Post-harvest Losses of Rice in Paro Valley

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ABSTRACT

Rice production in Bhutan was recorded at 86,385t in 2017 with self-sufficiency estimated at 45%. The current post-harvest loss of rice in Bhutan is estimated as high as 30%. Addressing post-harvest losses in rice through poor post-harvest handling and management of rice crop can significantly increase rice availability. Apparently, there is insufficient data on post-harvest losses of rice at different stages of post-harvest operations in Bhutan. For an effective reduction in losses, it is imperative to estimate the losses and the stages at which they occur. This study was conducted in Paro, which is one of the main rice growing districts in Bhutan. The study was aimed to assess the post-harvest losses in rice during harvesting, in field drying, in field transportation of harvested paddy to threshing floorand threshing process.Five commonly grown rice varieties (No. 11, Yusi Ray Maap-2, Yusi Raykaap-2, KhangmaMaap and Dum Ja (local) were assessed to determine the losses occurring during the different post-harvest operations. The total post-harvest loss, irrespective of the different varieties is estimated at 5.50% of the total production. The Dum Ja variety exhibited the maximum post-harvest loss of 11.60 % of the total production, while the No. 11 variety exhibited the minimum post-harvest loss of 1.33% of the total production.

Keywords: *Post-harvest loss, Rice varieties, Self-sufficiency*

1. Introduction

Rice (*Oryza sativa* L.) is the main staple food crop of the Bhutanese with per capita consumption of 172 kg per year and the current rice self-sufficiency in the country is estimated at 45% (Gautam et al., 2013). Rice is cultivated in all agro-ecological zones of Bhutan except the alpine zone in the north. The crop is grown at an elevation of 200 meter above sea level in the southern foothills to 2800 meter above sea level in the north (Shrestha, 2004). The mainrice growing districts by production are Punakha, Paro, Wangdue, Dagana, Sarpang, and Tsirang. Lhuntse, Samdrup Jongkhar and Tashigang are the other main rice producing dzongkhags in Bhutan (MoAF, 2017). Rice in Bhutan is cultivated under both irrigated and rain-fed systems (Chhogyel, Ghimiray, Wangdue & Bajgai., 2015).

Rice production in Bhutan was recorded at 83,332 t and 86,385 t in the year 2016 and 2017, respectively (RNR statistics, 2017). To achieve 60% rice self-sufficiency in the 12th FYP, the

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Department of Agriculture is assertively promoting high altitude and spring paddy cultivation across the country (Karchung, 2017; Gautam et al., 2013).

This preliminary study on post-harvest losses of rice grain in Bhutan with focus in Paro dzongkhag (district) was conducted to obtain the baseline data on post-harvest losses. The data on post harvest losses then could be used to develop interventions required to reduce losses at different stages of post harvest handling that could contribute to rice self sufficiency.

Rice availability can be improved by increasing production, introducing improved varieties, improving distribution, and reducing losses. Reduction of post-harvest losses in rice is an essential factor in safeguarding future global food security and it has been estimated that almost one third (1.3 billion t) of global rice production is lost annually (FAO, 2015). Poor methods of harvesting and handling of the produce, use of inappropriate container while packaging, poor storage conditions, poor transportation and distribution system are some of the major factors contributing to these losses (Kiaya, 2014). The constraints in cultivating rice in Bhutan are low soil fertility, prevalence of pest and diseases, cold temperature and high labour requirement (MoAF, 2001).

Proper post-harvest management techniques can be applied to reduce the post-harvest loss in rice. Timely harvest of paddy at optimal moisture percentage is critical. The right stage for harvesting paddy is when about 80% panicles have about 80% ripened spikelet. At the time of harvest the upper portion of the spikelet should be straw coloured and grain should have 20% moisture content (Guisse, 2010). While early harvest lead to immature grain, deterioration of quality and broken rice during milling, delay in harvesting will result in grain loss caused by rodents, pests, shattering and lodging (Guisse, 2010). Use of suitable technique while harvesting and avoiding too much drying, fast drying and wetting of grains can help in significant reduction of post-harvest loss in rice (Kader, 2002). The losses in threshing and winnowing can be minimized using improved mechanical methods. Proper storage after milling can help in minimizing losses caused by rodents and pests (Patil, 2011). Effective post-harvest handling and management of the crop can help in minimizing rice imports and achieving rice self sufficiency in the country. For effective reduction in loss of rice, it is essential to assess and estimate the post-harvest loss in rice occurring during the different stages of post-harvest operations in rice (Appiah, Guisse & Darty, 2011).

2. Materials and Methods

2.1 Survey area and data collection

This study was carried out in the rice growing areas within Paro dzongkhagduring the paddy harvesting season in October 2017 using questionnaire through random sampling technique. Five rice varieties (*No. 11, Yusi Ray Maap-2, Yusi Raykaap-2, Khangma Maap and Dum Ja (local)* commonly cultivated by the farmers in the study area was selected for data collection and field experiment.

Paddy plots were divided into quadrants (1 m × 1 m) and the harvesting losses were determined from each quadrant. Samples from same plot were used for losses for in-field drying, in-field transportation and threshing losses.

2.2 Determination of post-harvest losses

The post-harvest loss of rice in the study area was determined by collecting the data from different post-harvest handling operations of the rice viz. harvesting, in-field drying, in-field transportation and threshing.

2.3 Determining moisture content (MC) of paddy

The moisture content of the paddy grains was measured one day prior to harvesting. Five hills of paddy harvested from a plot were randomly picked and moisture content was measured using moisture tester (Riceter f506, Kett Electric Laboratory, Tokyo, Japan).

2.4 Determining maturity of the paddy

The matured paddy grains were calculated using the total number of grains and total immature grains. Maturity of the paddy grains at the time of harvesting in the study area was determined using following formula:

$$\%\ Maturity = Total\ no.\ of matured\ grains \div Total\ no.\ of grains \times 100$$

2.5 Determination of harvesting losses (HL)

Harvesting losses (HL) is loss of paddy grains from/or during the time of harvesting. Harvesting losses were determined according to the method adapted from Badawi (2003). Farmers were allowed to harvest the paddy using harvesting sickles. Leftover grains from each quadrant (on the ground and from standing plants) were collected, cleaned, dried and weighed and harvesting loss percent was calculated as below:

$$\%\ HL = Left\ over\ grains \div Total\ harvested\ paddy \times 100$$

2.6 Determination of infield drying losses (DL)

Farmers normally dry their paddy in the fields after harvesting for two-three days before stacking and threshing. The fallen grains from the sampling plots were collected, cleaned, dried and weighed. The percentage of in-filed drying loss was calculated using the following equation:

$$\%\ SL = Weight\ of fallen\ grains \div Total\ weight\ of\ harvested\ grains \times 100$$

2.7 Determination of in field transportation losses (TrL)

The dried paddy hills are then stacked in place before threshing in the field. To determine the infield transportation loss, the weight of the grains before transporting and the weight of the grains after reaching the stacking point were recorded and then expressed as:

$$\% \text{ TrL} = \text{Weight of the grains after transportation} \div \text{Initial weight of the grains to be transported} \times 100$$

2.8 Determination of threshing losses (TL)

The stacked paddy was threshed after two-three days in favorable sunny weather. Two kinds of threshing methods are currently used by Bhutanese farmers viz. pedal/power thresher and beating of rice stalk on wood or stone with tarpaulin sheet beneath. Threshing of the grains at the chosen study site was done with the latter technique. The amount of rice grains that fell outside the threshing area as well as those left on the rice stalks were weighed and accounted into threshing loss. The percent threshing loss was then determined as below:

$$\% \text{ TL} = \text{Weight of left over grains} \div \text{Total weight of collected grains} \times 100$$

2.9 Total post-harvest loss (TPL)

The total post harvest losses of rice grains in this study are the cumulative of losses from harvesting, in field drying, and in field transportation and threshing. A sum of losses at these post-harvest handling operations gave the total post harvest losses as given in the following equation:

$$\text{TPL} = \text{Harvesting losses} + \text{in field drying losses} + \text{in field transportation losses} + \text{Threshing losses}$$

3. Results and Discussion

3.1 Moisture content

The moisture content of the paddy grains before harvesting and at the time of threshing was measured to understand the maturity and the dryness of the grains for further processing. The moisture content of the grains varied among the varieties at the time of harvesting (Table 1). Among the varieties, Bajo No. 11 recorded the highest moisture content while Dum Ja (Local variety) recorded the lowest at 14.19%.

Table 1.Moisture content of the rice grains at the time of harvesting and threshing

Variety	Moisture content at harvest (%)	Moisture content at threshing (%)
No. 11	22.85	15.30
Dum Ja (Local)	14.19	11.35
Khangma Maap	23.20	14.25
Yusi Ray Maap -2	18.71	14.20
Yusi Ray kaap - 2	17.50	15.60
Mean	20.55	14.29

At the time of harvesting, the moisture content in all the varieties reduced significantly, indicating that the paddy grains were threshed at the optimum moisture level. The optimum moisture content for the rice grain storage is between 10 to 15% (Juliano, 1985). This indicates the farmers were not only harvesting the paddy grains at the right stage in terms of moisture content, but also the paddy grains were dried sufficiently in the field before threshing and storage.

3.2 Maturity of the grains

Maturity of the paddy grains was also measured day before harvesting according to the method previously discussed. The maturity was measured in terms of percentage. At the time of harvesting, the maturity percentage was slightly different among few of the rice varieties as shown in Table 2. Harvesting rice immediately after the cessation of biological maturity ensures maximum yield and better milling characteristics (Sarkar, Datta & Chattopadhyay, 2013). Too early harvest results in more chaff and ill-filled grains while delayed harvest results in low yield as the crop suffers various pre-harvest losses and milling quality is impaired.

Table 2.Maturity percent of the rice varieties at the time of harvesting

Rice Varieties	Maturity (%)
No. 11	87.17 ± 10.37^{ab}
Dum Ja (Local)	100.00 ± 0.00^{a}
Khangma Maap	74.63 ± 20.81^{b}
Yusi Ray Kaap 2	88.02 ± 1.87^{ab}
Yusi Ray Maap 2	91.88 ± 8.10^{ab}

The lowest maturity percentage was determined in the variety Khangma Maap while 100% maturity was recorded from another local variety (Dum Ja). This indicates that the former was slightly prematurely harvested while the latter was harvested at full maturity. Harvesting the grains at the right maturity will have impact on the shelf life and quality of the grains during post-harvest handling operations (Yang & Zhang, 2010). If grain were harvested prior to its physiological maturity, it would have low drymatter, poor quality grains and will shrivel upon drying (Kester et al., 1963).

3.3 Harvesting losses

Between the rice varieties no significant difference in losses was observed during harvesting operation. Harvesting losses was observed below one percent for all the varieties as shown in Table 3. Harvesting loss was highest in Yusi Ray Kaap 2 at 0.74% of the total harvested grains while Yusi Ray Maap 2 recorded lowest harvesting loss at 0.15% (Table 3).

3.4 In-field drying losses

Drying losses among the varieties was in the range of 0.246 to 1.084 with Yusi Ray Maap 2 recording lowest drying loss (0.024%) with statistically significant difference from other varieties ($p < 0.05$).

3.5 In-field transportation losses

Yusi Ray Kaap 2 recorded highest in-field transportation losses (1.124%) while No. 11 had minimum losses (0.145%) with significant differences ($p < 0.05$).

3.6 Threshing losses

Threshing losses was highest in the Dum Ja variety (9.31%) with statistically significant difference compared to all other varieties. The remaining varieties of rice recorded threshing losses in the range of 0.38% to 2.82%. A significant portion of losses occurs during the threshing operations compared to other post-harvest operations as per this study. Interventions with improvised methods of threshing in this stage of post-harvest handling operation could result in lowering the threshing loss and thus reduce the total post-harvest loss.

The percentage losses of rice in different stages of post-harvest operations were also determined for each variety of rice (five varieties) as shown in table 4. For No. 11, there was no significant difference in the percent losses of rice at different stages (0.14% - 0.70%).

For the other rice varieties (Dum Ja, Khangma Maap, Yusi Ray Kaap 2, Yusi Ray Maap 2), there was no significant difference in losses between harvesting, drying and in-field transportation stages. The percent losses during threshing of rice were statistically higher for all these varieties (Dum Ja, KhangmaMaap, Yusi Ray Kaap 2, Yusi Ray Maap 2) compared to harvesting, drying and in-field transportation operations. The mean of all the rice varieties included in the study also showed significantly higher threshing losses (5.69%) compared to harvesting (0.47%), drying (0.66%) and in-field transportation (0.72%).

Table 3.Percent post-harvest losses of rice at different stages of post-harvest operations between different varieties of rice in Paro

Rice Varieties	Harvesting loss (%)	Drying loss (%)	In-field transportation loss (%)	Threshing loss (%)
No. 11	0.706±0.934[a]	0.089±0.090[b]	0.145±0.070[c]	0.389±0.231[b]
Dum Ja (Local)	0.464±0.101[a]	0.904±0.218[a]	0.927±0.208[ab]	9.313±4.003[a]
Khnagma Maap	0.303±0.174[a]	1.000±0.337[a]	0.738±0.146[b]	2.237±0.825[b]
Yusi Ray Kaap 2	0.741±0.101[a]	1.084±0.258[a]	1.134±0.139[a]	2.823±0.585[b]
Yusi Ray Maap 2	0.159±0.056[a]	0.246±0.064[b]	0.672±0.225[b]	2.097±1.169[b]

Mean values within the column with different superscript are significantly different between the varieties at $p < 0.05$ by Tukey's test (Mean ± SD, n=5)

Table 4.Comparison of losses of rice at different stages of post-harvest operations among the varieties

Rice Varieties	Harvesting loss (%)	Drying loss (%)	In-field transportation loss (%)	Threshing loss (%)
No. 11	0.706±0.938[A]	0.089±0.090[A]	0.145±0.070[A]	0.389±0.231[A]
Dum Ja	0.464±0.101[B]	0.904±0.218[B]	0.927±0.208[B]	9.313±4.003[A]
Khangma Maap	0.303±0.174[B]	1.000±0.337[B]	0.738±0.146[B]	2.237±0.825[A]
Yusi Ray Kaap 2	0.741±0.101[B]	1.084±0.258[B]	1.134±0.139[B]	2.823±0.585[A]
Yusi Ray Maap 2	0.159±0.056[B]	0.247±0.246[B]	0.672±0.225[B]	2.097±1.169[A]

Mean values within the rows with different capital superscript are significantly different between harvesting operations for each variety at $p < 0.05$ by Tukey's test (Mean ± SD, n=5)

3.6 Total post-harvest loss

The total post-harvest loss of rice grains for all the varieties were calculated as the sum of losses from the post-harvest handling operations. From the five common varieties cultivated by the farmers, only No. 11 showed significantly low percent of total post-harvest loss at 1.33% while Dum Ja (local variety) showed significantly high total post-harvest losses at 11.60%. The total post-harvestloss in remaining varieties ranges from 4.27% in Khangma Maap to 5.23% in Yusi Ray Maap 2 as shown in Table 5.

Table 5.Total post-harvest losses of rice grains

Sl No	Variety	Total post-harvestlosses (%)
1.	No. 11	1.33
2.	Dum Ja (Local)	11.60
3.	Khangma Maap	4.27
4.	Yusi Ray Kaap 2	5.05
5.	Yusi Ray Maap 2	5.23
	Average	5.50

According to FAO (2015) report, the post-harvest losses of rice grains in Southeast Asia is 8% while the post-harvest loss of rice in neighboring Bangladesh is 10% (Nath et al., 2015). Thus, comparing the losses of rice grains in neighboring countries, the findings of this study indicates that 5.50% (Table 4) post-harvest losses of rice in Bhutan (Paro valley) is not significantly high though interventions can be made to further reduce the losses by putting in place proper post-harvest management practices.

4. Conclusion

This study conducted concludes that the post-harvest losses of rice in Paro dzongkhag occurs across all the post-harvest operations involved, irrespective of the varieties. Maximum grain loss occurred during threshing process which contributed the most to the total pot-harvest losses in all the varieties. While some matured grains stay attached to the panicle in the straw during threshing, some grains scatter on the ground, accounting for the total threshing loss. The total post-harvest loss, irrespective of the different varieties accounts to 5.50% of the total production. Dum-Ja variety showed the maximum total post-harvest losses with 11.60% of the total production, while the No. 11 variety exhibited the minimum post-harvest loss of 1.33% of the total production from this study.

The total post-harvest loss of 5.50% in rice is not so alarming. However, considering the country's increase in rice import every year, effective measures have to be put in place to minimize the post-harvest losses in rice. Effective post-harvest handling and management of rice crop includes use of appropriate tools and techniques during harvesting, in-field drying, in-field transportation and threshing. Approaches like awareness campaign and training programs on proper post-harvest handling and management of rice to the growers in the country can also have significant impact. These can not only help minimize losses incurred during the various post-harvest operations but also in reducing rice imports and in achieving rice self sufficiency in the country.

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