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## OPTIMUM PARAMETERS FOR DESIGN OF RICE POLISHER: A REVIEW

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**Abstract**— Quality of rice after milling process is depends on various factors, which include paddy drying, paddy harvesting parameters, environmental conditions, physical properties of Rice, type of rice and quality of polishing machine component. The objective of this paper is to identify the optimum parameter to achieve uniformly polished yield of rice with less broken. The selection of vertical and horizontal machine to design has large effect on the head rice yield and vertical design is mostly preferred. The optimum moisture content of paddy rice for milling process was reviewed and it is observed to be varied according to the variety of rice grain and it had the least rice breakage when using 3 abrasive polishers in series followed by one friction polisher. Another parameter is cylinder speed, when cylinder speed is increase from 600 to 1000 RPM, the percentage of broken kemels approximately gets doubled. Rice polishing cylinder material of contains two composite materials were binder material and abrasive material

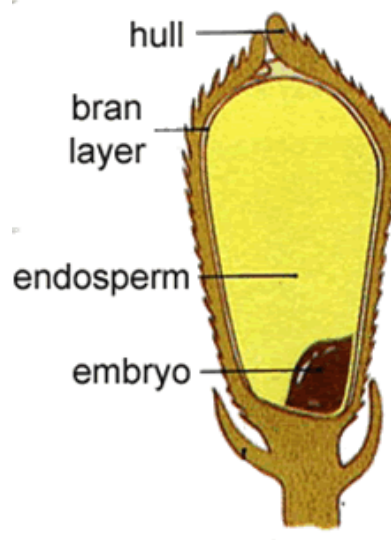
**Keywords**— Degree of polishing; Optimum parameters for rice polisher; Rice polishing machine

### I. INTRODUCTION

Rice is one of the staple food product widely used in Asia pacific. Rice is composed of husk or hull, bran layer, endosperm and embryo. Most outer layer of rice is husk. Before removal of husk the whole rice is called as paddy rice. See fig. 1. Since bran and husk are not eatable; thus, it need to process the rice to remove these layers from rice kernel. After removal of husk rice is called as brown rice. As Bran is tightly attached to the rice kernel it is difficult to polish out and need further processing. The removal of the bran is called polishing or whitening process. Polishing is a very vital step in the process of converting paddy into marketable rice, known as polished rice. Polishing operation removes the oil-rich (18 – 20% w/w) outer coat fraction of rice (called bran) so as to obtain grains with better digestibility and to create consumer acceptability with its smooth surface finish.

Although the extracted bran becomes a valuable by-product as a good source of edible oil, the nutritive value of polished rice kernels gets reduced considerably including significant loss of natural fibre. Besides this loss, a large quantitative loss is inherent with this operation. Harsh and excessive work done on the rice kernels during polishing, they break due to high amount of thermal and mechanical stresses. The large yield of broken may range between 20 to 50%, and reduce effective yield of head rice (whole kernel) as well. Finally it incurs significant economic loss.

yield of broken and quality of rice after milling process is depends on various factors, which include paddy drying, paddy harvesting parameters, environmental conditions, physical properties rice, type of rice and quality of polishing machine components. For designing an efficient rice polisher all the optimum parameters must be considered and should be studied accordingly.



**Fig. 1. Rice kernel.**

## **II. LITERATURE SURVEY**

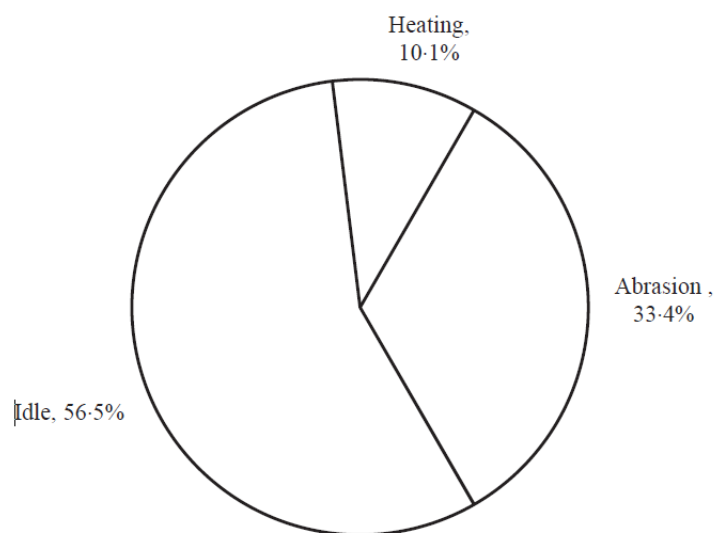
Rice is widely used food product in the world and it is second most consumable food grain in Asia pacific. Rice is main food for 60% population in world and about 90% population in Asia Pacific produce and consumes the rice [1]. Rice estimates for India in year 2014 is 106.29 million metric tons [2]. Hence there is large need of rice polishing machine with optimised power consumption. Polishing a material is nothing but the process of removing a layer from the surface of any solid with help of mechanical forces acting tangentially. This phenomenon is also known of wear. It involves rolling and sliding or both simultaneously. Along with mechanical forces thermal stress is also get generated which also help to remove the material.

Rice is made up endosperm which is called as white rice. White rice covered by bran known as brown rice. And brown rice is covered by husk or hull then rice is called as paddy. Brown rice consists of bran layer which include aleurone layer, seed coat and pericarp. Below bran layer a germ and scutellum is connected on the ventral side of the grain, and an edible portion or endosperm. Since husk is not eatable and bran is difficult to digest it is needed to be removed from brown rice [3]. Rice milling basically involve two processes. First is the removal of husk to produce brown rice which is called as dehulling. Second process is removal of bran layer which also remove germ and partial portion of the endosperm which may result into some percent of broken kernel. Hence polishing of rice kernel is very vital step in rice processing to remove bran. Although the extracted bran becomes a valuable by-product as a good source of edible oil, the nutritive value of polished rice kernels gets reduced considerably including significant loss of natural fiber.

The rice grain structure consists of a hard core of starch and soft bran layers covering the hard core, so that milling action is largely a matter of material strength. The coefficient of abrasion is the parameter which related the rate of wear to strength of rice kernel. The coefficient decreases as the milling progress. The outer material has more resistance compared to inner layer of rice kernel. The outer layer is composed of cellulose, hemicelluloses, fiber and rest of the part is oil, whereas inner layer or rice kernel is composed of starchy endosperm. [4].

Modeling of dynamic abrasion in a rice polisher provides better understanding of the basic phenomenon, and help to design and manufacture a better quality of rice polisher to get good quality and better surface finish of white rice. While polishing the rice, it is observed the temperature of rice kernel increases due to friction and abrasion phenomenon. Due to increase in temperature the thermal stresses are get generated inside the rice kernel and due to these stresses kernel become more prone to breakage. These increased breakage lead to reduction in the head rice. The model developed predicts the temperature rise of the rice grain in an abrasive milling.

Pie chart shows the energy consumption of the rice polisher. Maximum amount of energy is utilized in running the machine in idle condition. Around 56.5 % of energy is utilized in rotating machine part and only 33.4% of energy is utilized in abrasion process. this region is needed to be improved to improve the efficiency of polisher. The last remaining 10.1% energy is decapitated as heat and result into temp increase of rice grains. Debabandya Mohapatra studied the performance test on the polisher and the energy utilization in result is shown in fig. 2[5].



**Fig. 2. Pie chart shows distribution of energy in a rice milling operation.[5]**

Debabandya Mohapatra(2004) perform some experiments and observed that from total energy 55-60% of energy is utilized in running the rotor and other machine parts in no load condition. Also the energy consumption gets decreased from 60% to 55% as the milling time increases. Around 32.7-35.4% energy is untied in actual abrasion to polish the rice and rest 4.6% to as high as 11.9% of energy gets decapitated as heat energy and is transferred to rice kernel.

**TABLE I. ENERGY INPUT TO RICE POLISHER AT IDLE LOAD AND FULL LOAD TRAIL AT DIFFERENT POLISHING TIMES.**

Milling time (t), s	Energy under full load (E), kJ	Energy under no load (E0), kJ	Idle energy, %	Abrasion energy, %	Heat energy, %
15	3.60	2.16	60.0	35.4	4.6
30	7.32	4.32	59.0	34.9	6.1
45	11.16	6.48	58.1	34.3	7.6
60	15.12	8.64	57.1	33.7	9.1
75	19.20	10.80	56.3	33.2	10.5
90	23.40	12.96	55.4	32.7	11.9
105	27.30	15.12	55.4	32.7	11.9
120	31.20	17.28	55.4	32.7	11.9
135	35.10	19.44	55.4	32.7	11.9
150	39.00	21.60	55.4	32.7	11.9
165	42.90	23.76	55.4	32.7	11.9
180	46.80	25.92	55.4	32.7	11.9

The objective is to exert sufficient work against the outer bran layer to overcome its resistance to removal and yet avoid excessive work and pressure, which may crush or otherwise damage the integrity of the harder endosperm. Rice grain is consumed as whole seed. The main reason why rice break is the defective rice grain enters into the polishing chamber. If the rice grain contains small crack present inside the kernel then it lead to breakage. Harsh polishing of rice kernel breaks all defective rice kernel while gentle or soft milling protect some of the defective grain and increase the head rice yield.

Moisture present in rice kernel acts as a plasticizer hence wet grain survives the milling process. Hence paddy moisture content is important parameter rice polishing [6]. Saeed reported that Paddy moisture content and its harvest time at milling operations are two major factors that determine the milling quality of rice. A research conducted to study the effect of these factors on the breakage of milled rice and ratio of cracked kernels of Hashemi paddy cultivar in Iran. Four milling moisture contents of 8-9, 10-11, 12-13, and 14-15% dry basis and five harvesting times of 24, 27, 30, 33, 36 days after 50% flowering were considered for the research. And in order to gain the least milled rice breakage and ratio of cracked kernel, the optimal conditions for harvesting and milling the 'Hashemi' rice in Iran were determined to be harvesting for 30 days after 50% flowering and milling at suitable moisture content of 8-9% dry basis [7]. He also reported that the lowest percentage of broken rice is 10.14% took place in the abrasive type whither with moisture content of 8-9%. And whereas the highest percentage of broken white rice (around 17.19%) was generated in friction type bladeless whitener [8].

Sayed studied the effects of paddy mixture ratio and moisture content. The experiments conducted shows that paddy mixture ratio increased from 2 to 6%, the values of fissure kernel and whiteness percentage decreased, whilst head rice yield decreased by increasing paddy mixture ratio from 2 to 6%. At all of the evaluated paddy moisture ratios, the values of head rice yield, whiteness percentage and whiteness index decreased by decreasing moisture content from 14 to 8% (wet basis). It was observed that with decreasing moisture content from 14 to 10% (wet basis), the number percentage of fissure content decreased and then the further decrease in moisture content from 10 to 8% (wet basis) caused the fissure kernel to increase[9]. Dilday(1987) determined the percent broken of rice after threshing the grain at varying cylinder speeds of the thresher and moister contents of individual grain samples ranged from 12 to 26% and two cylinder speeds were 600 and 1000RPM. He studied and observed that which moisture content in increased from 12% to 16% the percent of rice breakage during polishing operation decreases 10]. Ntanos (1996) reported that the grain breakage was not significant when the grain moisture content was higher than 22.16% but it was increased with decreasing the grain moisture content. Thus to reduce the percent rice broken the optimum paddy moisture content for milling operation was 12 to 14% wet basis[11]. See Table 2

**TABLE II. AVERAGE WHITE RICE BREAKAGE OF MILLING OPERATION AT DIFFERENT PADDY MOISTURE CONTENTS.**

Paddy moisture content (%) wet basis)	Average rice breakage (%)
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8-10	21.64
10-12	21.26
12-14	17.09

To reduce the rice broken intensity of milling is another important factor taken into consideration. Rice-whitening action can be classified into two categories, namely at higher pressure of polishing chamber with lower rotational velocity and at lower pressure of polishing chamber with high rotational velocity. Polishing Action at higher Pressure of polishing chamber with Lower rotational velocity removes the bran layer of the grain by effective friction force (tearing) and cutting force of grains get rubbed over each other and over polishing screen of polishing wheel. This type of milling is termed "friction type milling." Polishing Action at Lower Pressure of polishing chamber with higher rotational velocity removes the bran layer of the rice kernel. There are two types of action are involved, first is grinding between rice kernel and abrasive material of polishing shaft and second is impact force between kernel and covering of the polishing chamber. This type of milling is termed "abrasive type milling" [12]. See Fig. 3

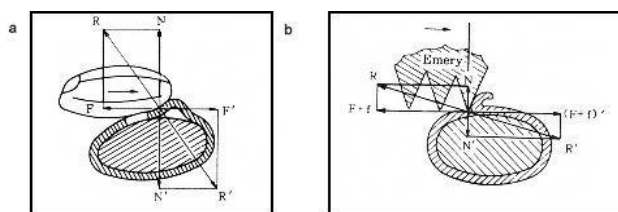


Fig. 3. (a) mode of tearing action; (b) mode of grinding action.

High speed milling and abrasion develops mechanical stress within the kernel. Generation of high temperature due this friction induces thermal stress in the kernels that facilitates development of fissure in it. Both these stresses finally result breakage of kernels. Thus, breakage susceptibility of rice kernel is largely determined by the intensity of processing and the intrinsic grain properties. If parboiling is carried out properly, it can increase head rice yield of any rice [13]. Parboiling is the process of hydrothermal treatment. Parboiling of rice improve the rice quality in many ways.. It helps to improve the surface finish, improve the amount of nutrition of polished rice and also improve the texture of cooked rice. Joke Buggenhout investigated polishing breakage sustainability in case of parboiled rice. In this experiment raw rice was parboiled and soaked at various temperatures. Sample temperature taken are 65, 55 or 40 C and steaming at 130, 120 or 106 C. From result of various parboiled rice sample it is observed that the rice grain breakage depend on the bending force acting on kernel. Bending force acting on a single kernel is observed to be 34.9 to 14.6 when polishing breakage sustainability is increased from 1% to 11% [14]. Kshirod also investigated the breakage of rice during milling operation and effect of parboiling. He reported that in case of raw rice most of the breakage occurred during the earliest stage of milling. While result after parboiling shows well known improvement in milling quality of paddy. It clearly shows that the kernel defects such as cracks, chalkiness and immaturity are completely eliminated on parboiling, hence breakage always be negligible after parboiling as compared to raw rice [15].

Sadegh reported that the milling operation had very wide effect on head rice yield. When abrasive type of whitener is used without polisher then it gives maximum head rice yield. Opposite to that when friction type whitener is used with polisher it gives least amount of head rice yield and maximum rice breakage. Using three abrasive whiteners in series followed by a friction type whitener had least breakage and highest head rice yield, comparatively low polishing cost, and best marketability and appearance, hence this method is best choice while developing the rice polisher mill [11].

The total milling recovery was significantly affected by both polishing time and pressure. The perusal of the means of polishing time showed that the total milling recovery was maximum (69.72%) for 10 seconds gradually decreased with an increase in polishing time and was minimum (66.58%) for 40 seconds. While total milling recovery reduced slightly with an increase in polishing pressure. The time and pressure of polishing and their interactions significantly affected the head rice recovery. The drop in head rice recovery was 11.75% when the polishing time was increased from 10 to 40seconds. Whereas, an increase in polishing pressure from 1 to 5 lbs lowered the head rice recovery to 10.68%. However, a greater increase on degree (5.08) was observed with increment in the polishing times than that of pressure (3.68).

TABLE III. AVERAGE WHITE RICE BREAKAGE OF DIFFERENT MILLING OPERATION METHODS.

Milling system	Average rice break age (%)
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Two friction type whitener without polisher	25.15
Three abrasive type whitener with rubber polisher	19.05
Three abrasive type whitener with friction type whitener as a polisher	16.9
Four abrasive type whitener without polisher	16.77

**TABLE IV. MARKETABILITY OF WHITE RICE WITH DIFFERENT MILLING OPERATION METHODS.**

Milling system	Milling system Average marks (out of 10)
Two friction type whitener without polisher	9.49
Three abrasive type whitener with rubber polisher	7.17
Three abrasive type whitener with friction type whitener as a polisher	5.96
Four abrasive type whitener without polisher	4.35

The rotating speed of cylinder is another important factor. To be effective, the friction-type whitening unit requires a peripheral speed of the milling rotor of less than 600 m/min and an average milling pressure of over 100 gf/cm<sup>2</sup> (10,000 N/m<sup>2</sup>) while Abrasive milling requires a peripheral speed of over 600 m/min and an average milling pressure of less than 50 gf/cm<sup>2</sup> (5000 N/m<sup>2</sup>) [12]. Dilday reported that if all factors were held constant except cylinder speed then as the cylinder speed increase from 600 to 1000 RPM, the percentage of broken kernels approximately gets doubled. This is probably due to the grain hitting the cylinder and cylinder walls at a higher force which results in more broken kernels at higher RPM. Consequently, head rice yields decreased about 6-7 percent as cylinder speed was raised from 600 to 1000 RPM [16]. Worlalluck reported that suitable setting parameters are Speed of whitening at 1050 rpm and Clearance at 1.5 time of grain for all three passes. With these settings it was possible to reduce overall costs by 20.45% and operating time by 21.11% [17].

Breakage of rice kernel also depends on the quality of rice polishing cylinder. Generally, the rice polishing cylinder contain two composite materials were binder material and abrasive material. The binder material contains magnesium chloride and magnesium oxide cement. The abrasive material contains silicon carbide and emery grain [18]. Applicability of binder material combines reused silicon carbide and MgCl<sub>2</sub>.6H<sub>2</sub>O containing quartz and calcined magnesite in equal proportion for abrasive type rice polishing cylinder. Under optimum values of process parameters, the complete rice processing mills was found for both the abrasive using binder combines MgCl<sub>2</sub>.6H<sub>2</sub>O and calcined magnesite. This mixture design was one of the best suitable methods and should implement first to optimize the best operating parameter to maximize the abrasive removing [19].

In further development and research on material of polishing cylinder Thitikan Boonkang studied the alternate binder material for rice polishing cylinder. The work is performed on the pozzolan materials. This pozzolan material is composed of bagasse ash, husk ash, and rice metakaolin. and New composition is made as as 40:60 ratio as respect to pozzolan: magnesium oxide cement. This composition is developed by design of experiment. For this experiment 10 various formulation of tensile and compressive strength are studied. The result of this formulation is metakaolin: bagasse ash: rice husk ash as 60: 25: 15. This composition is used in rice polishing cylinder and the test are performed. It found that head rice yield is 80.12 and wear rate of polishing cylinder is 4.43 g/hr. the result of original polishing cylinder has head rice yield 76.02% and wear rate of 7.02 g/hr [20].

### III. CONCLUSIONS

Vertical machine has various advantages over horizontal machine. The suitable paddy moisture content for milling operation was 12 to 14% wet basis and using three abrasive type whiteners in series followed by one friction type whitener as a polisher had the least percent of rice breakage. When the cylinder speed was increased from 600 to 1000 RPM, the percentage of broken rice kernels is approximately gets doubled. The rice polishing cylinder composed of two composite materials was emery grain and silicon carbide as abrasive material and magnesium oxide cement and magnesium chloride as binder material. The average polishing time of 10 second is best suited to reduce the rice breakage.

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