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Evaluation of the technical performance of root crop processing machines for sweetpotato grates and flour production

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ABSTRACT

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The performance of the root crop processing machines used in the production of sweetpotato grates and flour was determined. The machines included the Philippine Root Crop Research and Training Center (PhilRootcrops) pedal-operated root crop chipper/grater, hydraulic presser, spinner, motor-operated attrition grinder, flour finisher, and cross-beater mill. Each machine was evaluated based on the following parameters: operating power with and without load, revolution per minute (rpm), capacity, fineness modulus, dimensions of chips and grates, and percent recoveries.

The chipping capacity of the (PhilRootcrops) Chipper/Grater increased as the blade rpm increased (350 to 650 rpm), together with the amount of crumbs present in the chips, but the average weight of the chips decreased. On the other hand, the grating capacity increased and the fineness modulus of the grates decreased with an increase in blade rpm at the same rpm range. The grating operation had the most pronounced power fluctuation among the operations evaluated. Pressing the grates using the hydraulic presser at 5 kg loading rate reduced the moisture content level of grates from more than 60% to about 50%. Using the

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spinner of the washing machine, the moisture removed from grates was almost the same as that of the hydraulic presser although longer in time. The power required in running but the starting power increased as the load was increased, while the rpm of the spinner was alsothe same at different loads. The attrition grinder had a stable power fluctuation even in any kind and amount of material loaded to the hopper, but had the highest energy requirement among the machines evaluated. Average diameter of the fine flour produced after grinding the coarse flour was larger than the fine flour of the first grinding. The finisher, in separating the fine from the coarse flour, had the least amount of net power among the machines evaluated. Using the cross-beater mill, the power requirement in milling the different kinds of materials varied with the small sized Shiro satsuma chips and the cassava grates recording the highest and lowest power, respectively, among the materials evaluated.

INTRODUCTION

The Philippine Root Crops Research Center (Philrootcrops) developed and established the village level root crop flour processing system in the Philippines (Tan, 1990; Tan and Orias, 1986). The system consisted of machines, which were either designed, developed, and/or modified/adapted. These machines included the root washers, dryers, grinders and finishers. The flour processing system can process flour at the equivalent capacity of the finisher of about 20 kg/h fine flour for manual operation, but more than 50 kg/h using the motor-operated finisher. These machines have been reported to be in use in villages in the Philippines (Roa *et al.*, 1998; Tan *et al.*, 1996; Tan *et al.*, 1994). It was observed that the system performed satisfactorily in producing cassava flour and grates. However, product quality is low because of the use of the weather-dependent sun-drying method. Cassava is a highly perishable crop that should be processed or dried within three days after harvest. During rainy season, drying the products by natural means for three days is practically impossible resulting in quality deterioration. Furthermore, the efficiency of the system is also low because the machines used by the system operate independently with each other, which subsequently require time-consuming and laborious handling operations. The system was improved by combining the grinding and finishing operations into a single machine resulting in an output capacity of about 100 kg/h (Orias and Tan, 1997). The time devoted to grinding and finishing is 2-3 times less than that of the previous design. The new machine has a fine flour recovery of 90% which is 11.3% higher than that of the old design. Energy savings equivalent to 5.6 man-h was obtained for every 100 kg of dried chip processed. The new machine was able to cut down the unnecessary breaktime in grinding and finishing twice. It also minimized storage and processing space by combining the grinder and finisher units into a single machine.

The improvement, however, only covers the village level processing of chips into flour. The grates processing system is not yet improved. Moreover, details of the performance of the machines and the quality of the products they have produced have not been thoroughly evaluated. Such information is necessary for the design and performance efficiency of the machines of the village level processing systems.

This research was conducted in response to the need to evaluate the performance of these machines/systems as benchmark information for future improvement and modification, or as an aid in the design of new processing systems. It aimed to determine the perfomance of the machines used in the production of root crop flour and grates using sweetpotato as the test material.

MATERIALS AND METHODS

The machines evaluated included the following: 1) PhilRootcrops pedal-operated root crop chipper/grater which is used for grating or chipping the roots; 2) Hydraulic presser which is used to remove the water from grates; 3) Spinner of the washing machine that is used to remove water from grates by centrifugal force; 4) Attrition grinder for grinding the dried chips or grates into flour; 5) Flour finisher for separating the fine from the coarse flour after passing through the attrition grinder; and 6) Cross-beater mill that pulverizesthe dried grates or dried chips into fine flour without using the flour finisher.

The PhilRootcrops Pedal-operated Root Crop Chipper/Grater

The PhilRootcrops developed the machine shown in Figure 1. Tan (1989) described in detail the machine, its operation and the fabrication procedure. Based on the evaluation of the three kinds of chipper blades (plain knife, channelled, and the corrugated type), the corrugated type (Figure 1a) of blade for the chipper and the punctured plate for the grater blade (Figure1c) were selected. The products produced by the selected chipper and grater blades are shown in Figures 1b and 1d, respectively. Three chipper blades, which are equidistant to each other and offset in alignment, are mounted on the blades assembly. Each blade has 6 corrugations spaced at 25 mm from each other, and each corrugation has a height and length of 8 mm and 30 mm, respectively. The grater blade, on the other nand, is actually a punctured metal plate measuring 400 mm in diameter. The punctures protrude 1.5 mm from the surface and spaced at 6.54 mm, almost covering the whole surface of the plate.

Hydraulic Presser

The presser used in the Philippines is a screw-type manually-operated machine (Figure 2a). The fresh grates are placed inside a muslin cloth or cloth sack and loaded to the machine for pressing. A hydraulic presser of the Hokkaido Tokachi Area Regional Food Processing Technology Center in Obihiro City (Figure 2b) was evaluated instead of the screw-type presser.

The Spinner of the Washing Machine

The spinner,which is cylindrical, has a diameter of 190 mm and a height of 355 mm. The spinner revolution was measured at 1450 rpm. The spinner used in the experiment is part of a washing machine (HITACHI: PS 510, 2.2 kg-cap).

Attrition Grinder

The machine is commercially available (Figure 3)and is usually used for grinding rice and corn in the villages. But it can be used to grind different kinds of products. Henderson and Perry (1976) described it the simplest of all size reduction machines used for agricultural food products.It has two grinding plates: one stationary and the other rotating. It has been adopted for village level processing of root crop flour because of its simplest design and easy

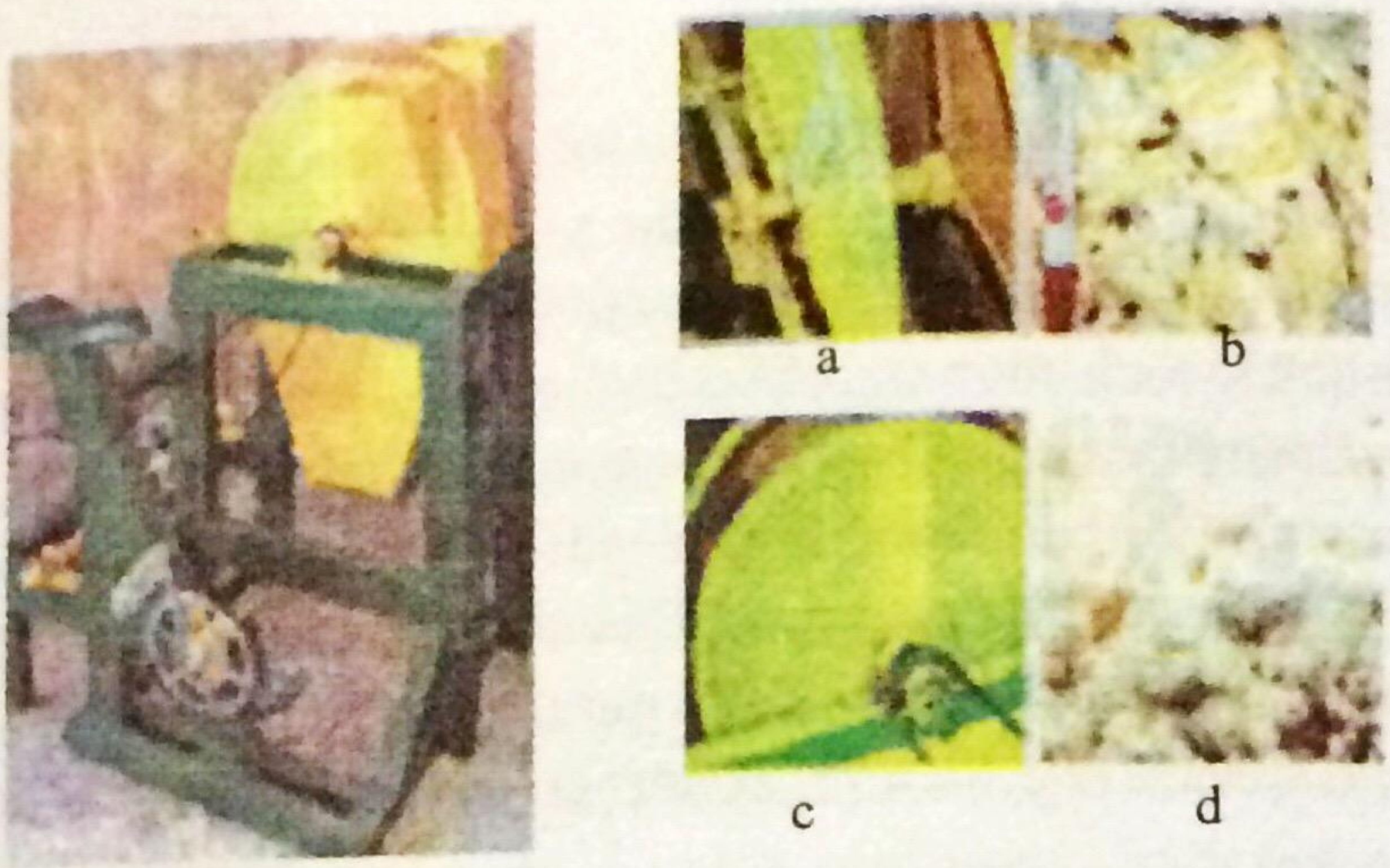
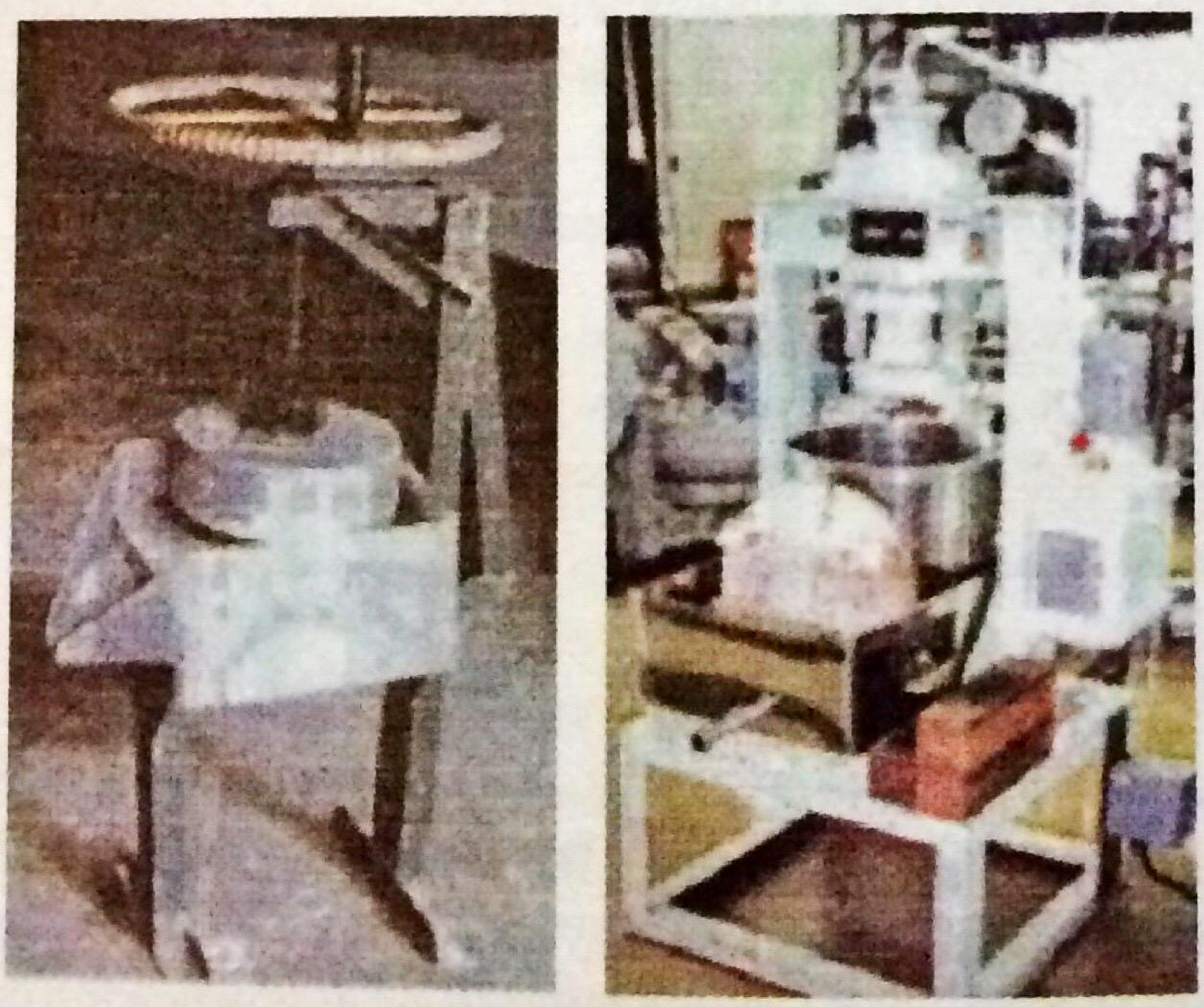


Figure 1. The PhilRootcrops pedal-operated root crop chipper/grater showing the a) chipper blade; b) and the chips produced , c) and the grater blade, d) and the grates produced



a) Screw-type presser b) Hydraulic presser

Figure 2. the pressers used in extracting water from grates

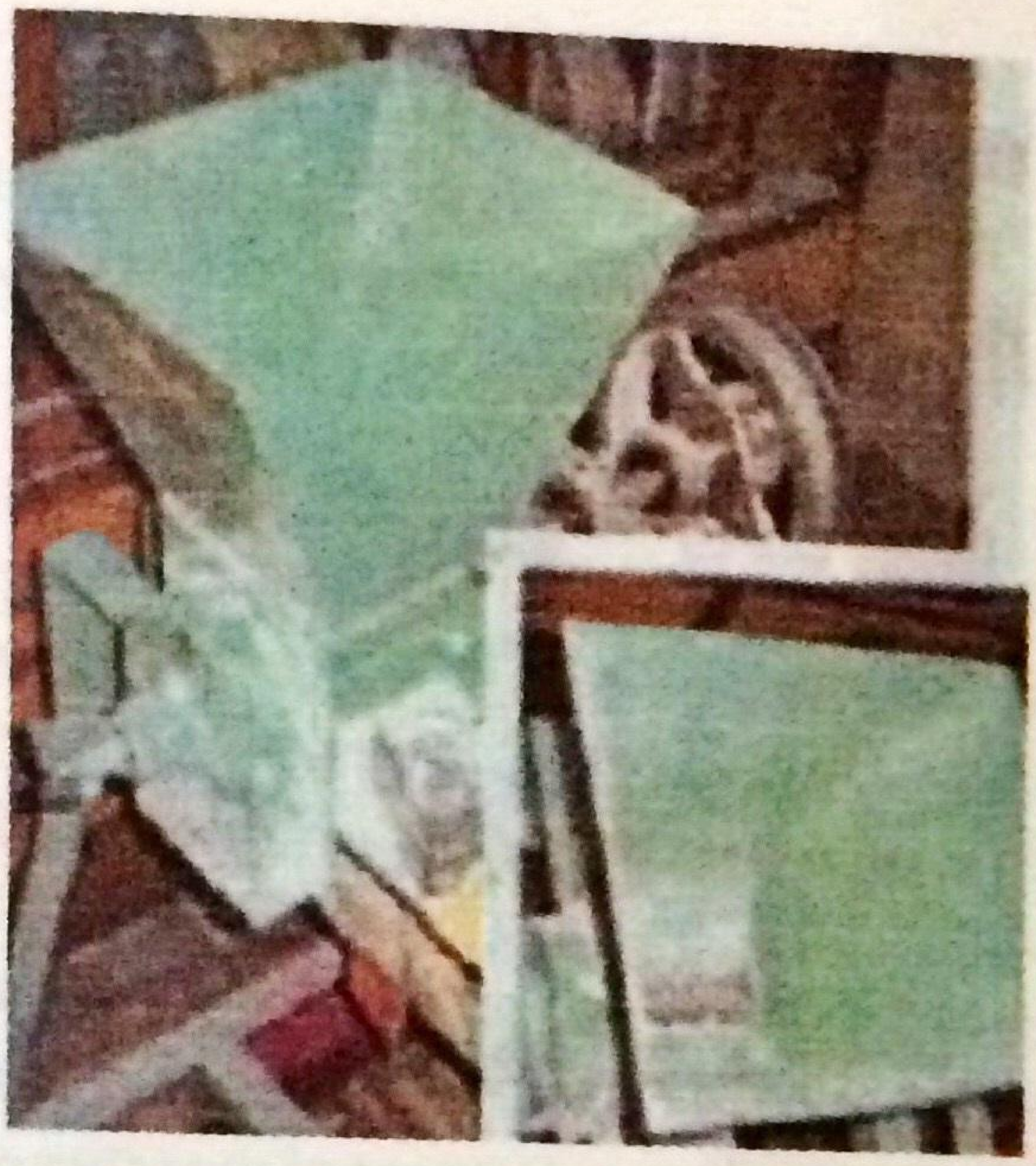


Figure 3. The attrition grinder

Figure 4 Perspective and interior views of the finisher

maintenance. Information is available on the grinding properties of rice and corn (Carpio and Aco, 1990) and other grains (Appel, 1987; Guritno and Haque, 1994) but none for root crops.

Flour Finisher

Figure 4 shows the prototype of the machine designed for this study. It is basically composed of a stationary screen cylinder covered with mesh #60 stainless screen and a rotating stirrer assembly located inside the screen cylinder. The product is loaded into one end of the cylinder and brought to the other end by the constant stirring of the stirrer and by gravity,and during which the fine flour passes through the screen and is brought down by gravity to the container while the coarse flour moves out of the other end of the cylinder.

Cross-beater Mill

The cross- beater mill (Figure5) is a commercially available machine made in Germany. It has three main parts: the frame,the milling assembly, and the motor. The milling mechanism consists of 4 equally rotating blades enclosed in a stationary hardened metal case with corrugated inside surface. At the bottom of the enclosure is the outlet hole with replaceable screen of different meshes.

The materials are loaded into the side opening of the mill going directly to the rotating blades where they are milled into fine particles until they pass through the screen openings at the bottom. From the screen,the materials are gathered into a closed container.

Set-up of Machines

Some of the machines used in the Philippines were set-up in the laboratory.Important machine parts like the chipper/grater blade assembly of the PhilRootcrops pedal-operated root crop chipper/grater, and disc plates of the attrition grinder were brought from the Philippines. Frame and body parts were fabricated and mounted with variable speed motors. The finisher with three fine flour outlet hopper compartments shown in Figure 4 was also fabricated. A hopper-metering device was also fabricated to provide the desired loading rate to the other machines during the tests.

Materials

Two sweetpotato varieties (namely: *Kogane sengan* and *Shiro satsuma*) were procured from Kyushu and stored under controlled (15°C and 59% relative humidity) until use (Edmond and Ammerman,1987). Table 1 describes some physical properties of the two sweetpotato varieties. The roots of *Shiro satsuma* were oval, while those of *Kogane sengan* were long.

Evaluation of the machines and experiments conducted

Operating performance of the machines

The output capacity, power consumption and the revolution per minute (rpm) of the main rotating parts of the machines were determined. The power consumption and rpm were determined using the clip-on type power monitor (SOAR: Energy Monitor 2720) and the digital tachometer (HIOKI: Tacho Hi Tester 3404), respectively. These data were stored in the data recorder (TEAC: RD-135T)and monitored using the digital memory recorder (NEC: OMNI Light, 8M37). The data gathered were transferred to the computer using A/D converter system (TEAC: QuikVu-RD/Win). A 5-kg sample per trial was used to evaluate the chipper, grater, and presser, while 0.5-1.0 kg sample was used to evaluate the grinder and finisher.

Chipping experiment

The chipper rpm was varied at 350, 500 and 650 rpm. Capacity, power requirement, chip size and shapes were determined. An investigation was conducted on the effect of tip angles of the blade (45 and 900) on the capacity, power requirement, and the quality of chips produced.

Five kilograms of fresh roots were used for each sample and replicated 2 times at 3 samples per replication. The replications were two varieties used. The revolution of the chipper blade determined the pace of the loading by the person loading the samples.

Table 1. Physical properties of fresh roots of the two varieties of sweetpotato used in the experiment

Variety	Ave. wt. /root, g	Ave. dimension, mm L	D1	D2	D3	Bulk Density kg/m3	MC %w.b.
Kogane sengan	244.8	207	35	42	37	232	63.7
Shiro satsuma	204.8	138	41	47	41	191	69.3

Legend: L=length of the roots; D1= diameters of the rootsabout 2 cm from either end; D3= mid-section diameter of the roots.

About 100 g of chip samples were gathered, and the number of chips were counted and individually weighed. The crumbs present in the chip samples were also determined. The crumbs were those pieces which were small and whose forms were the different from the chips.

Attrition grinding experiment

Grinding of chips and grates using the attrition grinder was compared in terms of power consumption, flour recovery, and physical characteristics of the flour produced. At 700 rpm of the grinder plate, and two plate adjustments, the following were treatments for the chips and grates:

T_1 - Grinding of chips/grates at fine adjustment (there is contact between plates), then sieving, and regrinding the coarse flour at fine adjustment.

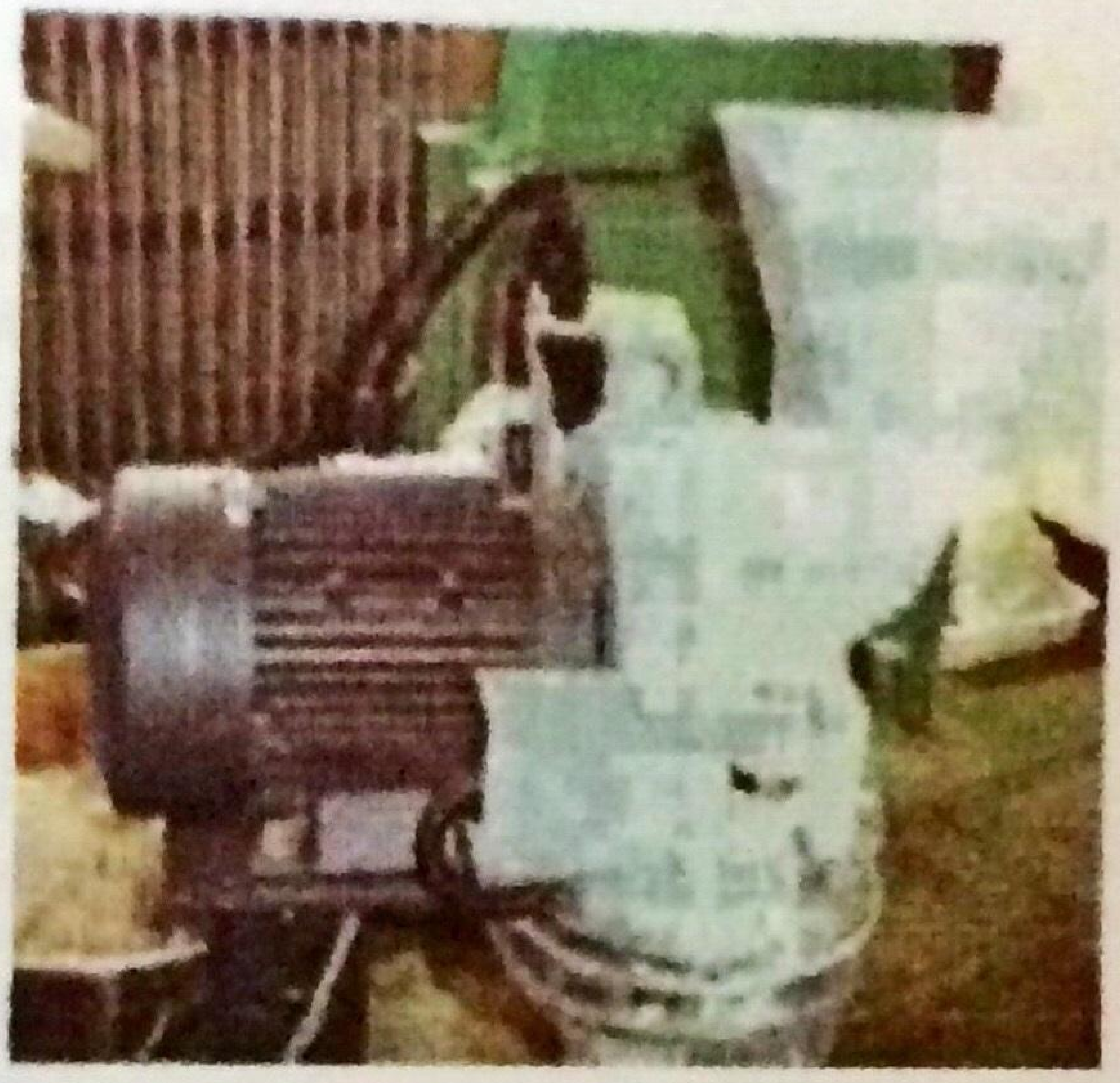
T_2 - Grinding of chip/grates at coarse adjustment (space of about 1 mm between plates), then sieving and regrinding the coarse flour at fine adjustment.

T_3 - Grinding of chips/grates at coarse adjustment, and immediately regrinding the material at fine adjustment, then finishing and regrinding the coarse flour at fine adjustment.

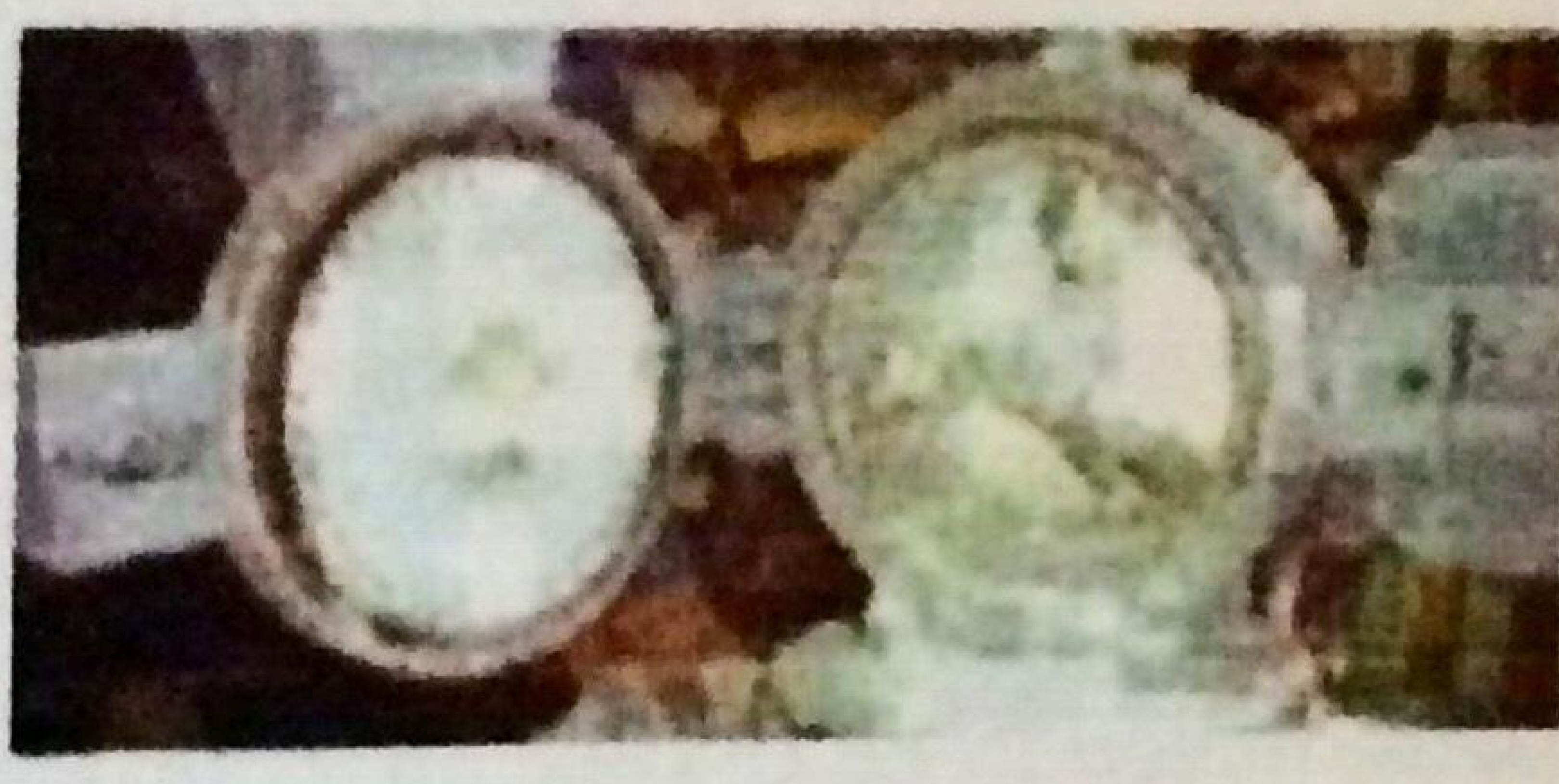
T_4 - Grinding of chips/grates at fine adjustment, and immediately regrinding the material at fine adjustment,then finishing and regrindingthe coarse flour at fine adjustment.

Finishing experiment

The fine flour distribution of the finisher during operation was determined. Three different loading rates (48, 73 and 105 kg/h), and three different stirrer



a) perspective view



b) interior view

Figure 5. The cross beater mill

rpm were selected as factors. The crude flour produced from chips that was ground using the attrition grinder at fine adjustment was the materials used for evaluation. The power consumption and rpm of the machine were also determined.

The outlet was divided into three equal compartments covering the whole length of the screen cylinder beginning from the inlet hopper to the outlet hopper. The metering hopper varied the amount of materials loaded to the finisher. One kilogram per sample was used and replicated three times. The amount of fine flour gathered in each compartment was determined and computed for the percentage distribution.

Grating and pressing/centrifuging experiment

The grates produced by the PhilRootcrops chipper/grater at three different rpm (350, 500 and 650) was pressed/centrifuged to determine the effect of the different rpm on the pressing/centrifuging characteristics and quality of the grates. Data gathered were the weight before and after the processing operations, the amount of water and starch separated from the grates, the moisture content of the materials before and after the processing operations, and the fineness modulus of the dried grates.

Hydraulic presser

For pressing, 5 kg/batch were loaded and pressed for 2 minutes at the maximum pressure reached by the machine (62 kg/cm2). After pressing for 2 minutes, the samples were mixed and stirred and pressed again.

Spinner

For the spinner, only 2 kg of grates per sample was used. The sample was placed inside the mesh cloth and loaded to the spinner of the washing machine first for 10 minutes, and the samples stirred or mixed and then loaded again to the spinner for 5 minutes.

A separate experiment to determine the rate of moisture removal at different amount of load using the spinner was conducted. The amount of load was set at 500, 1000, 1500, and 2000 g, and the weight was determined after every 5 minutes of spinning.

Power requirement in milling dried chips and grates

Using the cross beater mill, the power requirement in milling the dried chips and grates were determined using the *Kogane sengan* and *Shiro satsuma* sweetpotato varieties, and cassava grates and chips. The sweetpotato chip samples were divided into 3 different sizes, by grinding the chips at about 4 mm grinding plate adjustment, and then sieved. The chips sizes were the following: 1)chips retained at 4 mm sieve (considered as L-size chips), 2) chips that passed through the 4 mm sieve, but retained at 2.8 mm sieve (M-size), and 3) chips that passed through the 2.8 mm sieve, but retained at 250 um sieve (S-size). All the samples were subjected to 4 different loadingrates of 26, 30, 34 and 36 kg/h, and a particular moisture content level, by drying the samples at 70^{0}C in the oven overnight.

Statistical Analysis

Data were analysed using SPSS (1992) either by Completely Randomized Design (CRD) or Randomised Complete Block Design (RCBD). The Duncan's Multiple Range Test (DMRT) compared the treatment means at 5% level of significance.

RESULTS AND DISCUSSION

Performance of the machines

PhilRootcrops pedal-operated rootcrop chipper/grater

When the PhilRootcrops chipper/grater was operated at 400 rpm, the power curves exhibited wider fluctuations and higher average power consumption in grating than in chipping (Figure 6). The average power recorded for grating was 0.88 kW and only 0.65 kW for chipping (Table 2). This indicated that grating operation requires more effort than chipping operation

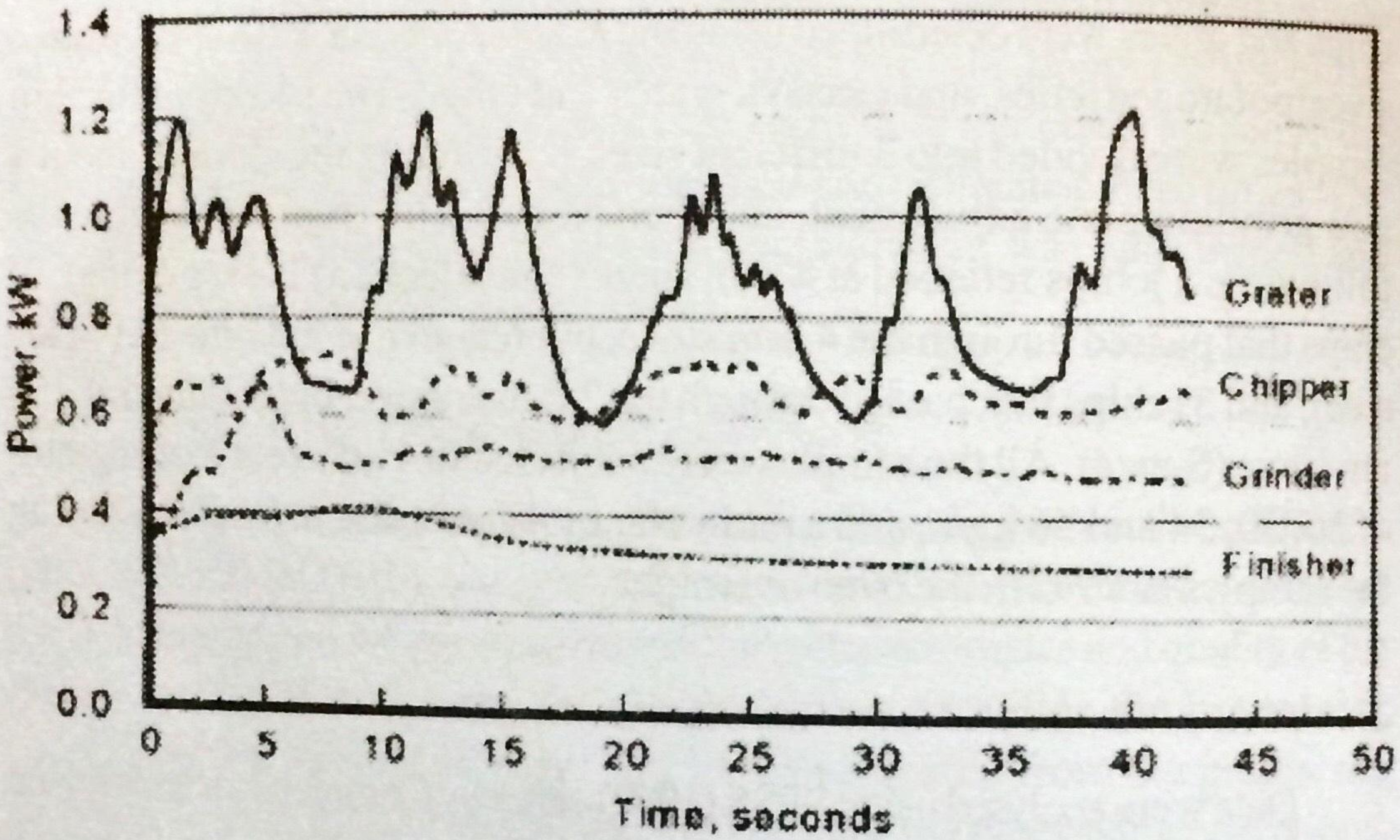


Figure 6. Samples of the typical power curves of themachines during operation (Source: Tan *et al.*, 2000)

Table 2. Performance of the evaluated machines (Source: Tan *et al.*, 2000)

Machine Operation	Net ave. power, kW	Energy requirement kW-h/100kg	Capacity kg/h	Machine RPM Without load	Machine RPM Ave. with load	Power reading, kW Without load	Power reading, kW Ave. with load
PhilRootcrops chipper/grater							
Chipping	0.08	0.020	400	400	393	0.57	0.65
Grating	0.31	0.133	233	400	391	0.57	0.88
Attrition Grinder							
Grinding chips	0.19	0.613	31	720	709	0.29	0.48
Siever/finisher							
Sieving	0.06	0.133	44	1000	991	0.27	0.33

because grates are reduced several times much smaller than chips. The net average power for grating (0.31 kW) was about three times that for chipping (0.08) kW). The grating capacity (233 kg/h), however, was almost half of the chipping capacity (400 kg/h). The blade rpm slowed down from 400 rpm (operating without load) to about 390 rpm (operating with load), both for chipping and grating.

In terms of net energy required to process 100 kg of materials per hour, chipping operation had the lowest (0.20 kW-h/100 kg) as compared to the other processing operations evaluated, because chip sizes were the largest of all products produced and which were also reduced from fresh roots.

Table 3 shows that there was an increase in both chipping and grating capacities as the rpm of the blades was increased. For chipping, while the capacity increased, the average weight of the chips decreased. This means that there were many more chips produced when the rpm was increased to satisfy the higher chipping capacity. The fineness modulus of the grates decreased as the blade rpm increased.

Table 4 shows no significant difference of using two different kinds of blade tip angles (45 and 90 degrees) in terms of capacity, power requirement, and the average weight of chips. However, between the two tip angles, the percent amount of crumbs present in the chips was significantly lower at 45-degree angle in all rpm values. This is the only advantage in using the 45-degree blade tip angle.

Table 3. Performance of the PhilRootcrops chipper/grater at three different revolutions of the blade assembly

Operation	Set rpm	Percent crumbs of total chips	Capacity kg/h	No. of roots/5kg	Ave. wt. of chips g	MC of chips/ grates % w.b.
	350	8.3a	453a	20.5	1.46a	68.4
Chipping	500	9.5a	566b	19.0	1.23b	69.0
	650	12.8c	611c	19.6	0.98c	69.4
		Losses %			Fineness Modulus	
	350	11.0	237a	33.8	4.20a	62.1
Grating	500	10.0	263b	34.4	4.04b	61.6
	650	9.0	328c	37.0	3.89c	62.4

Table 5 shows no significant difference of the grates produced at the three different rpms, in terms of the percent amount of starch and water removed, the percent amount of starch in water, and the moisture of pressed grates. The texture of the grates, however, showed a significant change when rpm of the blade was changed (finer as the blade rpm was increased), as reflected in the fineness modulus values.

Attrition grinder

The attrition grinder had a more stable power regardless of the kind and amount of material loaded to the hopper (Figure 6), but had the highest energy requirement (0.613 kW-h/100 kg) among the machines evaluated (Table 2). Tan *et al*. (2000) reported that almost the same average diameter of the first ground fine flour was obtained using the four different grinding conditions. However, the fine flour recoveries were different from each of the different grinding conditions, wherein grinding the chips once at fine adjustment had the lowest recovery of only 45.88%. Grinding the chips twice at fine adjustment produced relatively higher fine flour recovery at 57.30%, but still lower compared to the total recoveries of the other grinding conditions. The highest

Table 4. Average capacity of chipper, weight of chips, moisture content, percent crumbs,and power requirement (Kogane sengan variety)

Treatment combination rpm	Blade angle degree	Capacity kg/h	Power requirement kW	Weight of chip, g	Weight of crumbs %
350	45	400a	0.69a	1.31c	10.88a
350	90	419ab	0.72a	1.30c	22.66bc
500	45	461ab	0.79b	1.12ab	16.73ab
500	90	482bc	0.81b	1.20abc	30.55cd
650	45	543c	0.81b	1.05ab	26.89cd
650	90	539c	0.83c	1.08a	35.53d

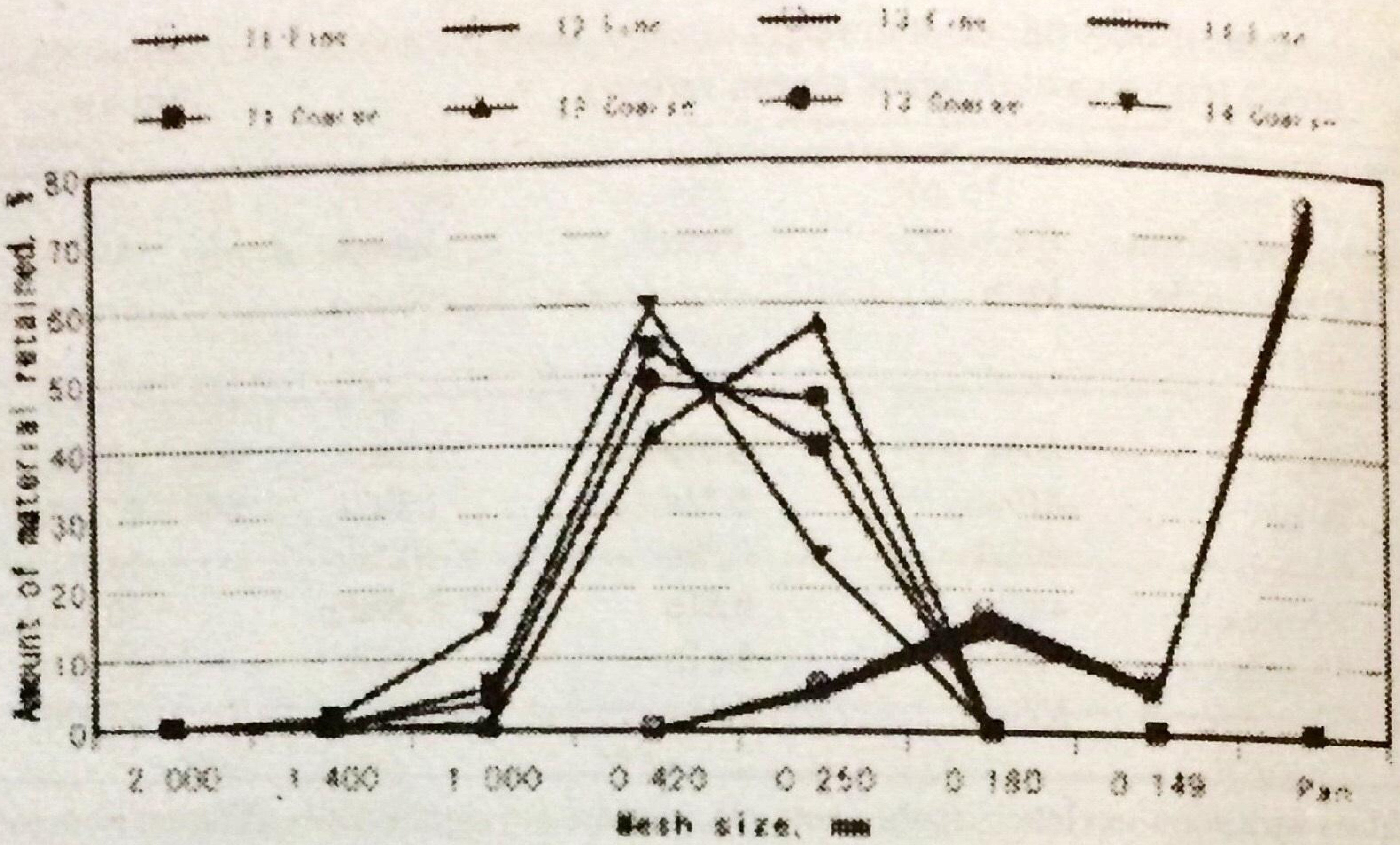
Note: Values with common letters in the same columns are not significantly different from each other at 5% level by DMRT.

recovery (64.67%) was obtained when the chips were ground twice at fine adjustment with sieving in between.

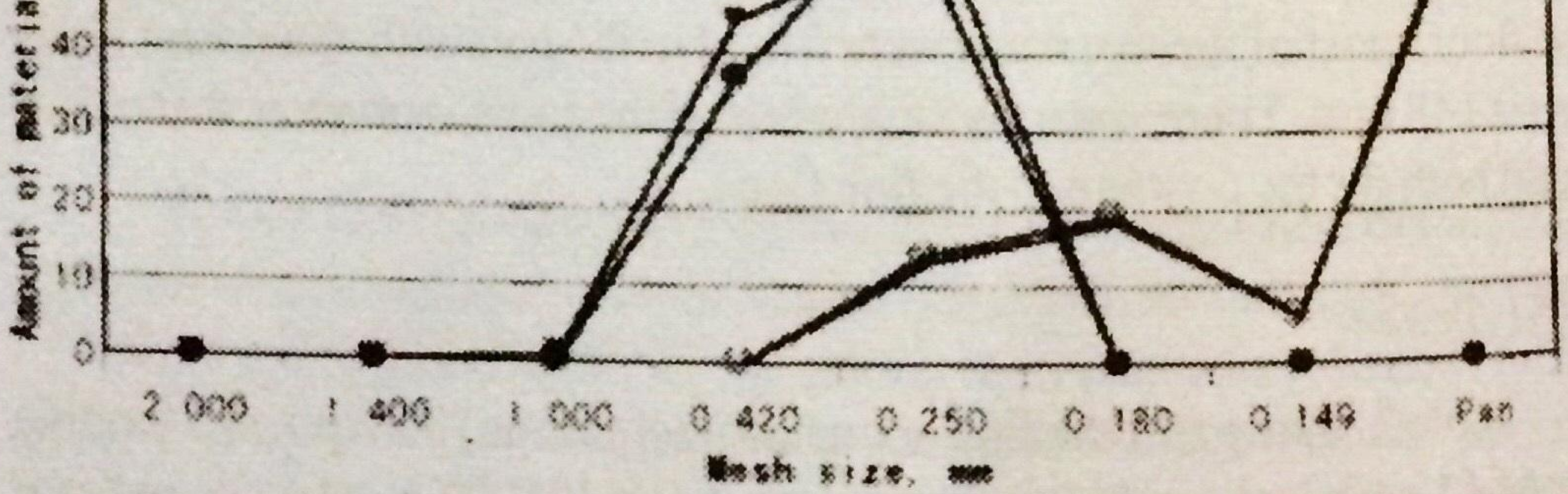
Figure 7 shows that percent amount of materials retained in the different sieve sizes of the materials produced at different grinding conditions for both the first and second passes in the grinding operation. For coarse flour, a greater percentage of the materials had a diameter between 0.18 to 1.0 mm, and for fine flour, most of the materials were found in the pan with diameters lesser than 0.148 mm. There were also materials of the same diameters that can be found both for the coarse and the fine flour.

Flour finisher

Table 2 shows that the finisher when operated at 1000 rpm and loading rate of 44 kg/h had a net average power of 0.06 kW. This is translated into 0.133 kW-h/100 kg of materials processed. Although it had the lowest net average power consumption among the processing operations, its capacity was lower compared to chipping and grating operations. The rpm of the stirrer, on the other hand, decreased as the load increased, indicating an increasing torque application. Figure 6 shows the typical power curve during the finishing operation.



a). First pass grinding and finishing



b). Second pass grinding and finishing

Figure 7. Amount of ground materials from chips (*Kogane sengan*) retained in the sieves (%) at different grinding conditions

Table 5. Characteristics of grates produced at three different blade rpms for Kogane sengan

rpm	Fresh MC of grates	Grating capacity kg/h	Losses %	MC of grates after pressing % w.b.	Water and starch removed %	Pressed grates recovered %
350	62.37	237c	21.00	49.50	46.37	52.73a
500	61.61	263b	20.00	49.78	45.22	54.65b
650	62.12	328a	19.00	51.59	45.33	54.68b

rpm	Amount of starch in water, %	Dry grates/ pressed grates, %	Wet starch/ water+starch, %	Fineness modulus (FM)	MC of grates, % w. b.
350	3.60	59.10	1.54	4.20c	6.32
500	3.34	59.61	1.39	4.04b	6.30
650	3.44	59.01	1.42	3.89a	6.37

Table 6 shows that only a third of the whole length of the cylinder can be used to separate the fine from the coarse flour. Very limited amounts of fine flour were gathered from the second and third output hopper compartments. Fine flour gathered from the three fine flour compartments indicated that almost all of the fine flour was gathered from the three fine flour compartments indicated that almost all of the fine flour was gathered in the first (88.25-92.95%) of the three compartments. The remaining amounts of 5.81-9.19% and 1.24-1.56% were distributed in the second and third compartments, respectivley. The percentage distribution was almost the same for all the different loading rates (48 -105 kg/h) and different rpm settings (800-1200 rpm). This means that less than half of the total length of the cylinder might not be necessary for the finishing operation. Therefore, this will allow the design of a smaller finishing machine.

The relationship of the loading rate and power consumption is shown in Table 7 and Figure 8. There was only a small but significant change in the power requirement as the input capacity was increased, in all the different rpms of the finisher. However, a very significant difference of the net average

Table 6. Distribution of fine flour (%) in the three compartments of the finisher outlet hopper at different loading rates

Finisher rpm	Loading rate kg/h	Finisher compartment No.		
		1	2	3
800	48	92.95	5.81	1.24
800	73	92.55	6.05	1.40
800	105	91.69	6.73	1.57
1000	48	88.25	9.19	2.56
1000	73	90.40	7.70	1.90
1000	105	91.50	7.17	1.33
1200	48	89.29	8.16	2.54
1200	73	90.97	7.08	1.95
1200	105	90.53	7.84	1.63

peak power requirement between the different finisher rpm was observed. At the set 105 kg/h loading rate and 1200 rpm of the finisher, the actual rpm of the finisher decreased significantly, indicating an increased load, overloading the motor. Also, increasing the rpm of the finisher, which consequently increased the power consumption, has no added advantage because the finisher output capacity and percent distribution of fine flour in the compartments were found to be the same in the 800-1200 rpm range.

Presser and spinner

The presser used in the evaluation was a hydraulic presser with about 62 kg/cm^2 maximum pressure exerted on the grates. In the village scale set-up, however, the screw-type presser used is similar to the one shown in Figure 2a.

Table 8 shows that grates subjected to the spinner of the washing machine accomplished the same purpose of removing the water from the grates. The results also indicated that spinning the grates could remove water of almost the same amount as that of the pressing operation (Table 5), although longer in time. The presser requires rigid machine parts, and therefore is more expensive

Table 7. Net power consumption (kW) and average rpm of the finisher measured at three different loading rates and three different rpm values (first grinding of Shiro satsuma chips)

Loading rate kg/h	800 rpm		1000 rpm		1200 rpm	
	Ave. peak power, kW	Ave. rpm	Ave. peak power, kW	Ave. rpm	Ave. peak power, kW	Ave. rpm
48	0.041a	790	0.063a	991	0.102a	1192
73	0.053b	790	0.090b	990	0.150b	1175
105	0.093c	790	0.141c	972	0.217c	1158

Note: Values with the same letter in the same column are not significantly different from each other at 5% level by DMRT

than the spinner. Figure 9 shows that irrespective of the amount loaded (500 g-2000 g) to the spinner, the resulting moisture rates of removal were practically the same. The moisture content after spinning was about 50% w.b. from moisture content of about 65%. Furthermore, Table 8 shows that the power required in running the spinner with load (from 500 g - 2000 g) and without load was almost the same. The starting power, however, increased as the load was increased. The rpm of the spinner was the same as different loads.

Milling power requirement

Figure 10 shows the results of the milling power requirements of the different materials milled using the cross beater mill at different loading rates. Sweetpotato had higher power requirement than cassava. Between sweetpotato varieties, the milling power requirement for *Shiro satsuma* was higher than that of *Kogane sengan*. This is because of the fibrous nature of *Shiro satsuma* roots. *Kogane sengan* also has a higher starch content than *Shiro satsuma*. Furthermore, as the loading rate was increased, *Shiro satsuma* had a sharp increase in power, which went beyond the 1-kW rated power and consequently overloading the mill. For other products, the power requirement did not exceed the rated power of the mill as the loading rate was increased in the loading rate range used in the evaluation.

The sizes of the chips also had significant effect on the power requirement

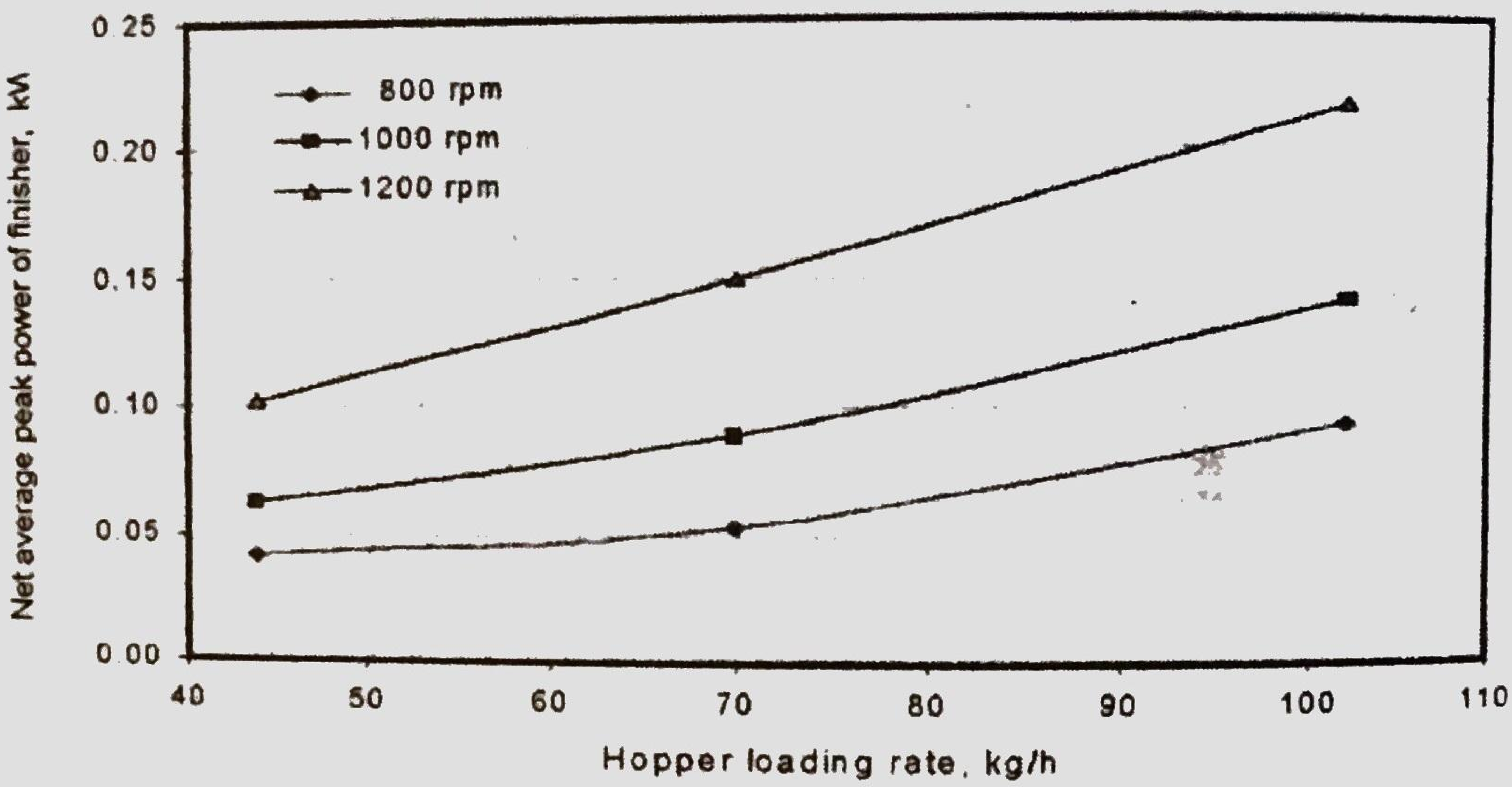


Figure 8. Relationship of the hopper loading rate, net average peak power and rpm of the finisher

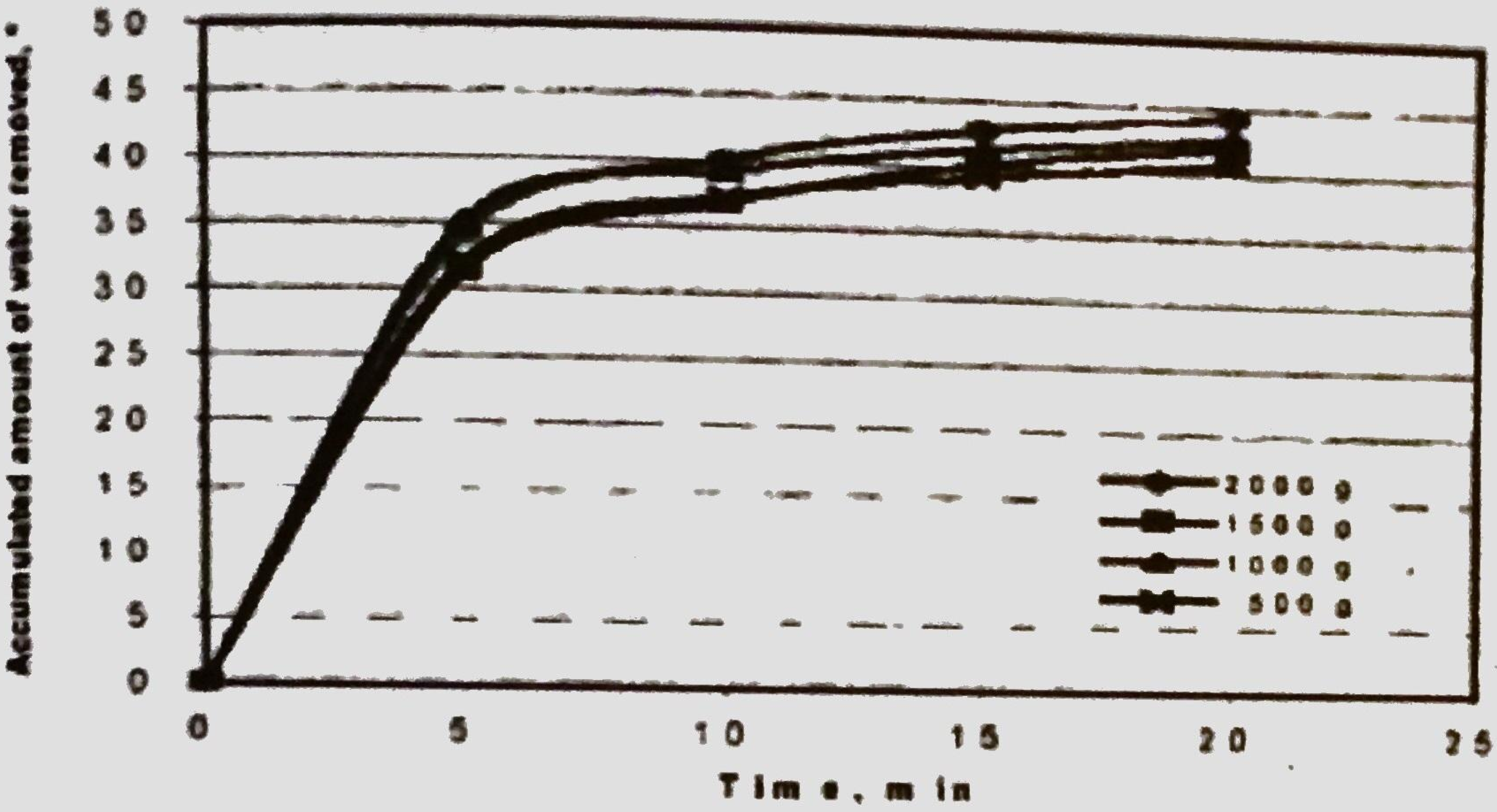


Figure 9. Percent accumulated moisture reduction of the grates at different loading rate during spinning operation

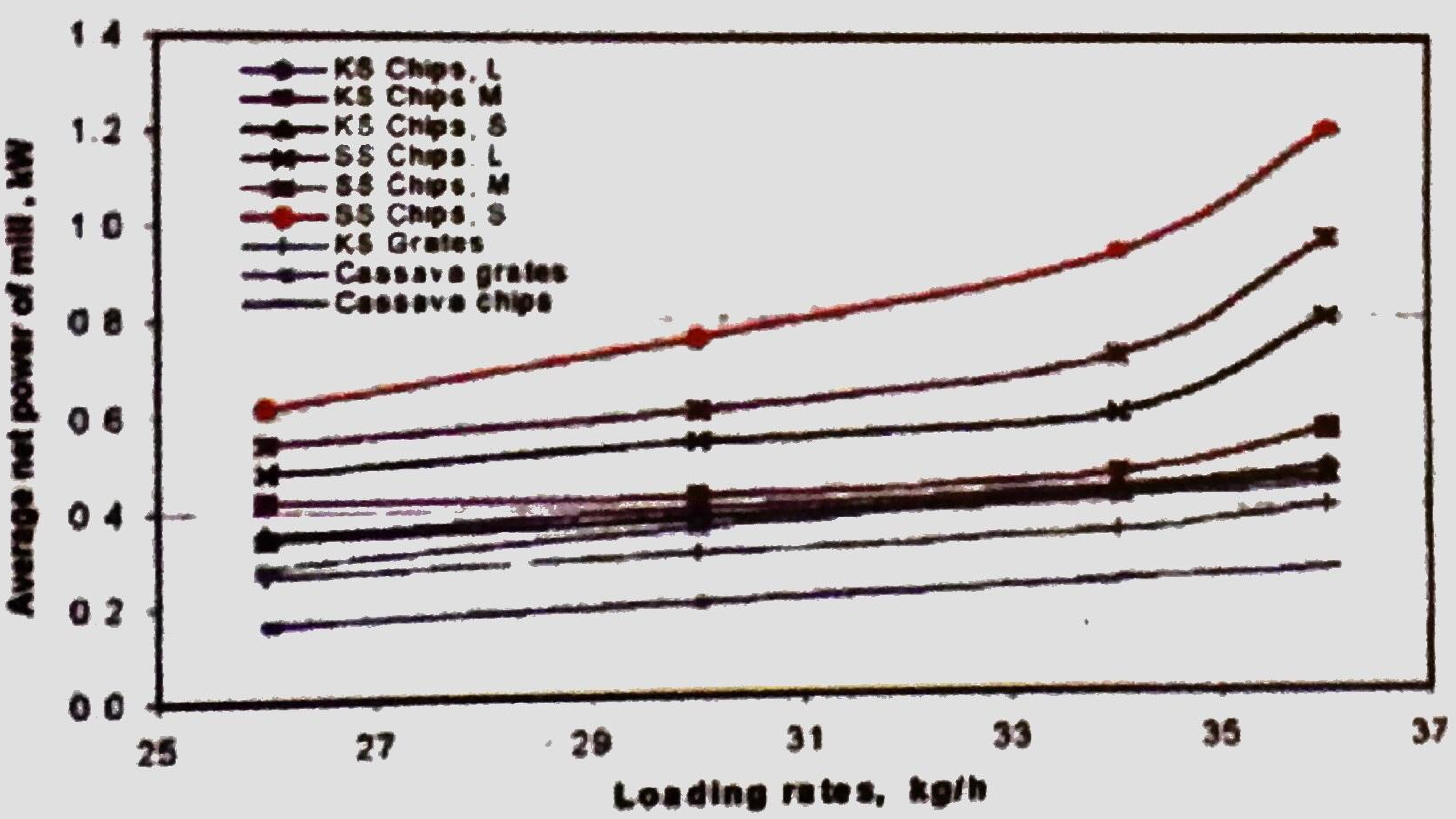


Figure 10. Average net power requirement of the material milled using the cross beater mill at different loading grates

Table 8. Power consumption of the spinner at different amount of load

Load, g	Starting power, kW	Net Satrting power, kW	Running power, kW	Running rpm
2000	0.253	0.016d	0.126	1450
1500	0.249	0.012c	0.125	1450
1000	0.247	0.010b	0.125	1450
500	0.243	0.006a	0.125	1450

Note: Values with the same letter in the same column are not significantly different from each other at 5% level by DMRT.

especially for *Shiro satsuma*. The small size chips had the highest requirement than the large size chips. This was because small chips when loaded to the milling compartment are compact than the chips that are larger in sizes, hence the higher power required to mill the chips. This was not true, however, for *Kogane sengan*. Statistically, the different sizes of chips of *Kogane sengan* had no significant effect on the milling power requirement at the different loading rates evaluated. The milling power requirement for grates was lower for cassava than sweetpotato (*Kogane sengan*).

CONCLUSION AND RECOMMENDATION

Conclusion

The PhilRootcrops chipper/grater had the most pronounced power fluctuation in the grating operation, peaking during the loading of the roots among the machines evaluated. The chipping capacity of the PhilRootcrops chipper/grater increased as the rpm of the blade was increased (350 to 650 rpm), together with the amount of crumbs present in the chips, but the average weight of the chips decreased. Between two kinds of blade tip angles (45 and 90 degrees), there was no significant difference in terms of capacity, power requirement, chips weight, but significant difference was observed in terms of the percent amount of crumbs present in the chips. The percent amount of crumbs in the chips produced by the 45-degree blade tip angle was lower than that of the 90-degree blade tip angle.

For grating, the capacity increased with an increase in blade rpm at the same rpm range. Also,the fineness modulus decreased as the rpm was increased. Pressing the grates using the hydraulic presser at 5 kg loading rate reduced the moisture content level of grates from more than 60% to about 50%. The rpm of the grater had no significant effect on the amount of moisture removed from the grates. Using the spinner of the washing machine, the moisture removed was almost the same as that of the hydraulic presser although longer in time.

The power required in running the spinner with load (from 500 g- 2000 g) and without load was almost the same, but the starting power increased as the load was increased, while the rpm of the spinner was also the same at different loads.

The attrition grinder had a more stable power even in any kind and amount of materials loaded to the hopper, but had the highest energy requirement among the machines evaluated. Almost the same average diameter of fine flour was obtained after the first finishing when grinding the chips at four grinding conditions. Average diameter of fine flour produced after grinding the coarse flour was larger than the fine flour of the first grinding. Percent total fine flour recovery when chips were ground twice with finishing in between obtained the highest recovery.

The finisher for separating fine from coarse flour had the least amount of net power among the machines evaluated.There was no significant difference in the percentage distribution of the fine flour in the compartments between loading rates, and between the stirrer rpm. The first of the three compartments (immediately after the inlet hopper) gathered about 90% of the total fine flour.

The power requirement in milling the different kinds of materials varied from each other, with the small size *Shiro satsuma* showing the highest among the materials evaluated. The lowest recorded power was that of the cassava grates.

Recommendations

The processing method to produce flour either from chips or from grates should be evaluated technically and economically. Milling grates using the cross beater mill for flour production is recommended.

A 45-degree tip angle of the chipper blade is recommended for use to produce lesser percentage amount of crumbs present with the chips.

The finisher maybe redesigned to make it shorter in length, thereby saving space and cost.

Spinning the grates is recommended as an alternative to pressing that uses an expensive and massive machine to perform the pressing operation.

LITERATURE CITED

APPEL, W. 1987. Comparison of hammermill and roller mill grinding of grain sorghum and corn. M.S. Thesis. Kansas State Univ., Manhattan.

CARPIO, E. V., V. ACO. 1990. Factors affecting the dry-milling characteristics pf rice flour using a pin mill. *The Philippine Agriculturist* **73**(3-4):387-398.

EDMOND, J. B. and G. R. AMMERMAN. 1971. Sweet Potatoes: Production, Processing, Marketing. AVI Publishing Co. Westport, CT.

GURITNO, P and E. HAQUE. 1994. Relationship between energy and size reduction of grains using a three-roller mill. *Trans. of the ASAE* **37**(4): 1243-1248.

HENDERSON, S. M. and R. L. PERRY. 1976. Agricultural Process Engineering. The AVI Publishing Co., Inc. Westport, Connecticut.

ORIAS, R. R. and D. L. S. TAN. 1997. Design and development of a combined grinder and finisher machine for root crop flour production. Terminal Report. PCIERD-DOST, PRCRTC, ViSCA, Baybay, Leyte.

ROA, J. R., E. A. GUNDAYA, D. L. S. TAN, and A. P. SALAMAT. 1998. Piloting and commercialization of cassava flour. In: Integrated root Crop Research and Development in the Philippines, Palomar, M. K. and Cagasan, E. G (eds.) Philippine Root Crop Research and TrainingCenter, Baybay, Leyte.

SPSS for Windows. 1992. Base System Release 5.0. SPSS Inc.

TAN, D. L. S., K. MIYAMOTO, K. ISHIBASHI, K.MATSUDA, and T. SATOW. 2000 Process and product analysis of the village scale processing of sweetpotato in the Philippines. *Journal of JSAM* **62**(4):160-172.

TAN, D. L. S. 1990. Village level cassava flour processing technology. Proceedings of the 8th Symposium of the International Society for Tropical Root Crops, pp 415-425.

TAN, D. L. S. 1989. Construction manual of the PRCRTC Pedal-operated Root Crop Chipper/Grater. A PRIS Publication.

TAN, D. L. S., J. R. ROA, and E. A. GUNDAYA. 1996. Women as processors and traders of cassava flour: The Philippine experience. In Cassava flour and starch: progress in research and development/ D. Dufour, G. M. Obrien, R. Best (eds), Centro Internacional de Agricultura Tropical, 364-379.

TAN, D. L. S. and R. R. ORIAS. 1986. Establishment and piloting of a village level root crop flour mill. Terminal Report. PRCRTC, ViSCA, Baybay, Leyte.