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Study of Postharvest Technology Interventions for enhancing food security

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Abstract
This study was conducted to test and install the modified STR dryer and super grain bags to establish post-harvest technology (PHTs) adoption and willingness to pay for PHT in selected villages of Banka and Bhagalpur districts of Bihar, India. It was observed that drying of cereal and pulses crops in STR dryer can remove the moisture up to 2-4 % in 6 to 8 hours of operation with quality retention of food material. The super grain bags were also tested which could arrest the moisture transmission up to some extent which helps in restoring the highest germination rate with better milling quality of paddy. The ample moisture migration and slight variation in lightness in super grain bags could retain the paddy quality than the other packing materials. It was found that farmer 'awareness on post-harvest technologies is increasing, especially on dryer and super grain bags. The study concludes that PHTs have received high acceptance by farmers who have awareness and knowledge. However, the technology uptake is limited mainly by price affordability, availability and proximity. The present study recommends for subsidizing PHT products with manufacturers to reduce the current market price and increase more awareness campaigns through agro dealers, physical visits to farmers and farmers associations to increase demand for PHTs among farmers.

Keywords: *Trainers, Profile of Trainers, training competencies, Constraints in Training Management*

Introduction
Postharvest Loss (PHL) of grains and pulses is expressed as the loss in dry weight and quality, happens during various stages such as at harvesting (4-8%), transportation from farm to home drying process, shelling, winnowing, farm storage (Hodges *et al*., 2014) [1]. It was estimated that farmers loose between 20-30 percent of their annual harvest due to weevils (Tefara, 2012) [3]. In any form, postharvest loss has an impact on farmers' income as farmers' loose quantity and quality of the stored food, which cannot fetch a good market price, and in longer run affect food security. The main causes of postharvest loss for grain is due to improper drying and storage facility which resulting in quality deterioration of grains. Food insecurity is aggravated by postharvest losses. The postharvest loss is defined as the degradation in both quality and quantity of produced foods (Siddiqui *et al*., 2016) [2]. The quality loss involves the effect on the nutrient caloric composition, the acceptability, and the edibility of grains and pulses; whereas, quantity loss refers to loss of the amount of a product. Postharvest losses can be minimized through postharvest management (Makalle, 2012) [4] and adoption to postharvest technologies. Research on postharvest technologies has resulted the in intervention of modified STR dryer and grain storage techniques including super grain bag, hermetic cocoons, metal and plastic silos (Helvetas and Ansaf, 2016) [5]. The adoption of postharvest technologies (PHTs) in India is emerging. The STR dryer & SGB have been introduced in selected villages of Bhagalpur and Banka districts of Bihar under collaborative project between UIUC and BAU, Sabour to reduce postharvest loss and it is slowly getting some acceptance by farmers.

Materials and Methods
The study was conducted in selected villages of Bhagalpur and Banka districts of Bihar, India for rice and lentil crops. A mixed method of quantitative and qualitative data collection was used. A Technology trail and cross-sectional survey questionnaire were conducted to determine the performance and demand by categories of PHTs; preference of PHTs, and willingness to pay for PHTs. Whereas; the qualitative methods used an in-depth interview and Focus Group Discussion (FGDs) for understanding end-users' preference of the PHTs. Two technologies such as STR dryer and Super grain bags were used under this study.

STR Dryer
The STR dryer consists of inner bin, outer bin, hot air pipe, blower (fan) and stove (chula). The dryer is modified with attaching 1 hp motor, provision of gate valve for ambient air entry

and 15° slope at bottom for easy discharge of dried grains. The diameter of outer bin is adjustable to hold desired volume of paddy sample. The dryer is made of two perforated concentric cylinders with grains inside the annular space. Hot air allows to pass from top to bottom through the inner cylinder bin grains inside the annular space. An axial flow blower is used to suck the hot air from the stove (Chula) through iron pipe and force the air radially through perforated bins (Fig. 1). Locally available rice husk briquette is used as fuel in a portable locally made stove.

Parameters observation during drying

Moisture content and temperature were measured from nine locations inside the bin during the operation. Among the nine locations namely T_1…..T_9 and M_1……M_9 respectively. Moisture content at M_1 and M_2 maintaining 45 and 55 cm from centre of inner bin; M_3, M_4, M_5 maintaining 65, 50, 35; M_6, M_7, M_8 and M_9 maintaining a distance of 65, 50, 35 and 65 cm distance from centre line of inner bin during drying operation. The experimental runs of vertical drying were conducted at initial moisture content of 21.5, 22.5, 23.10 and 24.78 % (w.b) with four air velocities (1.5, 2.0, 2.5 and 3.0 m/s). The moisture content was measured using probe sensor digital moisture meter at a time interval of 10 min during first hour of drying, 30 min for second hour and 60 min for third hour till the end of drying. Drying was terminated when the grains reached at Equilibrium moisture content.

Fig 1: Photographic view of modified STR dryer

Fig 2: Super grain bag

Super grain bag

The multi-layer super grain bags (SGB) having a capacity of 50kg was used for the study. The SGB put inside a second bag made of woven polypropylene to give additional protection and strength. The bags were 100 µm thick and measure 34×62 cm in width and length, respectively.

Determination of percentage damage

A random sample of 100 grains of each grain was taken from each storage bag using the cone and quarter method. Bored grains were separated from whole grains and their numbers counted. This was done at 15 days interval and repeated three times for each sub-sample and the value of means taken. The percentage damage was calculated using the formula described by (Duna (2003) [6].

$$\text{Damaged grains}(\%) = \frac{\text{No. of bored grains}}{\text{No. of bored grains}} \times 100$$

Assessment of weight loss

Grain loss bioassay was conducted to determine the damage caused by insects to paddy stored hermetically and to serve as basis for determining the effectiveness of hermetic double bagging technology. The Thousand grain mass (TGM) method was used to determine dry-weight loss (Boxal, 1986) [7]. A sample of 1 kg of each grain variety was taken and sieved to remove all unwanted material and to obtain a working sample. A sub-sample of the working sample was used to determine the moisture content. The moisture content was determined three times and the mean value was recorded. The remaining sample was accurately weighed and the number of grains counted. This was also repeated thrice. The TGM was calculated using the formula:

$$\text{TGM} = \frac{10\text{W}(100 - \text{MC})}{\text{N}}$$

Where, W = weight of sample N = number of grains in sample and MC=moisture content

This was done before storage and repeated five times monthly for six months for each sample stored in the SGB. At the end of each month, the percentage weight loss was determined using the formula:

$$\text{Weight loss, \%} = \frac{(\text{M}_1 - \text{M}_2)}{\text{M}_1} \times 100$$

Where M_1= The TGM of grain at the start of storage.
Mx=The TGM of grain at the time x (i.e. 1, 2 or 6 months).

Colour measurement

Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value and food is no exemption. The overall objective of colour to the food is to make it appealing and recognizable. The most common technique to assess the colour is colorimeter. There are several colour scales used in a Hunter Lab Colorimeter such as L^* a^* and b^* which represented the surface colour. The colour values are obtained as L^* is the lightness coefficient, ranging from 0 (black) to 100 (white), a^* is purple-red (positive a^* value) and blue-green (negative a^* value). a* and b^*, that represents yellow (positive b^* value) or blue (negative b^* value) colour (McGuire, 1992) [8].

Colour of the dried and stored samples paddy were measured using a Hunter Lab Colorimeter. A cylindrical glass sample cup (6.35 cm dia. x 4 cm deep) was placed at the light port (3.175 cm dia). Each sample was measured for colour values three times. The instrument was initially calibrated with a black as well as with standard white plate. From these values chroma (C) was calculated according to following relation as suggested by (Pomeranz and Meloan, 1971) [9]

$$h^0 = \arctan (b^*/a^*)$$

$$C = \sqrt{(a^*)^2 + (b^*)^2}$$

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Where,

$\Delta L^* = L^* - L^*_{st}$
$\Delta a^* = a^* - a^*_{st}$
$\Delta b^* = b^* - b^*_{st}$

Where, st subscript represents L*, a* and b* values of a standard rice & lentil.

Results and Discussion
Performance of dryer
The field performance of modified STR dryer was satisfactory in terms of drying capacity, drying efficiency and milling recovery of dried paddy. Paddy was dried unit it reaches the equilibrium moisture content when no more change in moisture content during drying was observed. The moisture content versus drying time for paddy at selected air velocity is shown in fig 4. It is apparent that moisture content decreases continuously with drying time. The moisture content after 50 min of drying at air velocity of 1.5, 2.0, 2.5 and 3.0 m/s was 11.67, 10.79, 9.76 and 8.31 % (wb) and after 107 min it was found to be 10.09, 9.37, 8.55 and 7.89 % (wb) respectively. The drying times to reach the equilibrium moisture content for paddy were 390, 250 and 210 min at 1.5, 2.0, 2.5 and 3.0 m/s respectively. As indicated in the curves (fig4), there was no constant rate period in drying of paddy. All the drying process occurred in the falling rate period, starting from the initial moisture content of paddy (24.75%, 22.50%, 21.50%, 23.10% wb) to final moisture content (8.5%, 9.0%, 8.75%, and 8.5%) wet basis. Diamante and Munro (1993) [10] studied that in the falling rate period the material surface is no longer saturated with water and drying rate is controlled by diffusion of moisture from the interior of solid to the surface.

Table 1: Test result of modified STR dryer at four different air velocity

Particulars	Air velocity			
	1.5 m/s	**2.0 m/s**	**2.5 m/s**	**3.0 m/s**
Loading Date	15/10/2017	22/10/2017	29/10/2017	03/11/2017
Unloading Date	15/10/2016	22/10/2017	29/10/2017	03/11/2017
Capacity(kg)	500	450	475	490
Initial MC (%, wb)	24.75	22.50	21.50	23.10
Final MC (%, wb)	8.5	9.0	8.75	8.50
Fan speed (rPM)	950	1050	1200	1400
Energy Consumption (kWh)	18	12.5	8.5	9
Drying Time (min)	7.5	6.5	4.17	3.5

The temperature sensors were set at the different distance from the centre line of the inner bin from where hot air was entering into grain pile. Temperature was varied initially among the horizontal locations because distances from the center of the inner bin were different. The temperature profile proved that the drying air uniformly distributed inside the dryer (Fig. 3). Table 2 shows that maximum temperature at T_1 (51 ºC) and minimum temperature was at T_3 (38 ºC) for air velocity of 1.5 m/s. Similarly maximum at T_1 (52 ºC) and lowest at T8 (42 ºC) for air velocity of 2.0 m/s; maximum at T_1 (55 ºC) and lowest at T_7 (40 ºC) for air velocity of 2.5 m/s; maximum at T_1 (57ºC) and lowest at T_8 (46ºC) for air velocity of 3.0 m/s. After certain time, temperature distribution of all horizontal sensors location became almost same.

Table 2: Temperature and Moisture content during drying after one hour

Point	Air velocity							
	1.5 m/s		**2.0 m/s**		**2.5 m/s**		**3.0 m/s**	
	T(°C)	**M(%,wb)**	**T(°C)**	**M(%,wb)**	**T(°C)**	**M(%,wb)**	**T(°C)**	**M(%,wb)**
T_1M_1	51.0	18.10	52.0	17.38	55.0	17.72	57.0	17.63
T_2M_2	46.0	18.13	50.0	18.32	51.0	17.91	53.0	17.81
T_3M_3	38.0	18.81	46.0	18.81	48.0	18.31	51.0	17.31
T_4M_4	40.0	18.14	48.0	18.06	46.0	18.21	49.0	17.14
T_5M_5	44.0	18.31	49.0	17.32	43.0	17.81	48.0	17.08
T_6M_6	47.0	18.19	48.0	17.25	41.0	17.51	49.0	17.28
T_7M_7	44.0	18.31	46.0	18.21	40.0	18.23	47.0	17.47
T_8M_8	40.0	18.64	42.0	18.37	43.0	17.76	46.0	17.51
T_9M_9	39.0	18.72	43.0	18.16	45.0	17.81	48.0	17.25

The drying temperature increased rapidly within two hours and then increasing rate was nearly steady or slowed down till the completion of drying. It proves that hot air temperature uniformly distributed to all over the drying section of the dryer. Moisture content measured from same points were also recorded. Rapid moisture removal was observed at M_1 (18.10%), M_6 (17.25%), M_6(17.51%) and M_5 (17.08%) for air velocity of 1.5, 2.0, 2.5 and 3.0 m/s respectively.

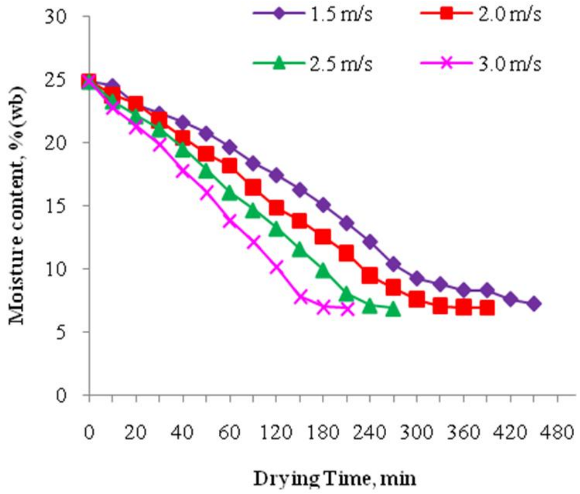

Fig 3: Effect of air velocity on drying curve at different air velocity

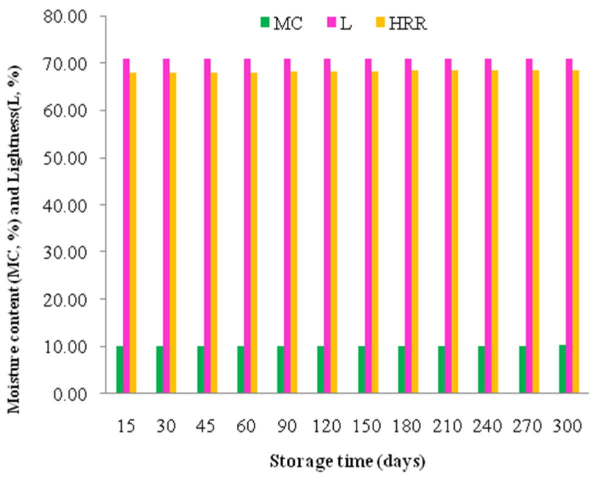

Fig 4: Effect of moisture content on L and HRR of paddy stored in super grain bag

However, variations of the temperature over the time depend on the efficiency of steady fuel supply for producing same hot air temperature which needs to be taken care of. The drying time varied with the variation of grain size. In first treatment, the drying time is lower than that of other treatments because of bold grain size. The spore space is much higher in bold grain compared to other medium grains. Drying air can easily pass through the big spore space from inner part to outer part of grain bin which directly affect temperature distribution and drying time. The grain was dried uniformly and reached same and desired moisture level in all part of the dryer in 3.5 to 7.5 hours depending on the initial moisture content of paddy and air velocity. Similar results have been reported for paddy seed drying in hybrid dryer (Hossain *et al.* 2012) [11]. The paddy was dried from 24.78% to 8.5%; 22.5 to 9%; 21.5 to 8.75 and 23.10 to 8.5 at air velocity of 1.5, 2.0, 2.5 and 3.0 m/s within the range of 3.5 to 7.5 hrs, respectively (Table 1).

Performance of Super grain bag

The Super grain bags effectively prevented moisture exchange between the surrounding air and the grains, and there was only a slight increase of about 1.01 % moisture content in the hermetic systems caused by respiration from grains and insects. In contrast the moisture content of the control treatment increased by an average of 4.9% to a final moisture content of 16.5- 18.2%, mainly through moisture exchange with the surrounding air, levels far above save storage moisture content. The Super bags also effectively reduced living insects to 1 insect/kg without using pesticides, while in open storage, insect levels increased to an average of 53 living insects/kg. The germination rate in the control treatment dropped to an average of 43% for the traditional varieties and to 6% for the new varieties under the open storage system, while hermetic storage maintained high germination rates of 90% compare to other traditional bags having low germination rate. Fig. 4 shows the effects of super grain bag on parameters like moisture, lightness and milling quality of paddy & lentil. A very negligible increase in moisture content from 10.07 to 10.32 (wb) was observed. The lightness was slightly decreased from 71.01 to 70.88. These changes were significant as compared to other packaging materials. Similar result was found by Divekar *et al.* 2015 [12] for paddy under different condition.

Damage and weight losses

Grain damage includes scarification of the pericarp and of the periphery of the endosperm, eating out of the germ, partial or complete consumption (hollowing out) of the kernel (Duna, 2003) [6]. The damage and weight losses caused by the tunneling and feeding activities of adult insects were observed to have increased gradually in the jute and polypropylene bags as the storage period progressed while a reduction was rather experienced in the triple-layer hermetic bags. This observation confirms the findings of Donahaye *et al*. (2001) [13] who reported little or no damage to hermetically stored grain. Super grain bag did not favour one insect species over the other. In other words, hermetic bag used in controlling loss due to insects.

Table 2: Study of various parameters of grains in Super grain bags after 6 months of storage

Grains	Parameters	Results	
		Initial	Final
Paddy	Moisture content (%wb)	10.58	11.08
	1000 Kernal wt (gm)	15.79	15.92
	L/B ratio	4.16	4.20
	Bulk density (Kg)	812.54	810
	Gelatinization Temperature (°C)	89.88	89.66
	Minimum cooking time (min)	9.58	9.71
	Gruel solid loss (%)	6.15	6.01
	Colour L, a and b	71.61;1.53 and 21.56	68.92, 8.64 and 23.57
	Insect mortality (Per cent)	10 Nos	100 percent
Lentil	Moisture content (%wb)	6.78	6.81
	1000 Kernal wt (gm)	38.56	36.02
	Bulk density (Kg)	833.56	801.37
	Minimum cooking time (min)	15.23	15.37
	Colour L, a and b	62.80; 12.54 and 33.87	65.87; 8.98 and 25.27
	Insect mortality (Per cent)	10 Nos	100 percent

Kinetics of *L** Changes
Unlike the measurement of MC, the *L** on the paddy declined during storage in LDPE bags, gunny bags and earthen bin. The initial *L** value of paddy was 71±0.61, and this value declined for the entire sample stored in above packaging indicating the whiteness on rice kernel decreased. Many papers have reported on the changes of rice during storage. Most of the papers stated that storage had an effect on the physical and chemical of rice, including cooking quality, texture, volatile components, and color (Tulyathan and Leeharatanaluk, 2007; Keawpeng and K. Venkatachalam, 2015) [14, 15]. Unfortunately, none of those mentioned in detail on the color changes on paddy during storage. Analysis of the kinetic orders and rate of changes for the *L** value of paddy during storage showed that the rate of changes for *L** value followed the first-order kinetics for all of the packing materials. The rate of decreases for the *L** values of paddy packed in super grain bag were 9.3×10^{-3}, 7.7×10^{-3} and 8.1×10^{-3} for first 15 days, respectively. This result was in line with Tamrin *et al.* (2015) [16] for Milled Rice during Storage in Plastic Packaging.

Willingness to pay for PHTs
Farmers' willingness to pay for the PHTs was determined by affordability and how much the technology can accommodate their harvests. Many farmer were used many bags each with 100kg as their unit measure. When asked on the willingness to pay at available price for PHTs given that the market price for PHTs is higher than the conventional bags, the results showed about 74% of responding farmers were willing to adopt the technology at given price. However, the mean score for use of STR dryer & SGB were found maximum with willing to pay with or without subsidy. The willingness to adopt the PHTs for farmers who have used SGB before was higher as they testified about the positive results of their adoption. In same way STR dryer was also gaining its popularity among the farmers on reasonable cost.

Conclusion
The results of the technologies and survey which were intervened on farmers field show an increasing demand for the new Postharvest Technologies in selected villages of Banka and Bhagalpur districts. The interviewed farmers echoed the retention of quality is fair of grains in STR dryer with timeliness operation. These were also stored for six or more months in super grain bags. This signifies their continued use of the improved PHTs, given that the price of SGB. On the other hand, testimonies for increased demand of PHTs came from distributors/ agrodealers/ traders who indicated more plans and desire to increase stocks during the 2017 crop harvest. They also described the increasing sales and demand for dyer and hermetic bags from their clients. With the new innovations on postharvest losses, one can affirmatively say the solution to the problem has been found by using Postharvest Technologies in India. Farmers are widely accepting the use of super grain bags as the solution to their problem of loosing crops. The demand for SGB for example, is high during beginning of harvesting season. As farmers are expecting harvests the demand gets high. The demand for PHTs is increasing as there is testimony to the effectiveness of PHTs. However the technology uptake is still low. The most barriers for the technology adoption were found to be on price, availability, proximity as well as preference to some technologies by end-users. Since price was found to be a critical limiting factor for the technology uptake by farmers, policy actions such as subsidizing the products with manufacturers could help to reduce the current market price and increase farmers' adoption to PHTs.

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