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Effect of Hybrid Greenhouse Drying on Milling Quality of Rough Rice

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A B S T R A C T

Paddy drying experiments were conducted in Solar greenhouse dryer during paddy growing seasons namely *kharif* and *Rabi* at three different bed thicknesses (5, 10 and 15 cm). Milling quality analysis showed that there was no significant effect of season, replication and interaction of season and thickness on brown rice yield, milling recovery and head rice yield, however, grain bed thickness had a significant effect at 5% significant level. Highest head rice yield of 66.4% was achieved at 10 cm bed thickness, as compared to 62.9% and 65.4% for 5 and 15 cm beds thickness, respectively. Broken rice obtained was 3.66% during *Kharif* season which was significantly lower than that the broken rice (5.11%) obtained during the *Rabi* season. Head rice yield in the greenhouse dryer was much higher than mechanical drying (63.5%) and open sun drying (62.91%). The highest germination percentage (90%) was achieved during *Kharif* paddy drying and there was no significant difference in germination among greenhouse and open sun drying at 5% significant level.

Keywords

Greenhouse drying, paddy drying, head rice yield, brown rice yield, milling recovery, statistical analysis.

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Introduction

Rice is the dominant staple food crop in India. Andhra Pradesh is the third largest rice producing state in India, paddy is cultivated about one-fourth of the total cropped area of the state. Andhra Pradesh is contributing 12% of rice production with 9.08% rice cultivated area (http://agricoop.ni.in). Indian rice identified as one of the major commodity for export and become highly competitive in the international trade. It was estimated that about 9% of paddy is lost due to use of improper post-harvest operations such as drying and milling, unscientific methods of storage, transport and handling (Basavaraj *et al.*, 2015).

Drying of food grains aids in substantial reduction of weight and volume, reduces storage, packing and handling costs and prolongs shelf life of the product under ambient conditions. About 13-14% moisture content (w.b.) is considered as optimum for safe storage and milling, with minimum of fungus and insect attack (Bonazzi, *et al.,* 1997, Hall, 1970). Studies on rough rice drying have revealed that drying can affect quality parameters of the product which in turn would affect the consumer acceptability of the rice (Wiset *et al.*, 2001).

Traditional method of sun drying is still popular method of drying in developing countries as it fits into the cultural, technological and economic situation of small farmers and medium-scale rice millers and traders. Disadvantages such as reliability on weather, uncontrolled grains heating, breakage of grins during milling, losses due to rodents and birds etc. are remains with this method. Drying of food grains usually carried out using heated air for commercial-scale drying. Mechanical dryers using hot air for faster drying of food grain are becoming popular but the cost of drying is major concern (Soponronnarit *et al.*, 1996).

To enhance the quality and to minimize post-harvest losses of food grains, drying in enclosed structures by active ventilation is a captivating way (Jain and Tiwari, 2003). Active solar greenhouses use auxiliary energy to move solar heated air across the bed of food material which placed inside the greenhouse dryer for more expeditious drying (Svejkovsky, 2006). Consequently, with the incrementing demand for better and higher quality products as well as for more efficient post harvest operations, processing methods and obviation of product degradation is a current challenge for rice processing industry.

Quality of milled rice is a paramount factor to be considered in paddy drying operation. Research studies were not available on milling quality of rice dried in the greenhouse dryers, Hence, the research work was carried out to study the effect of forced ventilated greenhouse drying on milling quality of rice.

Materials and Methods

Rough rice

Fully matured, combine harvested paddy (Variety: BPT 5204) which is commonly grown in Guntur district of Andhra Pradesh state was used for conducting drying experiments**.**

Drying Methods

Three different drying methods were used for drying of high moisture paddy comparative studies such as open sun drying, hybrid greenhouse dryer and PHTC on farm dryer.

Hybrid Greenhouse Dryer for Drying of Paddy

The PV ventilated hybrid greenhouse dryer was designed, fabricated and evaluated for paddy drying (Madhava *et al.*, 2017). A greenhouse dryer with 14×7 feet size with 8.5 feet height size was constructed using 50.8×25.4 mm MS pipe, 19×30.2 mm MS angles. Clear twin wall polycarbonate sheet with 6 mm thick was used insulate the greenhouse dryer structure (Fig.1). The drying chamber of the solar greenhouse dryer is divided into multiple tires. The trays were used for holding the paddy inside the drying chamber in two rows and three tires. Forced ventilation was provided with 9 inch diameter, 1200 rpm, 40 watt powered DC power operated exhaust fan. The two no 150 watt power capacity solar photovoltaic panels with 18.5 V rated voltage and 8.10 A rated current was used to drive the DC Exhaust fans.

Forced ventilation greenhouse drying experiments were carried out between 9:00 and 17:00 h. Fresh harvested paddy was filled in the trays uniformly up to the predetermined bed thickness (5,10, 15 cm). Trays were placed in the greenhouse dryer in three tiers and two rows. Each tier such as bottom, middle and top has six trays. Trays were undisturbed till the drying process completed. Paddy was agitated manually in the individual trays for every two hours to get uniform drying.

During night time greenhouse was closed and exhaust fans were stopped to aid tempering and prevent entry of moist air from outside to greenhouse. Drying was continued till 14%(w.b.) moisture content is reached(Madhava *et al.,* 2019).

Open sun drying

Open sun drying experiments were carried between 9:00 and 17:00 h. Paddy in a single layer was spread on plastic sheet with different thicknesses (5, 10& 15 cm). After 17.00 hour, the paddy was heaped up and covered with the LDPE plastic sheet to avoid absorption of moisture during night time. Drying was continued till 14 %(w.b.) moisture content is reached(Madhava *et al.,* 2019).

Mechanical drying

For comparative drying cost “on-farm paddy dryer for high moisture paddy” developed by post harvest technology centre, Bapatla and Kardi dryers (P) ltd, Chennai was used.

It is a flat bed type 5 tonnes capacity dryer. Duel fuel burner (kerosene or diesel) with indirect fired heat exchanger used for air heating. Centrifugal blower with 7.5 HP is used to force the air through grain.

Milling of Paddy

Dried paddy samples were sealed in polythene bags and stored at ambient conditions for a month. The rational was to assess the quality of the paddy after being dried for the storage period.

Number of literature indicated that cracking of dried paddy will be high immediately after drying but reduces as time goes on (Wongpornchai *et al.*, 2004, Sharma *et al.*, 1982 and Minkah, 2006)

Milling of dried paddy involved three stages: dehusking, polishing and grading. Milling was carried out at College of agricultural engineering, Bapatla.

Dried paddy samples were taken from different places (from top, middle and bottom trays), mixed and portioned such that the samples would represent the whole drying experiment for analysis.

The samples were sealed in plastic bags and stored at ambient temperature. The 150 grams of sample was used from each treatment and shelled using laboratory scale rubber roll de-husker (Make: Kartar) and obtained brown rice.

Brown rice was again weighed before being fed into the laboratory model rice polisher (Make: INDOSAW) to obtain polished rice, the weight of which was also taken to be used for the determination of head rice.

Polisher was set to low-medium whiteness level. An average time of 15 sec was used for each polishing process. Laboratory model rice grader (Make: AGROSAW) was used to separate the broken rice kernels from the whole rice after milling. The 3.2 mm screen size was used for separation of broken rice. Whole rice and the broken rice were weighed and recorded.

Analysis of Milling Data

The main quality parameters for milled rice such as Milling Recovery (MR), Brown rice yield (BRY), Head Rice Yield (HRY) and Broken Rice (BR) was calculated.

Brown rice yield

Brown rice yield was calculated as follows

$$\text{Brown rice yield, \%} = \frac{\text{Weight of brown rice}}{\text{Weight of dried paddy sample}} \times 100$$

Milling recovery

Using an abrasive whitener milled the dehulled samples. Computed milling recovery (MR) by dividing the weight of milled rice recovered by the weight of the paddy sample.

$$\text{Milling Recovery, \%} = \frac{\text{Amount of milled rice(head rice + broken rice)}}{\text{Weight of dried paddy sample}} \times 100$$

Head rice yield and broken rice

Head rice refers to the milled rice of ¾ or more of an actual kernel size. It is different from whole rice as any size kernel doesn't come in whole rice kernel category. Head rice recovery is the total fraction of weight of head rice in total weight of milled rice. Using a grain grader, broken grains were separated from the whole grains. The percentage of the head rice yield was computed using the following equation

$$\text{Head rice yield, \%} = \frac{\text{Weight of head rice}}{\text{Total paddy weight}} X100$$

Broken rice yield

Rice kernels which are lesser than three-fourth of the actual kernel size are called as broken rice. Broken rice percentage is the fraction of weight of total broken rice in total weight of milled rice (Karim *et al.*, 2002). It is given by:

$$\text{Broken rice, \%} = \frac{\text{Weight of broken rice}}{\text{Total paddy weight}} X100$$

It has been observed that 5-7% of kernels remain unhulled after dehulling with a rubber roller de-husker. These unhulled kernels are generally considered as part of the brown rice fraction, but may be manually separated, as dictated by further analysis requirements. Other fractions, such as hulls or bran, may be calculated as a percentage of rough rice in the same manner.

Statistical Analysis

Two factor experiments in factorial design were employed for the statistical analysis. To calculate the mean values, standard error mean (SEM) and analysis of variance of brown rice yield, head rice yield, milling recovery and broken rice percentage, the statistical software package SPSSv16 version was used. Duncan's Multiple Range Test (DMRT) analysis was employed for determination the differences in rice quality parameters among the drying treatments.

Effect of drying on germination of paddy seed

Germination test was conducted top-of-paper method (Agarwal, 2016). In this method absorbent paper was used as substrate, paper was cut in to size of Petri dish, sufficient moisture was added to moisten the paper, placed the randomly selected seed uniformly on the paper was used and covered with cap, counted the no of seeds germinated after 5 days and expressed in percentage. Paddy germination test was conducted to paddy dried at 10 cm bed thickness in greenhouse drying and open sun drying in both the seasons.

Results and Discussion

The brown rice yield (BRY), milling recovery (MR), head rice yield (HRY) and broken rice percentage (BR) was calculated and shown in the Table 1.

Brown Rice Yield

Brown rice yield (BRY) was calculated as ratio of mass of brown rice obtained to the total mass of rough rice and presented in the Table 1. Statistical analysis of the brown rice yield (Table 2) showed that, the mean of brown rice yield was 76.363% and 76.97% *Kharif* and *Rabi* seasons respectively. It was found that, the two factorial design was effectively used for analysing the brown rice yield. There was no significant effect of season (p=0.337), replication (p=0.767) and interaction of season and depth (p=0.949) on brown rice yield, however grain bed thickness has the significant effect on the brown rice yield (p=0.002) at 5% significant level. Highest brown rice yield achieved was 78.5% in 10 cm bed thickness, as compared to 74.8% and 76.7% in 5 and 15 cm bed thickness respectively. BRY was slightly higher in greenhouse drying as compared to open sun drying (OSD) at respective bed thickness. These results are in accordance with the results reported by, Wiset, 2001.

Head Rice Yield

The head rice yield (HRY) was calculated as ratio of mass of whole white rice kernel obtained to the total mass of rough rice. Head rice was considered as kernels that remained at least three fourth of the original kernel length after milling. Percentages of head rice yield obtained from the hybrid greenhouse dryer and open sun drying is shown in the Table 1.

Fig.1 Fabricated hybrid greenhouse dryer

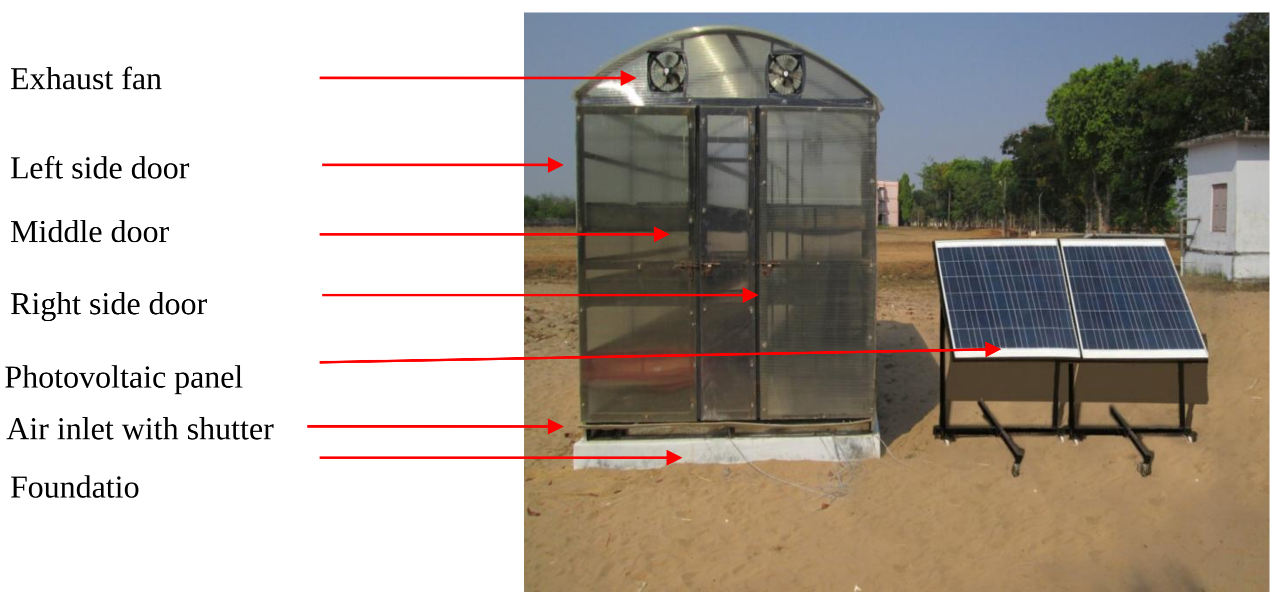

Table.1 Effect of season and bed thickness on rice milling quality

	Paddy weight (g)	Milled rice (g)	Brown rice (g)	Head rice (g)	Broken rice (g)	BRY (%)	MR (%)	HRY (%)	BR (%)
***Kharif* paddy**									
GH5 b	150	99.61	111.92	92.23	6.60	74.62	66.41	61.49	4.9
GH5 m	150	102.77	113.44	99.00	3.30	75.62	68.52	66.00	2.5
GH5 t	150	99.64	110.34	93.10	5.90	73.56	66.42	62.07	4.4
GH 5 cm	**150**	**100.67**	**111.90**	**94.78**	**5.27**	**74.60**	**67.12**	**63.19**	**3.93**
OSD 5cm	**150**	**99.80**	**111.63**	**92.65**	**6.40**	**74.42**	**66.53**	**61.77**	**4.8**
GH10 b	150	105.33	118.77	99.41	4.99	79.18	70.22	66.27	3.9
GH10 m	150	105.42	115.10	102.11	2.89	76.73	70.28	68.07	2.2
GH10 t	150	107.96	117.61	100.20	6.60	78.41	71.98	66.80	5.2
GH 10	**150**	**106.24**	**117.16**	**100.57**	**4.83**	**78.10**	**70.83**	**67.05**	**3.78**
OSD 10	**150**	**103.99**	**117.23**	**93.08**	**9.30**	**78.16**	**69.32**	**62.06**	**7.3**
GH15 b	150	104.85	117.15	100.07	4.10	78.10	69.90	66.72	3.2
GH15 m	150	102.66	113.31	98.91	3.30	75.54	68.44	65.94	2.5
GH15 t	150	102.84	113.26	96.71	5.40	75.51	68.56	64.47	4.1
GH 15	**150**	**103.45**	**114.58**	**98.57**	**4.27**	**76.38**	**68.97**	**65.71**	**3.26**
OSD 15	**150**	**102.15**	**114.26**	**94.83**	**6.40**	**76.17**	**68.10**	**63.22**	**4.9**
***Rabi* Paddy**									
GH5 b	150	101.28	110.45	93.39	7.89	73.63	67.52	62.26	5.3
GH5 m	150	104.56	115.35	96.36	8.20	76.90	69.71	64.24	5.5
GH5 t	150	101.02	111.41	92.39	8.63	74.27	67.35	61.59	5.8
GH 5	**150**	**102.29**	**112.40**	**94.05**	**8.24**	**74.94**	**68.19**	**62.70**	**5.5**
OSD 5	**150**	**100.22**	**110.32**	**91.29**	**8.93**	**73.55**	**66.81**	**60.86**	**6.0**
GH10 b	150	106.34	117.76	100.07	6.26	78.51	70.89	66.72	4.2
GH10 m	150	107.94	118.75	98.91	9.03	79.16	71.96	65.94	6.0
GH10 t	150	106.99	118.48	96.71	10.28	78.99	71.32	64.47	6.9
GH 10	**150**	**107.09**	**118.33**	**98.57**	**8.52**	**78.89**	**71.39**	**65.71**	**5.7**
OSD 10	**150**	**105.30**	**117.13**	**94.83**	**10.46**	**78.08**	**70.20**	**63.22**	**7.0**
GH15 b	150	104.35	116.30	98.71	5.64	77.53	69.57	65.81	3.8
GH15 m	150	103.62	114.26	97.13	6.49	76.17	69.08	64.75	4.3
GH15 t	150	103.38	116.35	97.08	6.30	77.57	68.92	64.72	4.2
GH 15	**150**	**103.78**	**115.64**	**97.64**	**6.14**	**77.09**	**69.19**	**65.09**	**4.10**
OSD 15	**150**	**102.52**	**113.80**	**95.41**	**7.11**	**75.87**	**68.35**	**63.61**	**4.7**

GH- greenhouse drying, OSD- Open sun drying, 5,10&15 indicates bed thickness, b,m&t indicates bottom, middle and top tyres in the greenhouse.

Table.2 Effect of bed thickness and season on BRY, MR, HRY and BR

	BRY	MR	HRY	BR
5cm	74.7667a	67.6550[a]	62.9417[a]	4.7333[a]
10cm	78.4967[c]	71.1083[c]	66.3783[b]	4.7333[a]
15cm	76.7367[b]	69.0783[b]	65.4017[b]	3.6833[a]
Kharif	76.363	68.97	65.314	3.66[a]
Rabi	76.970	69.59	64.500	5.11[b]

Table.3 Comparison of head rice yield among different methods of drying

Drying method	HRY, %
Open sun drying	62.91
Greenhouse drying	65.40
Mechanical drying	63.50

Table.4 Seed germination percentage of greenhouse dried paddy

	Greenhouse drying (%)	Open sun drying (%)
Kharif	90	86
Rabi	87	85

Statistical analysis head rice yield (Table 2) data showed that there was no significant effect of season (p = 0.172), replication (p = 0.069) and interaction of season and depth (p = 0. 801) on head rice yield, however grain bed thickness has the significant effect on the head rice yield (p=0.001) at 5% significant level. Highest head rice yield achieved was 66.4% in 10 cm bed thickness, as compared to 62.9 % and 65.4% in 5 and 15 cm bed thickness respectively. HRY was significantly higher in greenhouse drying as compared to open sun drying (OSD) at respective bed thickness. There was significant difference ($p \leq 0.05$) observed in the HRY between the hybrid solar greenhouse dried paddy and open sun dried paddy. Results are inline with the results reported by Alam and Sehgal, 2014, Mehdizadeh and Zomorodian, 2009 and Ibrahim *et al.*, 2014.

Milling Recovery

Milling recovery (MR) which includes head rice and broken rice was found to vary between 67.7 to 71.1% in greenhouse dryer. Percentages of milling recovery obtained from the solar greenhouse dryer and open sun drying is shown in the Table 1. Statistical analysis of milling recovery (Table 2) data showed that there was no significant effect of season (p=0.2), replication (p=0.509) and interaction of season and depth (p=0. 747) on milling recovery. However grain bed thickness has the significant effect on the head rice yield (p=0.000) at 5% significant level. Highest head rice yield achieved was 71.1% in 10 cm bed thickness, as compared to 67.7% and 69.1% in 5 and 15 cm bed thickness respectively. MR was significantly higher in greenhouse drying as compared to open sun drying (OSD) at respective bed thickness.

Results are in agreement with the results reported by Ibrahim *et al.*, 2014. The milling recovery more specifically graded rice (mixing of head rice yield and 15% broken rice) is usually used by the milling industry to estimate the milling results which might not be the proper parameter.

Therefore, head rice yield is suggested to be considered for evaluating the milling performance of the dryer (Ibrahim *et al.*, 2014).

Broken rice

Percentage of broken rice obtained during milling of hybrid greenhouse dried and open sun dried paddy is shown in the Table 1. Statistical analysis of percentage of broken rice data (Table 2) showed that there was no significant effect of grain bed thickness (p=0.11), replication (p=0.086) and interaction of season and depth (p=0. 596) on broken rice percentage.

However grain drying season has the significant effect on the head rice yield (p=0.006) at 5% significant level. Broken rice percentage varied in the range of 3.7-4.7% at different bed thickness. The mean of the broken rice obtained was 3.66% in *Kharif* season which was significantly lower that the broken rice obtained during *Rabi* season (5.11%). Broken rice was significantly higher in open sun drying (OSD) as compared to hybrid greenhouse drying at respective bed thickness. Results are in agreement with the results reported by Ibrahim *et al.*, 2014.

Sun drying is shown in the Table 2. Statistical analysis head rice yield (Table 2) data showed that there was no significant effect of season (p=0.172), replication (p=0.069) and interaction of season and depth (p=0.801) on head rice yield, however grain bed thickness has the significant effect on the head rice yield (p=0.001) at 5% significant level. Highest head rice yield achieved was 66.4% in 10 cm bed thickness, as compared to 62.9 % and 65.4% in 5 and 15 cm bed thickness respectively. HRY was significantly higher in greenhouse drying as compared to open sun drying (OSD) at respective bed thickness. Significant difference ($p \leq 0.05$) in the HRY between the forced ventilated solar greenhouses dried samples and open sun drying samples. Results are inline with the results reported by Alam and Sehgal, 2014, Ibrahim *et al.*, 2014.

Seasonal Variation in Milling Yield

Statistical analysis of milling yield among different seasons showed that, there was significant variation in brown rice yield, milling recovery and head rice yield at 5% significant level (Table 2).

However, there was significant variation in broken rice. Broken rice percentage was more during *Rabi* (5.11%) as compared to *Kharif* (3.66%).Broken rice was more during *Rabi* season may be due to higher greenhouse air temperature.

Comparison of Milling Yield among Different Methods of Drying

The head rice yield of paddy has been compared among the different methods of drying and shown in the Table 3. It was revealed that the head rice yield in greenhouse drying is 65.40% which is higher than mechanical drying method (63.5%) and Open sun drying method (62.91%).

Germination quality of greenhouse dried paddy

Germination test was conducted for greenhouse dried and open sundried paddy dried during *Kharif* and *Rabi* seasons. The average germination percentage was calculated and presented in Table 4. It was revealed that the germination percentage was slightly higher for greenhouse dried paddy compared to sun drying during both *Kharif* and *Rabi* seasons. Highest germination percentage obtained was 90% during *Kharif* paddy drying in greenhouse. Statistical analysis (t-test) showed that there was no significant difference in germination percentage among greenhouse and open sun dried paddy at 5% significant level. This concludes that drying does not impair germination of the seed. These results are in line with the results reported by Gill *et al.*, 2014. Hybrid greenhouse dryer can be employed for drying of paddy. Milling quality analysis showed that there was no significant effect of season, replication and interaction of season and thickness on brown rice yield, milling recovery and head rice yield, however, grain bed thickness had a significant effect at 5% significant level. The highest germination was achieved during *Kharif* paddy drying in hybrid greenhouse dryer and there was no significant difference in germination among greenhouse and open sun drying at 5% significant level

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