 per cent moisture. About 500 to 600 kg of arabica or 450 kg of rubusta, cherries required to produce about 125 kg of dried parchment coffee, which yields about 100 kg of green coffee as a marketable coffee (Gordon, 1988).

In the dry method, the cherry is dried with the skin and the husk is cracked to remove the beans. But in the wet processing method, the pulp is removed in the pulping machine with the supply of clean water (Anonymous, 1991). To avoid cuts of bean, the fruit is graded into atleast two grades as it is non uniform in size and also the pulping machine is carefully adjusted. Then the musilage is removed. If it is not removed, it will lead to 'sourness' in parchment and cup quality (Menon, 1989). It is rich in sugar particularly glucose, making it a good medium for the growth of bacteria, yeast and fungi.

In the demucilaging process the mucilage which is chemically made up of sugars, enzymes, protopectin and pectin esters is removed. The mucilage is composed basically of 85 per cent of water and 15 per cent of solids in the form of an insoluble and colloidal hydrogel. Out of the solid 80 per cent are pectic substance and 20 per cent sugars (Vania et al., 1989). This process is done in any one of the following methods.

(i) natural fermentation,
(ii) fermentation with added enzymes,
(iii) chemical methods,
(iv) warm water method and
(v) attrition or friction method

In the first method, the wet parchment is kept heaped in vats and the pectin and non-reducing sugars are digested by bacteria and the mucilage is rendered soluble after about 36 to 48 hours. The mucilage in robusta coffee can not be removed even after 70 hours fermentation. In order to accelerate the digestion of the mucilage small amounts of pectic enzymes or alkaline enzymes (Gunasegar and Verma, 1993) probably containing pectase, protopectinase, pectinase and pectinesterase (Horikoshi, 1971) are used as the chief active ingredients in the second method.

The removal of mucilage by treatment with alkali takes about half an hour for arabica and about one hour for robusta coffee. Dilute acids can also be used. Normally 10 per cent NaOH (Caustic soda) or 6 to 8 per cent sodium carbonate are alkaline carbonate (Joshi and Banojbal, 1993) is used as alkali. But the consumar acceptability is poor while going for chemical method.

A simple method for removing coffee mucilage quickly is to mix equal weights of pulped coffee and water and heat to ($50^{o}C \pm 3^{o}C$) as quickly as possible. After 3 minutes contact, the mucilage is removed. In the attrition method, the mucilage is removed by friction developed between the parchments. Then the parchment free from mucilage is washed with clean water (Anonymous, 1991). To complete all the above operations effectively, the clean water requirement is 80 m^3 to produce one tonne of clean coffee (Ananda Alwar **et al.**, 1992). Hence the water requirement and the labour involvement is more in estate level processing.

Though all the above methods are available, the frictional method is found to be better, because the unhygenic problem in fermentation method and chemical method (Anonymous, 1980) and more labour requirements are eliminated in this process. But the problems associated with the existing coffee washer are the high water requirement, highly sophisticated, highly rigid, non-availability of spare parts, corrosive nature and breakage to the beans. To avoid these problems it is necessary to develop the new coffee washing mechanisms. In the development of coffee washers the physical properties of the parchment with mucilage are important.

Based on the above discussion, this research has been undertaken with the following objectives.

(i) To study the various physical properties like bulk density, true density, mucilage content and co-efficient of static friction for the parchment with mucilage.

(ii) To develop coffee washing mechanisms with less water requirement and cost effective.

(iii) To evaluate the performance of the developed washers at estate level.

(iv) To work out the cost of operation of the developed washers.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Coffee as a refreshing beverage has been used at least two hundred years back. The fresh coffee beans are obtained from **Coffea arabica** L. and from **C.robusta** (Gopalakrishnan, 1990). Demucilaging of coffee is an essential process in the monsoon coffee preparation and is a second stage of wet method (Terry Mabbett, 1991). The presence of mucilage leads to the quality deterioration in storage and results in reduction of market value. Therefore it has to be removed thoroughly before going for drying which is the third stage of wet method. The subsequent process is washing to clean the parchment free from mucilage.

For the above processes water is very much essential and the quantity required is very high if the above two processes are done separately. The water requirement has to be minimised as it is a depleting source. By combining these two processes and developing the suitable mechanisms this can be achieved. To develop such mechanisms and carry out those processes effectively the physical properties like bulk density, true density, co-efficient of static friction of the wet parchment with mucilage are important. Therefore the different methods developed by various research workers to study the properties, demucilaging and washing are reviewed and given in this chapter.

2.1. Physical properties of coffee

Physical properties like density and co-efficient of friction of coffee are used in the development of coffee washer mechanisms. To study these properties the following materials were reviewed.

2.1.1. Density of parchment with mucilage

Ghosh (1966) determined the density of wet coffee beans by recording the volume as differences in the height of water column in a burette before and after immersing 100 beans and the mass. The density ranged between 1098 and 1145 kg/m^3.

Sreenarayanan **et al.** (1988) determined the porosity, bulk density and true density of CO.1 variety soybean. Bulk density was determined by filling the sample gently in a container and the ratio between the mass and volume was calculated as bulk density. They reported that the porosity, bulk density and true density of CO.1 variety soybean decreased with increase in moisture content.

Gumbe (1989) determined the bulk density of coffee by weighing known volume of coffee. The porosity was calculated by filling the voids of known volume of coffee with a known volume of water. The densities of cherry and parchment were 634 kg/m^3 and 440 kg/m^3 respectively and porosity of cherry was 39.1 per cent and that of parchment was 43.7 per cent.

2.1.2. Composition of coffee mucilage

Sivetz (1963) reported that chemical composition of mucilage was water 84.2 per cent, protein 8.9 per cent, sugars 4.1 per cent, pectic acid 0.9 per cent and ash 0.7 per cent.

Michael and Desrosies (1979) reported that the pulped coffee consisted chemically of protopectin, pectin, pectin esters, and small amounts of sugar along with naturally occuring enzymes pectase, pectinase, pectinesterase and protopectinase.

Vania and Chalfoun (1989) reported that the coffee mucilage was composed basically, of 85 per cent water and 15 per cent of solids in the form of an insoluble and colloidal hydrogel, of the solid portion, 80 per cent were pectic substance and 20 per cent sugars.

2.1.3. Co-efficient of friction for parchment with mucilage

Muir and Sinha (1988) determined the co-efficient of sliding friction of cereal and oilseed cultivars by using the apparatus as used by the Irvine **et al.** (1992).

Sreenarayanan **et al.** (1988) determined the static coefficient of friction of CO.1 variety soybean using the experimental set up consisted mainly of friction pulley fitted on a frame and a hollow circular sample holder connected to the weight pan. Experiments were conducted on various surfaces like plywood, galvanised iron, aluminium and glass.

Irvine **et al.** (1992) measured the sliding friction co-effcient of flax seed, lentils and fababeans. The various surfaces like galvanised iron and wood were attached to a tilting table. A frame constructed of 18 mm square wooden bars, was placed lengthwise on the surface to enclose an area of 305 mm long and 255 mm wide. The frame was filled with a grain sample and carefully levelled to frame height. The frame was then raised slightly so that it was not resting on the surface. The table was tilted slowely using a manually driven screw. Angles at which samples started to slide were measured with a plumb bob and a protractor.

2.2. Demucilaging

Demucilaging is an important process in wet processing of coffee as it decides the cup quality. Complete mucilage removal leads to the superior cup quality. The different methods of demucilaging reviewed are given below.

2.2.1. Natural fermentation method

Anonymous (1947) stated that the fermentation was the usual means of removing the sticky covering. Because of its effect on quality fermentation had been widely studied. It was generally thought to be due not to external microbial action, but to the diastages present in the cells of the mesocarp which brought about the disintegration of mucilaginous coating. If too prolonged the coffee acquired a dark colour and a disagreeable odour. The best quality coffee was obtained after 12 to 24 hours of fermentation.

Haarer (1956) observed that the pulped bean remained in a tank until fermentation was completed and the time of fermentation depended on seasonal variations and temperatures. The quality was improved by giving it a wash in the tanks every morning, irrespective of whether fermentation had been completed or not. Fermentation at high altitudes took more than 2 days.

Michael and Desrosier (1979) reported that natural fermentation method was the time honoured, simple process which had been in use since coffee was first pulped probably atleast 100 years back and 90 to 95 per cent of washed coffee was produced in this method. The water drained pulped coffee was held in tank and the natural enzyme like pectic enzyme present in the mucilage itself accomplished digestion.

Anonymous (1987) mentioned that natural fermentation was the most commonly used method for demucilaging coffee. In the case of arabica, it was completed in 24 to 36 hours. Fermentation took longer in cool weather than warm weather. Over fermentation and under fermentation were avoided since it reduces the quality of the end product.

Gordon (1988) observed that the best quality coffee could be obtained from the fruit having bright red all over and glossy in appearance. The cherries were pulped and the slimy parchment coffee filled in heaps or into tanks. After about a day the mucilage started to decompose and liquefy and could be washed from the parchment easily.

Menon (1989) reported that the wet parchment obtained after pulping was kept heaped in vats and allowed to undergo natural fermentation brought about by bacteria. The mucilage was rendered soluble after 36 to 48 hours. For arabica the time was 36 hours and for robusta the time was more than 72 hours.

2.2.2. Fermentation with added enzymes

Haarer (1956) mentioned that the use of 0.2 per cent pectic enzyme produced from moulds, based on the weight of the pulped coffee beans was added experimentally to accelerate mucilage digestion. Together with a little warming, it succeeded in completely digesting the mucilage in less than one hour, compared with an average of thirty-six hours for spontaneous fermentation. By the use of 0.025 per cent of the enzyme, the mucilage could be digested in five to ten hours depending on the temperature. If the pH of the bean reduced from 6.8 or 6.7 to a point between 4.2 and 4.5 then they were ready for washing. He also mentioned that from sanitary stand point, the elimination of fermentation and washing might be welcome.

Sivetz (1963) reported that the demucilaging was accelerated by the use of small amount of pectic enzymes containing pectase, protopectinase whose trade name was Benefax.

2.2.3. Chemical methods

Anonymous (1947) mentioned that an alkaline carbonate, which rapidly broke up the cells of the mesocarp, impregnated with calcium pectate.

Sivetz (1963) stated that the mucilage was removed by treating the pulped coffee either with alkali or with dilute acids. Sodium hydroxide solution dissolved coffee mucilage rather rapidly and it had been proposed commercial use and it had not been used commercially to any greater extent. Sodium carbonate might also be used in the same way.

Anonymous (1987) reported that the removal of mucilage by treating with alkali took about one hour for arabica and one and half to two hours in the case of robusta. Ten per cnet of caustic soda was used for this purpose.

Menon (1989) reported that the removal of mucilage by treatment with alkali took about 1/2 an hour for arabica and 3/4 to 1 hour for robusta coffee.

2.2.4. Warm water method

Sivetz (1963) stated that a simple method for removing coffee quickly was to mix equal weights of pulped coffee and water and heated to $50^{o}C \pm 3^{o}C$ as quickly as possible.

2.2.5. Attrition/friction method

Michael and Desrosier (1979) stated that the pulped beans were pressed against each other and against the roughened lining of the machine while being forcibly fed through the machine by a screw against resistance generated by a partially throttled discharge. Clearances were carefully adjusted so that the parchment layer was neither crushed nor broken and the corners of the ribs or projections were rounded to avoid cutting the beans.

He also stated that the Aquapulper or Raoeng pulper was a machine used for demucilaging. It was equipped with a 30 to 40 hp motor and its capacity was about the same as three regular pulpers requiring less than 1 hp each.

Srivastava **et al.** (1986) stated that the research and development was necessary to improve the efficiency of the existing machineries.

Anonymous (1987) stated that there were pulpers such as Raoeng and Aqua pulpa which pulped and demucilated the beans in one operation. These machines were especially suitable for demucilaging robusta parchment but number of naked and bruised beans were occured in the parchment.

Gordon (1988) stated that there was a type of pulper, the Raoeng or Aquapulpa developed in Indonesia and designed to remove the skin, the pulp and the mucilage in one operation. Though it was most suitable for robusta, it could be used to remove the mucilage from pulped arabica. He also reported that at least 4 m^3 of water at a minimum pressure of 0.5 KSC were required for each tonne of cherry processed.

Menon (1989) observed that the pulped parchment coming out of the pulper was fed directly to the aqua washer, which removed the mucilage by friction. Thus, the parchment coming out of the machine was free from mucilage after which the coffee was washed or taken up directly for drying.

Ananda Alwar **et al.** (1992) stated that about 400 to 450 litres of water was required to process 25 to 26 kg of fruits while using mechanical equipments.

Rene Coste (1992) stated that Raoeng pulper and mucilage remover simultaneously pulped, removed the mucilage and washed the coffee. It essentially consisted of a long, cylindrical, perforated casing with a current of water running through it under pressure in which a fluted cylinder ran rapidly about 400 to 550 runs/min. The cherries, which were carried along by the water, were compressed between the cylinder and its casing. The shredded pulp and the mucilaginous material were separated from the beans and washed away by the water. It needed 309 m^3 of water for 750 to 3000 kg of fruit per hour and the energy required was 8 to 25 horse power.

2.3. Washing

Anonymous (1947) stated that after fermentation, the coffee was washed clean of loose rubbish.

Sivetz (1963) observed that the washing was done either in washing machines or in concrete tanks fitted with paddles or by hand or mechanical paddles operating in long channels.

Haarer (1956) stated that between the pulper and fermenting tanks there should be space for the concrete channels in which the parchment coffee was made to flow. Some planters liked to arrange for a preliminary washing and perhaps a rough grading, as the coffee flows to the tanks, in which case the channel should be widened for the purpose.

Ananda Alwar **et al.** (1985) stated that the modified pulper cum washer could be used to minimise the water requirement.

Anonymous (1987) reported that a washing channel was of course inclined at a gently gradient with 4 feet wide and 100 feet long with outlets at 50, 75 and 100 feet. The fall was 3 per cent over the first 50 feet and 1 per cent over the remainder. Water was fed by a 3 inch water main and blocking boards were placed at 50 and 75 feet.

Gorden (1988) mentioned that as soon as the fermentation was complete the parchment had to be washed without delay, using three or four changes of clean water to remove all traces of mucilage on the parchment together with the breakdown products of fermentation of mucilage. The washing was easy when the coffee had been properly fermented. The beans were graded by density during washing. About 1300 litres of water was used to wash one tonne of wet parchment. Mechanical washing machines and washing pumps of vertical and horizontal types were also used.

Ananda Rao (1989) reported that water consumption was less to an extent of 80 to 90 per cent in dry pulper cum washer.

Menon (1989) observed that improperly washed beans or unwashed beans could start fermenting again, leading to 'Sourness' of the entire lot. On completion of fermentation, the coffee beans were washed before it was taken for drying.

Ananda Alwar **et al.** (1992) stated that wet process of coffee was more sophisticated than dry process and 75 per cent of arabica coffee produced in India was converted into washed coffee. The clean water requirement for wet process was 80,000 litres to produce 1 tonne of clean coffee.

2.4. Soaking

Gordon (1988) stated that after mucilage removal some processors soaked the coffee under water for upto a day. It there was no drying space free for the wet parchment it was better to store it under water than in a heap. If the coffee was soaked or stored under water for more than 24 hours, the water must be changed.

Menon (1989) stated that if the water was available in plenty, 5 to 6 hours soaking leads to enhance the colour of beans and the cup quality of beans.

Rene Coste (1992) reported that the water requirement for washing was about 10 litres per kg of coffee.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

In this study, the apparatus and technique used to measure the various properties of the parchment with mucilage and the details of the washer mechanisms fabricated are discussed in this chapter. Also the evaluation of the washers are discussed.

3.1. Physical properties of the parchment with mucilage

The various physical properties like density, static friction and proportion of the content of parchment with mucilage are very much essential for the development of washer mechanisms.

3.1.1. Materials and measurements

The arabica coffee berries were obtained from the nearby coffee estates and were the mixture of partly ripened, just ripened and over ripened fruits. The berries were stored in a refrigerator at $5^{o}C$ for conducting experiements. For conducting experiments, the berriers were pulped manually and the parchments were used along with the mucilage.

3.1.2. Densities

Densities of parchment with mucilage are important in the development of washer mechanisms and hence the bulk density and true density were measured experimentally.

3.1.2.1. Bulk density

Bulk density was determined by filling the wet parchments in a container of known volume and the content was weighed. The ratio between the mass and volume was calculated as bulk density (Sreenarayanan **et al.**, 1988). The experiment was repeated five times by emptying and filling with new samples each time. The mean value was reported.

3.1.2.2. True density

The true density was measured by the water displacement method (Dutta **et al.**, 1988). The mass of twenty five parchment with mucilage was measured in an electronic balance and were dropped into the water in a measuring cylinder. The rise in water level, which is proportional to the volume of the parchment was noted. Similar to the bulk density the experiment was replicated and the average value was reported.

3.1.3. Proportion of contents

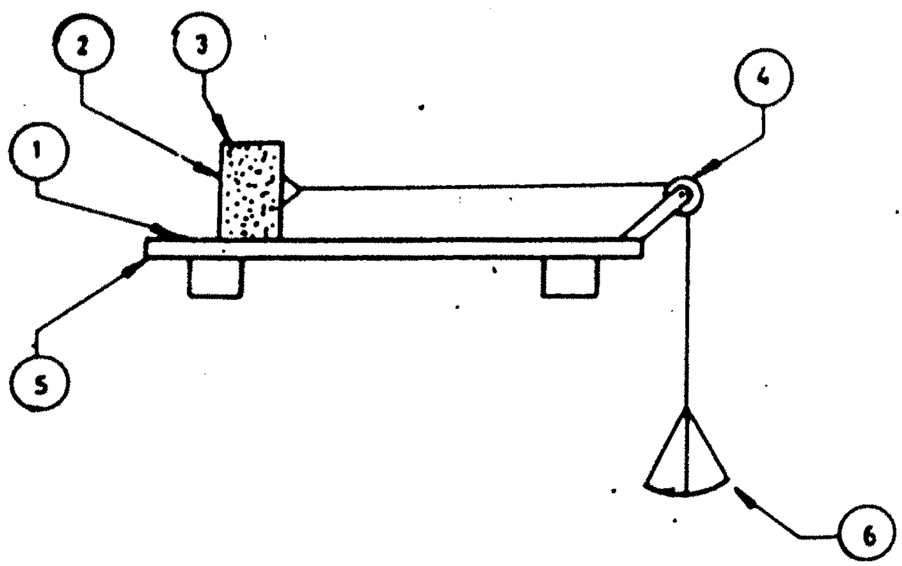
The proportion of parchment and mucilage was determined by keeping the 5 samples of parchment with mucilage of known weight in a container for 40 hours to undergo natural fermentation (Menon, 1989) and washed with clean water and weighed. The difference in weight was calculated for all the samples and the mean value was reported.

3.1.4. Static coefficient of friction

The apparatus consisted of a frictionless pulley fitted on a frame and a hollow sample holder connected to the weight pan through the frictionless pulley as shown in Fig.3.1 (Sreenarayanan **et al.**, 1988). The parchments with mucilage which has 80 per cent moisture content (Ghosh, 1968) were filled in the sample holder and the weight was added to the loading pan until the sample holder just started moving, overcoming the friction on the surface. From the weights in the pan (H) and the weight of parchment with mucilage (W) the static coefficient of friction (f) was calculated using the formula

$$f = H/W \qquad \text{.......} \ (3.1)$$

The experiment was repeated 5 times for different surfaces like mild steel, mild steel wound with coir rope of 6 mm diameter along the direction of movement of sample holder and nylon rope and the average value for each surface was reported.



1. TEST SURFACE
2. GRAIN CONTAINER
3. GRAIN
4. FRICTIONLESS PULLEY
5. PLATFORM
6. WEIGHT PAN

FIG. 3·1 APPARATUS FOR STATIC FRACTION . MEASUREMENT

3.2. Development of demucilaging and washing mechanisms

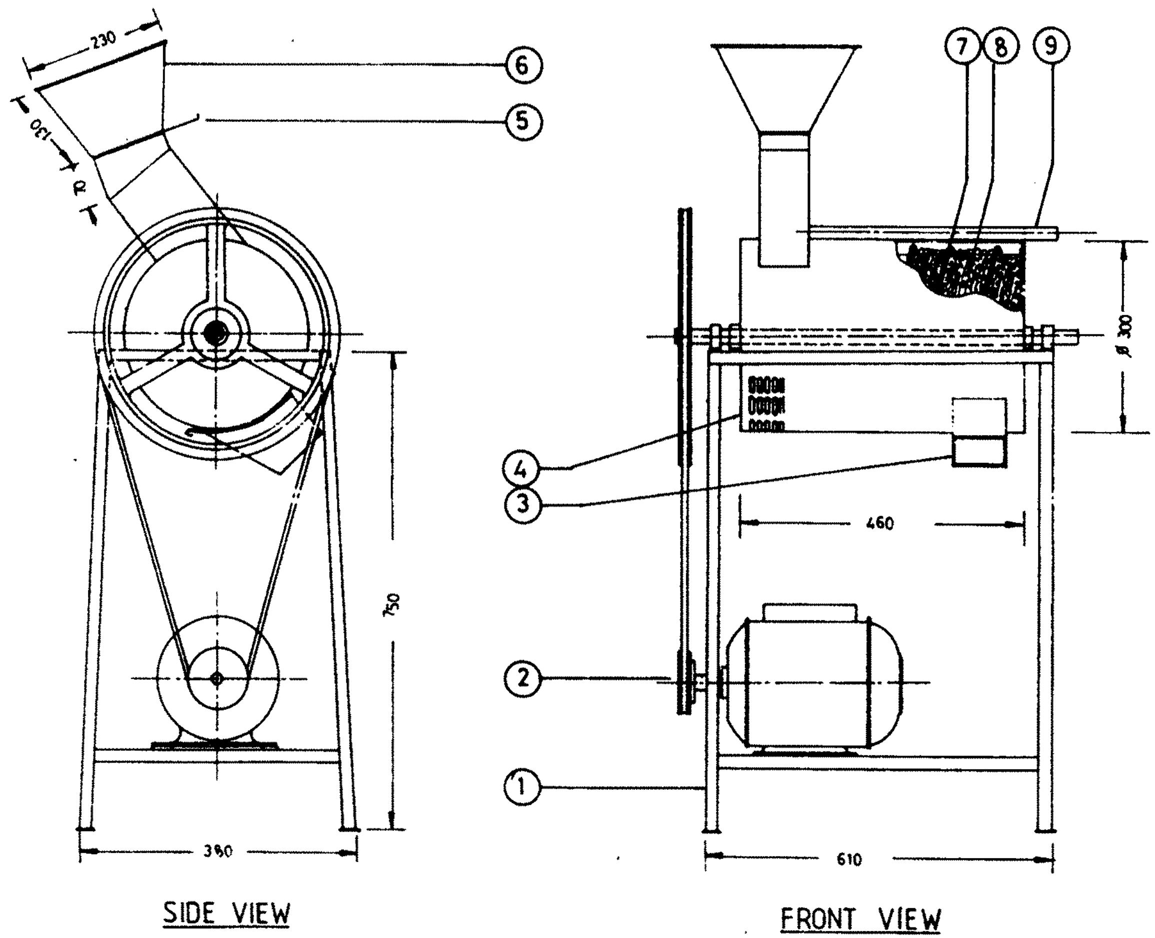
Since the existing demucilaging cum washers are very costlier and needs high amount of water of 3 litres per kg of parchment (Rene Coste, 1992) 2 models of demucilaging cum washing mechanisms were fabricated aiming to minimise the cost and water requirement. Both the models were power operated and an one horse power motor can operate these washers.

3.2.1. Model-I - Screw auger type

This model consisted of an inner cylinder, screw auger, outer cylinder with perforations, feed hopper, outlet with closing mechanism and a frame as shown in Fig.3.2.

3.2.1.1. Inner cylinder with screw auger

The inner cylinder was of mild steel plate of 6 mm thick, the diameter and length are 27 cm and 38 cm respectively as shown in the Fig.3.5. The two sides are closed with the plate of same size with provision to fix the cylinder on the shaft of 25 mm diameter. A screw auger was formed on the pheriphery of the inner cylinder at a pitch distance of 7 cm using the mild steel plate of 6 mm thick. The outer diameter of this cylinder including the screw auger was machined to 31 cm. This cylinder was mounted on a mild steel shaft of 25 mm diameter and mounted on two bush bearings made of brass on either side. A pulley of 'A' type



1.	FRAME (32 x 32 x 3 mm L ANGLE)
2.	MOTOR
3.	OUT LET
4.	PERFORATED OUTER CYLINDER
5.	FEED CONTROL VALVE
6.	FEED HOPPER
7.	SCREW AUGER
8.	COIR ROPE
9.	WATER PIPE

DIMENSIONS IN MM

FIG. 3·2 POWER OPERATED SCREW AUGER TYPE WASHER (MODEL-1) and 245 mm diameter was mounted on this rod at one side to receive the power. Coir rope of 3 mm diameter was wound over the inner cylinder along the screw to develop a rough surface.

3.2.1.2. Outer cylinder

The outer cylinder was made of a mild steel perforated sheet of 20 SWG thick. The perforations were of 25 x 3 mm size. The diameter and length were 32 cm and 43 cm respectively. The feed hopper and outlet are mounted rigid on the opposite side and the cylinder was mounted on the frame. The two sides of the cylinder was closed with mild steel sheet of 20 SWG thickness. This cylinder also had provision for mounting on the shaft. A water pipe line of 15 mm diameter with perforatious at the bottom was also mounted on the outer cylinder for supplying water during the process.

3.2.1.3. Feed hopper and outlet

The feed hopper was mounted with feed control mechanism. It was made up of 20 SWG thick mild steel sheet. A trapezoidal shape feed hopper of 23 cm top width and 14 cm bottom width was fabricated. It was mounted on the outer cylinder. A rectangular shape outlet of 10 x 18 cm was provided at the opposite side of the outer cylinder. A control valve was also provided at the outlet.

3.2.1.4. Frame

To withstand the entire load during the operation and to mount various components as discussed above, a frame was made up of mild steel angle of 30 x 30 x 3 mm. The size of the stand was 61 x 38 x 75 cm.

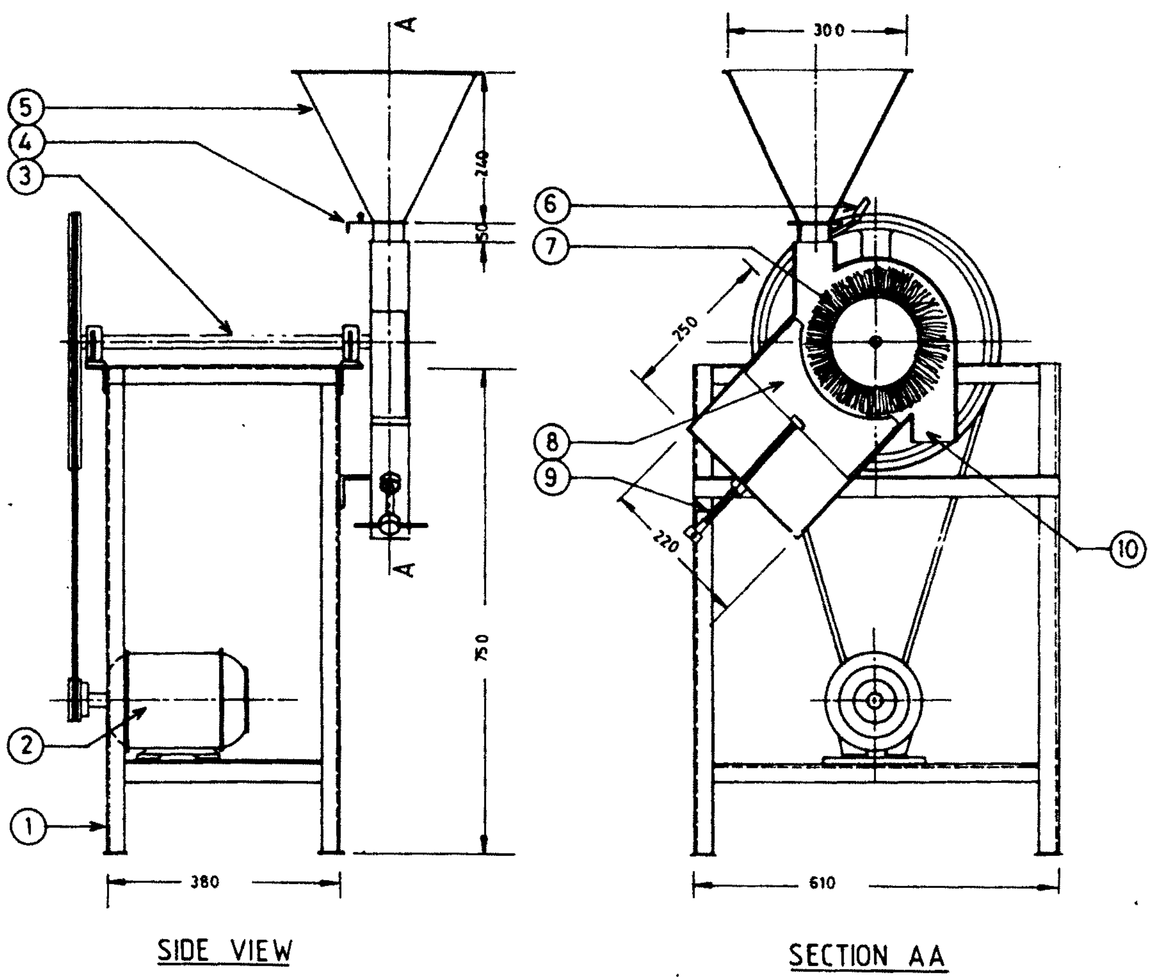
3.2.1.5. Operation

The raw parchment was fed in to the inner cylinder and it was conveyed by the screw anger (Ghosh, 1967) to the outlet and the outlet was closed for some time to load the mechanism. Simultaneously the water was applied through the water pipe. Slowly the outlet was opened till the feed rate coincided with the outlet. The mucilage was removed by friction developed (Ghosh and Gacanja, 1970) between the parchments, the coir rope and parchment and parchment with the outer cylinder as shown in the Fig.3.3. The mucilage removed by the friction was washed away by the water and discharged through the perforations provided on the outer cylinder. The washed and clean parchments was discharged through the parchment outlet.

3.2.2. Model II-Brush type

This mechanism consisted of a feed roller with nylon brush, loading mechanism, outlet, strainer, water inlet, central rod, ball bearings and stand as shown in the Fig.3.4.

Fig.3.3. Screw auger type washer in operation



1.	FRAME
2.	MOTOR
3.	CENTRAL ROD
4.	FEED CONTROL VALVE
5.	FEED HOPPER
6.	WATER PIPE LINE
7.	NYLON BRUSH
8.	RUBBING MATERIAL (WOODEN)
9.	SCREW ROD
10.	OUTLET

DIMENSIONS IN MM

FIG. 3·4 POWER OPERATED BRUSH TYPE WASHER (MODEL-II)

3.2.2.1. Feed hopper, outer casing and outlet

A trapezoidel feed hopper of 30 cm top width, 3.5 cm bottom width with control valve made up of 20 SWG thick mild steel sheet was mounted on the outer casing. The outer casing was made up of 3 mm thickness mild steel sheet with 4 cm diameter hole at the centre on either side and the diameter was 25.5 cm. The outlet of size 7 cm x 7 cm was mounted at the bottom of outer casing. A control valve was also provided for regulating the feed. A rubbing wooden surface was kept between the inlet and outlet. A water inlet was provided at the outer casing just below the feed hopper.

3.2.2.2. Rubbing surface, loading mechanism and strainer

A curved teak wood surface was used as the rubbing surface and size of wood was 21.5 x 11.5 cm. The curve was matched with the radius of nylon brush. A screw rod with thread of M12 x 1.5 for 8 cm length as shown in the Fig.3.3 was used for loading and to adjust the clearance between rubbing surface and nylon brush. To support the loading mechanism, a frame of 23.5 x 28 cm size made up of 3 mm mild steel sheet was used. A strainer of 60 x 20 x 20 cm size with 5 mm diameter perforations was used to separate the cleaned parchment.

3.2.2.3. Nylon brush, central rod, ball bearing and stand

Nylon brush of 0.5 mm size was mounted on the teak wooden roller of 14 cm diameter and 5 cm thickness as shown in the Fig.3.5. A hole of 18 mm diameter was made at the centre of the roller to insert the central rod with check nut. The diameter of the central rod was 25 mm and it was reduced to 18 mm at one end. A key way of 4 x 2 mm was taken on both rod and roller to make them grip. The rod was rested on two ball bearings and a pulley of 125 mm was mounted at the opposite end of the rod to receive the power. The same stand used in model I was used for mounting the entire mechanism.

3.2.2.4. Operation

The raw parchment was fed into the casing through the feed hopper and it was conveyed by the rotating nylon brush to the outlet. Initially the outlet was closed to load the mechanism. Simultaneously water was also applied. The screw rod was adjusted to optimise the clearance between the rubbing surface and nylon brush. The mucilage was removed due to the friction developed between the brush and parchment, parchment and rubbing surface and the mucilage was carried by the flowing water. The outlet was opened after attaining sufficient load inside and the outlet was matched with the feed rate. A strainer was used to separate the cleaned parchment from mucilage as shown in Fig.3.6.

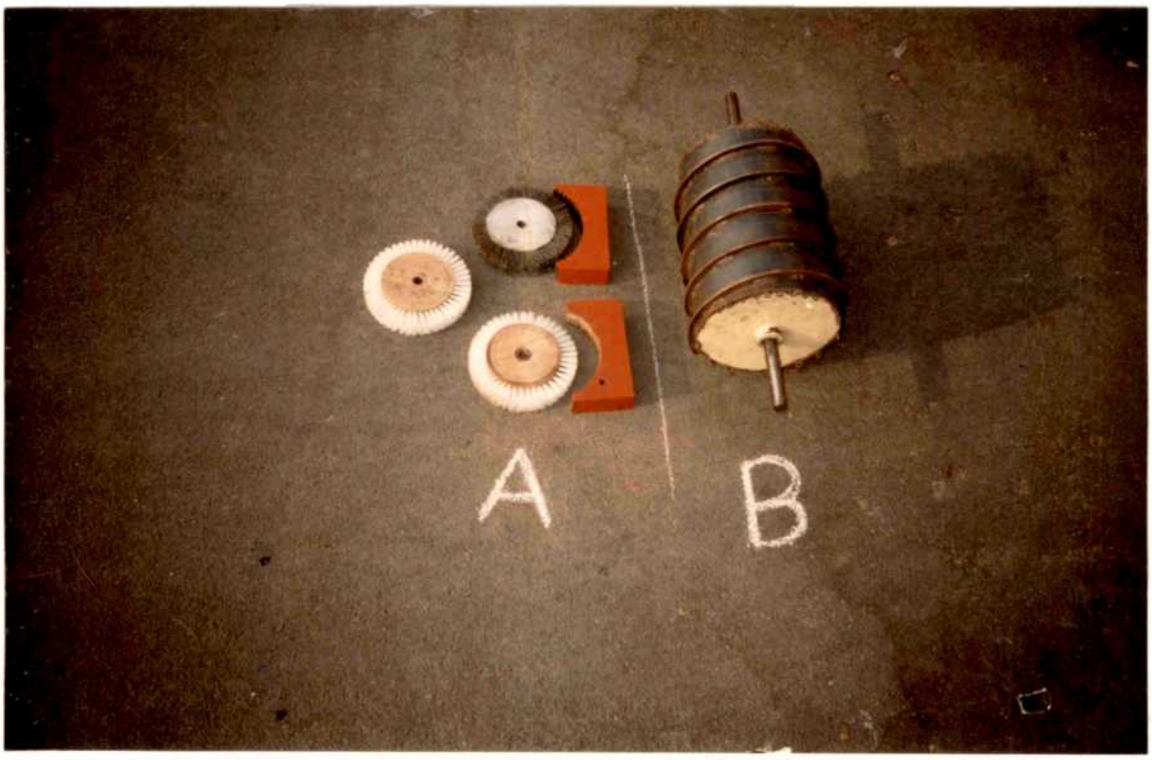


Fig.3.5. A view of the screw auger (B) and brush (A) assembly

Fig.3.6. Brush type washer in operation

3.3. Evaluation of washers

The developed washers both model I and II were evaluated at Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud during January 1996 with the parchment of arabica fruits. They were evaluated for their efficacy, capacity, breaking percentage and water requirement.

The units were evaluated at different speeds, feed rates and water flow rates. The speed of the units was varied by changing the pullies and the drive shaft appropriately to the calculated levels. The speed selected were 40, 50 and 60 rpm for the screw auger type model and 450, 620 and 840 rpm for brush type. The feed rates selected for the trials were 150, 175 and 200 kg/hr for screw auger and 21, 23 and 25 kg/hr for brush type. The water flow rate was regulated and calculated from the time taken to fill a known volume. The various levels of water flow rates used in the trials were 0.38, 0.40, 0.42 and 0.44 lps for screw auger type and 0.03, 0.04, 0.05 and 0.06 lps for brush type.

To evaluate the washers for their efficacy atleast five samples of known weight of the parchment with mucilage was taken in a container and kept for about 40 hours to undergo natural fermentation. Then the parchment was washed with clean water and weighed after keeping the cleaned parchment over the perforated sheet for 5 minutes to drain the water completely so that there might not be any water adhered with parchment. The difference in the above two weights indicated the weight of mucilage presented in the parchment immediately after pulping. By comparing the presence of mucilage in the parchment at the inlet and outlet of the washers, the efficiency of washing was calculated using the following equation.

$$\eta = \frac{A}{F} \times 100 \qquad \text{....... (3.2)}$$

where,

η - washing efficiency in percentage,

A - per cent mucilage present after washing,

F - per cent mucilage present in the feed.

The capacity of the washers were calculated using the following formula (Arnold, 1968) from the time taken for the known feed as,

$$C = \frac{P}{T} \times 60 \qquad \text{....... (3.3)}$$

where

C - Capacity of the unit in kg/hr,

P - Weight of parchment washed in kg,

T - time taken in minutes

The percentage brokens was calculated by taking the 3 samples in random of 100 g each washed parchment and the brokens or damaged parchment was manually separated in each sample (Panesar and Pathak, 1974). The broken parchments of each sample was weighed and the percent breakage was calculated using the following relationship (Rademachar, 1981).

$$B = \frac{D}{S} \times 100 \qquad \ldots\ldots (3.4)$$

where,

B - per cent broken,

D - weight of broken or damaged parchment in gm,

S - total weight of sample in gm.

The mean value for each model had been reported.

The water requirement was calculated by measuring the time required to fill the known volume in a measuring cylinder. The flow rate of water was varied by adjusting the flow valve according to the requirement.

3.4. Cost of operation of the washers

The cost of the models developed were estimated by considering the cost of the raw material, overhead charges and labour charges. The cost of operation was calculated by estimating the fixed cost and variable cost. The following items of expenditure were considered for fixed cost and variable cost and the values assumed are detailed below.

Fixed cost :

(i) Depriciation - estimated by straight line method

(ii) Life of the washer - 5 years

(iii) Salvage value - 10 per cent of the purchase value

(iv) Interest - 12 per cent per annum on average investment

(v) Repairs and maintenance - 10 per cent of intial cost

(vi) Tax and insurance at the rate of 2 per cent of initial cost.

Variable cost :

(i) Working hours per year - 500 hours
(at the rate of 3 hours per day for 125 days in a year)

(ii) Number of labour required and wages - 2 at the rate of Rs.60 per day

(iii) Electricity charges - as consumed.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, the results of the various experiments and the evaluation trials conducted are discussed.

4.1. Physical properties of the parchment with mucilage

The various physical properties like bulk density, true density, content of mucilage of parchment and co-efficient of static friction against various surfaces determined for the parchment are discussed.

4.1.1. Bulk density and true density of parchment with mucilage

The bulk density and true density were determined for the arabica parchment. The average value of bulk density and true density are 681.37 and 856.57 kg/m^3 respectively at the average moisture content of 75 to 80 per cent w.b.

4.1.2. Content of mucilage

For the determination of the mucilage content of arabica coffee, raw parchment was kept for about 48 hours in the laboratory to under go natural fermentation. By calculating the weight difference between before and after washing, the mucilage content was found as 20.09 per cent.

4.1.3. Co-efficient of static friction against various surfaces

To select the appropriate material for effective washing, the co-efficient of static friction was found for the beans against the various surfaces, viz., mild steel, coir rope and nylon rope. The average values for these surfaces are 0.418, 0.80 and 0.316 respectively. As the coir rope has the highest frictional value of 0.80, it was selected as the surface to create friction for washing.

The values of these physical properties are given in the following table.

Table 4.1. Densities, mucilage content and friction co-efficients of parchment with mucilage

Sl.No.	Particulars	Value
1.	Bulk density	681.37 kg/m^3
2.	True density	856.57 kg/m^3
3.	Mucilage content	20.09 per cent
4.	Co-efficient of static friction against	
	(i) Mild steel	0.418
	(ii) Coir rope	0.80
	(iii) Nylon rope	0.316

4.2. Evaluation of washer mechnisms

The two models of the washer mechanisms developed were evaluated for their efficiency and breakage of beans. The trials were conducted at Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud and in the Agricultural Processing Workshop with arabica parchments. The trials with robusta coffee was conducted at Coffee Demonstration Field, Coffee Board, Yercaud during January, 1996. The results are discussed to optimise various parameters viz., speed, feed rate and water requirement with respect to the washing efficiency and breakage.

4.2.1. Model-I power operated screw auger type washer

The screw auger type washer was evaluated for its efficiency of washing and per cent breakage. This model was initially run at various speed range of 20 to 75 rpm and found that 40 to 60 rpm range was adequate. At this speed range the initial evaluation was done with arabica parchment at 4 levels of water flow, keeping the feed rate as 200 kg/hr, the designed capacity.

4.2.1.1. Effect of water flow rate and speed on the performance of washer, (model-I)

The performance of the washer, screw auger type model-I evaluated for washing effciency and per cent broken are given in Table 4.2 for the various speeds and waterflow rates at 200 kg/hr rate.

Table 4.2. Performance of auger type washer at various speeds and water flow rates at 200 kg/hr feed rate

Sl. No.	Speed (rpm)	Water flow rate (lps)	Washing efficiency (%)	Percentage broken
1.	40	0.376	74.91	10.37
2.	40	0.398	79.62	10.41
3.	40	0.424	82.76	10.42
4.	50	0.444	84.46	10.43
5.	50	0.376	69.63	12.12
6.	50	0.378	73.25	12.18
7.	60	0.424	79.29	12.18
8.	60	0.444	79.49	12.24
9.	60	0.376	70.18	16.74
10.	60	0.398	74.55	16.82
11.	60	0.424	76.10	17.15
12.	60	0.444	78.89	17.39

From the Fig.4.1. it can be seen that the washing efficiency increased at all speeds with increase in water flow rate in the range of 0.38 to 0.44 lps. The washing efficiency ranged between 69.6 and 84.9 per cent in the speed range of 40 to 60 rpm for the water flow rate studied.

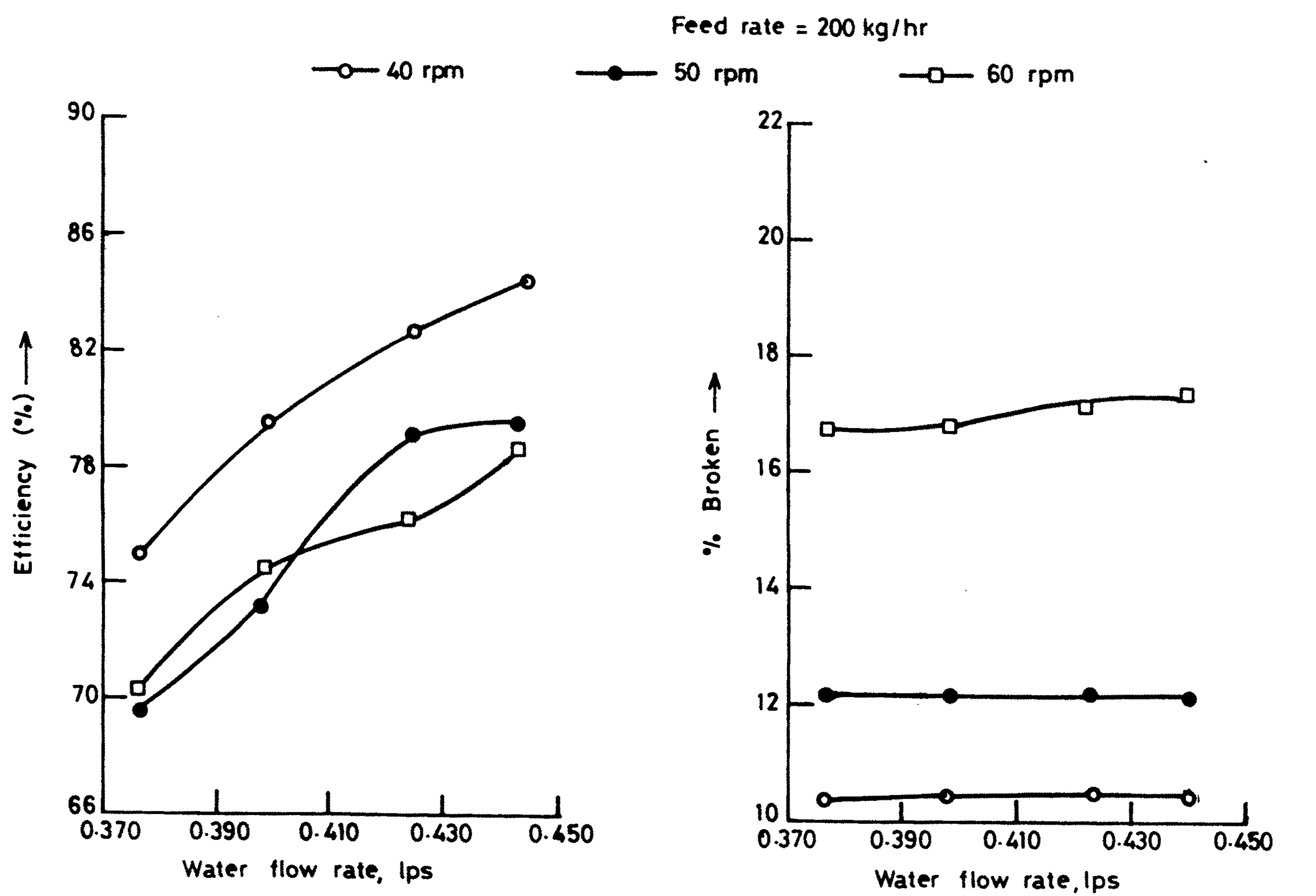


FIG. 4·1 EFFECT OF WATER FLOW RATE AND SPEED ON THE PERFORMANCE OF SCREW AUGER TYPE WASHER, (Model-1)

With respect to water flow rate the washing efficiency decreased initially and increased for increase in the speed of the auger. This decreasing trend was witnessed in the water flow rate range of 0.38 to 0.41 lps and above this range the efficiency is decreased. The highest washing efficiency of 85 per cent was achieved at auger speed of 40 rpm with water flow rate of 0.44 lps, whereas the least washing efficiency of 69.6 was found at a speed of 50 rpm with water flow rate of 0.38 lps.

The per cent broken in this model washer had no effect at speeds of 40 and 50 rpm at all water flow rates and the per cent broken found are around 10.4 and 12.1 for the speeds 40 and 50 rpm respectively. However at the speed of 60 rpm the per cent broken was in the range of 16.7 to 17.4. With respect to the water flow rate the per cent broken increased with increase in speed.

4.2.1.2. Effect of feed rate and speed on the performance of washer model-I

In Table 4.3. the performance of the model-I is given at the water flow rate of 0.44 lps.

Table 4.3. Performance of auger type washer (model-I) as influenced by speed and feed rate at 0.44 lps of water flow rate

Sl. No.	Speed (rpm)	Feed rate (kg/hr)	Washing efficiency (%)	Percentage broken
1.	40	150	69.17	11.46
2.	40	175	75.83	11.74
3.	40	200	84.50	10.51
4.	50	150	67.60	12.15
5.	50	175	73.94	12.20
6.	50	200	79.82	12.38
7.	60	150	65.42	16.56
8.	60	175	71.00	16.76
9.	60	200	79.24	16.89

As seen from Fig.4.2. the washing efficiency increased with feed rate at all speeds at the water flow rate of 0.44 lps. At a constant feed rate and water flow rate the efficiency decreased with increase in the speed. The highest efficiency of 84.5 per cent was achieved at the feed rate of 200 kg/hr for a speed of 40 rpm. The efficiency was least at 150 kg/hr feed rate for a speed of 60 rpm.

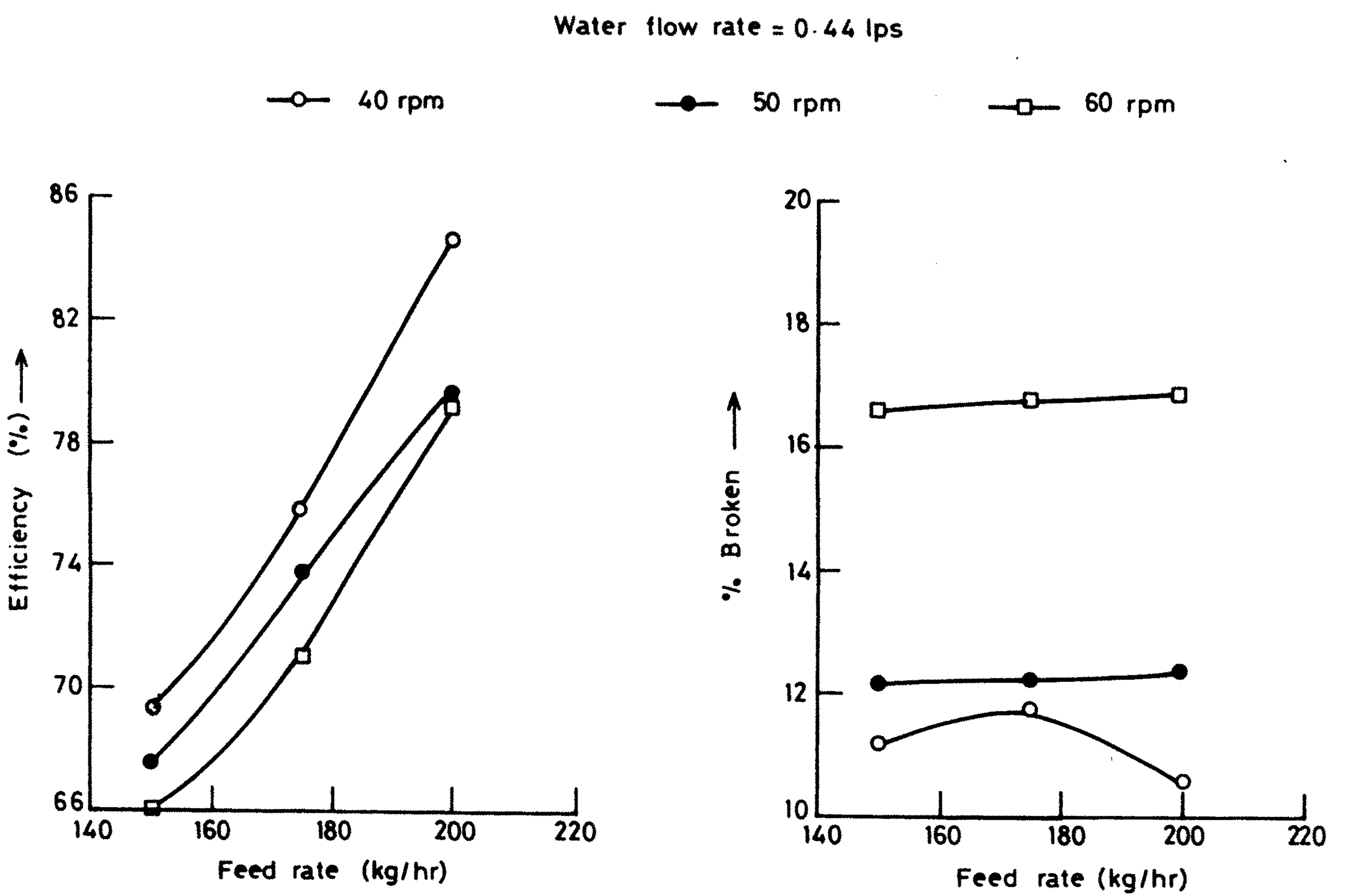


FIG. 4·2 EFFECT OF FEED RATE AND SPEED ON THE PERFORMANCE OF SCREW AUGER TYPE WASHER, (Model-1)

As similar to the effect of waterflow rate on per cent broken the feed rate also influenced. The per cent broken increased with increase in speed at all feed rates. However the influence of feed rate on per cent broken at speeds 50 and 60 rpm are negligible, whereas the per cent broken increased for the feed rate of 150 to 175 kg/hr and decrease with further increase in feed rate.

4.2.1.3. Effect of feed rate, water flow rate and speed on the performance of model-I

From the figures 4.1 and 4.2 it can be seen that speed, feed rate and water flow rate influence both the washing efficiency and per cent broken for this model. The washing efficiency increases with both water flow rate and feed rate for all speeds with respect to water flow rate and feed rate, the washing efficiency increased with decrease in speed. Similar trend was found in per cent broken also with increase in breakage with increase in speed.

4.2.2. Evaluation of model-I washer with robusta parchment

The screw auger type washer (model-I) was evaluated with robusta parchment at the optimum speed, feed rate, water flow determined as per the evaluation trials conducted with arabica parchment and discussed in section 4.2.1. The performance of washer with robusta parchment is given in Table 4.4.

Table 4.4. Efficiency of screw auger type washer for robusta coffee

Sl. No.	Speed (rpm)	Feed rate (kg/hr)	Water flow rate (lps)	Mass of parchment sample (gm)		Mucilage removed (gm)	Washing efficiency (%)
				Before washing	After washing		
1.	40	200	0.444	246.39	197.11	49.28	95.25

A washing efficiency of 95.3 per cent as achieved at the optimum conditions of 50 rpm, 200 kg/hr and 0.44 lps of auger speed, feed rate and water flow rate respectively. It was also witnessed that no breakage of the parchment occured.

4.2.3. Model-II - Power operated brush type washer

The brush type washer fitted with smooth and hard brushes were evaluated. This was initially run at various speed range of 300 to 1000 rpm and found that 450 to 840 rpm is suitable. At this speed range the initial evaluation was done with arabica parchment at four levels of water flow, keeping the feed rate as 25 kg/hr, the designed capacity.

4.2.3.1. Smooth brush

The brush fitted on the washer was 0.35 mm thick bristles and termed as smooth brush.

4.2.3.1.1. Influence of water flow rate and speed on the performance of washer fitted with smooth brush

The performance of this type washer, model-II with smooth brush was evaluated for its efficiency of washing and the per cent broken and the results are given in Table 4.5 for the various speeds and water flow rates at 25 kg/hr feed rate.

Table 4.5. Performance of brush type washer with smooth brush at various speeds and water flow rates at 25 kg/hr feed rate

Sl. No.	Speed (rpm)	Water flow rate (lps)	Washing efficiency (%)	Percentage Broken
1.	450	0.032	82.59	3.08
2.	450	0.039	82.34	3.16
3.	450	0.050	82.14	3.53
4.	450	0.057	81.95	3.64
5.	620	0.032	99.90	0.00
6.	620	0.039	98.40	0.00
7.	620	0.050	98.19	0.00
8.	620	0.057	97.95	0.00
9.	840	0.032	79.79	7.84
10.	840	0.039	79.34	7.87
11.	840	0.050	78.79	8.02
12.	840	0.057	78.19	8.16

As seen from the Fig.4.3, the washing efficiency decreased at all speeds with increase in water flow rate from 0.03 to 0.06 lps. The washing efficiency ranged from 78.19 to 99.90 per cent for the speed range of 450 to 840 rpm for these water flow rates. The maximum efficiency of 99.90 per cent is achieved at 620 rpm with the water flow rate of 0.03 lps. The least value of washing efficiency is achieved at 840 rpm with the water flow rate of 0.06 lps.

The per cent broken in this brush type model with smooth brush was maximum of 8.16 at 840 rpm with the water flow rate of 0.06 lps. There is no broken at 620 rpm for all the water flow rates. The variation in per cent broken is very less in 450 and 840 rpm for these water flow rates.

4.2.3.1.2. Influence of feed rate and speed on the performance of washer fitted with smooth brush

The performance of the washer model-II with smooth brush at the waterflow rate of 0.03 lps is given in Table 4.6.

The Fig.4.4, shows that the washing efficiency decreased with increase in feed rate at 620 rpm for the same water flow rate. The maximum washing efficiency of 99.85 per cent is obtained at 620 rpm with the feed rate of 25 kg/hr. The minimum washing efficiency of 79.34 is obtained at 840 rpm with same feed rate.

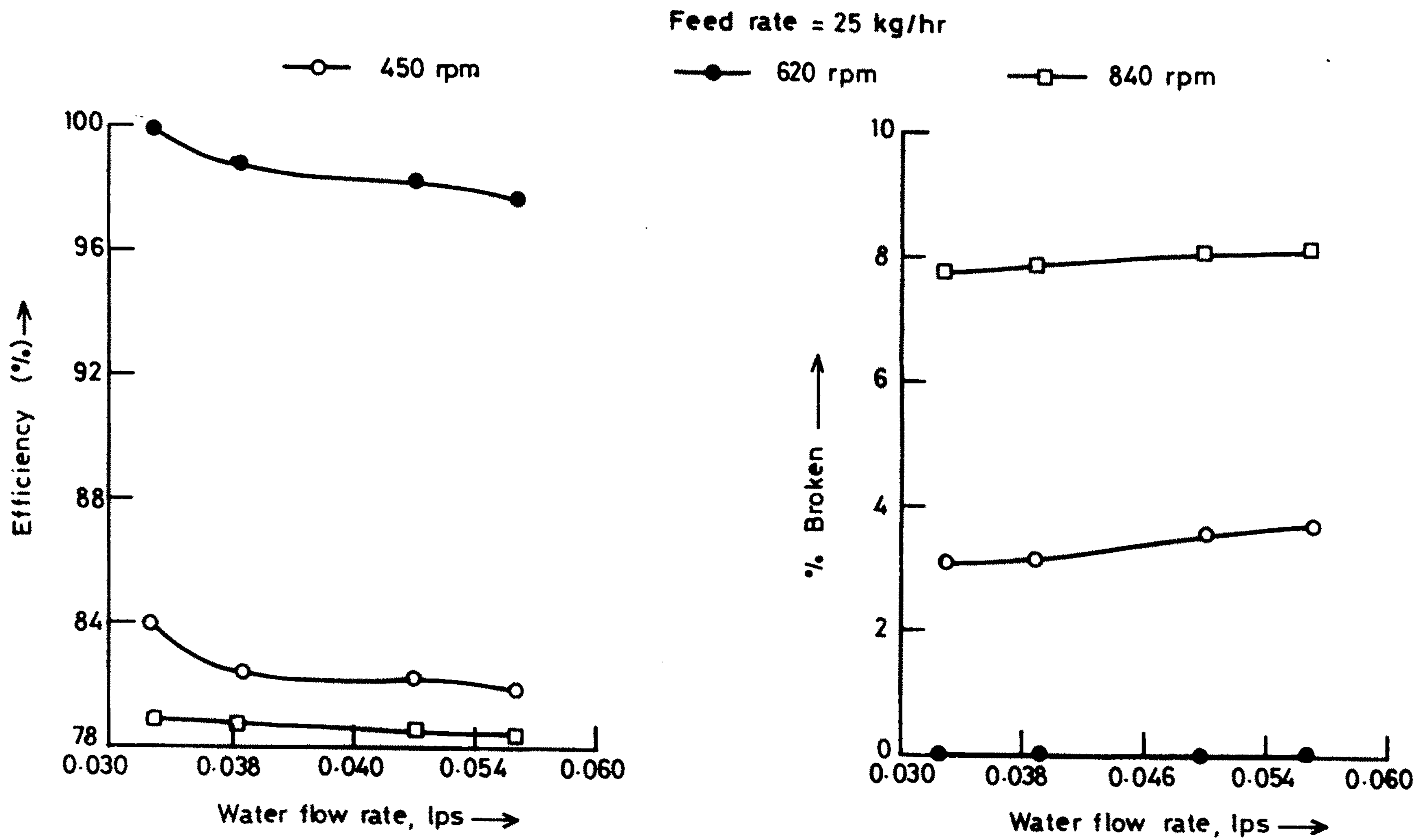


FIG. 4.3 INFLUENCE OF WATER FLOW RATE AND SPEED ON THE PERFORMANCE OF WASHER FITTED WITH SMOOTH BRUSH (MODEL II)

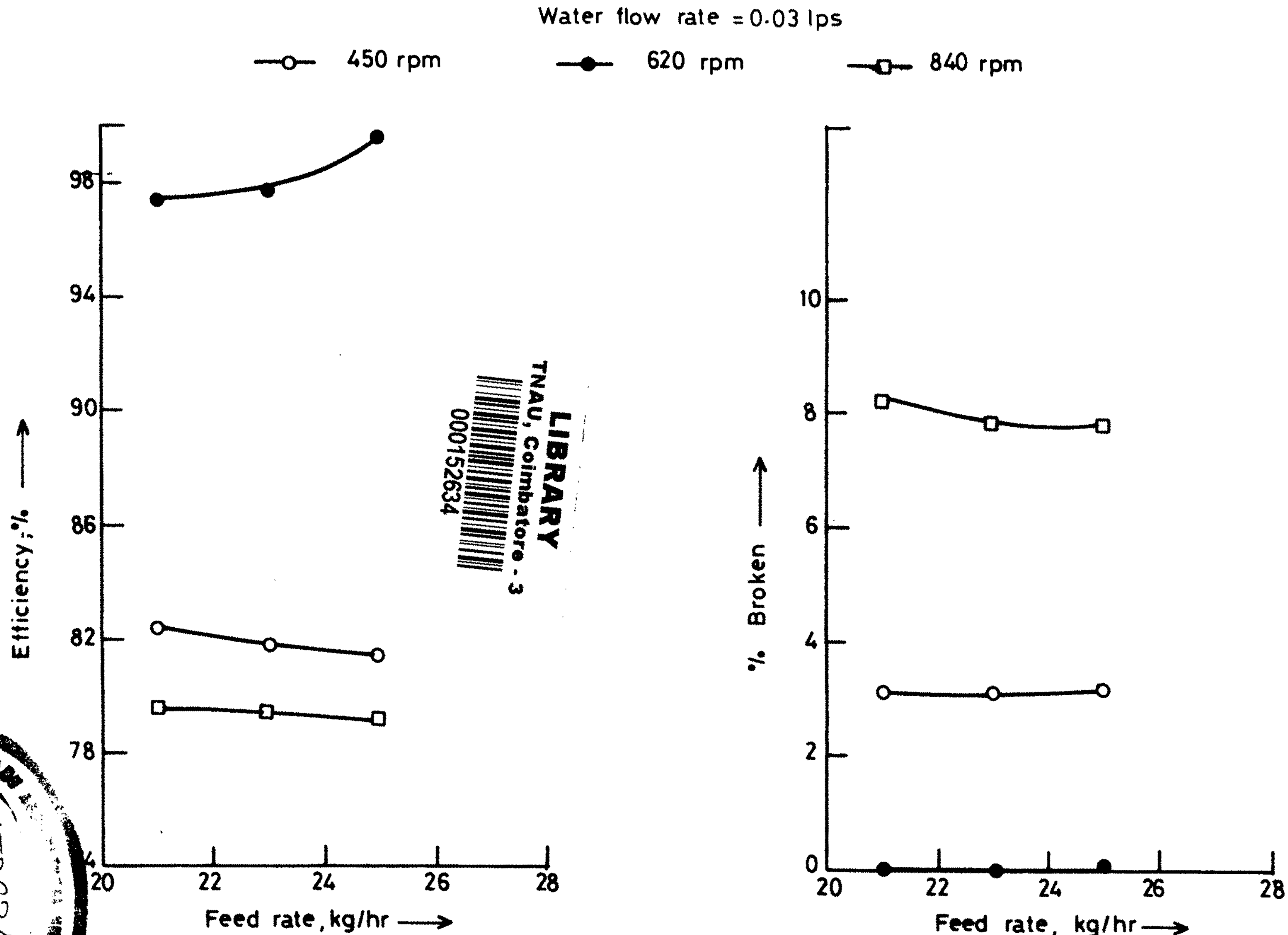


FIG. 4·4 INFLUENCE OF FEED RATE AND SPEED ON THE PERFORMANCE OF WASHER FITTED WITH SMOOTH BRUSH(MODEL II)

Table 4.6.Performance of brush type washer with smooth brush at various speeds and feed rates at 0.03 lps water flow rate

Sl. No.	Feed rate (kg/hr)	Speed (rpm)	Washing efficiency (%)	Percentage broken
1.	25	450	81.49	3.17
2.	25	620	99.85	0.00
3.	25	840	79.34	7.97
4.	23	450	81.69	3.11
5.	23	620	97.99	0.00
6.	23	840	79.44	7.97
7.	21	450	82.04	3.14
8.	21	620	97.35	0.00
9.	21	840	79.54	8.09

The per cent broken in this washer model is maximum of 8.09 at the speed of 840 rpm with the feed rate of 21 kg/hr whereas the minimum of zero was obtained at the speed of 620 rpm for all the feed rates with the water flow rate of 0.03 lps. The increase in feed rate leads to the decrease in per cent broken at 450 and 840 rpm. The variation is negligible.

4.2.3.1.3. Effect of feed rate, water flow rate and speed on the performance of washer fitted with smooth brush

From the figures 4.3 and 4.4 it can be seen that the effect of speed, feed rate and water flow rate influenced both the washing efficiency and per cent broken for this model. The washing efficiency increased with increase in speed upto 620 rpm and then decreased for decrease in both water flow rate and feed rate and increase in speed.

The reason for this lower washing efficiency at lower and higher speeds (450 and 840 rpm) may be that the friction created for removing the mucilage is not achieved at lower speeds. At higher speeds the parchments may not have been gripped well by the brush resulting decrease in washing efficiency.

In the case of per cent broken, increase in speed upto 620 rpm leads to decrease in per cent broken and then increased for decrease in both water flow rate and feed rate. At the lower speed of 450 rpm the increase in the retention time of the parchments and the higher impact exerted on the parchment at higher speed of the brush (840 rpm) has resulted in higher breakage.

4.2.3.2. Hard brush

The brush fitted on the washer with 0.5 mm thick bristle was termed as hard brush.

4.2.1.3.2.1. Influence of water flow rate and speed on the performance of washer, model-II

The performance of the brush type washer, model-II fitted with hard brush was evaluated for washing efficiency and per cent broken and are given in Table 4.7 for the various speeds and water flow rates at 25 kg/hr feed rate.

Table 4.7. Performance of brush type washer with hard brush at various speeds and water flow rates at 25 kg/hr feed rate

Sl. No.	Speed (rpm)	Water flow rate (lps)	Washing efficiency (%)	Percentage broken
1.	450	0.032	82.69	3.23
2.	450	0.039	82.47	3.76
3.	450	0.050	82.19	4.00
4.	450	0.057	82.04	4.06
5.	620	0.032	100.00	0.00
6.	620	0.039	98.45	0.00
7.	620	0.050	98.20	0.00
8.	620	0.057	98.10	0.00
9.	840	0.032	98.10	8.00
10.	840	0.039	79.44	8.12
11.	840	0.050	78.90	8.15
12.	840	0.057	78.30	8.22

The Fig.4.5, shows that the washing efficiency decreased at all speeds with increase in water flow rate in the range of 0.03 to 0.06 lps. The washing efficiency ranged from 78.3 to 100 per cent for the speed range of 450 to 840 rpm for these water flow rates. The maximum efficiency of 100 per cent was obtained at the speed of 620 rpm with the water flow rate of 0.03 lps and the minimum value of washing

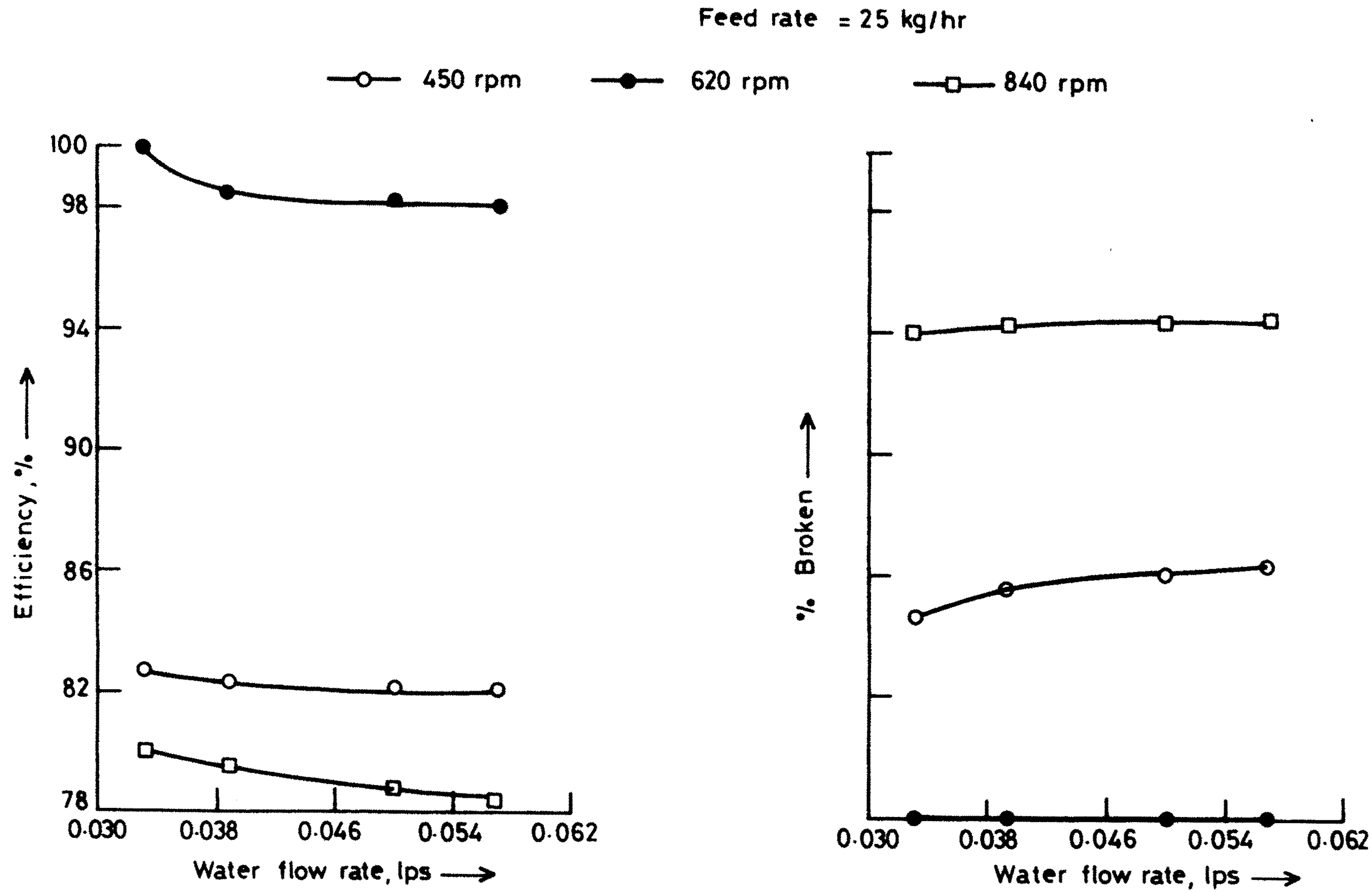


FIG. 4.5 INFLUENCE OF WATER FLOW RATE AND SPEED ON THE PERFORMANCE OF WASHER,(MODEL - II) FITTED WITH HARD BRUSH

efficiency was obtained at a speed of 840 rpm with water flow rate of 0.06 lps.

The per cent broken in this brush type model washer was maximum of 8.22 at the speed of 840 rpm with water flow rate of 0.06 lps. There was no broken at 7620 rpm for all the water flow rates. But the per cent broken is not varied widely at 450 rpm for all the waterflow rates as similar to the speed 840 rpm. The increase in waterflow leads to increase in per cent broken at the speeds of 450 and 840 rpm but it is negligible.

4.2.3.2.2. Influence of feed rate and speed on the performance of washer model-II

The performance of the brush type washer with hard brush at the water flow rate of 0.03 lps is given in Table 4.8.

It is seen from Fig.4.4, that the washing efficiency decreased with increase in feed rate at 450 and 840 rpm for the water flow rate of 0.03 lps. But the efficiency increased with increase in feed rate at 620 rpm for the same water flow rate. The maximum efficiency of 100 per cent was achieved at the feed rate of 25 kg/hr with the speed of 620 rpm. The minimum value of 79.4 per cent was found at the speed of 840 rpm with the feed rate of 25 kg/hr.

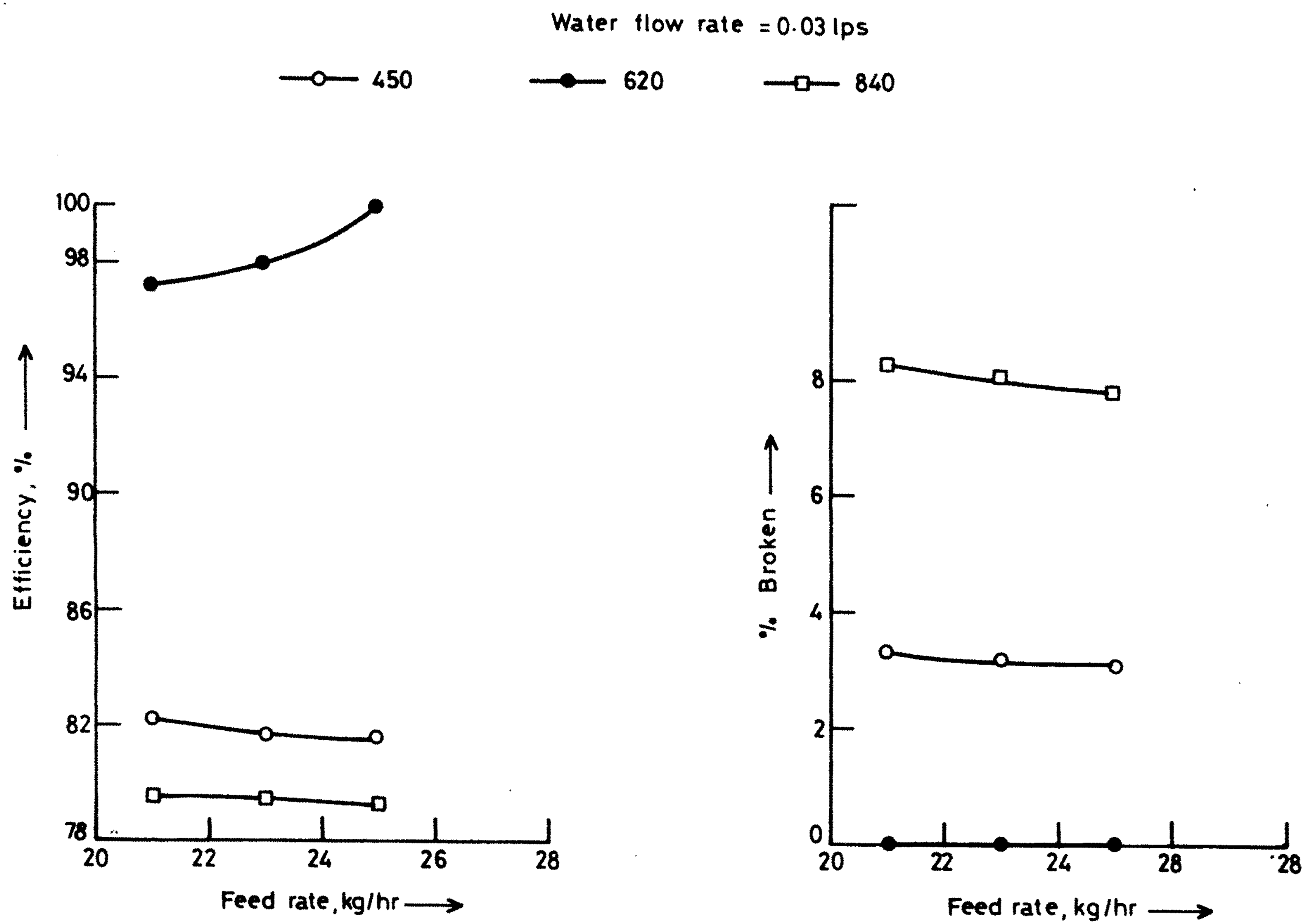


FIG. 4·6 INFLUENCE OF FEED RATE AND SPEED ON THE PERFORMANCE OF WASHER, (MODEL - II) FITTED WITH HARD BRUSH

Table 4.8. Performance of brush type washer with hard brush at various speeds and feed rates at 0.03 lps water flow rate

Sl. No.	Feed rate kg/hr	Speed (rpm)	Washing efficiency (%)	Percentage broken
1.	25	450	81.54	3.15
2.	25	620	100.00	0.00
3.	25	840	79.44	7.87
4.	23	450	81.79	3.19
5.	23	620	98.00	0.00
6.	23	840	79.54	8.06
7.	21	450	82.20	3.25
8.	21	620	97.45	0.00
9.	21	840	79.64	8.19

The maximum per cent broken of 8.19 per cent was found at the speed of 840 rpm with 21 kg/hr feed rate. There was no brokens at 620 rpm for all the feed rates. The increase in feed rate leads to decrease in per cent broken at 450 and 840 rpm speeds.

4.2.3.2.3. Influence of speed, feed rate and water flow on the performance of washer, model-II

From figures 4.5 and 4.6 the influence of speed, water flow and feed rate on the performance of hard brush fitted washer mechamism can be seen. The washing efficiency decreased at all speeds with increase in water flow rate and with feed rate excepting the speed 620 rpm which has shown an increasing trend with feed rate. The washing efficiency of 100 per cent was achieved at a feed rate of 25 kg/hr and water flow rate of 0.03 lps at a speed of 620 rpm.

The per cent broken which decrease with both feed rate and water flow rate at all speeds excepting the speed 450 rpm which resulted in increase in per cent broken with increase in water flow rate. The highest breakage of about 8.22 per cent was seen at the feed rate of 21 kg/hr and water flow rate of 0.06 lps at 840 rpm speed. Thus the combination which has resulted in higher washing efficiency is optimum.

4.2.4. Evaluation of model-II with robusta parchment

The brush type washer mechanism model-II fitted with both smooth and hard was evaluated with robusta parchment at the optimum levels 620 rpm, 25 kg/hr and 0.03 lps of brush speed, feed rate and water flow rate respectively. During the trials it was observed that the mechanisms fitted with smooth brush was incapable of removing mucilage and washing the parchment. The mechanism with hard brush was able to demucilage and wash the parchment by repeated passing of the washed parchment. It was required to pass the parchment repeatedly for 2 times because of the more sticky nature of mucilage in robusta coffee (Menon, 1989).

The results of the evaluation trials with hard brush is given in Table 4.9. A washing efficiency of 85.7 per cent was obtained at the parameters optimised in section 4.2.3.2.

Table 4.9. Efficiency of brush type washer fitted with hard brush for robusta coffee.

Sl. No.	Speed (rpm)	Feed rate (kg/hr)	Water flow rate (lps)	Mass of parchment (gm)			Mucilage removed (gm)	Washing efficiency (%
				Before washing	I time washing	II time washing		
1.	620	300	0.039	120.37	110.37	98.70	85.73	21.67

4.3. Cost of operation

The cost of the washers are arrived as follows

	Model I	Model II
Cost of materials	Rs.1585.00	Rs.2065.00
Cost of motor (1 hp), cable and switches	Rs.5000.00	Rs.5000.00
Labour charges at the rate of 1/3 of cost of materials motor, cable and switches	Rs.2195.00	Rs.2355.00
Overhead charges at the rate of 17.5% of cost of material, motor, cable and switches	Rs.1150.00	Rs.1235.00
Total cost of the unit	Rs.9930.00	Rs.10655.00

I. Fixed cost		
(i) Depreciation	Rs.1754.00/ year	Rs.1917.90/ year
(ii) Interest @ 12% per annum on average	Rs. 655.40/ year	Rs. 703.23/ year
(iii) Repair and maintenance @ 10% of initial cost	Rs. 993.00/ year	Rs.1065.50/ year
(iv) Tax and insurance @ 2% of initial cost	Rs. 198.60/ year	Rs. 213.20/ year
	Rs.3601.00/ year	Rs.3899.73/ year
Total (I)	Rs.7.20/hr	Rs.7.89/hr
II. Variable cost		
(i) Labour charges	Rs.15.00/hr	Rs.15.00/hr
Total (II)	Rs.16.15/hr	Rs.16/15/hr
Total cost of operation (I + II) =	Rs.23.35/hr	Rs.23.95/hr

The cost of the units model-I and model-II were estimated as Rs.9930/- and Rs.10,655/- respectively. The cost of operation for these models were also worked out as Rs.23.35 and Rs.23.95 per hour for the capacities of 200 kg/hr and 25 kg/hr respectively.

In working out the cost of the two models of washers, the various costs involved like cost of the material, labour charges and other overhead charges were included. The material used for model II can be used for the unit of higher capacity also. When this unit, model II is required to be scaled up for the higher capacity the work involved is making only a larger size casing and the brush. This work involves only a nominal increase in the cost of the material. Also the large scale production will bring down the cost. This will also result in the proportionate cost of operation.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSIONS

From the mechanization point of view, to avoid the human drudgery in demucilaging of coffee and unhygenic fermentation process, to minimise the water requirement in this process which needs about 80 m^3 of water per tonne of cleaned parchment, this study proposed. In this study it was attempted to develope suitable coffee washing mechanisms requiring less quantity of water and ease of fabrication.

In the development of the washers, the physical properties of wet parchment like bulk density, true density, content of mucilage and static co-efficient of friction against various surfaces are involved. Therefore these properties were determined for the arabica parchments following the methods and techniques explained earlier. In this present washing study two mechanisms viz., screw auger type (model-1) and brush type (model-II) were developed. The mechanisms consisted of simple components and operated by 1 hp motors. Brush type and screw auger type mechanisms were developed with locally available materials. Screw auger type consisted of coir rope wound auger cylinder, outer cylinder with perforations, main shaft, bearings, water pipe, feed hopper and outlet with sieve, motor with pulley. Brush type model consisted the different components like wooden roller mounted with nylon brush, wooden rubbing surface, outer casing, water pipe, feed hopper and outlet, shaft with check nut, bearings, motor and pullies, and a common stand for both mechanisms.

These two mechanisms were tested for their efficiency in demucilaging and in washing at Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud for arabica coffee and at Coffee Demonstration Field, Coffee Board, Yercaud for robusta coffee. The cost of the units and the cost of operation were worked out for these mechanisms.

Based on the above work, the following conclusions are made.

1. The average values of the bulk density and true density of the arabica parchment with mucilage were 681.4 and 856.60 kg/m^3 respectively. The content of mucilage in the arabica coffee was found to be 20.1 per cent. The average static co-efficient of friction against the coir rope surface was the highest followed by mild steel and nylon rope. The friction co-efficients were 0.80, 0.42 and 0.32 for the coir rope, mild steel and nylon rope respectively.

2. In the screw auger type, model-I the performance with arabica parchment viz., washing efficiency and per cent broken increased with increase in water flow rate and feed rate at all speeds of operations. The highest washing efficiency of 84.9 per cent was achieved at 40 rpm, 200 kg/hr and 0.44 lps of auger speed, feed rate and water flow rate respectively. The minimum breakage of 10.4 per cent was also found at this combination which is optimum.

3. At the optimum conditions of 40 rpm, 200 kg/hr and 0.44 lps of auger speed, feed rate and water flow rate respectively, the mechanism model-I also performed well with robusta parchment resulting in 95.3 per cent of washing efficiency with negligible breakage of parchments.

4. In the mechanism, model-II brush type, fitted with smooth type brush the washing efficiency for the arabica parchment increased in the speed range 450 to 620 rpm and decreased further at all feed rates and water flow rates. similar trend was found in per cent broken also.

5. The percentage washing efficiency for the arabica parchment decreased at all speeds with increase in water flow rate. Similar trend was also found with increase in feed rate excepting the speed 620 rpm which

increased with increase in feed rate. The treatment combination with 620 rpm, 25 kg/hr and 0.03 lps of brush speed, feed rate and water flow rate respectively has resulted in the highest water efficiency of 100 per cent with negligible breakage.

6. The performance of the brush type washer (model II) fitted with hard brush was on par with the model fitted with soft brush for the arabica parchment. The efficiency of 100 per cent with negligible breakage was obtained at the treatment combination found optimum for the soft brush.

7. The model fitted with hard brush at the optimum conditions of 620 rpm, 25 kg/hr and 0.3 lps of brush speed, feed rate and water flow rate resulted in washing efficiency of 85.7 per cent with negligible breakage for the robusta parchments which required 2 passes of washing.

8. The cost of the two models of washers are worked out to Rs.9930/- and Rs.10655/- for their capacities of 200 kg/hr and 25 kg/hr for the screw auger type and brush type respectively. The cost of operations were around Rs.24/hour for these two models.

9. The capacity of both these models can be increased for higher out turn and less cost of operation.

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APPENDICES

APPENDIX I

Evaluation of washer mechanisms developed

Model I : Power operated brush type
Effect of brushes over washing
I **Hard brush** : 0.5 mm thickness

1.1. Performance of brush type washer with hard brush at various speeds and water flow rates at 25 kg/hr feed rate

Sl.No.	Speed (rpm)	Weight of parchment (gm) Initial weight = 100 gm Weight after fermentation = 80.01 gm: Water flow (ml\sec)	Before washing	Washing Efficiency (%)	Weight of broken (gm)	Weight of good parchment (gm)	Breaking percentage (%)
1.	450	32.26	83.42	82.69	2.58	77.43	3.23
2.	450	38.46	83.52	82.47	3.01	77.00	3.76
3.	450	50.00	83.57	82.19	3.20	76.81	4.00
4.	450	57.15	83.00	82.04	3.25	76.76	4.06
5.	620	32.26	80.01	100.00	0.00	80.01	0.00
6.	620	38.46	80.32	98.45	0.00	80.01	0.00
7.	620	50.00	80.37	98.20	0.00	80.01	0.00
8.	620	57.15	80.39	98.10	0.00	80.01	0.00
9.	840	32.26	84.01	80.00	6.50	73.69	8.00
10.	840	38.46	84.12	79.44	6.52	73.51	8.12
11.	840	50.00	84.23	78.90	6.58	73.49	8.15
12.	840	57.15	84.35	78.30	6.58	73.43	8.22

1.2. Performance of brush type washer with hard brush at various speeds and feed rates at 0.03 lps water flow rate

Sl.No.	Speed (rpm)	Weight of parchment (gm) Initial weight = 100 gm: Feed rate (kg/hr)	After washing	After fermentation	Washing Efficiency (%)	Weight of broken (gm)	Weight of good parchment (gm)	Weight of sample (gm)	Breaking percentage (%)
1.	450	25.00	83.70	80.01	81.54	2.52	77.49	80.01	3.15
2.	450	23.00	83.55	80.01	81.79	2.55	77.46	80.01	3.19
3.	450	21.00	83.55	80.01	82.20	2.60	77.41	80.01	3.25
4.	620	25.00	80.01	80.01	100.00	0.00	80.01	80.01	0.00
5.	620	23.00	80.41	80.01	98.00	0.00	80.01	80.01	0.00
6.	620	21.00	80.52	80.01	97.45	0.00	80.01	80.01	0.00
7.	840	25.00	84.12	80.01	79.44	6.30	73.71	80.01	7.87
8.	840	23.00	84.00	80.01	79.54	6.45	73.56	80.01	8.06
9.	840	21.00	84.08	80.01	79.64	6.55	73.46	80.01	8.19

1.3. Performance of brush type washer with smooth brush at various speeds and water flow rates at 25 kg/hr feed rate

Sl.No.	Speed (rpm)	Weight of parchment (gm) Initial weight = 100 gm Weight after fermentation = 80.01 gm: Water flow (ml\sec)	Before washing	Washing Efficiency (%)	Weight of broken (gm)	Weight of good parchment (gm)	Breaking percentage (%)
1.	450	32.26	83.49	82.59	2.48	77.53	3.08
2.	450	38.46	83.54	82.34	2.53	77.48	3.16
3.	450	50.00	83.58	82.14	2.82	77.19	3.53
4.	450	57.15	83.62	81.95	2.91	77.10	3.64
5.	620	32.26	80.03	99.90	0.00	80.01	0.00
6.	620	38.46	80.33	98.40	0.00	80.01	0.00
7.	620	50.00	80.39	98.19	0.00	80.01	0.00
8.	620	57.15	80.42	97.95	0.00	80.01	0.00
9.	840	32.26	84.05	79.79	6.27	73.74	7.84
10.	840	38.46	84.14	79.34	6.30	73.71	7.87
11.	840	80.00	84.25	78.79	6.42	73.59	8.02
12.	840	57.15	84.37	78.19	6.53	73.48	8.16

1.4. Performance of brush type washer with smooth brush at various speeds and feed rates at 0.03 lps water flow rate

Sl.No.	Speed (rpm)	Weight of parchment (gm) Initial weight = 100 gm: Feed rate (kg/hr)	After washing	Washing Efficiency (%)	Weight of broken (gm)	Weight of good parchment (gm)	Breaking percentage (%)
1.	450	25.00	83.71	81.49	2.50	77.51	3.17
2.	450	23.00	83.67	81.69	2.49	77.52	3.11
3.	450	21.00	83.60	82.04	2.51	77.50	3.14
4.	620	25.00	80.09	99.85	0.00	80.01	0.00
5.	620	23.00	80.43	97.90	0.00	80.01	0.00
6.	620	21.00	80.54	97.35	6.25	73.76	7.81
7.	840	25.00	84.13	79.34	6.38	73.63	7.97
8.	840	23.00	84.12	79.44	6.38	73.63	7.97
9.	840	21.00	84.10	79.54	6.47	73.54	8.09

APPENDIX II

Analysis of parchment sample for the determination of washing efficiency and per cent brokens

Screw auger type : Washer - model I

2.1. Performance of auger type washer at various speeds and water flow rates at 200 kg/hr feed rate

Sl.No.	Speed (rpm)	Water flow (ml/sec)	Weight of parchment (gm) Initial weight = 100 gm — After washing	After fermentation	Efficiency (%)	Weight of broken (gm)	Weight of good parchment	Weight of sample (gm)	Breaking (%)
1.	40	376	85.13	80.15	74.91	8.31	71.84	80.15	10.37
2.	40	398	84.10	80.03	79.62	8.33	71.70	80.03	10.41
3.	40	424	83.53	80.10	82.76	8.35	71.75	80.1	10.42
4.	40	444	83.15	80.05	84.46	8.35	71.70	80.05	10.43
5.	50	376	86.15	80.11	69.63	9.71	70.40	80.11	12.12
6	50	398	85.46	80.15	73.25	9.76	70.39	80.15	12.18
7.	50	424	84.30	80.20	79.29	9.77	70.43	80.20	12.18
8.	50	444	84.15	80.06	79.49	9.80	70.20	80.06	12.24
9.	60	376	86.14	80.25	70.18	13.43	66.82	80.25	16.74
10.	60	398	85.21	80.16	74.55	13.48	66.68	80.06	16.82
11.	60	424	84.78	80.00	76.10	13.72	66.28	80.25	17.15
12.	60	444	84.23	80.01	78.89	13.91	66.10	80.01	17.39

2.2. Performance of auger type washer (model-I) as influenced by speed and feed rate at 0.44 lps of water flow rate

Sl.No.	Speed (rpm)	Feed rate (kg/hr)	Weight of parchment (gm) Initial weight = 100 gm — After washing	After fermentation	Efficiency (%)	Weight of broken (gm)	Weight of good parchment	Weight of sample (gm)	Breaking (%)
1.	40	150	86.70	80.05	69.17	8.23	71.82	80.05	11.46
2.	40	175	84.50	79.56	75.83	8.36	71.20	79.56	11.74
3.	40	200	83.10	80.00	84.50	8.41	71.59	80.00	10.51
4.	50	150	86.50	80.03	67.60	9.72	70.31	80.03	12.15
5.	50	175	85.25	80.05	73.94	9.77	70.28	80.05	12.20
6.	50	200	84.10	80.08	79.82	9.91	70.17	80.08	12.38
7.	60	150	86.85	79.20	65.42	13.23	66.67	79.90	16.56
8.	60	175	85.80	80.00	71.00	13.41	66.59	80.00	16.76
9.	60	200	84.20	80.00	79.24	13.52	66.54	80.06	16.89