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Varietal influence on milling yield of rice

Aakanksha Sinha, Virendra K Tiwari and Prabha Haldkar

Abstract
Three Indian rice varieties namely Pusa basmati-1, Pusa-1460, Kshatriya were selected for study of varietal difference on milling characteristics. The rice varieties varied in their husk content. The experiment was conducted at different time of milling i.e. 0, 30, 60 and 90 seconds. The maximum head rice recovery (56.9, 54.3, 50.8%) was observed in Kshatriya variety followed by Pusa basmati-1 (53.6, 51.3, 47.5%), Pusa-1460 (50.5, 47.8, 43.7%) for 30, 60 and 90s time of milling respectively. Minimum broken percentage was observed in variety Pusa basmati-1 for each time of milling. Maximum removal of bran (2.0, 3.57 and 4.54%) was observed in variety P-1460 for each time of milling. Degree of milling (DOM) affects the total milling recovery, head rice yield, brokens. Increase in degree of milling results in reduction of milling yield. The maximum milling yield (77.5, 77.1 and 76.1%) was observed in Kshatriya variety for 30, 60 and 90s time of milling respectively. However consumers prefer rice commercially on the basis of their appearance (whiteness), which actually had higher degree of polish with low nutrient value.

Keywords: Head rice recovery, brokens, milling yield, degree of milling, varietal influence

1. Introduction

Rice (*Oryza sativa* L.) is an edible starchy cereal grain belongs to the family of grasses, Gramineae (*Poaceae*). The harvested rice kernel known as paddy or rough rice is enclosed with the husk. Rice is one of the most important field crops of the world providing staple food to around half of the world’s population. Rice's value has been recognized from ages; in India, it was originally referred to as 'dhanya,' which meant 'the sustainer of the human race."

India is the second largest rice producer country followed by China. As per the Ministry of Agriculture and Farmers Welfare, total rice grain production is 122.27 MT in 2020-21, grown in area about 45 million hectares.

Basmati rice is the longest aromatic and favourite cuisine rice in the world. India is the largest producer of basmati rice accounting for over 70% of the world’s total basmati rice production and it is also a leading exporter of basmati rice in global market, generating higher income (APEDA, 2020). Balaghat is a leading district of Madhya Pradesh in paddy production, therefore called the paddy bowl of the state. The renowned basmati rice is sown in the budni region of the sehore district in Madhya Pradesh. Rice could be grown in a wide range of agro-climatic conditions, from hilly regions (Jammu) to low-lying delta locations like the Sundarbans (Kenneth and Kriemhild, 2000) [6]. Rice crop is the cheapest among cereal and produces more energy and protein per hectare than wheat and maize, based on mean grain yield. Due to low economic status in some parts of country, their diet often lacks in both quantity and quality, leading to malnutrition. These nutrition deficiencies inflict long term damage to individuals and society thus contributing towards global poverty and hunger. According to Global Hunger Index 2021, India ranked 101 out of 116 countries. As per growing population, to feed the predicted 9.1 billion people on the planet by 2050, current agricultural production will have to be raised by 70%. The annual cereal output will need to be increased by over a billion tonnes.

A brown rice kernel is covered by the hull or husk (18-28%). Brown rice (72-83%) is made up of a bran layer (5-8%), germ (2-3%), and a starchy centre (89-94%) by weight (Singh & Sahay, 1994). The husk is the most visible portion of a rough rice grain. When the husk and bran are removed during milling, the endosperm is left with carbohydrates and a little amount of protein, as well as few minerals, vitamins, oil and carbohydrates; because of its high percentage of carbohydrate its energy value is high. The entire oil is present within bran layer which is (2-3%) (FAO, 1964) [2]. In India rice is utilized for a variety of industrial purposes, depending on its properties *viz*. popped, puffed and flaked.

In agro processing industries, rice milling includes a number of unit operations aimed to transforming paddy into white rice for better cooking and nutritional quality. Milling is a wear phenomenon that includes removing material from a solid surface either mechanically or through a mixture of mechanical and non-mechanical motions such as rolling, impact, or sliding. Commercial milling is a multi-stage process that begins with the dehusking of paddy and ends with the removal of the exterior brown bran layer during the whitening process. This bran contains edible oil in it, which can be expelled from it and used in cooking. Polishing is the final stage of rice milling in which the left-over bran is entirely removed from the grain surface (dhillon *et al*, 2014) [1]. Head rice recovery (HRR) is an important rice characteristic that makes the variety valuable. If variety's HRR is higher, then it has higher economic value. However, this attribute varies between varieties. The broken rice obtained during milling process is grinded into flour and utilized as a food additive. Husk can also be used as manure.

Rice that has been milled to a lower degree is more nutritious than rice milled to a higher degree. The nutritional composition, as well as the appearance, yield, physico-chemical, and functional qualities, were all influenced by milling degrees. Low milled rice has a brownish look. However, rice that has been milled to a lower degree has been found to have a greater Head Rice Yield (HRY) than white rice (Dhillon *et al*., 2014) [1]. According to FAO (1992) [2], degree of milling (DOM) has been categorized into four classes such as (3-4%) under milled, (5-6%) medium milled, (7-8%) fully milled and (>8%) over milled. Indian government recommended 5% polish to be done in the rice grain.

2. Materials and Methods

The paddy varieties (PB-1, P-1460, Kshatriya) was first procured from Department of Plant Breeding and Genetics J.N.K.V.V., Jabalpur and cleaned in an air classifier to eliminate light foreign matter such dust, dirt, chaff, immature, and broken kernels, some heavier materials like stone, are removed manually using hand pounding method. The laboratory experiment was conducted in Department of Food Science and Technology, J.N.K.V.V., Jabalpur. Moisture content is determined by using hot air oven, standard AOAC (2002) method, by drying them at 130 °C for 2 hours and moisture content was found 13.7 ≈ 14% (wet basis).

2.1 Milling characteristics

The procured paddy was dehusked by using lab model rubber roll sheller (Indosaw, Mc Gill Type- 0.5hp, 230V) to produce brown rice and polished by using (Indosaw rice polisher) for different time of milling (0, 30, 60, 90). To calculate the percentage of head rice recovery, brokens, total milling yield and degree of polish. The head rice, brokens and bran were separated manually and weigh them by using precise electronic balance.

2.1.1 Head Rice Recovery (HRR %)

Milled rice with length greater than or equal to three fourth length of kernel is termed as head rice. Head rice is one of the most important criteria for measuring milled rice quality and is defined as ratio of weight of head rice to total weight of paddy. It was calculated as follows:

$$\text{HRR (\%)} = \frac{\text{Weight of head rice(g)}}{\text{Total weight of paddy(g)}} \times 100$$

2.1.2 Broken Rice (BR %)

Broken rice refers to fractured milled rice which broken during milling and the size of broken rice kernels having size less than three fourth of kernel length. Broken rice percentage is the fraction of weight of broken in total weight of milled rice (Karim *et al*., 2002) [5]. It was calculated as follows:

$$\text{BR\%} = \frac{\text{Weight of broken (g)}}{\text{Total weight of paddy (g)}} \times 100$$

2.1.3 Total Milling Yield

Total milling yield is the weight percentage of rough rice that remains as milled rice*; i.e* sum of head rice and brokens rice percentage. It is computed as follows:

$$\text{TY (\%)} = \text{HRR (\%)} + \text{BR (\%)}$$

Where,
TY = Total yield (%)
HRR = Head Rice Recovery (%)
BR = Brown Rice (%)

2.1.4 Degree of Polish

The percentage of bran removed from the brown rice during polishing referred as degree of polish and is also known as polish percentage. It is the ratio of weight of bran removed dividing by weight of brown rice. It is calculated as follows:

$$\text{Polish (\%)} = \frac{\text{Weight of bran (g)}}{\text{Weight of brown ricce (g)}} \times 100$$

3. Results and Discussion

The milling characteristics of different rice varieties have been studied.

3.1 Effect of time of milling on head rice recovery

Head Rice Recovery is a milling property that has a significant impact on the rice value. It is the percentage of rice that succeed in retaining three fourth of its original length after milling. To determine the percentage of head rice recovery, rice varieties PB-1 (V_1), P-1460 (V_2), Kshatriya (V_3) were milled by lab-model rubber roll sheller and abrasive polisher at different time of milling.

For 30 seconds milling, the head rice recovery for V_1, V_2, and V_3 is 53.6, 50.5, and 56.9%, respectively. For 60 seconds milling, the test results for varieties V_1, V_2, and V_3 were 51.3, 47.8, and 54.3%, respectively. Similarly, for 90 seconds milling, the head rice recovery for varieties V_1, V_2, and V_3 are 47.5, 43.7, and 50.8%, respectively shown in Table 1. By comparing 30 and 60 seconds, it was revealed that V_1 losses 2.3%, V_2 losses 2.7%, and V_3 losses 2.6%. By comparing 60 and 90 seconds, it was revealed that variety V_1 losses 3.8%, V_2 losses 4.1%, and variety V_3 losses 3.5%. Table 4 shows the influence of degree of polish on head rice recovery at different time intervals (0, 30, 60, and 90) for varieties of rice. The regression equation for head rice recovery at different times of milling was developed as y = -0.129x + 58.86, giving R^2 = 0.965, indicating that V_1 could predict 96.5% of HRR through TOM. For V_2 it was developed as y = -0.156x + 57.12, giving R^2 = 0.949; and y = -0.146x + 63.25, giving R^2 = 0.939; for variety V_3 variety. For varieties V_1, V_2, and V_3

head rice recovery predicted as 96.5, 94.9, and 93.9%, respectively, according to TOM. As milling time increases, the weight of the grains often decreases due to bran removal. The graphical representation of head rice recovery is shown in fig. 1.
From the obtained result we can conclude that the variety V_2 has a lower head rice recovery and V_3 found to be higher head rice recovery (HRR) because short grain varieties results less breakage, than long grain varieties. The head rice yield for short grain varieties was found higher. It was also observed that lower the degree of milling, the higher the head rice yield. Above results are in agreement with Dhillon *et al.*, (2014) [1]

The following models were developed
For variety PB-1 the head rice recovery is expressed as
HRR=-0.129TOM+58.86 ………………………………. V_1

For variety P-1460 the head rice recovery is expressed as
HRR=-0.156TOM+57.12 ………………………………. V_2

For variety Kshatriya the head rice recovery is expressed as
HRR=0.146TOM+63.25 ……………………………….. V_3

Where
HRR = Head rice recovery
TOM = Time of milling

Table 1: Effect of time of milling on head rice recovery

Varieties	Time of milling (sec)				Mean
	0	30	60	90	
PB-1	59.7	53.6	51.3	47.5	53.02
P-1460	58.4	50.5	47.8	43.7	50.10
Kshatriya	64.6	56.9	54.3	50.8	56.65
Mean	60.90	53.66	51.13	47.33	

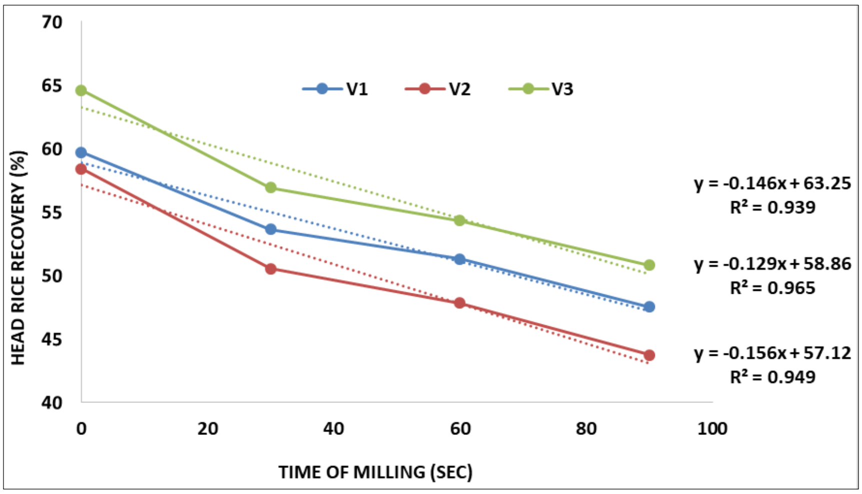

Fig 1: Effect of time of milling on head rice recovery (V_1= Pusa basmati-1, V_2= Pusa-1460, V_3= Kshatriya)

3.2 Effect of time of milling on brokens
To determine broken rice percentage three rice varieties PB-1 (V_1), P-1460 (V_2), Kshatriya (V_3) were milled using a lab model rubber roll sheller and abrasive polisher. HRR and broken rice were separated manually and weighed.
The obtained results shows that at 30 seconds time of milling, the broken percentage for varieties V_1, V_2, and V_3were 16.6, 22.8, and 20.6%, respectively. For 60 seconds milling, the outcome of brokens for varieties V_1, V_2, and V_3were 18.3, 25.1, and 22.8%, respectively. Similarly, for 90 seconds milling, the test result of brokens for varieties V_1, V_2, and V_3 were 20.6, 27.8, and 25.3%, respectively shown in Table 2.
While comparing 30 and 60 seconds, it was revealed that V_1 has a 1.7% increase in broken rice, V_2 has a 2.3% and V_3 has 2.2% rise in broken rice. By comparing 60 and 90 seconds, it was observed that V_1 has a 2.3% rise, V_2 has 2.7% increase, and variety V_3 has 2.5% increase. It was noticed that broken rice did not have a definite trend because of different rice variety which was highly influenced by time of milling.
The regression equations for broken rice at different time of milling for variety V_1 was developed as y = 0.099x + 12.19, giving R^2 = 0.930 and for variety V_2 was developed as y = 0.121x + 17.55, giving R^2 = 0.937 and for the variety V_3 equation was developed as y = 0.117x + 15.47, giving R^2 = 0.931.It was found that as the time of milling increased, the percentage of broken rice increased. These equations indicate that broken rice estimated with milling time, maximum in variety V_2 as compared to V_1 and V_3. The graphical representation of brokens percentage is shown in fig. 2.
It was revealed that varieties that have higher head rice recovery gives lowest percentage of broken and variety that have low head rice give maximum broken. The weight of a head of rice is proportional to the size of the grain. Short grains are less likely to break when milled, resulting in improved quality and higher recovery. Breakage is higher in longer grains, and milled rice recovery is lower. Above result is in agreement with Sison *et al.*, (2006) [10].

The following models were developed
For variety PB-1 the broken rice is expressed as
HRR=0.099TOM+12.19 ……………………………….. V_1

For variety P-1460 the broken rice is expressed as
HRR=0.121TOM+17.55 ……………………………….. V_2

For variety Kshatriya the broken rice is expressed as

HRR=0.117TOM+15.47 ……………………………….. V_3

Where

BR = Broken rice
TOM = Time of milling

Table 2: Effect of time of milling on brokens

Varieties	Time of milling (sec)				Mean
	0	30	60	90	
PB-1	11.2	16.6	18.3	20.6	16.67
P-1460	16.4	22.8	25.1	27.8	23.02
Kshatriya	14.3	20.6	22.8	25.3	20.75
Mean	13.96	20.00	22.06	24.56	

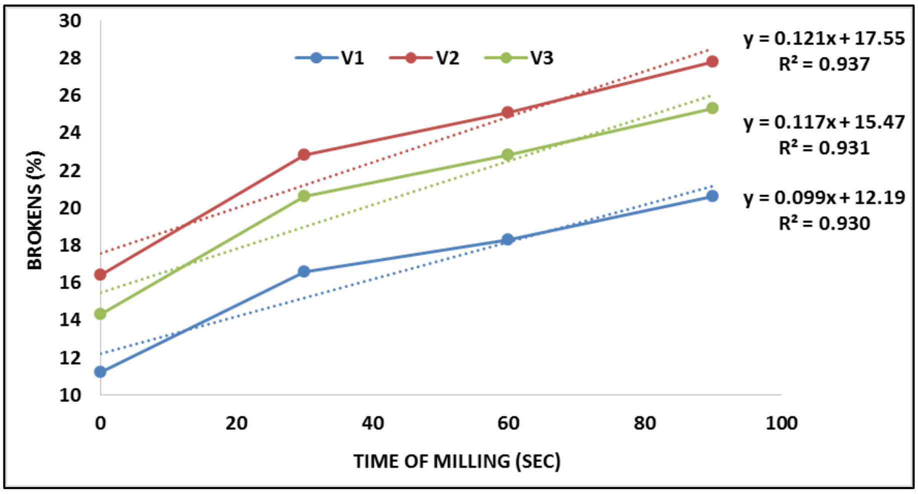

Fig 2: Effect of time of milling on brokens (V_1= Pusa basmati-1, V_2= Pusa-1460, V_3=Kshatriya)

3.3 Effect of time of milling on total milling yield

Total milling yield is the sum of head rice and broken rice, to determine the total milling yield. Varieties are milled using a lab model rubber roll sheller and abrasive polisher.

The result shows that at 30 seconds time of milling, overall milling yields for V_1, V_2, and V_3 was 70.2, 73.3, and 77.5%, respectively. For 60 seconds milling, the test results for varieties V_1, V_2, and V_3 were 69.6, 72.9, and 77.1% respectively. Similarly, for 90 seconds milling, the yield percentages for varieties V_1, V_2, and V_3 were 68.1, 71.5, and 76.1%, respectively shown in Table 3.

By comparing 30 and 60 seconds, it was shown that milling yield decreased by 0.6% for V_1, 0.4% for V_2, and 0.4% for V_3. By comparing 60 and 90 seconds, it was found that V_1, V_2, and V_3 have a drop in milling yield of 1.5%, 1.4%, and 1.0%, respectively. As a result of the varietal differences, it was found that milling yield does not follow a consistent pattern.

The regression equations for milling yield at different time of milling for variety V_1 was developed as $y = 0.03x + 71.05$, giving $R^2 = 0.950$ and for variety V_2 was developed as $y = 0.034x + 74.67$, giving $R^2 = 0.959$ and for the varieties V_3 equation were developed as $y = 0.029x + 78.72$, giving $R^2 = 0.958$. The graphical representation of milling yield is shown in fig. 3.

From the above results we can conclude that total milling yield is maximum in variety V_3 because of its low husk content and low degree of polish. V_1 has the lowest milling yield because of its high husk content. The variety V_3 has also low brokens because of its medium slender size and shape and V_1 and V_2 has maximum broken because of its longer length and shape of kernel. As milling time increased, the weight, milling yield decreased, established an inversely proportional relationship. Whiteness of kernel corresponds to higher degree of milling. Similar results were reported by Haq *et al*., (2016) [3]

Usually, rice grains require 7-8% of milling for a pleasant appearance, but as per government of India guidelines it should not be above 5% milling (Mohapatra, 2004) [7].

The following models were developed

For variety PB-1 the total milling yield is expressed as
HRR=-0.03TOM+71.05 ……………………………….. V_1

For variety P-1460 the total milling yield is expressed as
HRR=-0.034TOM+74.67 ……………………………… V_2

For variety Kshatriya the total milling yield is expressed as
HRR=-0.029TOM+78.72 ……………………………… V_3

Where

MY = Milling Yield
TOM = Time of milling

Table 3: Effect of time of milling on total milling yield

Varieties	Time of milling (sec)				Mean
	0	30	60	90	
PB-1	70.9	70.2	69.6	68.1	69.70
P-1460	74.8	73.3	72.9	71.5	73.12
Kshatriya	78.9	77.5	77.1	76.1	77.40
Mean	74.86	73.66	73.20	71.90	

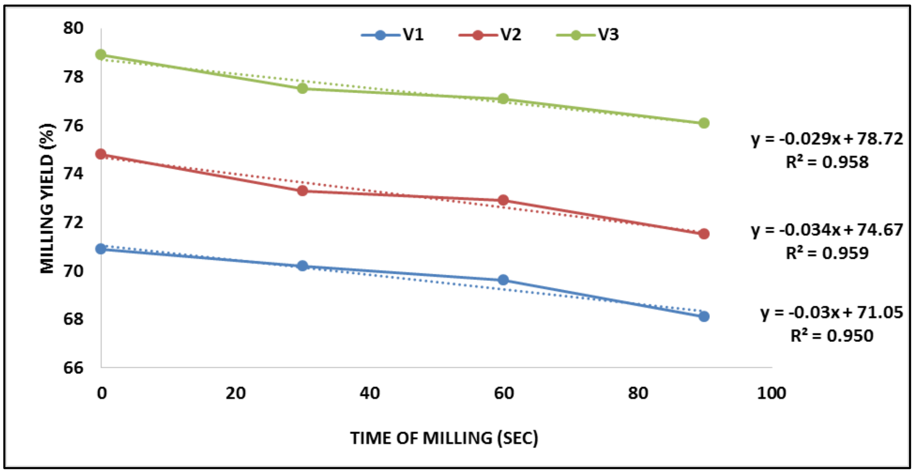

Fig 3: Effect of time of milling on total milling yield (V_1= Pusa basmati-1, V_2= Pusa-1460, V_3=Kshatriya)

3.4 Effect of time of milling on degree of polish

The degree of polish refers removal of bran during polishing. As milling time increased, more and more bran layer is eliminated. Varieties were milled in lab model rubber roll sheller and abrasive polisher.

The obtained result shows that at 30 seconds milling 1.81, 2.00, and 1.39% bran were removed from varieties V_1, V_2, and V_3 respectively. For 60 seconds milling 3.33, 3.57, and 2.40% bran removed from varieties V_1, V_2, and V_3 respectively. Similarly, for 90 seconds milling bran removal was 4.35, 4.54, and 3.18% for varieties V_1, V_2 and V_3 respectively.

By comparing 30 and 60 seconds milling, the proportion of bran removed is 1.52% for V_1, 1.57% for V_2, and 1.01%for V_3. By comparing 60 and 90 seconds, there was bran removal of 1.02% for variety V_1, 0.97% for variety V_2, and 0.78% for variety V_3. As the time of milling increase the polish percentage increased.

The regression equations for milling yield at different time of milling for variety V_1 was developed as $y = 0.048x + 0.187$, giving $R^2 = 0.985$ and for variety V_2 was developed as $y = 0.050x + 0.249$, giving $R^2 = 0.977$ and for the varieties V_3 equation were developed as $y = 0.035x + 0.16$, giving $R^2 = 0.983$. The graphical representation of degree of polish is shown in fig. 4.

It was found that as the time of milling increased, the percentage of bran removal increased. These equations indicate that degree of polish for same time of milling is maximum in variety V_2 and minimum in variety V_3, the results are in agreement with Sison *et al.*, (2006) [10] and Dhillon *et al.*, (2014) [1]

MRY and HRY are significantly depend on the physical quality of rough rice kernels and degree to which bran is removed during milling Sison *et al.*, (2006) [10]. Degree of polishing results loss in nutritional quality of rice reported by Jagbir *et al.*, (2017) [4]

The following models were developed

For variety PB-1 the degree of polish is expressed as
HRR=0.048TOM+0.187……………………………..V_1

For variety P-1460 the degree of polish is expressed as
HRR=0.050TOM+0.249…………………………….V_2

For variety Kshatriya the degree of polish is expressed as
HRR=0.035TOM+0.16………………………………..V_3

Where
DOP = Degree of polish
TOM = Time of milling

Table 4: Effect of time of milling on degree of polish

Varieties	Time of milling (sec)				Mean
	0	30	60	90	
PB-1	0	1.81	3.33	4.35	2.37
P-1460	0	2.00	3.57	4.54	2.52
Kshatriya	0	1.39	2.40	3.18	1.74
Mean	0	1.73	3.10	4.02	

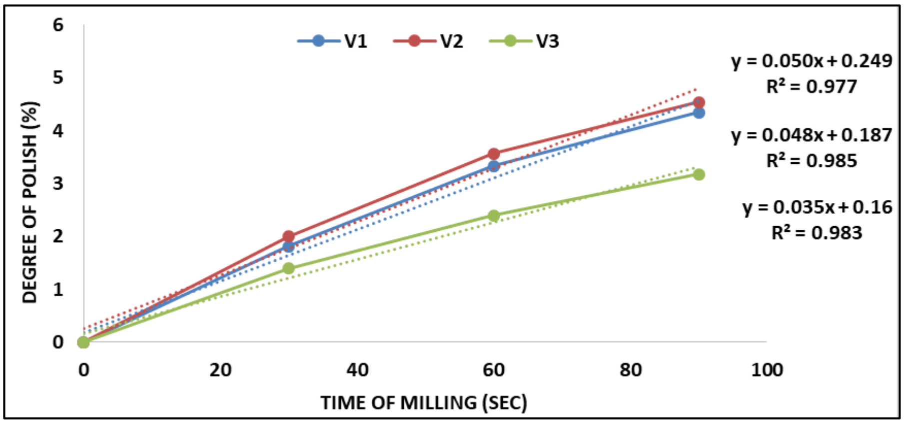

Fig 4: Effect of time of milling on degree of polish (V_1= Pusa basmati-1, V_2= Pusa-1460, V_3=Kshatriya)

4. Conclusions
Varietal influence on head rice, brokens and total milling yield was studied and the results are as follows:
1. The maximum head rice recovery (56.9, 54.3, 50.8%) was observed in Kshatriya followed by Pusa basmati-1(53.6, 51.3, 47.5%), Pusa-1460 (50.5, 47.8, 43.7%) for 30, 60 and 90s time of milling respectively.
2. The minimum broken (16.6, 18.3, 20.6%) was observed in Pusa basmati-1 followed by Kshatriya (16.6, 18.3, 20.6%) and P-1460 (22.8, 25.1, 27.8%) for 30, 60 and 90s time of milling respectively.
3. Maximum total yield was observed in Kshatriya (77.5, 77.1, 76.1%) followed by P-1460(73.3, 72.9, 71.5%) and Pusa basmati-1 (70.2, 69.6, 68.1%) for 30, 60 and 90s time of milling respectively.

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