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Analyzing microwave-heated soaked paddy: A study of soaking characteristics and milling quality attributes

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Abstract
Rice (*Oryza sativa*) is the staple food of half of the world population. However, it is necessary to reduce the losses in the postharvest processing of rice for completing its demand. To reduce these losses, there is a very important process of parboiling which is done before the rice milling, parboiling of paddy is also known as the milling treatment of paddy. So in this study, the moisture uptake behavior of paddy at different soaking time at room temp was studied and optimized. For the effect of microwave heating on moisture absorption during hot soaking of paddy for parboiling, the effect of different power levels of microwave heating of soaked paddy on its milling quality was also studied. It was found that the moisture absorption by paddy increased with the increase in time duration. For a longer duration of 36 h the moisture absorption was better as compared to other shorter duration. It was observed that 27%, 30% and 33% could be achieved at approximately 10 h, 24 h, and 33 h respectively. The Head Rice Yield (%) was found to be higher for higher power level. For equal time interval, the Head Rice Yield (%) was found to be highest for 450 W followed by 300 and 180 W due to proper gelatinization of the starch which resulted in hardening of rice which ultimately provided better head rice. The percentage of broken was found to decrease with increase in power level. For equal time interval the broken% was found to be lowest for 450 W followed by 300 and 180 W due to proper gelatinization of starch, this resulted in decrease of brittleness ultimately affecting the breakage. As a result of higher gelatinization of starch, the broken observed were less during milling.

Keywords: Optimization, parboiling, milling quality, microwave heating, paddy, moisture behavior

Introduction
Paddy (*Oryza sativa*) is one of the most important crop grown in Asia. India is among the world's largest producers of rice, producing 20% of all world rice production and is also the fourth largest exporter of rice in the word. In the khariff season of 2021-22 crop year (July-June), rice production is estimated to be 121 million tonnes against 112.9 million tonnes in the previous year (Indian rice market update, 2022). In India, majority of the people are still dependent on rice alone for much of their nutrition. As they cannot afford foods such as fruits, vegetables, milk products & animal foods. As a result rice has to fulfil the daily energy needs (calorie) and the daily requirements of vitamins, proteins & other nutrients. In this respect, nutritive value of rice is of great importance for the population of South East Asia and for the large part of the world. In general, paddy is normally harvested at high moisture content (20% to 24% (wb)). After harvesting to prevent postharvest deterioration the paddy should be dried to safe moisture content of about 12 to 14% (wb) basis, which is considered to be safe for storage, milling and further storage of milled rice. Most of the rice varieties are composed of roughly 20% rice hull or husk, 11 percent bran layers, and 69 percentage starchy endosperm also referred to as the total milled rice. In an idle process of milling this will result in the following fractions: 20% husk 8 to 12% bran depending on the degree of milling and 68 to 72% milled rice or white rice depending on the variety selected during milling. Total milled rice contains the following: whole grains (head rice) and broken rice. The by-product in rice milling obtained after the process of milling are rice hull, rice germ and bran layers and find broken rice. Parboiling is a hydrothermal process in which paddy is deliberately allowed to absorb water and later steamed to gelatinize the starch present in the endosperm before drying and milling. The process of parboiling seals internal fissures present in the rice grain resulting in Higher head rice you (HRY) during milling. About one fifth of total world's rice harvest is parboiled. The process changes the starch structure from amorphous and hardens the endosperm, making it appear translucent.

The hardening process makes the grain tough and increases its resistance to breakage during the milling operation, resulting in improved head rice yield. It also increases grain resistance to insect attack and improve its overall nutritional quality. Parboiling is an ancient method of rice processing widely used in the developing countries like India, Sri Lanka, and Bangladesh and in some other rice exporting countries. Parboiled rice (PBR) has been produced by both traditional and high end modern methods. Various parboiling devices and techniques have been developed in the recent years. Modern methods are energy and capital intensive and are not suitable for small scale operation at the village level where it's required the mostly. Parboiling treatment induces various physicochemical changes in the paddy and rice which play a very important role in the subsequent storage, cooking, milling and eating qualities. Although PBR is known to have number of advantages, it requires more energy, water and time for processing and cooking then uncooked raw rice. The parboiling treatment gelatinize the starch in rice, improves the overall hardness of the rice upon drying process, minimises the breakage and other losses & thus increases the milling yield of paddy. Overpowering result in opening of the husk components followed by bulging out of the endosperm which initiates surface scouring during milling process and the resultant ground particles being lost into the husk and bran. However non uniform or incomplete parboiling produces white bellied rice which breaks easily during milling and reduces the head rice yield. This process consists of mainly three major steps soaking, steaming and drying. The processes involved soaking the paddy in the hot water usually between 10 to 24 hours in order to saturate the paddy with the moisture the soaked paddy is then heated till it is gelatinised and followed by drying and the milling. The overall advantages of parboiling, due to hardening of the grain, insect find it more difficult to infect and destroy the paddy. Total killed after milling increases by three to four percent when compared to regular rice all the breakage reduces due to parboiling process. Parboiled rice is rich in minerals as it contains 3% of calcium, potassium, zinc, iron and magnesium. It losses less starch during the cooking once cooked it is tense for long times and stays fluffy. Parboiled rice is rich in vitamin mainly vitamin b and niacin with low glycaemic index. Microwave heating refers to the use of electromagnetic waves of certain specific frequencies to generate heat in a material and is mainly used for defrosting and low pressure drying. Microwave uses of 915 MHz to 2450 MHz For home ovens 2450 MHz are used and in industries both frequencies are employed. Heating mechanism is based on the interaction between water di polar molecules and the electromagnetic field generated by the microwave. Thus the higher moisture content part of a product can absorb more energy which results in more heating and faster drying. The use of microwave heating allows achieving the following effects in rice: Improve its physical and chemical characteristics, to optimise cooking condition, to keep its sensory and nutritional properties, substitute steam and conventional drying during rice parboiling process buy microwave heat treatment, to optimise the processing of puffed rice products. The process of parboiling is a hydrothermal process which increases the overall strength of rice grain by its gelatinization. This process consists of four main unit operation namely soaking, draining, heating and drying. For all this unit operations update setup is required for steaming in drying. This causes a large amount of heat losses. Thus in order to reduce the loss of energy, in our study, microwave oven was used for heating action during the parboiling process because in microwave oven heat application is very efficient uniform and less time consuming.

Materials and Methods

The present study was conducted for evaluating the effect of microwave heating of paddy for parboiling and determination of M.C. of soaked paddy and its effect on milling quality. This chapter deals with materials, instrument, equipment, techniques and experimental procedures used to fulfil the objectives of present investigation. The research work was undertaken at the Department of Post-Harvest Process and Food Engineering, College of Agricultural Engineering, JNKVV, Jabalpur (MP).

Sample Collection

Variety of paddy (JR-81) 20 kg (approx) was procured from the Department of Plant Breeding, College of Agriculture, JNKVV, Jabalpur. Paddy sample was cleaned and moisture content was determined. Each of sample (300 g) was carefully weighed and stored in microwaveable container and later subjected to different power and time combinations as per experimental plans discussed (Table 1). Three different power levels (180, 300, 450 W) of microwave were selected along with different time combinations.

In this research work, First of all moisture absorption during hot soaking was measured then milling qualities of parboiled paddy determined and compared with that of freshly harvested paddy sample (raw paddy) at 13.6 (%db) moisture content and at last optimization of process parameters for parboiling were calculated.

Table 1: The dependent and independent parameters used in the study

Sr. No	Independent parameters	Levels	Dependent parameters
1.	Moisture content of soaked paddy	3 Moisture Content (wb): 27,30,33%	• Moisture absorption during hot soaking of paddy. • Milling quality of parboiled paddy.
2.	Microwave power levels	3	
3.	Microwave heating time	7	

Experimental procedures

As per the developed plan the experiments were conducted under following sub heading…

Moisture content determination by hot air oven method

Temperature controller and air oven was used for gravimetric method of moisture content determination. The temperature and time combination of 130ºC and 1 h. was used to find the moisture.

Procedure

a) Sample in petridish
b) Placing in hot air oven
c) Setting time and temp.

The samples were weighed initially before placing in the hot air oven. Final weight was also recorded and the moisture content was calculated using the following equations.

$$\text{Moisture content (wb)} = \frac{\text{intial weight} - \text{final weight}}{\text{intial weight}} \times 100$$

$$\text{Moisture content (db)} = \frac{\text{intial weight} - \text{final weight}}{\text{final weight}} \times 100$$

It was found that 27%, 30% and 33% moisture content (db) were obtained in 10 hr, 24 hr and 36 hr respectively

Process of parboiling

The research work is based on parboiling which is a hydrothermal treatment and has steps of soaking, draining, heating and drying.

Soaking: The initial moisture content of 10 g paddy sample was 8% (db). The main aim of this process is to increase the moisture content so that all the voids and cracks of the rice grains can be filled by water. Due to hydrogen bonding, the intermolecular forces of attractions within the rice kernel are increased up to a great extent and the partial pre-gelatinization of starch in endosperm of rice kernel starts. For the processes of soaking; 11 samples each weighing 50 g each were soaked for the duration of 2 hr, 4 hr, 6 hr, 8 hr, 9 hr, 10 hr, 14 hr, 20 hr, 24 hr, 28 hr, 36 hr respectively.

Draining: The soaked samples contain a lot of surface moisture along with free gravitational water which can be easily drained out by gravity. The samples are left free into a sieve for draining out the free water with the effect of gravity. Then these drained samples were wrapped in blotting paper to remove hygroscopic water from their surface.

Sample Preparation

Then three samples (each weighing 6 kg) rice was soaked for 10 h, 24 h, 36 h for achieving the 27%, 30%, 33% mc (db) respectively. Each of these three soaked samples (6 kg) were used to form 22 samples each weighing 300 g constituting for 66 samples.

Microwave Heating Treatment

Drying was performed in a domestic digital Microwave oven (Samsung trio CE107 MDF). MW oven at three different microwave power levels (180,300,450 W) three energy levels were selected. Various parameters were used to compare the differences of these selected treatment combinations between the treated paddy sample and freshly harvested paddy sample. Each set of samples were subjected to different microwave heating as given in Table 2

Table 2: Microwave power level and heating time

Sr. No	Power level (W)	Heating time (min.)
1.	180	2, 4, 6, 8, 10, 12, 14
2.	300	1, 2, 3, 4, 5, 6, 7, 9
3.	450	1, 2, 3, 4, 4.3, 5, 5.30, 6

Drying and weighing

The samples are allowed to dry normally for 24 h and the samples were weighed and labelled accordingly. Each of the sample shown a varying degree of reduction in weight from 300 g due to removal of absorbed water. Hence, for the uniformity of the samples new samples of 200 g were formed and labelled accordingly.

Milling

Process of milling

The procured paddy was converted into brown rice through a laboratory model Rice Miller at Department of Food Science, College of Agriculture, JNKVV, Jabalpur. Milling refers to the size reduction and separation operations used for processing of food grains into edible from by removing the milling process. It includes both de-husking and polishing simultaneously in a rice processing lab McGill type rice miller which collectively operates both the operations of de-husking and polishing with a sample range up to 250 g. The rice miller removes the husk of paddy grain with the help of two rubber rolls rotating in opposite direction at different speeds. Broken from husked Rice were seprated using various openings of sieves size (3.5, 4.2, 4.6 and 4.8 mm). These separated components were weighed using a weighing machine of least count 0.01 g.

The milling action of 66 treated samples and 1 controlled sample of 200 g each gave us following products of milling:

a. Husk
b. Head rice
c. Broken
d. Unshelled paddy
e. Bran, with very little losses during operation.

Milling qualities of parboiled paddy

The qualities of parboiled paddy can be calculated by following formulas:

$$\text{Degree of milling} = \frac{\text{weight of milled rice}}{\text{total weight of sample regained after milling}} \times 100$$

$$\text{Degree of polishing} = \frac{\text{weight of bran}}{\text{weight of brown rice}} \times 100$$

$$\text{Head rice yield} = \frac{\text{Degree of polishing}}{\text{total weight of sample regained after milling}} \times 100$$

$$\text{Broken percentage} = \frac{\text{weight of brokens}}{\text{weight of sample(brokens + Head rice) after milling}} \times 100$$

Result and Discussion

Results pertaining to different facets of the work have been categorized and explained with appropriate headers and subheadings. From the findings, conclusions have been made. The impact of microwave heating on the absorption of moisture in paddy during hot soaking in preparation for parboiling. The next section covered the moisture uptake by the paddy during hot soaking by microwave parboiling at various exposure times and energy levels.

Milling parameters for control paddy sample

1. Husking Efficiency of control sample was found to be 85.4%
2. Polish (%) of control sample was found to be 14.1%
3. Total yield (%) of control sample was found to be 56.2%
4. Head yield (%) of control sample was found to be 18.5%
5. Broken (%) of control sample was found to be 66.8%

To study for different parameters of control sample

Moisture uptake behaviour of paddy at different soaking time at room temperature

The moisture absorption in paddy increases with the increase in the duration of soaking time. (Fig 1). It was observed that for shortest duration of 2 h the moisture absorption was lowest as compared to other duration i.e.: 4,6, 8, 9, 10, 14, 20, 24, 28, 36 hr. More the time of soaking, the moisture absorption was high as compare to other duration of soaking. It was due to the reason that for longer duration of soaking result in increases of the moisture penetration in the paddy and that the rate of moisture absorption was higher. The results for milling parameters of control sample are shown below:

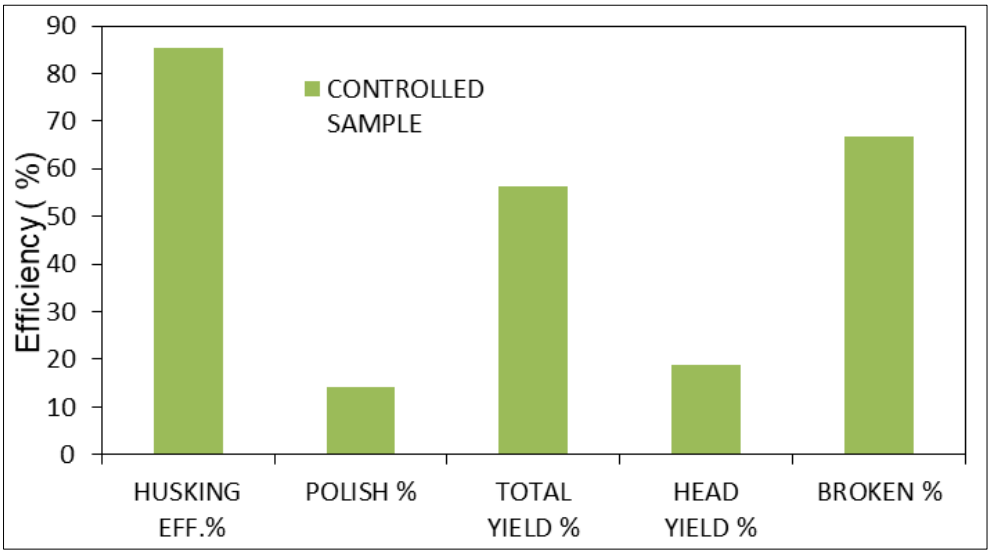

Fig 1: Different parameters of control sample

The above Fig. 1 clearly show that milling process of controlled sample have a higher% of broken (66.6%) and very low % of head yield (18.7).

Optimization of soaking duration to achieve three selected moisture levels of 27, 30, and 33% (wb)

The moisture absorption in paddy increased with the increase in soaking duration given in fig 2. It was observed that 27%, 30% and 33% could be achieved at approximately 10 h, 24 h and 33 h respectively.

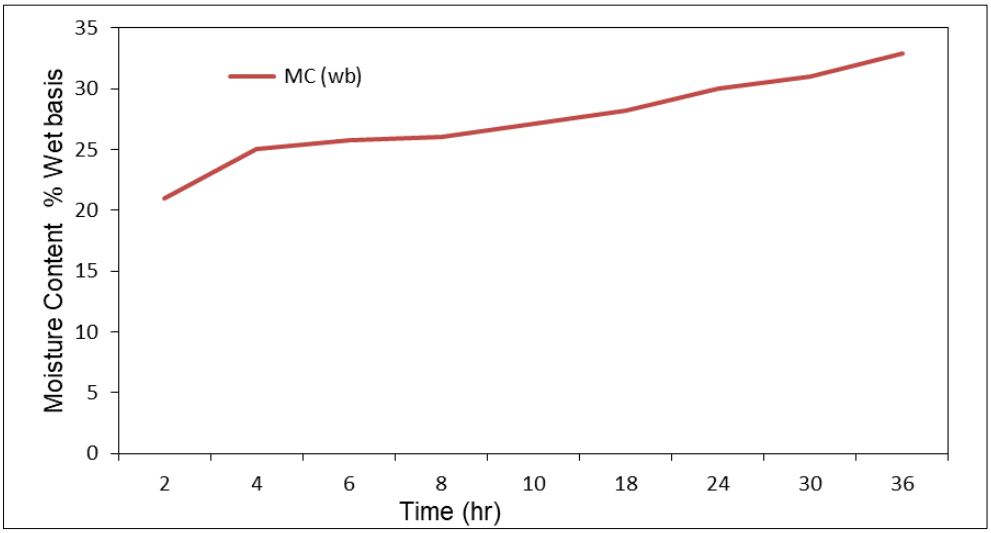

Fig 2: Moisture uptake behaviour of paddy at different soaking time

To study the effect of different power level of microwave heating of soaked paddy on its milling quality.

The effects of microwave heating at different power levels were discussed in the following sections:

Husking efficiency (%) for parboiled paddy at different power levels of microwave heating

As shown in figure 3, 4 & 5 the husking efficiency (%) increases with increase in power level. The husking efficiency (%) was found to be highest for 450 W followed by 300 W & 180 W. The husking efficiency (%) was found to be highest for moisture content (WB) 33% followed by 30% & 27%.It was observed that 95.8% could be achieved in 6 min. The husking efficiency (%) increases due to hardening of rice and proper gelatinization of rice as well as the hydrothermal treatment helps to loosen the husk.

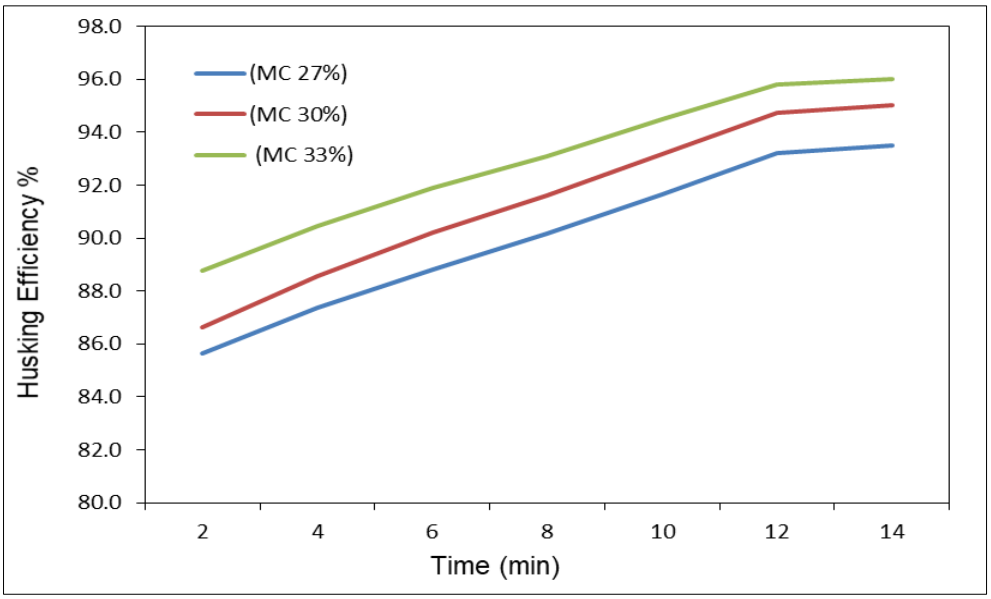

Fig 3: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on husking efficiency when microwave heating power level is 180 watt.

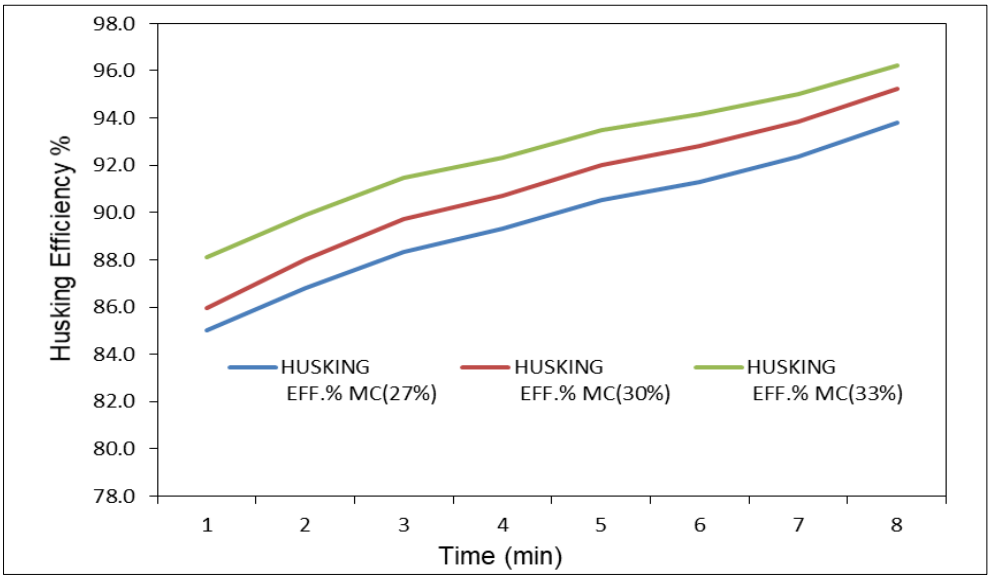

Fig 4: Observations on the effect of M.C. (wb) of soaked paddy and microwave heating time on husking efficiency when microwave heating power level is 300 watts.

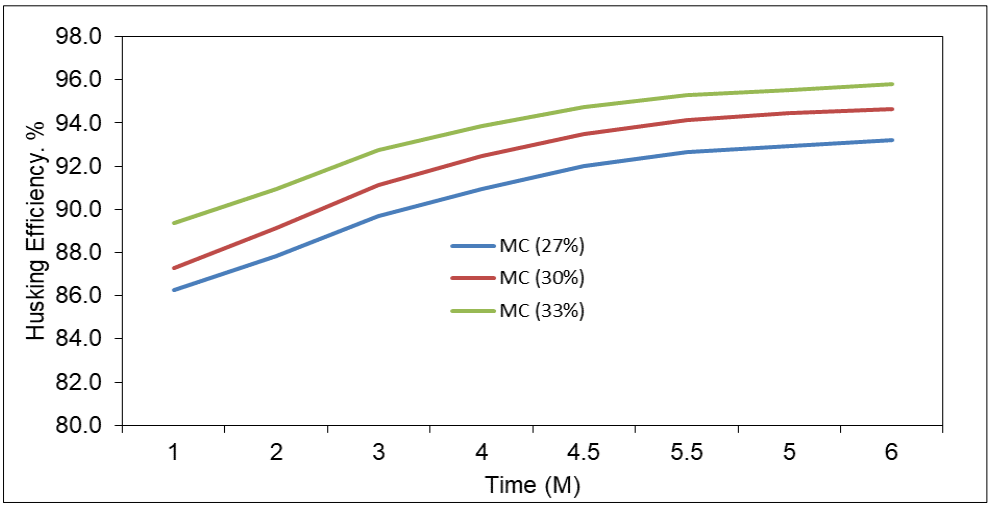

Fig 5: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on husking efficiency when microwave heating power levels 450 watt.

Polishing (Bran%) for parboiled paddy at different power levels of microwave heating

As shown in figure 6, 7 & 8 the bran (%) first decreases with increase in power level. The bran (%) was found to be lowest for 450 W followed by 300 W & 180 W. The bran (%) was found to be lowest for 33% moisture content (WB) followed by 30% & 27%.

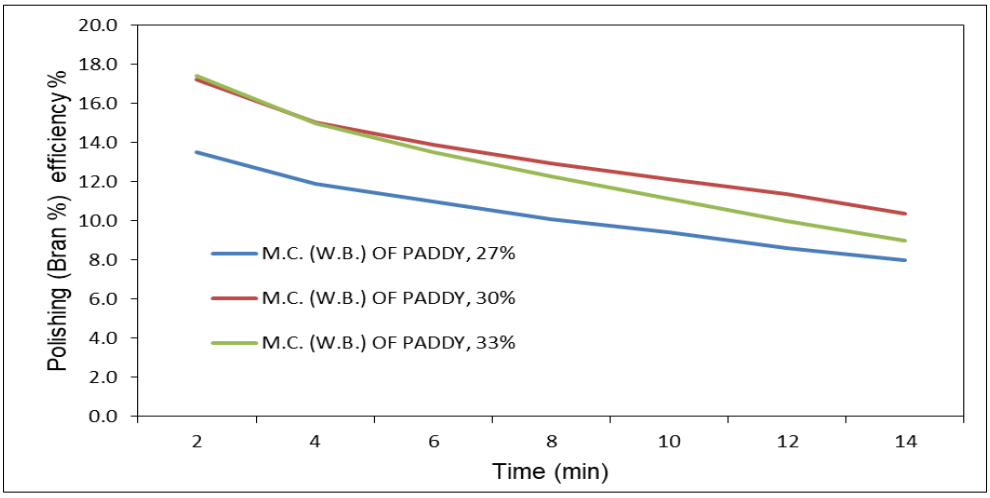

Fig 6: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on polishing (bran%) when microwave heating power level is 180 watts

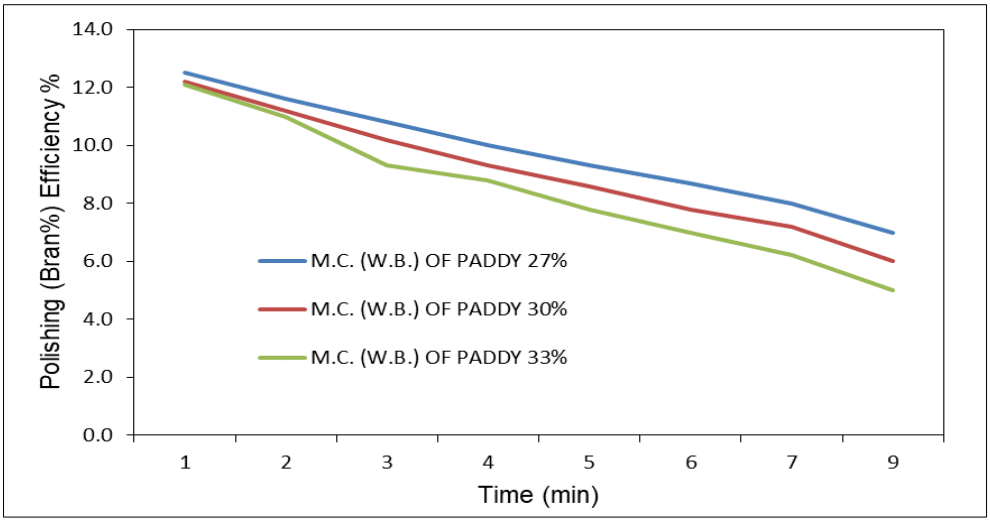

Fig 7: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on polishing (bran%) when microwave heating power level is 300 watts

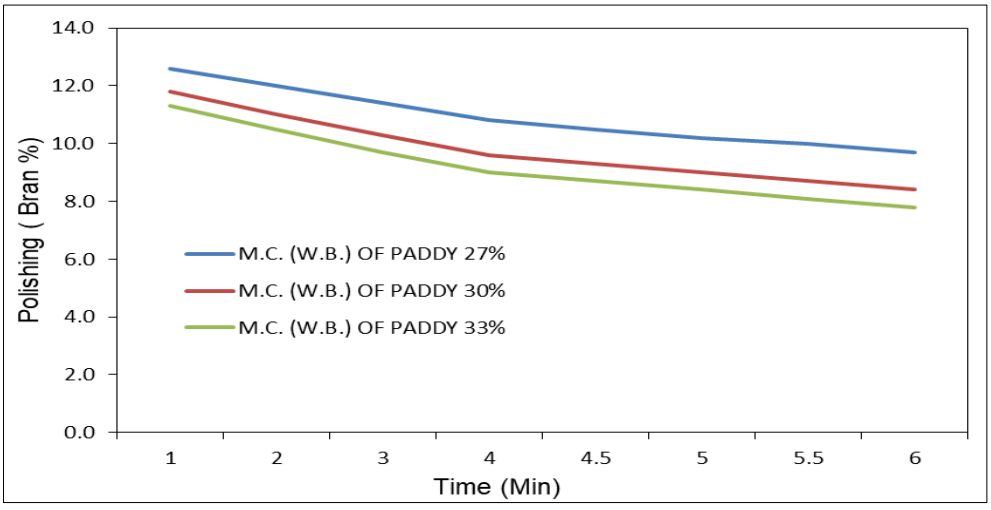

Fig 8: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on polishing (bran%) when microwave heating power level is 450 watts.

Total Yield (%) for parboiled paddy at different power levels of microwave heating

As shown in figure 9, 10, 11 the total yield (%) increases with increase in power level. The total yield% was found to be highest for 450 W followed by 300 W & 180 W. The total yield% was found to be highest for moisture content (WB) 33% followed by 30% & 27%.It was observed that 68.5% could be achieved in 5.5 min.

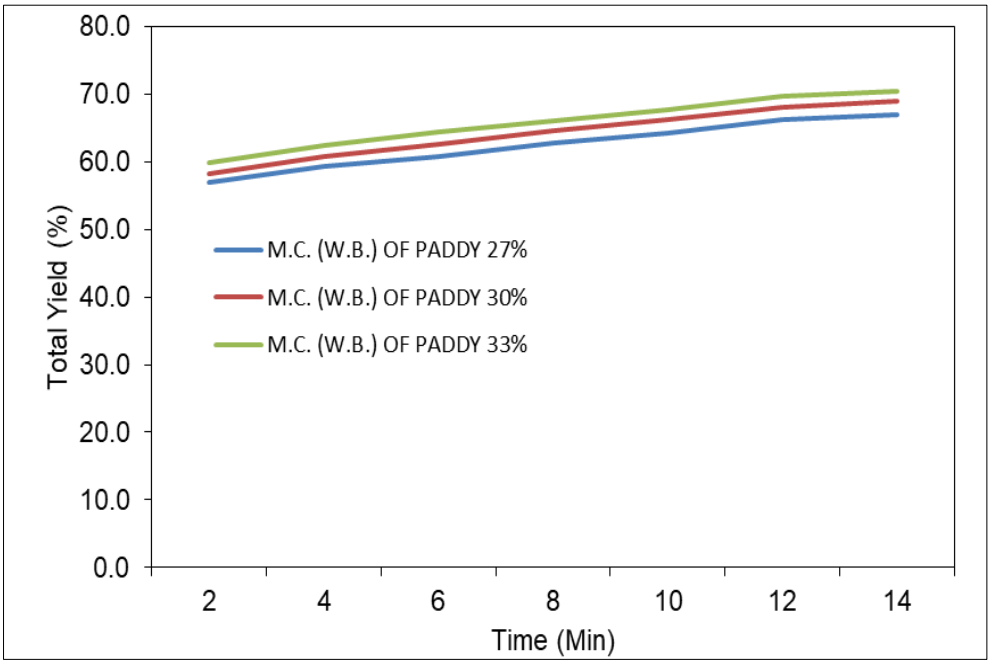

Fig 9: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on total yield% microwave heating power level 180 watts.

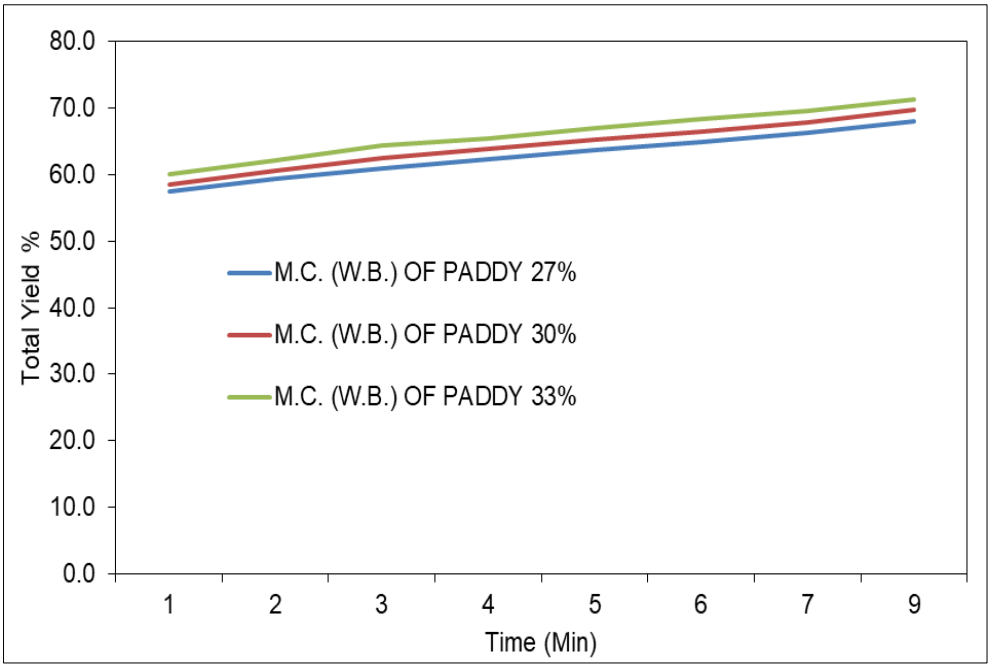

Fig 10: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on total yield% microwave heating power level 300 watts.

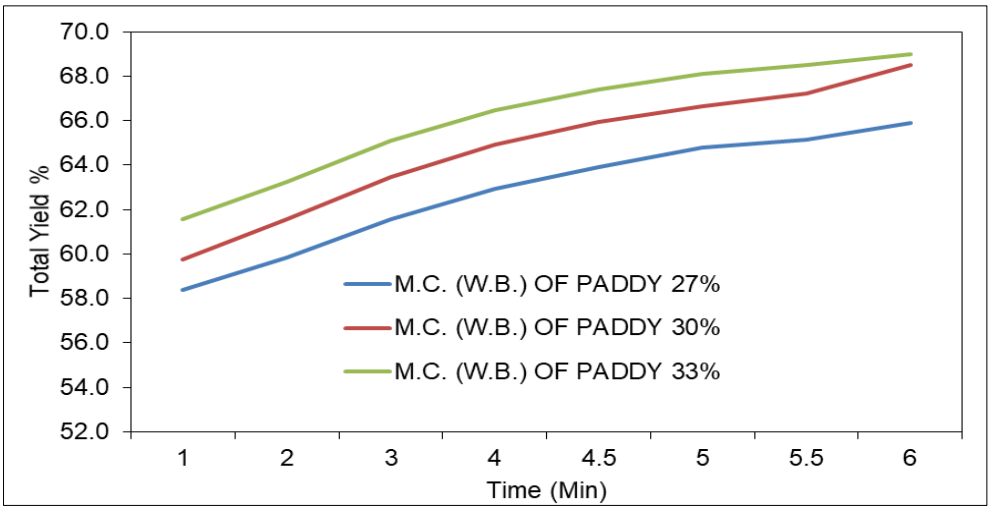

Fig 11: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on total yield% microwave heating power level 450 watts.

Head Rice Yield (%) for parboiled paddy at different power levels of microwave heating

As shown in figure 12, 13 & 14 the head rice yield (%) increases with increase in power level. The head rice yield (%) was found to be highest for 450 W followed by 300 W & 180 W. The higher power level facilitated the gelatinization of the starch which resulted in hardening of rice which ultimately provided better head rice yield.

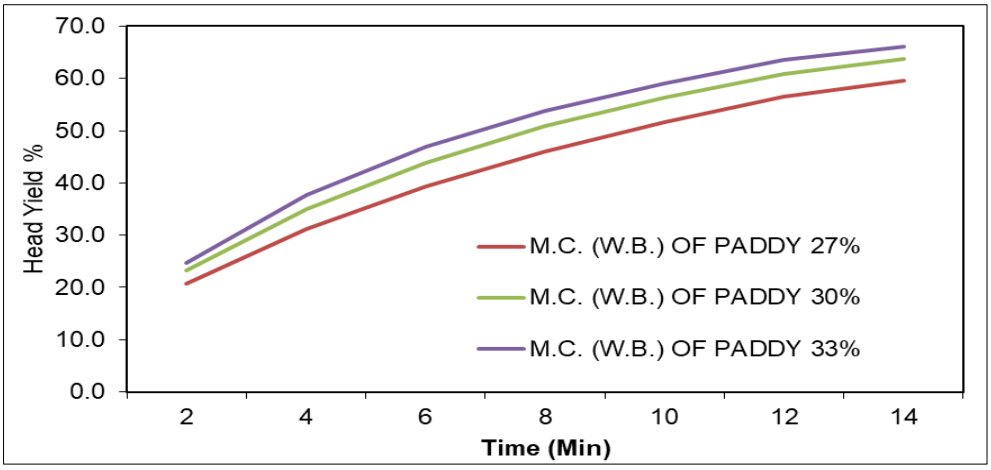

Fig 12: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on head yield (%) microwave heating power level 180 watt

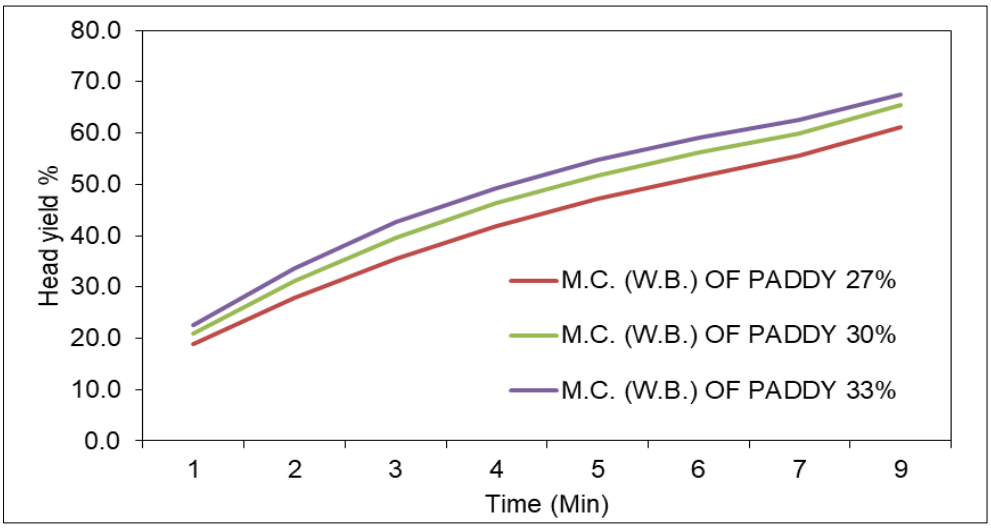

Fig 13: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on head yield (%) microwave heating power level 300 watt

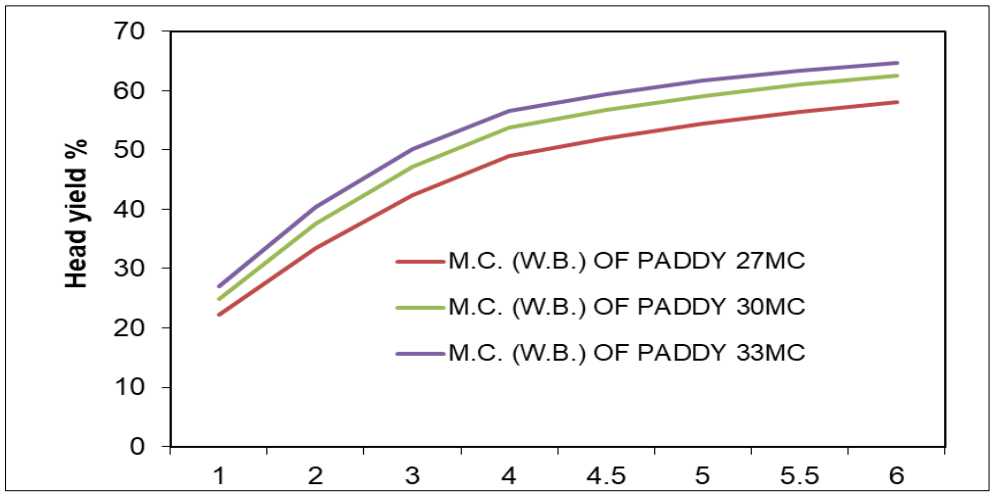

Fig 14: Observations on effect of M.C. (wb) of soaked paddy and microwave heating time on head yield% microwave heating power level 450 watt

Broken (%) for parboiled paddy at different power levels of microwave heating

As shown in figure 15, 16, 17 the amount of broken was found to reduce as the power level increased. For a given power higher energy level is attained at more exposure time. More exposure time allowed better moisture absorption and proper gelatinization of starch, this resulted in decrease of brittleness ultimately affecting the breakage. As a result of higher gelatinization of starch the broken observed were less during milling.

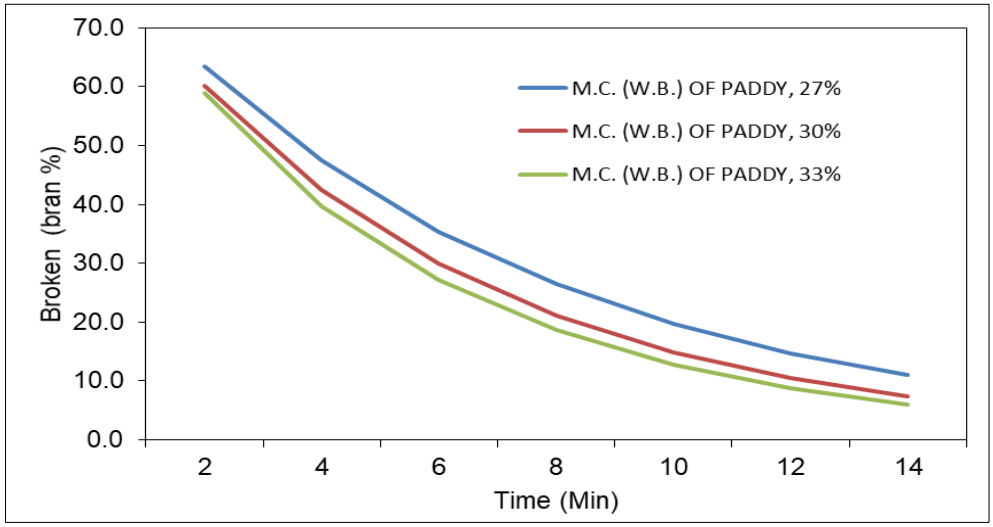

Fig 15: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on broken microwave heating power level 180 watt

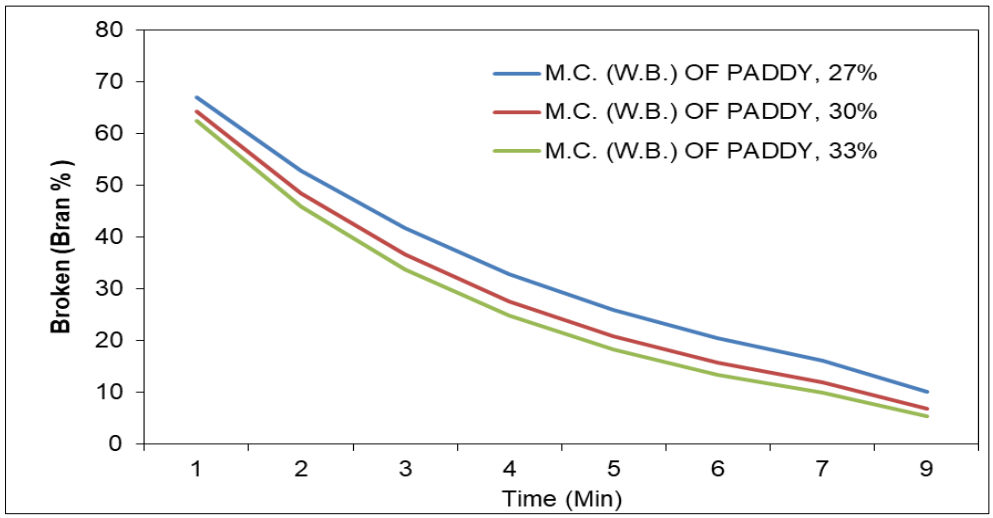

Fig 16: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on broken microwave heating power level 300 watt

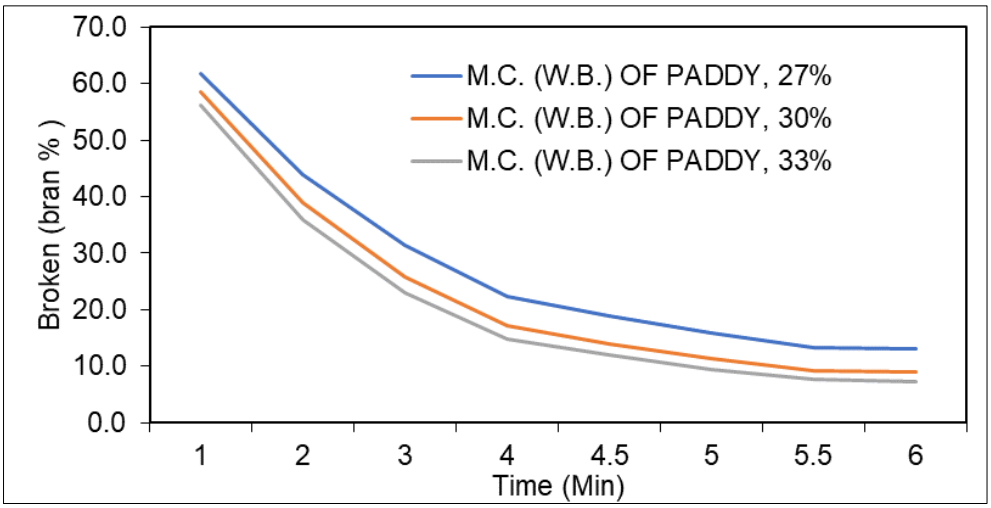

Fig 17: Observations on effect of M.C. (w.b.) of soaked paddy and microwave heating time on broken microwave heating power level 450 watt

Conclusion

The process of parboiling is a hydrothermal process which increases the strength of rice grain by its gelatinization. This process consists of four main unit operation namely soaking, draining, heating and drying. For all these unit operations a big setup is required for steaming and drying. There is a very large heat (energy) loss during this process which adds additional cost to production. To reduce these losses of energy, microwave oven can be used for heating action during parboiling because in microwave oven heat application is very efficient, uniform and less time consuming. The results obtained during the study period may be concluded as the moisture absorption by paddy increased with the increase in time duration. For longer duration of 36 h the moisture absorption was better as compared to other shorter duration. Effect of different power level of microwave heating of soaked paddy on its milling quality. The Head Rice Yield (%) was found to be higher for higher power level. For equal time interval the Head Rice Yield (%) was found to be highest for 450 W followed by 300 and 180 W due to proper gelatinization of the starch which resulted in hardening of rice which ultimately provided better head rice. The percentage of broken was found to decrease with increase in power level. For equal time interval the broken% was found to be lowest for 450 W followed by 300 and 180 W due to proper gelatinization of starch, this resulted in decrease of brittleness ultimately affecting the breakage. As a result of higher gelatinization of starch, the broken observed were less during milling.

References

1. Abdul.Hamid A, Sulaiman RR, Osman A, Saari N. preliminary study of the chemical composition of rice milling fractions stabilized by microwave heating. Journal of food composition and nalysis. 2007;20(7):627-637.
2. Agu HO, Michael-Agwuoke A. Optimization of Soaking Duration and Temperature for Two Nigerian Rice Cultivars. Nigerian Food Journal. 2012;30(2):22-27.
3. Alizadeh MR. Effect of paddy husked ratio on rice breakage and whiteness during milling process. Australian Journal of crop science. 2011;5(5):562.
4. Andres M, Tuates Jr, Shiela Marie Villota A, Aileen Ligisan R, Ofero Caparino A. Optimization of Parboiling Conditions of Local Rice Varieties in the Philippines. Asian Journal of Applied Sciences (ISSN: 2321 —0893); c2016.
5. Anonymous 2019-04-01,12:22, Rice Knowledge Management Portal, http://www.rkmp.co.inicontent/advantages-of-parboiling.
6. Anonymous. Rice Knowledge Bank; c2010. https://www.knowled ebank.irri.org/training/fact-sheets/postharvest-management/rice-quality -fact-sheet-category /item/measuring fact-sheet.
7. Anonymous, Indian Rice Market Update,htt .//www.magships.com/rice market update/ Anonymous, 2010. Measuring Physical Quality of Paddy- IRRI Rice Knowledge Bank; c2018. www.knowledgebank.irri.org.
8. Anonymous, Milling and Parboilinghttp:// www.knowledgebank.irri.orq/ grain Qualit/module 4/06.htm
9. Bakshi AS, Singh RP. Kinetics of water diffusion and starch gelatinization during rice parboiling. Journal of Food Science. 1980;45(5):1387- 1392.
10. Banu S. Studied on effect of soaking and steaming on parboiling, milling. cooking. and storage characterstics of some paddy varities of Chhattisgarh; c2006.
11. Bello MO, Loubes MA, Aguerre RJ, Tolaba MP. Hydrothermal treatment of rough rice: effect of processing conditions on product attributes. Journal of food science and technology. 2015;52(8):5156-5163.
12. Bello M, Baeza R, Tolaba MP. Quality characteristics of milled and cooked rice affected by hydrothermal treatment. Journal of Food Engineering. 2006;72(2):124-133.
13. Buffler CR. Microwave cooking and processing. New York: Nostrand Reinhold, 1992, 47-68.
14. Buggenhout J, Brijs K, Celus L, Delcour JA. The breakage susceptibility of raw and parboiled rice: A review. Journal of Food Engineering. 2013;117(3):304-315.
15. Chitra M, Singh V, Ali SZ. Effect of processing paddy on ability of rice starch by in vitro studies. Journal of food science and technology. 2010;47(4):414-419.
16. Danbaba N, Nkama I, Badau MH, Ukwungwu MN, Maji AT, Abo M Ey, *et al*. Optimization of rice parboiling process for optimum head rice yield: a response surface methodology (RSM) approach. International Journal of

Agriculture and Forestry. 2014;4(3):154-165.
17. Das 1, Das SK, Bal S. Specific energy and quality aspects of infrared (IR) dried parboiled rice. Journal of Food Engineering. 2004;62(1):9-14.
18. Demuyakor B, Dogbe W, Owusu R. Parboiling of paddy rice, the science and perceptions of it as practiced in Northern Ghana. International Journal of Scientific & Technology Research. 2013;2(4):13-18.
19. Doos HA, Rizk LF, EI-Shirbeeny M. Technological properties of microwave parboiled rice. Molecular Nutrition & Food Research. 1993;37(5):470-475.
20. Dumais S, Mayer S, 'Ian_ A. Improved Parboiling Practices in Benin. West Africa; c2010.
21. Dutta H, Mahanta CL. Traditional parboiled rice-based products revisited: Current status and future research challenges. Rice Science. 2014;21(4):187-200.
22. Graham-Acquaah S, Manful JT, Ndindeng SA, Tchatcha DA. Effects of soaking and steaming regimes on the quality of artisanal parboiled rice. Journal of food processing and preservation. 2015;39(6):2286-2296.
23. Guirai HS, Singh J, Sodhi NS, Singh N. Effect of milling variables on the degree of milling of unparboiled and parboiled rice. International Journal of Food Properties. 2002;5(1):193-204.
24. Taghinezhad E, Khoshtaghaza MH, Suzuki T, Minaei S, Brenner T. Quantifying the Relationship between rice starch gelatinization and moisture-electrical conductivity of paddy during soaking. Journal of Food Process Engineering. 2016;39(5):442-452.
25. Tirawanichakul S, Prachayawarakorn S, Varanyanond W, Tungtrakul P, Soponronnarit S. Effect of fluidized bed drying temperature on various quality attributes of paddy. Drying Technology. 2004;22(7):1731-1754.
26. Uyeh DD, Seung WM, Ha YS. Optimization of parboiling conditions for rice milling. In 2016 ASABE Annual International Meeting (p. 1). American Society of Agricultural and Biological Engineers; c2016.
27. Velupillai L, Verma LR. Parboiled rice quality as affected by the level and distribution of moisture after the soaking process. Transactions of the ASAE. 1982;25(5):1450-1456.
28. Wadsworth JIL, Verma LR. Microwave-vacuum drying of parboiled rice. Transactions of the ASAE. 1990;33(1):199-0211.
29. Yousaf K, Kunjie C, Cairong C, Abbas A, Huang Y, Arslan C, *et al*. The Optimization and Mathematical Modeling of Quality Attributes of Parboiled Rice Using a Response Surface Method. Journal of Food Quality; c2017.
30. Zhao S, Xiong S, Qiu C, Xu Y. Effect of microwaves on rice quality. Journal of Stored Products Research. 2007;43(4):496-502.