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Design and Development of A Small /Medium Scale Rice Flaking Machinery for Manufacture of Rice Flakes

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Abstract: Non-availability of appropriate rice flaking machinery at a reasonable price is one of the major constraints for initiating small/medium scale manufacture of rice flakes in rural farming areas. Therefore a study was undertaken to develop an efficient low cost rice flaking machine for production of rice flakes in view of improving the quality of conventional rice flakes and improving the rural level industry of rice flakes production.

The machine operates on the basis of pressing the paddy grain between two rollers made out of mild steel with stainless steel sleeves in horizontal position. The rollers are set to rotate at 600 rpm and at a roller clearance of 0.05 mm to produce flakes with minimum breakage.

Red long paddy variety was first soaked for 24 hours and then roasted at 100^{0}C for 35 minuets with stirring. The paddy was then fed into the machine while still in hot condition. The capacity of the machine was 200 kg/hr with a flake recovery of 57%. The husk separation efficiency and flake breakage were 99% and 20% respectively. The operating cost of the machine was LKR 2.20 per kilogram of flakes.

Keywords: Rice, Flakes, Machinery

1. Introduction

Rice (*Oryzae sativa*), which is a foremost food crop, is the staple food of more than half of the world population [4]. And, it is also an important food crop among the developing countries. As for rice, the gross amount of yield obtained from a unit land area is second only to that of maize. A more turnout can be expected from paddy for a hectare than from all other cereal crops [13]. In most of the Asian countries the per capita consumption of rice exceeds 100 kg per year which is twice that of maize. All over the region, consumers seem to prefer wheat-based foods to rice-based food items [13].

Bread made of wheat flour is popular in Asia as being suitable for breakfast. But, as for the Asian economy, especially for the poor Asian farmers, manufacturing of rice flakes is much suitable for it is more beneficial to consume rice etc that are produced locally than to import wheat. Food items that are based on wheat flour is more popular among the masses not because anything special feature it possesses but merely because the wide range of foods that can be made from it and the fact that the quality of foods so produced seem to be of better quality. Nevertheless, more demand can be seen in the present market for rice based products than for wheat based products and the reason for this could be seen as that the people are even more aware of the peculiar nutritional values of rice as well as its ability to cope with the disorders like diabetes, and also of the qualitative aspects of rice than before. Along with the new trends in rice processing, rice based products of similar quality could be obtained in the near future and, in the present day context, some of the traditional rice processing methodologies are being modernized. The whole kernel of rice grain is partaken of at the consumption and also it is consumed after being turned into various products.

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Rice flakes are one of such popular rice based products in the island. In the regions of the wet zone of Sri Lanka ratoon crop is commonly used for producing rice flakes and it is also appreciated among the people engaged in fishery as a snack food. Rice flakes mixed with sugar and scraped coconut is a delicious eating among them.

Since rice flakes are produced with unpolished rice with bran intact they have high nutritional value due to presence of high fiber, vitamins, mineral and protein [7].

In the traditional method of producing rice flakes, the activities of paddy cleaning, soaking, roasting and flaking in the mortar are followed. This method not only takes much time, and is also tedious, but appearance of flakes seems to posses a texture of bad quality due to mixing of paddy husks. A limited number of imported machines (especially from India) for manufacturing rice flakes in Sri Lanka could be seen and these are not suitable for rural community because of their high expensive nature. Normally this machinery set up costs about two million rupees. However, the rice flakes, too, which are made by utilizing these machines, are not of high quality. Much of flakes so produced are of broken nature and the external appearance is not satisfactory either.

Therefore in order that the main disadvantages of the present and the conventional process of rice flakes manufacture can be addressed, designing and development of a machine was initiated that can produce rice flakes in small and medium scales at the Institute of Post Harvest Technology, Anuradhapura. Thereby manufacture of rice flakes of high quality can be done satisfactorily in an easy way at commercial level and even in the rural areas

2. Design

The machine consists of two horizontal steel rollers rotating in opposite directions with a pressure applying system to flake paddy grains. Pre-treated paddy grains are fed to the inlet hopper in hot condition. Rollers are made out of mild steel with stainless steel sleeves to prevent contamination of feeds.

Each roller has 375 mm outer diameter and 300 mm length, which rotate in the opposite directions at speeds of 600 rpm. Power is supplied to the machine by a three-phase 7.5 hp motor.

Feeding hopper is having a manual control to control the feeding rate. Roasted paddy is fed to the machine in hot condition through the hopper.

2.1 Design consideration:

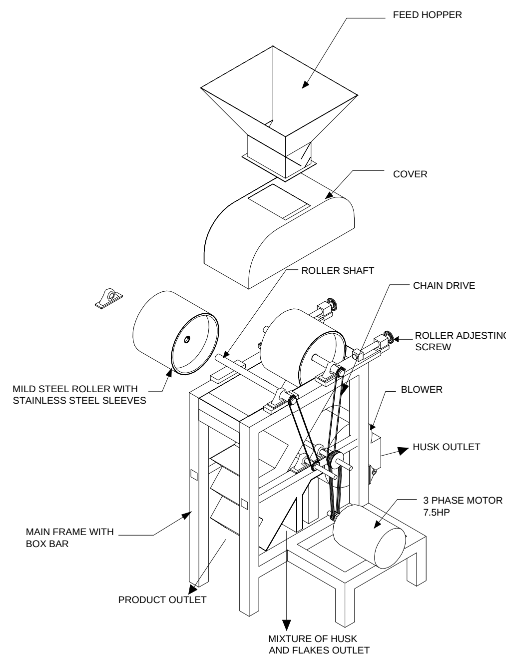


Figure 1: A diagram of the Flaking machine showing dismantled components.

The important parameters in designing the rollers are length of rollers, rotational speed of the rollers and designing the roller shaft. The frame designing includes selecting the proper bars. This frame structure must be strong enough to withstand the pounding they take from the flaking process and rigid enough to keep the rolls in tram. A sub frame with rectangular shape was supported to the main frame to place the motor. These two frames were made out of 72x72x6mm mild steel box bars and the structure consisted of 785x470 x 1279 mm main frame and 485x 375x529 mm sub frame.

Design of flaking machine includes designing of four basic components, i.e. rollers, blower, motor selection and material selection for the frame of the machine.

Other than that the transmission system was also very crucial for the design. The power transmission system consisted of main and sub frames, pulleys, V-belts, Chain drive, sprocket wheels and gear wheels.

To reduce rotor shaft speed, different size B groove double pulleys and different size sprocket wheels were used on the motor shaft to reduce the rpm required for the experiment. Two spur gears were used to transfer the power and change the rotating direction of the other roller.

2.1.1 Diameter of the rollers

Diameter of the roller was assumed to be 375mm

2.1.2 Length of the rollers

Length of the roller was assumed to be 300mm.

2.1.3 Rotational speed of the rollers

Weight of a soaked, roasted rice grain =40 mg

Let the length of roller be 300mm

Grain passing through the clearance takes up 4 mm,

No. of maximum grains along the roller

$$=300/4=75$$

The distance along the perimeter of the roller on which the grain will pass

$$=250*8/(40*10^{-6}*75) \quad =667m$$

(It was noted that the length of a grain is 8mm)

For rotation of a roller, v

$$= 667/3600 = 0.185\ m/s^{-1}$$

Since $v = r\omega$

$$\text{Therefore } 0.185 = \frac{0.375}{2} * \omega$$

$$\omega = 1\ rad/s$$

$$=10\ rpm$$

Although the calculated value is 10 rpm, the operational value was obtained from trial and error method. Therefore, the speed of the rollers was taken as 600 rpm.

2.1.4 Selection of motor

Motor with 7.5 hp was selected for the machine and it was satisfied with machine requirement.

2.1.5 Designing of the shaft

Shaft subjected to combine torsion and bending. If the diameter to transmit a given horse power is desired, it may be found by submitting for the term (KtT) in eq [01] its value in terms of horse power as follows[2].

$$(KtT)^2 = (396{,}000KtP)/\ 2\pi N)$$

$$D = \sqrt[3]{(16/\pi S_S)}\sqrt{(Km)^2+(Kt)^2} \quad \text{...[01]}$$

Where, Kt=fatigue factor, Km= shock factor, Ss=maximum shearing stress of shaft, D=Out side diameter of shaft, N=revolution per minute, T = maximum torsional moment

Shock and fatigue factors for rotating shaft:
For gradually applied or steady loads

Km	Kt
1.5	1.0

$$Ss = (16T/\pi D^3) + (16V/3\pi D^2) \quad \text{...[02]}$$

Where, T=Maximum torsional moment, V=transverse shear
Size of the shaft obtained from Figure 04 chart of Kent's Mechanical Engineering Hand book.

Diameter of the shaft was taken as 30 mm.

2.1.6 Dimensions of the box bar

Ensuring the given box bar is safe in operation:
Therefore, the maximum bending moment,

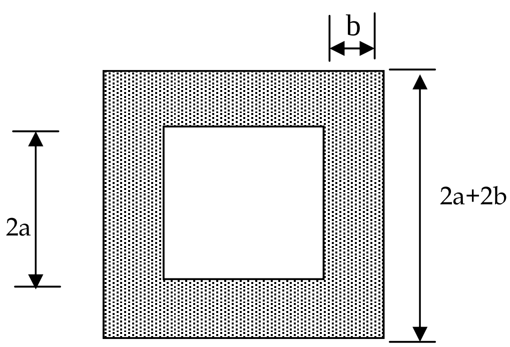


Fig.02 Cross section of the box bar

Second moment of area could be given as,

$$I = (4/3) \times (b) \times (b+2a)\ \ (2a^2+2ab+b^2)$$

From simple bending formula,

$$\sigma = \frac{My}{I}$$

$$\sigma_{max} = \frac{M_{max} \times y_{max}}{I} \quad \text{...[03]}$$

Where, M=bending moment, I= second moment of inertia, σ = normal stress
Therefore, $\sigma_{max} = 3.71$ MPa

Tensile strength for mild steel is 550 Mpa.

σ_{TS} = 550 MPa

Therefore $\sigma_{max} < \sigma_{TS}$

Therefore the box bar is safe in tension due to the weight of the rollers.

2.1.7 Design of the blower

Role of impeller is to supply required amount of air efficiently. The design requirement is as follows.

Velocity of air required for cleaning (V), cross sectional area of air stream over the screen (A). Therefore, actual airflow (Q_A) can be estimated

$$Q_A = V \times A \qquad \ldots[04]$$

Where A = πr^2

R = radius of the screen

A = 0.00358m^2, $V=7.8\ ms^{-1}$

$Q_A=0.0279\ m^3s^{-1}$

The efficiency of blower can be considered as 30%. The theoretical discharge (Q_T) can be estimated as:

$$Q_T= Q_A/0.3 \qquad \ldots[05]$$

$Q_T=0.93m^3s^{-1}$

The theoretical discharge of a blower can be also obtained as;

$$Q_T = \pi \times d_1 \times b_1 \times v_1 \qquad \ldots[06]$$

$$= \pi \times d_2 \times b_2 \times v_2 \qquad \ldots[07]$$

Where b_1 and b_2 are the width of blades at diameter d_1 and d_2 of impeller v_1 and v_2 are tangential components of absolute velocities.

v_2 can be approximated as 20% of the peripheral velocity of impeller tip for the design. Therefore

$$v_2 = 0.2 \times \pi \times d_2 \times N \qquad \ldots[08]$$

Where N is the speed of the impeller rpm

We can obtain the impeller diameter (d_2) by using equation (07) and (08), while the width of the impeller can be decided on the basis of the width over which airflow is required.

Where $Q_T=0.093\ m/s^2$

$b_2=0.05\ m$

$d_2=0.236\ m$

The casing of the blowers plays an important role in regard to the efficiency of the blower. The outer casing of the blower may follow an arithmetic spiral of the form

$$r = r_0\,(1+k\theta) \qquad \ldots[09]$$

Where k=0.0020 to 0.0023

θ = in degrees

r= radius of impeller at θ degrees shift from initial radius of the casing.

If r = 11.8, according to the equation r_1= 14.16, r_2=19.64…

Therefore, the shape of the spiral can be decided on the basis of this equation.

2.1.8 Design of the screws

Adjusting screws which are used to tighten the adjustable roller unit were loosened and the adjusting screw was rotated to adjust the roller clearance. If the adjusting screw is rotated in clockwise direction the roller clearance will increase. Whilst the adjusting screw is rotated in anti clockwise direction the roller clearance will be reduced.

Diameter of the shaft taken (D) = 31.75 mm

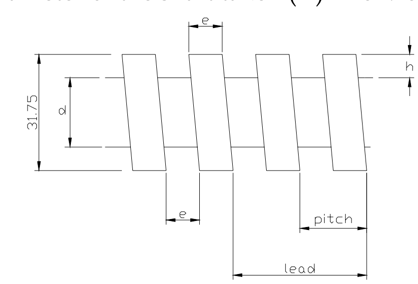
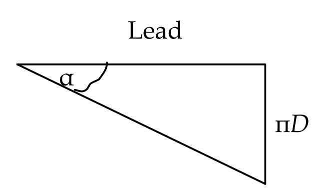


Fig 3: Thread profile of the screw

Checking for irreversibility of the screws

'D' is the minor diameter (i.e. D=31.75 mm)

Let the helix angle be α



Accordingly, $\tan \alpha = \dfrac{\pi \times D}{lead}$

$\alpha = 81^0$

For the screw to be irreversible, $\alpha > 50^0$

Therefore screw is irreversible.

3. Operational Methodology

3.1 Preparation of paddy samples

Preparation of rice flakes basically consists of three operations namely soaking of paddy, roasting and flaking. Paddy of red long variety used in these trials was obtained from the storage section of IPHT, and the initial moisture content was 12.0%. The moisture content was determined using an infrared moisture analyzer (OHAUS, Model: MB45) of accuracy ±0.1. Paddy should be soaked for 24 hours before subjected to roasting for 35 minutes.

The search for optimal conditions of the rice flaking process was the main aspect of developing this process line. In order to produce rice flakes of best quality, it was essentially required to optimize the conditions of the process line such as time of soaking, roasting, adjustment of machinery set up etc.

Process line of manufacture of rice flakes:

Soaking in water at room temperature

↓

Roasting

↓

Feeding to flaking machine

↓

Flakes

3.2 Testing procedure

There are two parameters to optimize for better output of flakes, i.e. paddy roasting time and roller clearance. Three roller clearances were considered to deduce the flaking efficiency, percentage of breakage and husk separation efficiency for a particular toasting time. This toasting time was varied under three times (35min, 40min and 45min) and hence nine flakes samples were obtained. Out of these replicates the best possible clearance and the suitable toasting time deduced.

3.3 Capacity

Desired capacity of the process line is required to lie between 200kg/hr and 250kg/hr because this is intended to manufacture flakes in small and medium scale.

3.4 Power consumption

Currant drawn by the machine was measured by using an analog type Clip-On Ampere meter (KYORITSU, Model: 2608A) of accuracy ± 0.1 A, and the voltage to the machine is 415V. So the power is

$$W=VI\cos\varphi$$

3.5 Husk Separation Efficiency

The husks were separated by blower, fixed in the machine, while the mixture of flakes and husk was falling down to the collecting bucket. Husk remained in the sample was separated manually and the flakes sample was weighed to estimate the husk present in the sample.

Husk separation efficiency =

$$\frac{\text{weight of the husks removed by the machine}}{\text{Weight of total husks}} \times 100\%$$

Where, weight of total husks= weight of husks removed by the machine + weight of the manually separated husks

3.6 Flaking efficiency

Broken and dust were separated from good dried flakes by sieving with 2mm perforations. Husk separation of the dried sample was done manually, to measure the flaking efficiency. Weight of the samples was measured by the electronic balance (Precisa 1620 C).

Flaking Efficiency;

$$= \frac{\text{Amount of good flakes}}{\text{Amount of paddy sample}} \times 100\%$$

3.7 Percentage of breakage

Percentage of breakage

$$= \frac{\text{Weight of broken}}{\text{Weight of flakes}} \times 100\%$$

3.8 Determination of cost of production per kg of rice flakes.

The cost of production was calculated by considering fixed cost; machinery depreciation, maintenance and variable costs: labour, power requirement and miscellaneous cost. Following assumptions were taken into consideration when computing the cost of production: 8 hours working per day: 300 days working per year, working condition of machine at full capacity.

3.9 Determination of palatability

Palatability means food must be pleasant to taste i.e. food must be palatable if it is to be eaten. Two samples were selected for testing palatability i.e. the best sample from IPHT rice flaking machine and other from market.

The characters of the flakes considered were texture, taste and smell of prepared flake sample. A model questionnaire was prepared and allowed for the panel.

4. Results and Discussion

4.1 Selection of optimum roller clearance and toasting time

Table: 4.1 Results obtained on different roller clearance at roasting time 35 min

Roller Clearance (mm)	Husk Separation Efficiency (%)	Percentage of Breakage (%)	Flaking Efficiency (%)
0.05	99	20	57
0.1	80	10	56
0.15	0	0	0

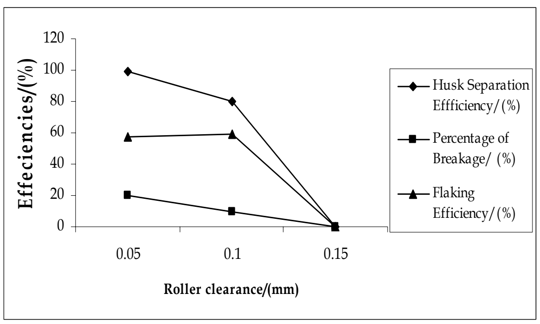


Figure: 5.1 Effects on machine efficiencies at different roller clearances at roasting time of 35min.

Table: 4.2 Results obtained on different roller clearance at roasting time of 40 min

Roller Clearance (mm)	Husk Separation Efficiency (%)	Percentage of Breakage (%)	Flaking Efficiency (%)
0.05	99	12	34
0.1	95	11	32
0.15	0	0	0

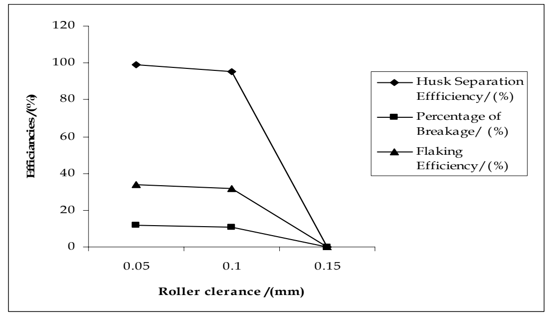


Figure: 4.2 Effects on machine efficiencies at different roller clearances for time roasting time of 40min.

Table: 4.3 Results obtained on different roller clearance at roasting time 45 min

Roller Clearance (mm)	Husk Separation Efficiency (%)	Percentage of Breakage (%)	Flaking Efficiency (%)
0.05	99	35	37
0.1	92	30	36
0.1	0	0	0

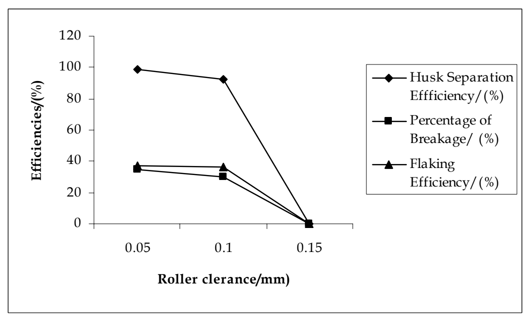


Figure: 4.3 Effects on machine efficiencies at different roller clearances at time roasting time of 45min.

The performance data reported in the tables which show that the flaking efficiency with the clearance of 0.05 (maximum roller clearance) was higher 55% at 35^{0}C and 34% and 37% at 40^{0}C and 45^{0}C respectively.

4.2 Cost of production per kg of rice flakes

The lowest cost of production of LKR.2.20 was obtained for the optimum possible clearance of less than 0.05mm and the corresponding roasting time was 35 minutes. The main disadvantage observed with the best condition of producing flakes was achieved was the comparably higher level of breakage. This occurs because a larger fraction of grains is pulverized while the machinery conditions are set to turn out better quality flakes. As a result there is a reduction in the flaking efficiency of the machine, which leads to an increased quality texture of flakes. .

4.3 Palatability

The result shows that there are no considerable difference between IPHT rice flakes and those obtained from the market. Generally, the taste and odour are almost the same for two samples.

5. Conclusions

The results obtained from the study are summarized and concluded as follows.

1. Machine was able to operate at the capacity of 200kg/hr at all the operating conditions.

2. The suitable roller clearance was a possible value that was less than 0.05mm.

3. The recommended paddy soaking time and paddy roasting time were 24 hours and 35 minutes respectively.
4. Flaking efficiency was in the range from 32% to 59%. And the recommended value for flaking efficiency is 57% at optimum operating conditions.

5.The Husk separation efficiency at corresponding optimum operating conditions is 99%.

6. Percentage of breakage varied from 10% to 35%and the value for the optimum operating conditions was 20%.

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References

1. Chapman W.A.J.; "*Workshop Technology (Part 2)*"; ELBS & Edward Arnold (Publishers) Ltd.; 4th edition, 1972.

2. Colin Carmichael., "*Kent's Mechanical Engineers Hand Book*" 12th edition.,John Willey and Sons,Inc.,New York, 1950.

3. Earle, R.L., *Unit Operation in Food Processing*, 2nd ed.,Pergamon Press, Oxford, 1983, p. 159.

4. Houston, D.F., *Rice Chemistry and Technology,* 1972, pp 86,87

5. Jayasena, W.V. and Ilangantileke, S.G., *Losses of Rice during milling in commercial rice of Sri Lanka,* Agricultural Mechanization In Asia, Africa and Larin America(AMA), 1986, pp 37-40.

6. Jonsson, L.O., Dendy, D.A.V., Wellings K., and Bokalders, V., *Small Scale Milling:A Guide fordevelopment workers,* 4th ed., Intermediate Technology Publications Limited,1994, pp 4-10,46-51

7. Juliano, B. O., *Rice Chemistry and Technology,* 2nd ed.,The American Association of Cereal Chemist Inc.,USA, 1985,pp. 60,539-553.

8. Kuprits, Ya.N., *Technology of grain processing and provender milling,* 1st ed.,Israel Programme for scientific translation, Jerusalem, 1965,pp. 199.

9. Meyer L.H., *Food Chemistry*, 1st ed., CBS publishers and distributors, New Delhi, 1987.

10. Palipane, K.B. and Discroll, R.H., Moisture sorption characteristics of In-shell Macadamia nuts, Journal of Food Engineering, pp 63-75 1992.

11. Pujra K., Junoja B.A., Bhandari A.C., Singh G. and Pujra R.S.; "Machine Design"; Dhanpat Rai & Sons, New Delhi; 2nd edition, 1984.

12. Rajapakse, D., Jayasingha, S., Jayewardane, A.L. and Gunatilake, K.G., *Evaluation of Sri Lankan Rice Varieties for the presentation of Traditional pasta processing*, Industrial Technology Institute, 1988.

13. Robert, B. and Elwood,F.C,"*Sreakfirst Ceareals and how they are made*" American Association of Ceareal Chemists., St, Paul, Minnesota, USA,1993.

14. Robert.E.Machol.,Wilson. P., Tanner. J.R., Samual N. Alexander., "*System Mechanical Hand Book*"., Mcgbaw-hill Book Company., USA,965

15. Roomi, M.S.M., Senanayake, D.P. and Plaipane K.B, *Evaluation of Milling Performance with Different Types of Rice Polishing Machines Available in Sri Lanka,* Annual Transaction of IESL, Institution of Engineers, Sri Lanka, 2004.

16. Sahay,K.M., Singh, K.K., *Unit Operations of Agricultural Processing*, 2nd ed., Vikas Publishing House, Private Limited, New Delhi, 2005, pp219-287.

17. Sri Lanka Standard: 913.Speciation for Rice Flour, 1991.

Figure: 5.0 IPHT Rice Flaking Machine

Figure: 6.0 Rice flakes