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The scope of the journal is specifically on postharvest and mechanization research, development and extension (RD&E). It is divided into the following content categories: Engineering, Biology and Chemistry, and the Social Sciences.

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CONTENTS

STORAGE PERFORMANCE OF BULB ONION (*Allium cepa L.*) IN NON-REFRIGERATED STORAGE SYSTEM

Rodelio G. Idago[1], Domingo R. Miranda[2], Ma. Cecilia R. Antolin[3] and Edgar D. Flores[4]

ABSTRACT

The study aimed to evaluate the storability of bulb onion (*Allium cepa L.*) in non-refrigerated storage system (NRS) using the extent and rate of storage losses as indicators of storage performance. NRS in this study refers to storage systems that utilize ambient or higher temperature and relative humidity (RH) conditions to extend the shelf life of bulb onion. Two types of NRS were investigated: 1) Hanger ambient storage (HAS) and 2) High-temperature storage (HTS). Cold storage which is the principal storage system applied for onion was used as control. Percentages of physiological weight loss, sprouting, rotting were measured and recorded at 14 days interval over the 224 days storage period. Results revealed that percentage physiological weight loss and sprouting loss is not significantly different between HAS and HTS. However, percentage rotting loss in HTS is significantly lower ($P<0.05$) compared with HAS throughout the storage period suggesting that elevated temperature can effectively minimize the occurence of rotting in bulb onion. Comparing HTS and HAS with cold storage, percentages physiological weight loss, rotting and sprouting is significantly lower ($P<0.05$) in cold storage throughout the storage period. In 70 days, total storage loss in HAS, HTS and cold storage were recorded at 12.15%, 11.52% and 9.07%. This increased to 42.87%, 38.92% and 21.80% in 140 days, respectively. Total storage loss for HAS, HTS and cold storage after 224 days were recorded at 93.45%, 85.25% and 37.87%, respectively. With acceptable level of storage loss in eight weeks averaging over 8%, the result of the study suggests that NRS can be potentially applied for short to medium duration storage of bulb onion.

Keywords: Bulb onion, Non-refrigerated storage, Smallholder farmers, Storage loss

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INTRODUCTION

Onion (*Allium cepa L.*) is one of the Philippines' major economic crops. The Philippines has an annual average production of 280,747 MT bulb onion with an estimated value of Php 26.95B (PSA, 2018). The onion industry is also a major source of employment in the countryside creating an estimated labor demand of 95 man-days $ha^{-1}season^{-1}$ or equivalent to 1,207,023 man-days $season^{-1}$ at 120-day period of onion production, to include the labor requirement from production to postproduction, excluding the labor for marketing and retailing (Calica, et al.; 1999). An essential condiment and a common ingredient for every household, the country's per capita consumption is 2.37 kg yr^{-1} (PSA; 2012).

While the onion crop provides immense opportunities both in the domestic and export market, the onion industry is confronted with challenges. Among which is the high postharvest system losses. Study on postharvest losses conducted by BPRE and PHTRC UPLB (2009) revealed that onion's system loss ranges from 45% to 65% from the farm to the stall retailers. Majority of these losses occurs during storage period. To prolong its shelf life and preserve its marketable attributes, onion is stored in commercial cold storage facilities for a maximum storage period of eight months.

However, the service fee of cold storage is expensive because of high energy cost. Also, access to these commercial facilities is often limited and economically practical only for traders handling bigger volume (Idago et al., 2015). In effect, smallholder onion farmers which represent majority of the players that contribute to the country's local production doesn't have direct access to these storage facilities because of the relatively smaller volume they handle averaging only 10.58 MT season-1 at 1.29 hectares average production area (Castillo, 2008).

The time gap between harvesting and on-farm marketing and the volume of supply during harvest period highly influence the prevailing market price of onion. Inevitable market glut during peak harvest placed smallholder farmers in a disadvantaged position in the market trade. If smallholder onion farmers can program their marketing for two to four months after harvest, they can wait for better price. Hence, alternative storage system other than cold storage such as non-refrigerated storage system would be very practical and within the farmers' reach considering their limited resource. For smallholder farmers, it will be a window to attain higher gains while at the same time reducing the country's actual energy demand for storing onion in cold storage facilities.

Non-refrigerated storage systems (NRS) are storage technologies or practices that do not apply refrigeration system which is typical for cold storage. The study of Jallorina et al. (2012) on the storage of bulb and shallot onions underscored that onion can be effectively stored in near ambient condition of 35°C for almost four months. Several studies also support the findings that onion can be effectively stored in a non-refrigerated condition for shorter storage period (Dabhi,et al., 2008; Opara, 2003;)

However, there is scarce information on the technical performance of the NRS when specifically applied for red bulb onion under Philippine conditions. To address this gap, the study aimed to assess the storage performance of bulb onion under NRS. Specifically, the study determined the extent of storage of storage losses such as physiological weight loss, rotting and sprouting losses when applied under farmers level of operation. Experimental design

METHODOLOGY

Experimental design

The study applied repeated measure experimental design to determine the progress of storage losses across the different storage systems. Storage losses such as physiological weight loss, sprouting and bulb rot were recorded at 14 days, interval for 224 days. Under each storage system, 36 red bags of 25 kg each were used as storage samples. With the type of storage system as the only treatment, each storage treatment has 36 replications with each red bag as the experimental unit. Every 14 days, each bag was weighed and data on physiological weight loss, sprouting and rotting were recorded throughout the 224 days storage period. Storage conditions such as temperature and RH were also recorded using data loggers.

NRS Evaluated and Cold Storage as Control

Hanger ambient storage (HAS). The HAS is a storage structure that uses natural ventilation. It is made up of combinations of concrete columns and beams with steel-framed galvanized roofing (Figure 1) Designed as a two-storey building structure, the flooring is made of 2in x 2in wooden slat spaced at 1 inch apart. The walls on all sides are covered with 2” x 2” steel screen to allow unrestricted movement of air for maximum natural ventilation. Onion in red bags of 25kg each are stacked two to threelayers with 1m spacing in between to allow ease of movement of people during regular inspection and cleaning of infected onion bulbs (Figure 2). This type of storage facility was distributed by the Department of Agriculture in 2013 in major onion producing provinces such as Nueva Ecija and Nueva Vizcaya as a short-duration storage facility for onion.

Figure 1. Hanger ambient storage structure

Figure 2. Stored onion bulb in red bags inside HAS.

High-temperature storage (HTS). The tunnel type UV plastic covered structure was utilized as high-temperature storage. Inside temperature in this structure is higher at daytime hence providing the effect of higher temperature storage condition. (Figure 3).

Onion in crates at 25kg each were stacked at 3 layers and provided with working space on both sides to allow movement during regular inspection and cleaning (Figure 4). This structure popularly known as "greenhouse" among onion farmers was likewise distributed by the Department of Agriculture. A farmer scientist claimed that onion stored in this greenhouse structure can last longer compared to hanger storage that uses ambient temperature and RH condition.

Cold storage. The commercial cold storage facility owned and operated by the KASAMNE onion growers cooperative was used for the storage of onion samples as control. Storage temperature inside the cold room is maintained at 1C throughout the storage duration which lasted for 224 days.

Bulb onion samples

The Red Pinoy onion cultivar was used as storage sample. Red Pinoy is popularly and widely grown among local onion farmers in major onion producing areas. The study followed the typical pre-harvest and postharvest operations practiced by onion farmers in the field. Onion bulbs were harvested 90 days after transplanting (DAT) which is already mature as indicated by bending of leaves and drying of bulb neck which is used as index of maturity. Bulb necks were manually cut or trimmed 1-2 inches above the bulb using sickle which is the traditional method used by farmers. Onion of good qualities, completely free of defects, medium size (2-3 inches in diameter or 40 to 50 grams average weight) was used as storage samples.

Figure 3. Hanger ambient storage structure

Figure 4. Hanger ambient storage structure

Analytical Tools

The storage performance of the different storage systems were anawas based on percentages of physiological weight loss, bulb rot sprouting and marketable bulb. The formula used for the computation of these performance indicators are presented below.

Percentage weight loss (%WL)

Weight loss refers to physiological weight loss of the onion bulb which is largely due to water loss. Percentage weight loss (%WL) was computed using the formula:

$$\%WL = \frac{IW_0 - FW_t}{IW_0} \times 100$$

where:

%WL = weight loss, in percent
IW_0 = weight of bulb onion at day 0, in grams
FWt= final weight of bulb onion at day t, in grams

Percentage bulb-rot (%BR)

Rotten bulb refers to decaying of onion bulb which is manifested by darkening and oozing of moisture from the neck and softening of the bulb. Unpleasant rotting smell is also an immediate indication of rotting onion. Percentage bulb rot (%BR) was computed using the formula:

$$\%BR = \frac{BR_t}{IW_0} \times 100$$

where:

%BR = bulb rot, in percent
BR_t = weight of rotten bulb at day t, in grams
IW_0 = weight of bulb onion at day 0, in grams

Percentage sprouted bulbs (%SB)

A bulb is considered to have sprouted when leaves emerge from the bulb neck. Percentage sprouted bulb (%SB) was computed using the formula:

$$\%SB = \frac{SB_t}{IW_0} \times 100$$

where:

%SB = sprouted bulb, in percent
SB_t = weight of sprouted bulb at day t, in grams
IW_0 = weight of bulb onion at day 0, in grams

Analysis of Variance

Analysis of variance (ANOVA) was used to determine if there was statistically significant differences among the three storage systems. The difference among treatment means were analysed using Bonferroni post hoc test. Statistical data was analysed using the SPSS software.

RESULTS AND DISCUSSION

Temperature and relative humidity

Daily mean values of temperature and relative humidity are plotted in Figures 5 and 6. The temperature inside the Hanger and high temperature followed a similar pattern with the prevailing ambient condition with significantly ($P<0.05$) higher values observed for HTS. The range of temperature for HTS and HAS is 27-39°C, and 22-34°C, respectively. On the other hand, the mean temperature inside the cold storage is 0°C with temperature range of -0.5°C to 0.4°C. Among the storage methods, the relative humidity inside the HTS had the lowest mean value at 77% as compared to HAS and cold storage at 80% and 86%, respectively. On the other hand, the relative humidity inside the cold storage is consistent throughout the storage period being a closed system. Whereas in HAS and HTS the RH ranges from 65-93% with higher values observed on 112th day onwards since this period coincided with the onset of rainy season in the study area.

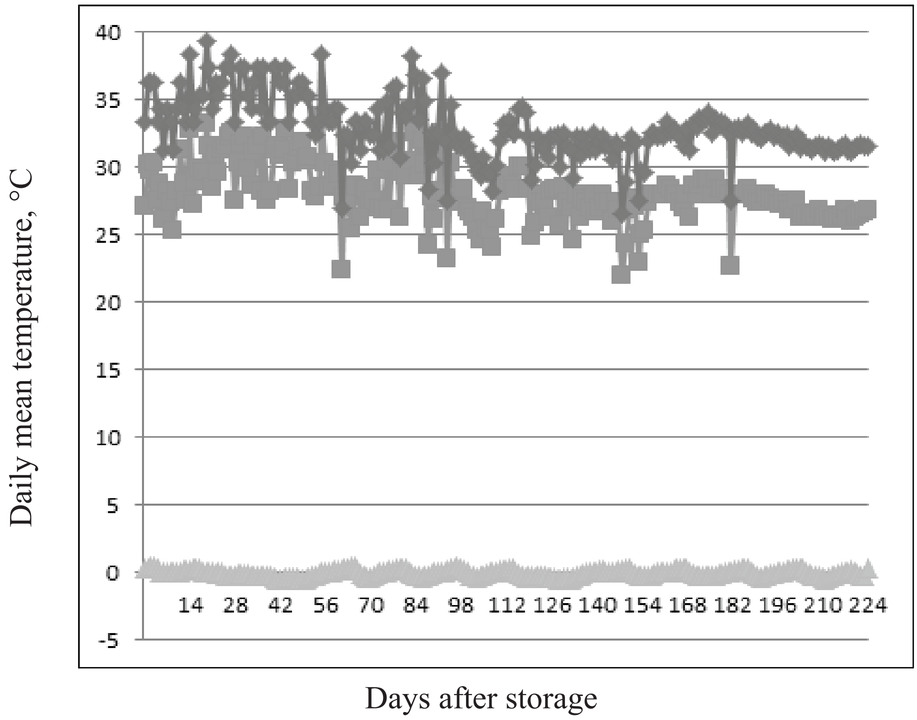

Figure 5. Daily mean temperature.

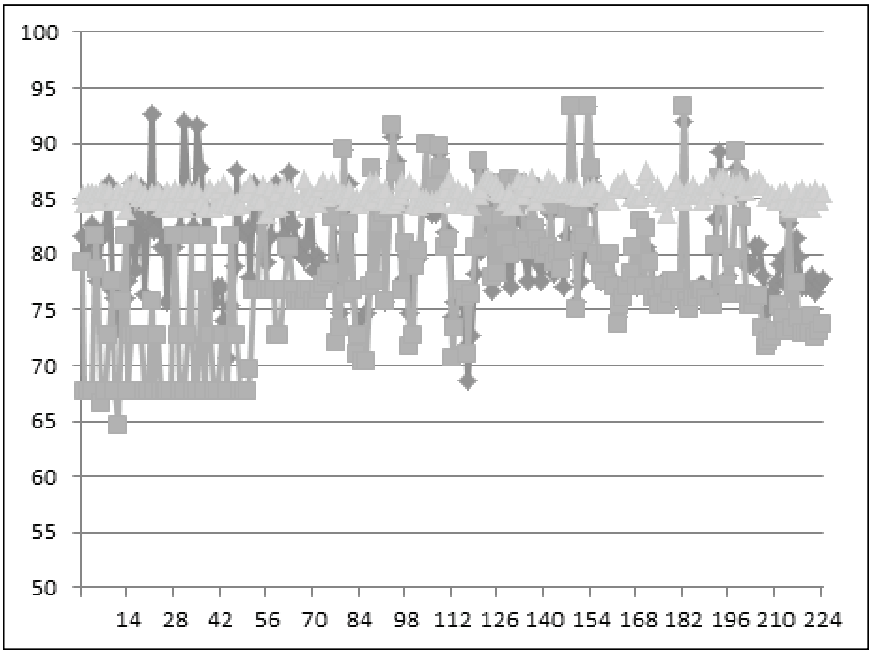

Figure 6. Daily relative humidity.

Physiological weight loss

The result of ANOVA showed no significant (P>0.05) difference between HAS and HTS in relation to physiological weight loss throughout the storage period (Table 1). However, the physiological weight loss in cold storage is significantly lower than HAS and HTS Physiological weight loss of stored bulbs increases progressively with increase in storage period for all storage methods (Figure 7). According to Endalew et al., (2014) the initiation of sprouting also contributed to increase in physiological weight loss in bulb.

Sprouting

Sprouting was first observed 84 days after storage both in HAS and HTS while sprouting in cold storage was first observed after 140 days. Sprouting loss of stored bulbs increases progressively with increase in storage period for all storage systems (Figure 8). Mean sprouting percentage between HAS and HTS is not significantly different almost throughout the storage period (Table 2). Sprouting in cold storage is significantly (P>0.05) lower than HAS and HTS incurring only 2.78% at the end of storage period. Low percentage sprouting in cold storage is attributed to near zero temperature that maintained the onion bulbs dormant.

On the other hand, the high percentage sprouting observed in HAS and HTS can be attributed to high relative humidity on the 112th day ranging from 85-93% as this period already coincides with the peak rainy season in the study area in the months of July to September.

Table 1. Percentage mean values of cumulative physiological weight loss of stored onion under different storage methods; Nueva Ecia, 2014.

Days After Storage	Storage Method		
	HAS	HTS	Cold Storage
14	2.72[a]	2.61[a]	0.63[b]
28	4.47[a]	4.63[a]	1.81[b]
42	6.40[a]	6.35[a]	3.52[b]
56	8.28[a]	8.21[a]	8.12[a]
70	10.57[a]	10.35[a]	9.07[b]
84	11.85[a]	11.36[a]	9.76[b]
98	12.87[a]	12.46[a]	10.74[b]
112	15.45[a]	16.11[a]	14.68[a]
126	18.31[a]	18.36[a]	16.41[b]
140	22.46[a]	20.77[a]	17.94[b]
154	27.33[a]	23.63[b]	18.86[c]
168	30.19[a]	28.57[a]	20.96[b]
182	33.21[a]	31.02[a]	22.05[b]
196	34.43[a]	32.40[a]	23.60[b]
210	34.99[a]	32.93[a]	23.69[b]
224	35.26[a]	33.13[a]	23.81[b]

*In each row, means followed by a common letter are not significantly different at 5% level using Bonferroni post hoc test.

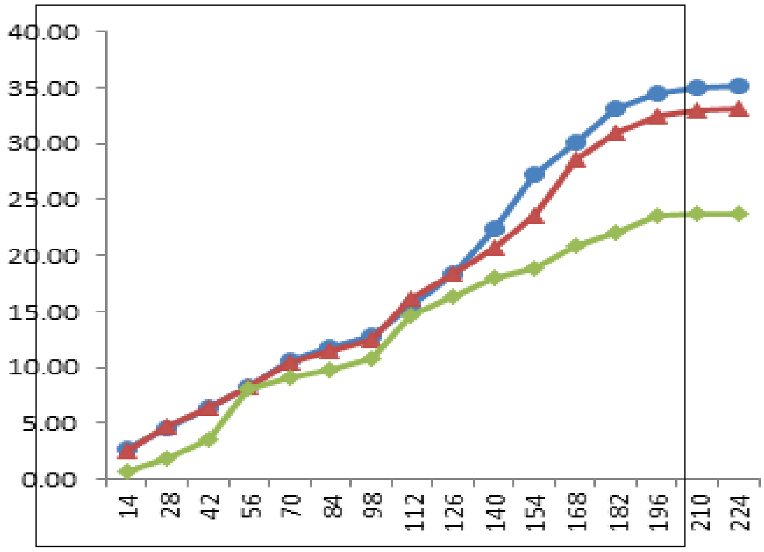

Figure 7. Physiological weight loss of stored bulb onion

Table 2. Percentage mean values of cumulative sprouting loss of stored onion under different storage methods; Nueva Ecija; 2014.

Days After Storage	Storage Method		
	Hanger	High Temperature	Cold Storage
14	0.00[a]	0.00[a]	0.00[a]
28	0.00[a]	0.00[a]	0.00[a]
42	0.00[a]	0.00[a]	0.00[a]
56	0.00[a]	0.00[a]	0.00[a]
70	0.00[a]	0.00[a]	0.00[a]
84	0.06[a]	0.04[ab]	0.00[b]
98	0.14[a]	0.07[a]	0.00[b]
112	0.28[a]	0.14[b]	0.00[c]
126	0.42[a]	0.29[a]	0.00[b]
140	1.96[a]	1.94[a]	0.58[b]
154	2.61[a]	2.60[a]	0.99[b]
168	4.47[a]	4.46[a]	1.21[b]
182	5.39[a]	5.39[a]	1.50[b]
196	5.97[a]	6.00[a]	2.65[b]
210	6.02[a]	6.04[a]	2.69[b]
224	6.10[a]	6.13[a]	2.78[b]

* In each row, means followed by a common letter are not significantly different at 5% level using Bonferroni post hoc test.

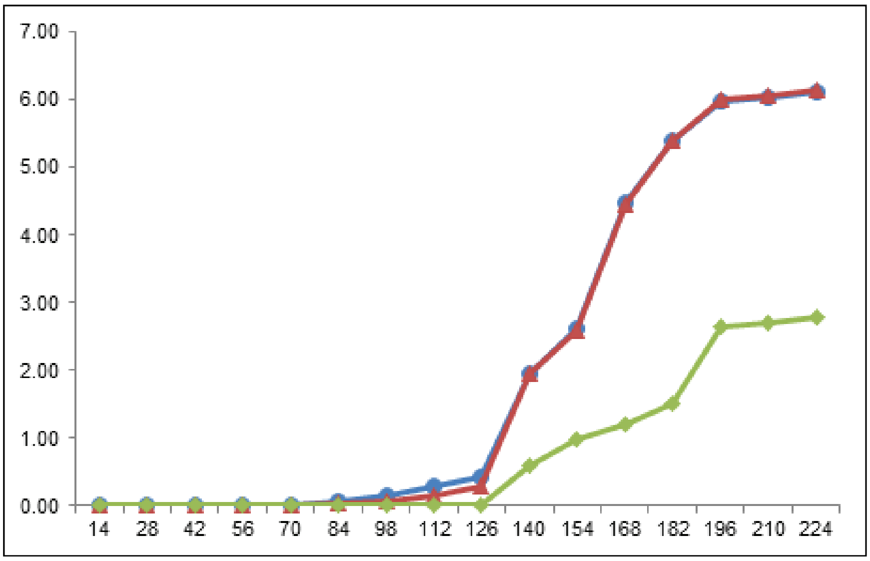

Figure 8. Sprouting of stored bulb onion.

Table 3. Percentage mean values of cumulative rotting loss of stored onion under different storage methods; Nueva Ecija; 2014.

Days After Storage	**Storage Method**		
	Hanger	**High Temperature**	**Cold Storage**
14	0.18[a]	0.02[b]	0.00[b]
28	0.25[a]	0.06[b]	0.00[c]
42	0.40[a]	0.13[b]	0.00[c]
56	0.49[a]	0.20[b]	0.00[c]
70	1.58[a]	1.17[b]	0.00[c]
84	2.73[a]	2.19[b]	0.43[c]
98	3.87[a]	3.05[b]	0.76[c]
112	8.25[a]	6.25[b]	1.64[c]
126	13.47[a]	10.20[b]	2.26[c]
140	18.45[a]	16.21[b]	3.28[c]
154	27.07[a]	22.89[b]	4.46[c]
168	36.44[a]	32.85[b]	5.39[c]
182	45.54[a]	39.66[b]	6.01[c]
196	49.95[a]	43.78[b]	8.96[c]
210	51.47[a]	45.47[b]	9.68[c]
224	52.09[a]	45.99[b]	11.28[c]

* In each row, means followed by a common letter are not significantly different at 5% level using Bonferroni post hoc test.

Rotting

Rotting was first observed both in HAS and HTS 14 days after storage. In cold storage it was first observed on the 84th day of storage period. Rotting percentage in HAS is significantly (P<0.05) higher than HTS and cold storage from the 28th days onward (Table 3). This suggests that rotting can also be minimized using higher temperature creating a condition that is not favorable for mold growth, other than the use of very low temperature such as cold storage.

On the 154th day, percentage rotting is 27% and 23% for HAS and HTS, respectively and only 4% in cold storage. After 224 days about half, 46% and 52%, have already rotted in HAS and HTS, respectively, with only 11% in cold storage.

Total storage loss

Total storage losses which comprise of physiological weight loss, rotting and sprouting is significantly higher (P<0.05) in HAS and HTS as compared with cold storage with HAS becoming significantly higher than HTS from 126th day onwards (Table 4). Among the storage methods, total loss in cold storage had the lowest recorded value at 37.87% after 224 days followed by HTS and HAS at 85.25% and 93.45%, respectively (Figure 10).

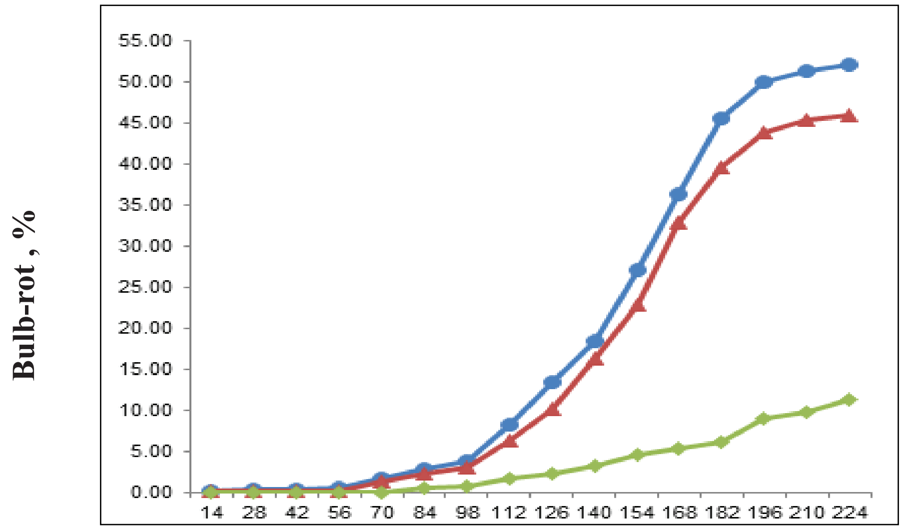

Figure 9. Rotting of stored bulb onion

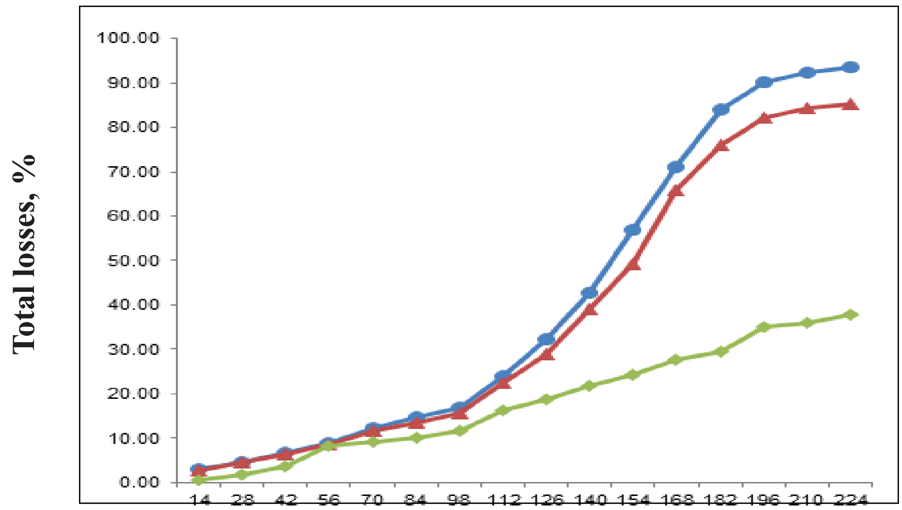

Figure 10 Total storage loss of stored bulb onion

Table 4. Percentage mean values of cumulative total loss of stored bulb onion under different storage methods; Nueva Ecija; 2014.

Days After Storage	**Storage Method**		
	Hanger	**High Temperature**	**Cold Storage**
14	2.90[a]	2.63[a]	0.63[b]
28	4.72[a]	4.69[a]	1.81[b]
42	6.80[a]	6.48[a]	3.52[b]
56	8.77[a]	8.41[a]	8.12[a]
70	12.15[a]	11.52[a]	9.07[b]
84	14.64[a]	13.59[a]	10.19[b]
98	16.88[a]	15.58[a]	11.50[b]
112	23.98[a]	22.50[a]	16.32[b]
126	32.20[a]	28.85[b]	18.67[c]
140	42.87[a]	38.92[b]	21.80[c]
154	57.01[a]	49.12[b]	24.31[c]
168	71.10[a]	65.88[b]	27.56[c]
182	84.14[a]	76.07[b]	29.56[c]
196	90.35[a]	82.18[b]	35.21[c]
210	92.48[a]	84.44[b]	36.06[c]
224	93.45[a]	85.25[b]	37.87[c]

* In each row, means followed by a common letter are not significantly different at 5% level using Bonferroni post hoc test.

CONCLUSION

The study evaluated the storability of bulb onion by measuring and evaluating the different forms of storage losses: physiological weight loss, rotting and sprouting, under three storage systems: HAS, HTS and cold storage as control, in 224 days using Red Pinoy cultivar of bulb onion.

The results revealed that there is no significant difference in physiological and sprouting losses between HTS and HAS. In terms of rotting loss however, the HTS has significantly lower values as compared with HAS suggesting that HTS' elevated temperature storage condition can effectively minimize the occurrence of rotting in bulb onion.

The elevated temperature of 5-10 °C over ambient temperature creates a condition that is not favorable for mold growth that promotes rotting. With total storage loss of 8.41% and 8.77% in 56 days and increasing to 22.50% and 23.98% in 112 days for HTS and HAS, respectively, suggests that NRS can be potentially applied for short to medium duration storage of bulb onion.

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THE INFLUENCE OF AGRICULTURAL TRAMLINE SYSTEM ON LAND USE IN UPLAND FARMING

Rodelio G. Idago[1] and Carmelita M. Rebancos[2]

ABSTRACT

The study aimed to assess the influence of agricultural tramline system (ATS) on land use in the remote farming uplands in Benguet, Philippines. ATS is a mechanical conveyance system similar to the principle of a cable car designed as a transport facility of agricultural products in locations inaccessible by road. A survey of 310 farmers representing the “with ATS” and “without ATS” was conducted in three major farming municipalities using structured survey questionnaire. Land use change was analysed by comparing data on land use types between 2008 and 2018. Data were analysed using descriptive statistical methods, t-test and regression analyses to measure significance in differences and disaggregate the effect of ATS on land use. The results revealed that idle lands increased significantly ($P<0.01$) by 4.26% between 2008 and 2018. For areas serviced with ATS land use for agriculture increased significantly ($P<0.01$) by 6.38% in contrast with land use as forest which was significantly ($P<0.01$) reduced by 4.31% suggesting that a portion of forested areas were converted for agricultural production. Regression analysis results suggest that amongst the drivers of these land use change is the presence of ATS ($P<0.1$). Looking at the rate of inputs utilization, farms “with ATS” had significantly ($P<0.01$) higher rates of inputs utilization particularly organic fertilizer which represents the bulk of fertilizer used in the uplands in the form of chicken manure. Similarly, one of the drivers of this behaviour is the presence of ATS. Consequently, average yield for temperate vegetables like cauliflower, potato, carrot, and chayote were also significantly ($P<0.01$) higher in areas with ATS. The effects of ATS in the remote farming uplands of Benguet can be divided into two land use issues: 1) its positive influence on the productivity of the uplands and 2) the potential negative long term effect due to conversion of forest areas to agriculture. This information will be vital for policy makers and program planners who may intend to maximize the potential of the technology in addressing the problem of transport to increase the productivity of the marginal uplands without compromising sustainability.

Keywords: Agricultural tramline, Land use, Temperate vegetables, Transport, Upland farms

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INTRODUCTION

The Philippines is a country characterized by vast areas of rolling to mountainous regions. The highlands, with a slope above 18% which is categorized as rolling to steep landform constitute about 55% of the land surface of the country (Cruz et al., 1986). Predominantly relying on agriculture, majority of the population in the highlands depend on farming as a major source of livelihood particularly those that are situated under rural setting. The agriculture sector is one of the key economic sectors of the country next to industry and services in terms of gross national product (GNP) value.

In spite of its relatively low contribution to GNP of only 9% (Phil. Statistics Authority; 2018), the agriculture sector provides employment for about one-third of the country's population, including its critical role in addressing the country's food security.

The vast highland of the country offers a number of opportunities and challenges. Owing to its cool climatic condition the highlands make it ideal for the production of high value temperate vegetables (Dela Cruz et al., 2000) hence, salads in the supply chain are produced from these mountainous regions.

On the other hand, owing to the rugged topography however, movement of products to and from the remote farms is costly and difficult. This is due to lack and/or poor road access, making traditional manual hauling the only mode of transport still practiced by the upland farmers (Idago and Ranola, 2009).

In these remote and rugged production areas, construction of road is technically difficult and economically unviable to maintain due to its inherent vulnerability to landslides during inclement weather, hampering the highlands productivity.

In an effort to address the problem the government, spearheaded by the Department Agriculture (DA), engaged on a nationwide program of establishing ATS in selected mountainous producing areas. A tramline (Figures 1 and 2) is a transport facility that uses steel cables and pulleys, and motorized prime mover, similar to the principle of cable cars, to move products from the production areas to the nearest road.

The objective of the tramline program was to mechanize the transport of farm input/output and replace manual hauling, making it faster, efficient and improves the working condition of the upland farmers (Paz, et al. 2017; Tesorero; 2017). Also, it was intended to enhance upland farms productivity and maximize contribution of these remote areas to food security and poverty alleviation.

Already more than 15 years since the tramline program was implemented, there were about 129 tramlines constructed nationwide (Paz et al., 2017) where majority of which are situated in the mountainous regions of Luzon, specifically in the Cordillera Administrative Region where Benguet province, the "salad bowl" of the Philippines, is situated.

The provision of ATS in the highlands offer upland farmers more favorable working conditions as well as economic opportunities that influence their land use decisions. Being a more efficient transport system, it induces upland farmers to modify land use system (Idago and Ranola, 2012).

However, the highlands is considered a fragile ecosystem, and production in steep slopes would expose the system to environmental problems such as soil erosion, water contamination, sedimentation of river system (Rola, 2004; Briones, 2005).

Understanding how ATS influence the uplands through their land use change response and their consequences would reveal how benefits can be enhanced while mitigating the negative impacts. This can provide vital information for decision makers on designs of sustainable rural development interventions specifically intended for the marginalized uplands.

Against this background, the study aimed to measure the effects of ATS on land use in the remote farming uplands of Benguet where it was first established.

METHODOLOGY

Time and place of the study

The study was conducted in 2018 in major temperate vegetable growing municipalities of Benguet province. Benguet is geographically located between 160 33' N latitude and 120^{o} 34' to 120^{o} 52' E longitude.

It is bounded by Mt. Province on the North, Pangasinan on the South, Ifugao and Nueva Vizcaya on the East and by La Union and Ilocos Sur on the West.

The province is geographically mountainous characterized by rugged, irregularly patterned ridges, canyons and peaks, many of which are above 2,400 meters above sea level (masl) in elevation. The slope classification of Benguet ranges from gently sloping to very steep.

Of the total land area, more than half have very steep slopes (slope gradient of 84% and above) while almost one-seventh belong to the steep slope category (51-84%) slope (PDPFP; 2018).

Figure 1. One of the ATS' established by DA

Figure 2. A private tramline put-up by farmers

Sampling and selection of respondents

Assessing the effects of ATS on land use required comparing two scenarios: "with ATS" and "without ATS". Hence, purposive sampling was done with the following type of respondents described as follows:

1. Farmers "without ATS" - referring to farmers in remote farms that has no direct access to farm-to-market road and generally utilized manual methods in their farm operations from land prepara tion, crop management and hauling of agricultural products.

2. Farmers "with ATS" – referring to farmers in remote farms that are serviced by ATS in the transport of their agricultural products. The required sample size (n) was computed using Slovin's formula:

$$n = N / (1 + Ne^2)$$

where:

n = sample size
N = population size
e = error tolerance (0.05)

With an estimated population size (N) of 250 representing the of upland farmers "with ATS" the sample size (n) for each classification of farmer-respondents was computed as:

$n = 250/ (1 + 250 (0.05)^2$
$= 250/ (1 + 0.625)$
= 153.8, or about 155 farmer respondents

Land use type allocations, inputs utilization and average yield

This section describes the methods used for the computation of the effect variables. In the computation of land use types urban land use was not included since a great majority of the farmers interviewed have their residences situated in the village while their parcels of land located a few kilometres away situated in terraced mountains where farming activity is concentrated. Hence, ATS in general has no direct effect on urban land use allocation. The formula used for the computations of effect variables are presented below:

Percentage land use-agriculture (%LUa)

Agriculture land use refers to land use type that is devoted and maintained for agriculture measured in percentage. Percentage land use-agriculture (%LUa) was computed using the formula:

$$\%LUa = LUa/TA \times 100$$

where:

%LUa = Land use for agriculture, in percent
LUa = agricultural area, in m2
TA= total land area, in m2

Percentage land use-forest (%LUf)

Forest land use refers to land use type that is under natural cover not engaged in human activity except as a source of water and fiber materials, measured in percentage. Percentage land use-forest (%LUf) was computed using the formula:

$$\%LUf = \frac{LUf}{TA} \times 100$$

where:

%LUf = Land use for forest, in percent
LUf = forest area, in m2
TA= total land area, in m2

Percentage land use-idle (%LUf)

Idle land use refers to land use type that was cultivated before but for a long period of time is now in a state of disuse, abandoned or in a state of fallow, measured in percentage. Percentage land use idle (%LUi) was computed using the formula:

$$\%LUi = \frac{LUi}{TA} \times 100$$

where:

%LUi = Land use as idle, in percent
LUi = idle land area, in m2
TA= total land area, in m2

Rate of fertilizer utilizaton (FU)

Fertilizer utilization refers to the average number of bags of fertilizer, categorized into organic and synthetic, per unit area per crop per season, measured in bags/hectare/ season. The crops grown included cauli flower, potato, cabbage, carrot and chayote. Fertilizer utilization (FU) was computed using the formula:

$$FU = \frac{F}{A}$$

where:

FU = fertilizer utilization, in bags/ hectare/ season
F = no. of bags applied
A= land area, in m2

Average yield (Y)

Average yield refers to the total weight of harvest per unit area per crop per season, measured in kg/ha. Average yield (Y) was computed using the formula:

$$Y = \frac{W}{A}$$

where:

Y = average yield, kg/ha
W = weight of harvest per crop
A = farm area, in m2

Methods of Analyses

Descriptive statistical methods. This was used for data on socioeconomic characteristics and farm profile of farmer-respondents. Quantitative data such as rate of inputs utilization, percentage allocation of land uses, size of area, household income, distance of farm to market center, yield per hectare, etc. were presented using mean values. For qualitative data such as types of land uses, crops grown, land tenure etc., frequency count or frequency distribution was applied.

T-test. This statistical analysis was used to determine if there is significant difference on the effect variables represented by the "with ATS" and "without ATS". The effect variables were as follows: 1) percentage allocation of land use types; 2) organic fertilizer utilization 3) inorganic fertilizer utilization, and 4) average yield

Regression Analysis. This statistical analysis was used to estimate the influence of ATS on the effect variables. The specifications of the regression models are presented below:

Land use type allocation model

$$f\,(I, A, T, f, ts, d, y, l)$$

In equation form, the model is specified as:

$$LU = a + \beta_1 I + \beta_2 A + \beta_3 T + \beta_4 f + \beta_5 ts + \beta_6 d + \beta_7 y + \beta_8 l + \mu$$

where:

LU = land use, in percentage
a = model's constant
I = on-farm income, in pesos
A = total land area, in hectares
T = tramline dummy; 1=with; 0=without
f = farm type dummy; 1=irrigated; 0=rainfed
ts = tenurial status dummy; 1= owner; 0= leaseholder
d = distance of farm from nearest road, in kilometers
y = years of experience in farming, in years
l = number of family labor
μ = error term

Fertilizer utilization model

$$f\,(T, tr, d, I, ts, A)$$

In equation form,

$$FU = a + \beta_1 T + \beta_2 tr + \beta_3 d + \beta_4 I + \beta_5 ts + \beta_6 A + \mu$$

where:

FU = fertilizer utilization, in bags/hectare
a = model's constant
T = tramline dummy; 1=with; 0=without
tr = agricultural trainings attended, in years
d = distance of farm from nearest road, in kilometres
I = on-farm income, in pesos
ts = tenurial status dummy; 1= owner; 0= leaseholder
A = total land area, in hectares
μ = error term

Average yield model

$$(AY)\ L = f(O, IO, ts, tr, d)$$

In equation form, using Cobb-Douglas function:

$$\ln(AY) = a + \beta_1 \ln O + \beta_2 \ln IO + \beta_3 \ln(ts) + \beta_4 \ln(tr) +- \beta_5 \ln(d) + \mu$$

where:

AY = kg/ha
a = model's constant
O = rate of organic fertilizer use, in bags/ha
IO = rate of inorganic fertilizer use, in bags/ha
ts = tenurial status dummy; 1= owner; 0= leaseholder
tr = agricultural trainings attended, in years
d = distance of farm from nearest road, in kilometres

RESULTS AND DISCUSSION

Land use change

Land use change can be aptly defined as a change of a land use category or a change in intensity of a particular land use (Briassoulis;2000). In the case of agricultural land use, an example of a change in intensity will be a change in the rate of material inputs use in agricultural production. The land use change was determined by comparing the survey results in 2008 to the survey results conducted in 2018.

While the use of GIS and remote sensing is available to measure changes in land use by analysing satellite imagery taken between two time periods, the small parcels of land (around 4,000m^2 per farmer) however made it practically impossible to observe such changes. Hence, survey method at the ground level was used through interviews to determine land use allocations. Results revealed that land use allocations for agriculture and forest did not change after 10 years. On the other hand, land use as idle lands increased significantly by 4.26 percent (Table 1) suggesting that a portion of the forest and mainly agriculture was freed up or unutilized.

On the other hand, comparing the "with ATS" and "without ATS" for 2018, land use for agriculture is significantly higher for areas serviced by ATS (Table 2). However, areas with ATS had significantly lesser forest area (4.31%), suggesting that the presence of ATS encourages expansion of agriculture by converting forested/naturally covered areas for agricultural production.

Facilitating the movement of agricultural products provide incentives for land owners to engage more areas for agricultural production through opening up forest lands.

Table 1. Land use type in percentage allocation between 2018 and 2008.

ITEM	2018 n=309	2008 n=180	MEAN DIFFERENCE
Land use, agri (%)	85.46	85.92	-0.46ns
Land use, forest (%)	6.90	7.31	-0.41ns
Land use, idle (%)	7.14	2.88	4.26***

*** significant at 1% level of significance
ns - not significant at 10% level

Table 2. Land use type in percentage allocation between with and without in 2018.

ITEM	WITH n=155	WITHOUT n=155	MEAN DIFFERENCE
Land use, agri, (%)	89.07	82.24	6.83***
Land use, forest(%)	4.90	9.21	-4.31***
Land use, idle (%)	5.06	6.17	-1.12ns
Land use, others (%)	0.097	0.51	-0.41ns

*** significant at 1% level of significance
ns - not significant at 10% level

Drivers of land use change

In any land use change study, the first question is "What drives these land use changes?" (Lambin et al. 2003). This question was addressed by regressing land use allocation for agriculture against the socioeconomic and biophysical conditions prevailing in the area. Results of the regression analysis revealed that the presence of tramline, average land area, tenurial status and source of income influence the choice of land use in the area (Table 3).

The presence of ATS positively influence the percentage allocation for agricultural land use as it provides a more efficient, cost-effective and mechanical means of moving agricultural products in the area.

Rate of fertilizer utilization

Comparing the utilization of organic fertilizer between farms with and without ATS revealed that majority of crops serviced with ATS were utilizing significantly higher amount of organic fertilizer (Table 4).

Based on key informants interview, the cost of transport is one major deterrents in applying the recommended amount of fertilizer. The presence of ATS that reduced the costs and drudgery transport addressed this limitation leading to higher rate of fertilizer use.

To establish what influences this behaviour, rate of organic fertilizer application (bags/ha/season per crop) was regressed against selected biophysical and socioeconomic predictors (Table 5). Results revealed that ATS, in general, significantly influenced the increase in fertilizer use.

For inorganic fertilizer utilization, some of the crops (cauliflower, carrots and chayote) situated in areas with ATS applies significantly higher amount of inorganic fertilizer (Table 6).

Regressing inorganic fertilizer utilization rate against selected predictors revealed that ATS, and partly, distance, income and size of land area influenced the rate of inorganic fertilizer use (Table 7).

The presence of ATS that addresses the problem of moving agricultural products to and from the farm encourages intensive use of production inputs.

Table 3. Result of the regression model of land use for agriculture; Kabayan, Atok and Tublay Benguet; 2018.

PREDICTORS	COEFFICIENTS	SIGNIFICANCE LEVEL
Constant	65.77***	0.00
On-farm income	2.84**	0.07
Total area	-0.001***	0.00
Tramline dummy 1=with; 0=without	4.01*	0.10
Farm type	2.92ns	0.26
Land tenure	6.58***	0.00
Distance of farm from road	-2.00ns	0.19
Years of experience in farming	0.12ns	0.89
No. of family labor	0.40ns	0.48

Adjusted R2=0.30
*** significant at 1% level of significance
** significant at 5% level of significance
* significant at 10% level of significance
ns - not significant at 10% level

Table 4. Rate of organic fertilizer application of farms "WITH" and "WITHOUT" tramline transport facility in Kabayan, Atok and Tublay, Benguet; 2018.

CROPS GROWN		FERTILIZER UTILIZATION RATE (bags/ha/season)		DIFFERENCE
		WITH	WITHOUT	
Cauliflower	(WS)	102.00	53.59	48.41**
	(DS)	100.00	147.00	47.00ns
Potato	(WS)	256.60	99.07	157.53**
	(DS)	193.00	90.00	103.00**
Cabbage	(WS)	327.78	122.65	204.63***
	(DS)	276.9	125.46	151.44***
Carrot	(WS)	120.15	43.77	76.38**
	(DS)	92.45	46.20	46.25*
Chayote		73.59	69.88	3.71ns

*** significant at 1% level of significance
** significant at 5% level of significance
* significant at 10% level of significance
ns - not significant at 10% level

Table 5. Summary of the result of regression models for organic fertilizer utilization for various crops; Kabayan, Atok and Tublay, Benguet. 2018.

CROPS	PREDICTORS AND LEVEL OF SIGNIFICANCE						
	C	*T*	*Tr*	*D*	*I*	*t*	*A*
Cauliflower	9.90	27.11	3.75	7.05	7.68	12.83	-0.07
	0.63	0.00	0.76	0.14	0.05	0.08	0.00
Potato	6.39	83.88	84.31	16.18	-12.43	-77.15	0.00
	0.92	0.09	0.02	0.38	0.43	0.61	0.98
Cabbage	286.00	188.00	-150.45	44.16	14.20	-132.83	0.001
	0.15	0.07	0.20	0.68	0.69	0.36	0.32
Carrot	110.38	40.02	25.20	-1.99	-16.72	115.80	-0.01
	0.06	0.08	0.50	0.90	0.12	0.00	0.01
Chayote	12.55	-13.43	7.96	-3.43	8.53	5.46	0.00
	0.74	0.19	0.32	0.46	0.37	0.77	0.86

Note: For each crop numbers on the first row correspond to coefficients while numbers on the second row correspond to level of significance.

Table 6. Rate of inorganic fertilizer application of farms "WITH" and "WITHOUT" tramline transport facility in Kabayan Atok and Tublay, Benguet; 2018.

CROPS		FERTILIZER UTILIZATION RATE (bags/ha/season)		DIFFERENCE
		WITH	WITHOUT	
Cauliflower	(WS)	66.42	26.65	39.77**
	(DS)	60.77	55.20	5.57^{ns}
Potato	(WS)	21.70	10.85	10.85^{ns}
	(DS)	16.41	9.00	7.41^{ns}
Cabbage	(WS)	31.00	14.29	16.71^{ns}
	(DS)	21.67	13.37	8.30^{ns}
Carrot	(WS)	39.46	19.29	20.17*
	(DS)	34.26	18.00	16.26**
Chayote		12.3	8.19	4.11**

*** significant at 1% level of significance
** significant at 5% level of significance
* significant at 10% level of significance
ns - not significant at 10% level

Table 7. Summary of the result of regression models for inorganic fertilizer utilization for various crops; Kabayan, Atok and Tublay, Benguet. 2018.

CROPS	PREDICTORS AND LEVEL OF SIGNIFICANCE						
	C	*T*	*Tr*	*d*	*I*	*t*	*A*
Cauliflower	10.00	27.00	3.75	7.05	7.68	12.87	-0.007
	0.63	0.00	0.77	0.14	0.05	0.07	0.00
Potato	12.00	-5.30	4.79	-4.70	3.04	38.55	-0.002
	0.36	0.47	0.48	0.20	0.26	0.00	0.04
Cabbage	32.00	10.04	-17.62	-5.93	4.45	-14.2	-0.002
	0.15	0.38	0.19	0.62	0.27	0.38	0.32
Carrot	38.00	17.32	-7.43	9.45	1.50	-8.51	-0.01
	0.06	0.02	0.57	0.07	0.68	0.33	0.00
Chayote	5.71	0.48	0.31	0.05	0.03	0.02	0.00
	0.21	0.68	0.74	0.92	0.98	0.99	0.18

Note: For each crop numbers on the first row correspond to coefficients while numbers on the second row correspond to level of significance.

Table 8. Average yield of crops in farms with and without tramline facility in Kabayan Atok and Tublay, Benguet; 2018.

CROPS		YIELD, kg/ha/season)		MEAN DIFFERENCE
		WITH	WITHOUT	
Cauliflower	(WS)	39,134	18,451	20,683***
	(DS)	39,724	28,600	11,124 ns
Potato	(WS)	17,479	10,135	7,344***
	(DS)	16,904	9,855	7,049***
Cabbage	(WS)	18,500	18,206	294 ns
	(DS)	25,250	15,034	10,216*
Carrot	(WS)	30,761	13,937	16,824***
	(DS)	25,644	14,042	11,602*
Chayote		1,918	1,496	422**

*** significant at 1% level of significance
** significant at 5% level of significance
* significant at 10% level of significance
ns - not significant at 10% level

Table 9. Summary of the results of regression models for yield; Kabayan, Atok and Tublay, Benguet; 2018.

CROPS	PREDICTORS AND LEVEL OF SIGNIFICANCE					
	C	*o*	*io*	*t*	*tr*	*d*
Cauliflower	-35,571	0.25	0.44	0.06	-0.06	2.27
	0.00	0.04	0.00	0.49	0.45	0.03
Potato	-28,442	0.11	0.63	0.17	0.28	-0.78
	0.01	0.53	0.00	0.22	0.06	0.46
Cabbage	9,502	-0.00	2.24	-0.16	-0.07	-0.30
	0.53	0.98	0.04	0.93	0.71	0.15
Carrot	-49,929	0.19	0.39	-0.09	0.07	0.56
	0.10	0.10	0.00	0.34	0.50	0.00
Chayote	667	0.49	-0.04	-0.03	0.10	-0.14
	0.00	0.00	0.79	0.82	0.39	0.22

Note: For each crop numbers on the first row correspond to coefficients while numbers on the second row correspond to level of significance

Crop Yield

Comparing the average crop yield between farms with and without ATS revealed that, in general, the average yield of crops in farms with ATS were significantly higher (Table 8). It can be generalized that higher yield is due to higher rate and timely application of fertilizer.

Regressing average yield against selected predictors revealed that the rate of organic and inorganic fertilizer used significantly influenced crop yield. The study also generalized that the presence of ATS provided an indirect influence to this effect that lead to higher farm productivity (Table 9).

CONCLUSION AND RECOMMENDATION

The introduction of ATS in the remote farming uplands of Benguet, Cordillera significantly contributed in the shift in land use in favour of agricultural production. This was evidenced by the agricultural land use intensification in the form of area expansion and extensive use of agricultural inputs. These changes created both positive and negative impacts that may affect the sustainability of the farming uplands in the long run: 1) its positive influence on the productivity of the uplands, and 2) the potential negative long term effect of deforestation due to conversion of forest areas to agriculture. Given these findings, the study can conclude that ATS can be an effective intervention to address the problem of transport in remote marginal areas.

In putting up this intervention, however, it must be carefully planned particularly in remote farming areas that are in proximity to natural forest cover and other fragile ecosystems. Due to the evident influence of ATS on potential deforestation in favour of agricultural land use expansion, the study recommends that its environmental impact be further investigated to provide clear policy recommendations and measures on how the benefits from the technology can be maximized while mitigating its negative and undesirable impacts.

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TECHNICAL AND FINANCIAL VIABILITY OF-NEAR-AMBIENT TEMPERATURE STORAGE SYSTEM FOR BULB ONION

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ABSTRACT

The study evaluated the technical and financial viability of near-ambient temperature storage for storing bulb onion. Based on the evaluation, the system could store bulb onions in bags for 18 weeks (4.5 months) and 16 weeks in bulk with uniform weight reduction in all locations of the storage bin. The estimated optimum storage duration for bulb onion which gave the highest profit was determined at 16 weeks (4 months) of storage. Extending the storage period beyond 16 to 22 weeks, a profit can still be realized. However, afar 22 weeks; where the cost outweighed the revenue, a negative benefit was realized. Financial analysis showed favorable results from the viewpoints of technology users. The adoption of near-ambient temperature storage system suggests that the farmer-owners can be realized a positive benefit mainly from increased price of onion after four months of storage and can be recovered the investment in just one cropping season. The near-ambient storage system can be an alternative storage facility that provides opportunities for farmers with relatively smaller volume of harvest to temporarily store while waiting for a better price. A more extensive pilot testing of the technology using solar panel as source of energy was recommended not only to validate its technical and financial performance but to demonstrate and create awareness of the presence of an alternative storage technology.

Keywords: Onions, Near-ambient temperature, Storage system, Storage loss, Viability

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INTRODUCTION

Onion (*Allium cepa L.*) is one of the most important crops grown worldwide. In the Philippines, onion production registered an average annual yield of 153,316 MT and estimated value of Php 3.67 B (PSA, 2017). Bulb onions are largely coming from Central Luzon particularly Nueva Ecija which contributed about 78.69% to the total production. This was followed by Mindoro Occidental (10.95%), Nueva Vizcaya (5.58%) and Pangasinan (3.25%).

Onion has to be stored to prolong the availability of fresh onion supply and partially meet the requirements for the whole year (Dela Cruz et al., 2014). While in storage, onions are subjected to quantity and quality losses (Idago e al., 2015; Calica, 2009). The major sources of losses in storage are sprouting, rotting or decay due to disease infection and physiological loss in weight or moisture loss or shrinkage (Milenkovic et.al, 2009; Ko et al., 2003; Opara, 2003; Tripathi and Lawande, 2006). This storage loss was reported to be as high up to 56% using different storage structures in ambient conditions (Biswas et al., 2010).

Storing bulb onion in cold storage is one way of reducing postharvest losses. However, service fees for cold storage facilities have become very high with storage operators demanding fixed fees of Php 210/27-kg bag of red onion for maximum period of seven months and Php 160/27-kg bag of white onion for four months (KASAMNE, 2018). Additional fee of Php35/bag-month is charged beyond seven and four months of storage period for red and white onion, respectively.

In some of the major production areas, cold storages are not available or the capacities of existing units are insufficient to accommodate the total volume produce in the area. Moreover, it has been claimed that bigger onion consolidators are given the priority to use cold storage rooms because of their capability to maximize the use of storage rooms and pay for the rentals. Small farmers have to group themselves to fill-up and pay for the rental of one storage room, with capacity of approximately 10,000-11,000 bags of bulb onion/room or 297 MT/room.

Hence, individual small-scale onion farmers with relatively smaller volume of harvest, averaging only 10.6 tons/season (Castillo et al., 2008), have limited opportunity to use cold storage facilities. Moreover, cold storage loss was estimated 23.89% despite of maintaining temperature and relative humidity due to sprouting, rotting and weight loss (Calica and Cabanayan, 2018).

Likewise, some cold storage facilities are not efficiently operated and maintained. Losses ranging from 32 to 39% have been reported due to power interruptions, inadequate facilities and problems in maintaining proper storage temperature (Marzan, 1995).

Several studies have shown that-near ambient conditions can be used to store bulb onion for three to four months after harvest (Tripathi and Lawande, 2006) with relatively lower postharvest losses. Near-ambient temperature storage systems are storage technologies that do not apply refrigeration system which is common for cold storages.

The studies of Dela Cruz et al., 2018 and Idago et al. (2015) on the storage of onions stressed that onion can be effectively stored above ambient temperatures. Several studies also support the findings that onion can be effectively stored in this condition for shorter storage period (Endalew et al., 2014; Yadav, 2012; Opara, 2003).

Considering the high losses of traditional farmer's storage system and the inaccessibility of cold storage facilities to small-scale farmers, PHilMech prompted to develop an alternative near-ambient storage system. A research work was undertaken to establish the optimum requirements needed for the development of a near ambient-temperature onion storage systems.

At the laboratory scale, the near ambient-temperature onion storage system was found to extend the shelf-life of onion up to six months using 35°C storage temperature setting with 0.04 m/s air velocity (Jallorina, 2012).

With this, it is noted that the use of near-ambient temperature would be suitable storage technique for tropical country like the Philippines with known for high ambient temperature and therefore the required energy to meet the storage setting temperature is low. Thus, in this study the research findings were evaluated in actual field condition to assess itstechnical and financial viability in storing bulb onions.

METHODOLOGY

Conceptual Framework

The conceptual framework, as shown in Figure 1, illustrates the thrust of the research work. This framework served as guide in the conduct of the study. In this research paradigm, the input variables were examined and analyzed to come up with a near ambient-temperature onion storage system.

Considering the basic design requirements, developed and established near-ambient storage system during the previous project, the study was designed to evaluateits technical and financial viability. The technical viability of the near-ambient storage system was analyzed based on the extent of total storage losses comprising of rotting, physiological weight loss and sprouting/rooting across the storage period. The financial viability on the other hand was evaluated by looking at the costs and benefits associated with its use.

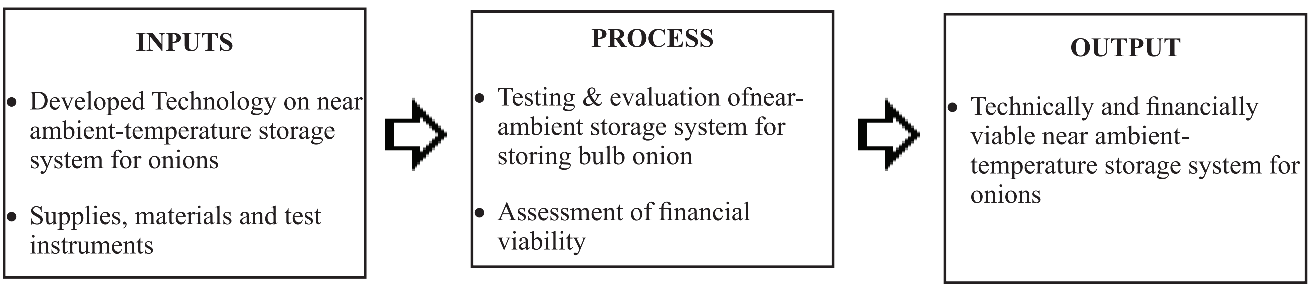

Figure 1. The conceptual framework of the study

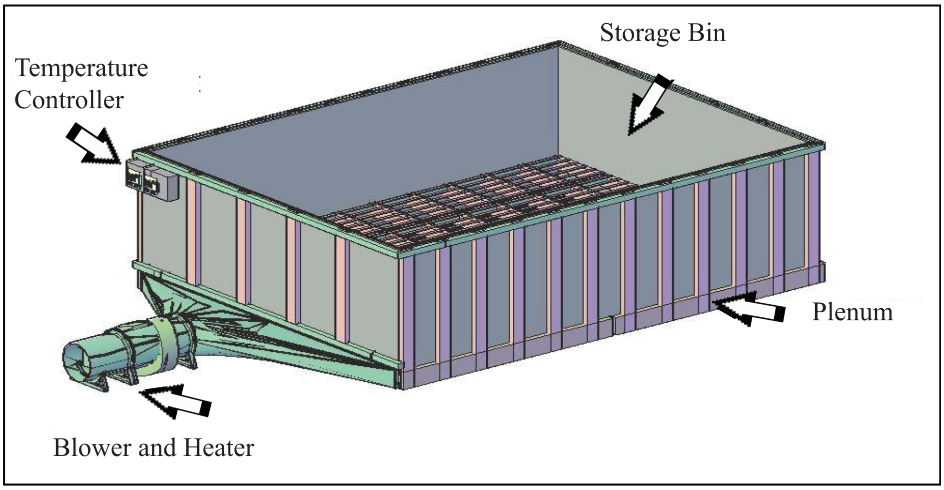

Figure 2. The semi-commercial scale near-ambient temperature storage system.

Description of the Storage Technology

The developed near-ambient storage structure consists of heater, blower assembly and a storage bin (Figure 2). The storage bin is made of wood and ¾ ply board with a dimension of 3 m x 4 m x 1 m which can store about 240 bags (about 6 tons) per batch of onions.The heating system is made-up of five electric finned heaters installed at the opening of the plenum.

An industrial fan is provided to deliver the required air flow rate to the plenum through the storage bin. A temperature controller which serves as switch and regulator of the heating system and fan was also provided to maintain the desired storage temperature setting all throughout the storage duration. An existing structure were utilized as shed of the near ambient storage system.

Testing and Evaluation

The storage trials were conducted at PHilMech, Science City of Muñoz and Bongabon, Nueva Ecija in collaboration with Mr. Crispulo M. Ceña.

The Science City of Muñoz is one of the leading onions producers in the province of Nueva Ecija. It is situated 147km north of Manila. With its rich topography and tropical climate, it is now home to agricultural research and technology centers, committed to the production of information and technological breakthroughs to promote rural development, productivity and food security. On the other hand, Bongabon is a second class municipality of Nueva Ecija and the leading producer of onion in the Philippines and Southeast Asia.

Freshly harvested bulb onions were stored in near-ambient temperature storage structure installed in Bongabon, Nueva Ecija and PHilMech Compound, Muñoz, Nueva Ecija. As to the need to validate the research findings in actual field condition, the experiment used 35°C storage temperature setting with 0.04 m/s air velocity for 24-week storage trial. Two cases were studied: Storage of bulb onion in mesh red bags at Bongabon and storage of bulb onion in bulk at PHilMech, Science City of Muñoz, Nueva Ecija.

For the sampling procedure, 18 marked bags of onion contained in 25kg capacity polypropylene bags were randomly selected and positioned at front, middle, rear, top, middle and bottom. The onion samples were assessed for percentage weight loss, bulb-rot and sprouting intensities.

Assessments were done before loading and two weeks thereafter for six months. Prior to storage trials, some physical properties of onion such as moisture content, bulk density and size of bulbswere also determined. The following parameters were determined using the following formula:

Percentage weight loss (Pwl)

This was determined by estimating the difference in the initial and final weight of samples before and after storage. This was expressed as percentage using the formula:

$$Pwl = \frac{\text{Initial weight-Final weight}}{\text{Initial weight}} \times 100$$

Bulb-Rot Intensity (BRI)

Bulbs that were obviously rotten were segregated, counted and weighed. This was expressed in percentage using the formula:

$$BRI = \frac{\text{Weight of rotten bulbs}}{\text{Weight of total bulb onion samples}} \times 100$$

Sprouting intensity (SI)

Bulbs that were obviously sprouting were segregated, counted and weighed. This was expressed in percentage using the formula indicated below.

$$SI = \frac{\text{Weight of sprouting bulbs}}{\text{Weight of total bulb onion samples}} \times 100$$

The data were analyzed by the method of analysis of variance to determine significant differences of the different treatments applied. Comparison among treatment means was obtained using the LSD at 5% level of significance.

Financial Analysis

In this study, the financial viability of the generated technology was determined using common project worth measures such as Net Present Value (NPV), Cost and Return Analysis using the Benefit Cost Ratio (BCR), and Payback Period. Under this study, the optimum storage period or duration was also considered.

The optimum storage period is the number of days, weeks or months of storage where the highest net profit is obtained. The price of bulb onion that has been used for this analysis is the average price for the recent five years based on PAS data.

RESULTS AND DISCUSSION

Performance Evaluation of Near-Ambient Storage System

Physical properties of onion samples

Prior to storage, the physical properties of experimental bulb onion samples were determined. As summarized in Table 1, the bulb onion has a mean moisture content of 90.42%, mean bulk density of 103.9 kg/m3 with mean diameter, height and weight per bulb of 48.59 mm, 47.45 mm and 49.28 g, respectively

Storage of onion in red bags (Bongabon, Nueva Ecija Case)

About five tons or 198 bags of bulb onion were stored in 24-week storage trial using the developed near-ambient temperature storage.

Table 1. Physical properties of experimental bulb onion samples

Physical Properties	Mean values
Moisture Content, %	90.42
Bulk Density, kg/m3	103.9
Diameter (per bulb), mm	48.59
Height (per bulb), mm	47.45
Weigh (per bulb), g	49.28

Physiological Weight Loss

The weight reduction of onion samples during the 24-week storage experiment is shown in Figure 3. The weight of stored bulb onion decreases progressively with increase in storage period for all storage location. The gradual weight reductions were observed from the beginning of storage until the 18th week of storage period which showed no significant difference (P>0.05) between locations (front, middle rear).

A faster weight reduction was registered in the 19th to 24th week of storage. At the end of 18th week storage period, the mean weight of onion samples per bag all throughout the storage location was reduced from 25.02kg to 18.57kg with a computed percentage weight loss of 25.76%.

The samples stored at the rear, middle and front parts of the storage bin had the computed percentage weight loss of 50.5%, 38.9%, and 40.3%, respectively. At the end of the storage trial, the mean weight per bag was reduced to 14.20 kg with a computed mean percentage weight loss of 43.25%

These losses may be due to the moisture loss during respiration of onion bulbs during storage. Similar results were also observed by Soomro et al. (2016) and-Jamali et al. (2012).

Sprouting Intensity

The sprouting of stored bulb onion is shown in Figure 4. It is expressed in terms of the ratio of the total number of bulb sprouting to the number of stored bulbs expressed in percent. As depicted, sprouting intensity of stored bulb onion increases progressively with increase in storage period in all storage location. Sprouting is gradual from the beginning of storage until the 20 weeks of storage (P>0.05) and further increased from 20 to 24 weeks of storage. At the end of the storage experiment (24th weeks), the computed mean bulb sprouting intensity was 2.62 %, 0.79 % and 1.02 % at the rear, middle and front location of the storage bin.

Across the storage location, the computed mean sprouting intensity was 1.47% with an equivalent of 0.015 kg/wk weight reduction.The low percentage of sprouted bulbs could have been brought about by the use of maintained temperature above ambient coupled with superficial ventilation which may help in removing heat and humidity build-up inside the storage structure.

This is also similar with the observations of Dela Cruz et al., (2018) using high temperature in storing onion with proper aeration which could help minimize bulbrotting and sprouting losses (Yadav et al., 2012).

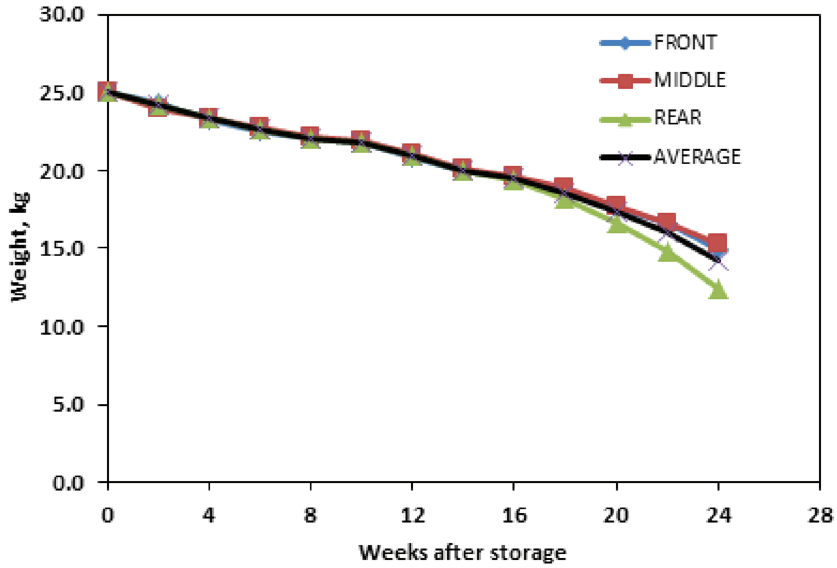

Figure 3. Physiological weight loss of stored onion under different storage l locations throughout the storage period; Bongabon, Nueva Ecija

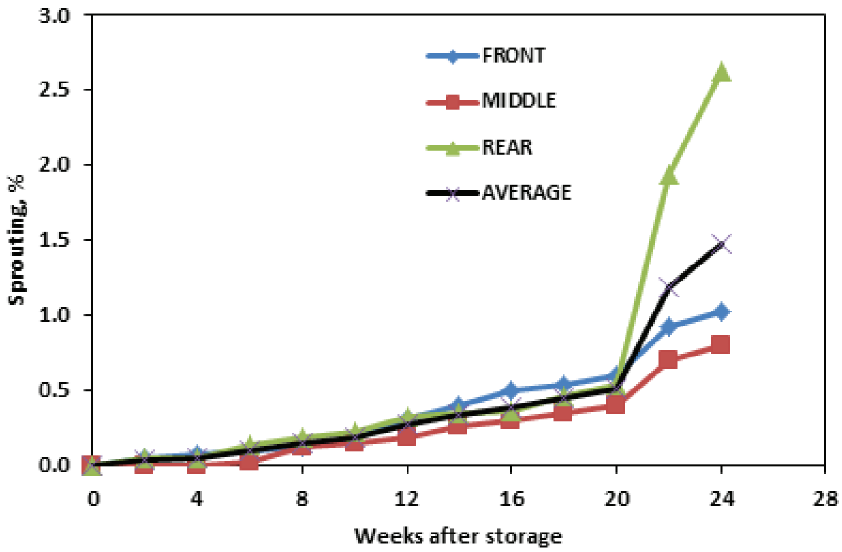

Figure 4. Sprouting intensity of stored bulb onion under different storage locations throughout the storage period, Bongabon, Nueva Ecija

Rotting Intensity

Figure 5 shows the bulb-rot intensity of stored bulb onion samples stored in Bongabon, Nueva Ecija. The rotting intensity of stored bulb onion increased progressively with increase in storage period in all storage locations. Rotting was gradual from the beginning of storage until the 18th week of storage period (P>0.05) and further increased from 19 to 24th week of storage.

This gradual increase of rotting in bulb onion with the storage period increases was also observed by Endalew et al. (2014) where rotting was observed in the first 10 days of storage. At the end of storage experiment, the computed mean bulb-rot intensity at the rear, middle and front of the storage bin was 18.03%, 11.75%, and 11.63%, respectively. Across the entire locations, the mean bulb-rot intensity was computed at 13.8%, with an equivalent of 0.144 kg/wk weight reduction.

Storage of onion in bulk (Science City of Muñoz Case)

Science City of Muñoz is one of the leading onion producers in the province of Nueva Ecija. It is situated 147 km north of Manila. With its rich topography and tropical climate, it is now home to agricultural research and technology centers, committed to the production of information and technological breakthroughs to promote rural development, productivity and food security. For storage trial, about 3800 kilograms of bulb onion were stored in near-ambient temperature storage system.

Physiological Weight Loss

The weight reduction of onion samples during the 24-week storage experiment is shown in Figure 6. Results showed that gradual weight reductions were observed from the beginning of storage until the 16th week of storage (P>0.05) and registered a faster weight reduction in the 17th to 24th week of storage. At the end of 16th week of storage, the mean weight of onion samples per bag all throughout the storage location was reduced from 25.02 kg to 20.15 kg. The computed percentage weight loss at the 16th week of storage was 19.48%. At the end of the storage trial (24th week), the computed mean percentage weight loss increased to 44.23%.

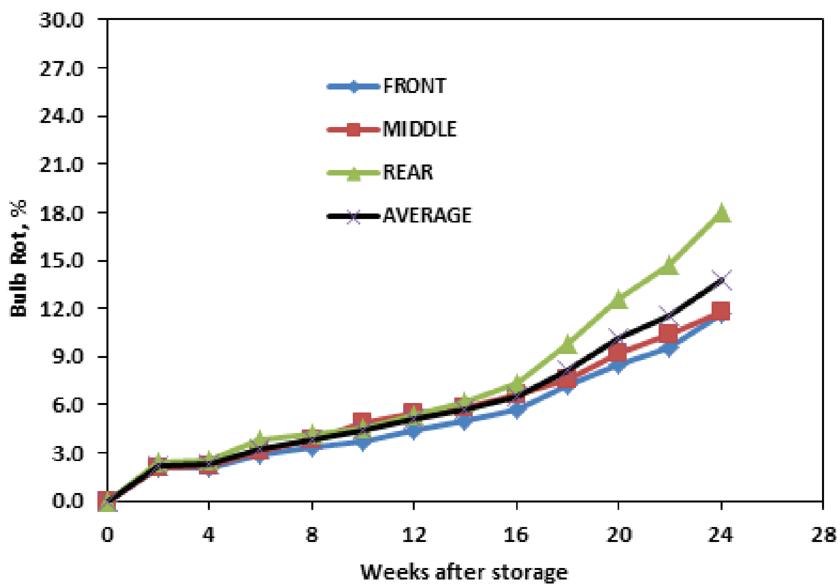

Figure 5. Rotting intensity of stored onion under different storage methods throughout the storage period, Bongabon, Nueva Ecija

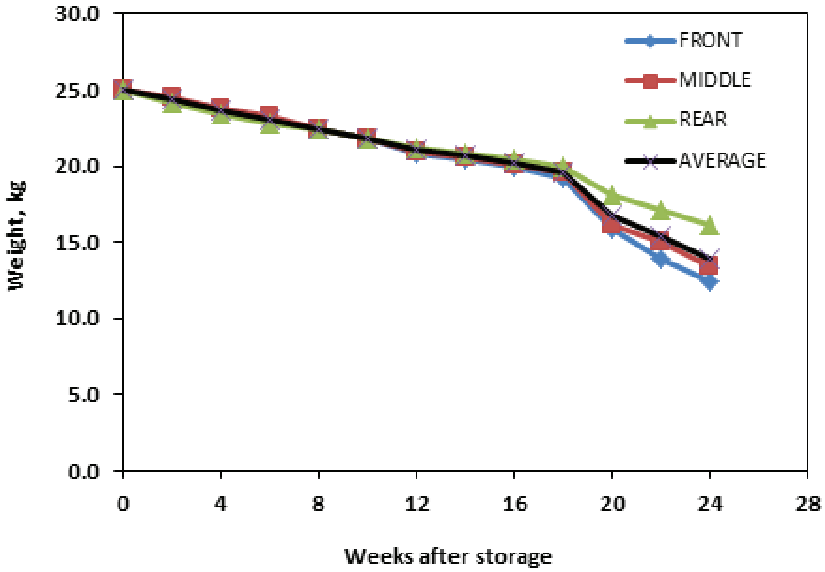

Figure 6. Physiological weight loss of stored onion under different storage locations throughout the storage period, Muñoz, Nueva Ecija

Sprouting Intensity

As shown in Figure 7, the sprouting intensity of stored bulb onion increased with increase in storage period in all storage location. Sprouting is abrupt from the beginning of storage until the four weeks of storage and gradually increased from four to 24 weeks of storage. Mean sprouting percentage between locations is not significantly different (P>0.05). At the end of the storage experiment (24th weeks), the computed mean bulb sprouting intensity was 0.597 %, 0.519 % and 0.539 % at the front, middle and rear location of the storage bin, respectively (Table 18). Across the storage location, the computed mean sprouting intensity was 0.552%.

Rotting Intensity

Figure 8 shows the bulb-rot intensity of stored bulb onion samples stored in near-ambient storage system. As in the case of Bongabon, the rotting intensity of stored bulb onion increases with increase in storage period in all storage locations. As illustrated, rotting is gradual from the beginning of storage until the 14th week of storage period and further increased from 15 to 24th week of storage.

Mean percentage of bulb-rot between locations was not significantly different (P>0.05) until beyond 14^{th} week of storage period. At the end of storage experiment, the computed mean bulb-rot intensity at the front, middle and rear of the storage bin was 19.09%, 26.42% and 11.43%, respectively. Across the entire locations, the mean bulb-rot intensity was computed at 18.98%.

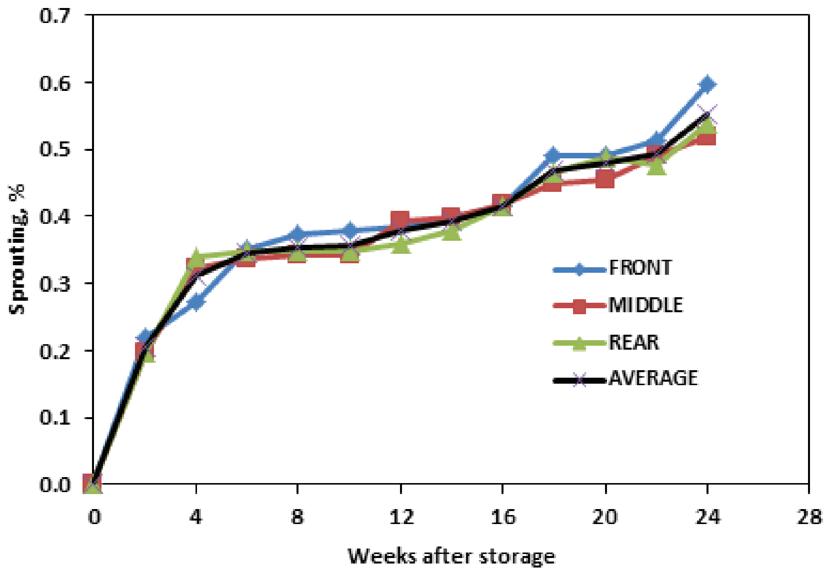

Figure 7. Sprouting intensity of stored bulb onion under different storage locations throughout the storage period, Munoz, Nueva Ecija

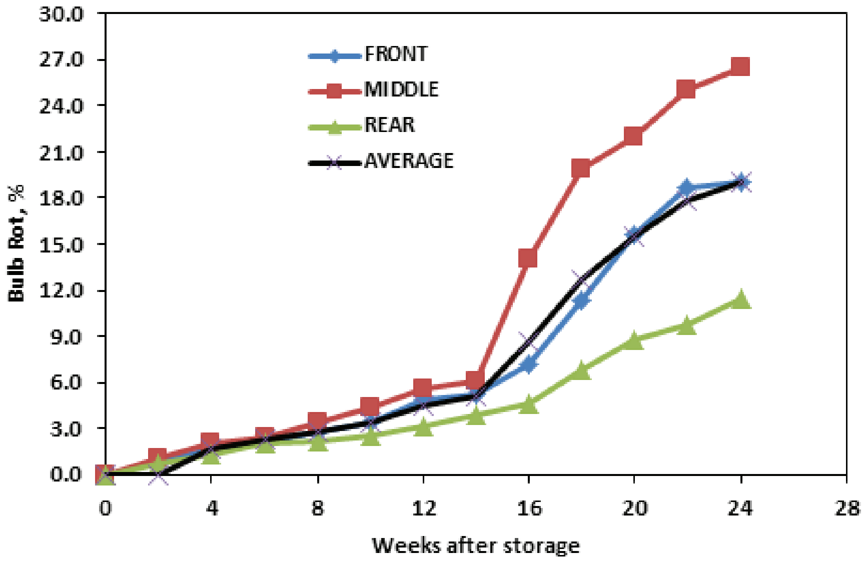

Figure 8. Rotting intensity of stored onion under different storage methods throughout the storage period

Financial Performance of Near-Ambient Storage System

The financial viability of near-ambient temperature storage system was assessed by first determining the optimum storage period.The optimum storage period is the number of days where the highest net profit is obtained. In this case, the storage losses were translated into recovery or percentage of marketable onion after storage to get the revenue for every storage period.

The optimum storage period was affected by losses, storage cost and prevailing price. The price of onion increased with lengthier storage period but losses and storage cost also increased over time.

This means that while potential revenue increases due to increase in price, the amount of saleable onion decreases due to storage losses. In the same manner, the potential revenue was also reduced due to increase in storage cost.

Figure 9 shows the cumulative revenue and cost of storing bulb onion in near-ambient temperature storage system. This suggests that a little profit can already be realized four weeks after storage but the maximum profit can be obtained by selling the stored onion after 16 weeks with profit of Php266.90 per bag (Table 2). Within 16 to 21 weeks, profit can still be realized however beyond 22 weeks; where the cost outweighs the revenue, a negative benefit will be realized.

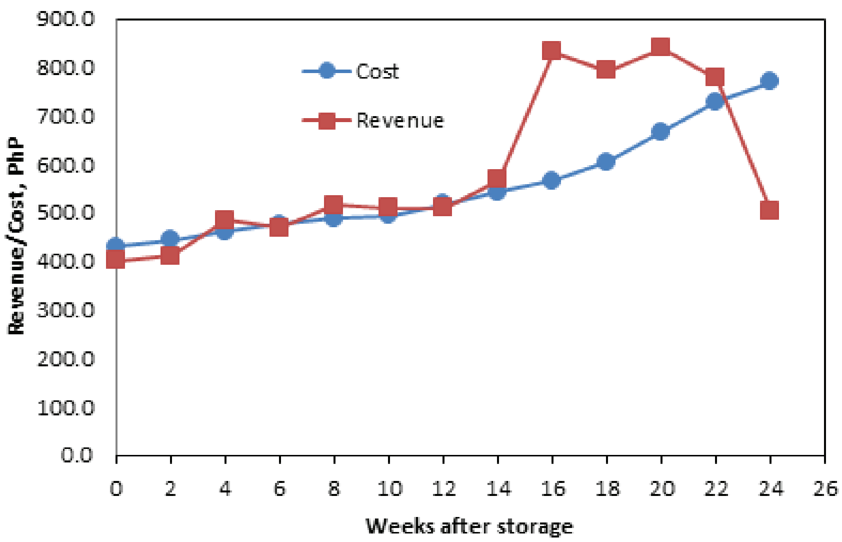

Figure 9. Rotting intensity of stored onion under different storage methods throughout the storage period

The viability indicators of investing and using near-ambient temperature storage system for storing bulb onion are shown in Table 3.

With an investment cost of Php60,000 for the construction and installation of near-ambient temperature storage system, actual stored volume or quantity of 4,950kg/batch of bulb onion and percentage recovery of 77.94% at the end of four months as the optimum storage period based on previous analysis, the estimated netpresent value (NPV), payback period (PBP), benefit-cost ratio (BCR) and Internal Rate of Return (IRR) was Php110,530.18, 0.86 year, 1.84 and 40.36% respectively.

This indicated that the estimated IRR of the technology was higher than the 12% interest rate in commercial bank for loans showing a good financial performance. With a storage recovery yield of 3,858 kg and a market price of Php42.5/kg, storing bulb onion in near-ambient storage system was found financially viable.

At a price lower than Php29/kg, storing of bulb onion will no longer be viable. A potential onion farmer/owner of the technology could invest borrowing the needed capital from a bank at an interest rate of 12% and realize positive net benefits and eventually recover his investment in one just season (0.86 year).

Table 2. Potential profit of onion stored in near-ambient storage system given prevailing price, recovery and storage cost

WAS	Q	P	C	R (P*Q)	Π (R-C)
0	25.02	16.00	430.13	400.32	-29.81
2	24.16	17.04	444.78	411.69	-33.10
4	23.34	20.74	461.79	484.07	22.28
6	22.65	20.74	476.10	469.76	-6.34
8	22.09	23.32	489.16	515.14	25.98
10	21.83	23.32	495.22	509.08	13.85
12	20.95	24.38	516.68	510.76	-5.92
14	20.04	28.38	542.50	568.74	26.23
16	19.50	42.69	565.56	832.46	266.90
18	18.57	42.69	605.26	792.75	187.50
20	17.30	48.57	666.94	840.26	173.32
22	16.01	48.57	729.60	777.61	48.01
24	14.20	35.31	793.51	501.40	-292.11

WAS = weeks after storage, weeks
Q = marketable onion, initial weight of 25 kg at day 0
P = price at period t, pesos
C = cost, pesos
R = revenue, pesos
Π = profit, pesos

Table 3. Financial performance of Near-ambient temperature storage system, Bongabon, Nueva Ecija case

Financial Indicators	Value
Investment cost	60,000.00
Fixed cost, P/year	7,800.00
Variable cost, P/year	86,304.00
Total operating cost	94,104.80
Gross income, P/year	163,966.28
Net income, P/year	69,861.48
Payback period, years	0.86
Internal rate of return (IRR), %	40.36
Benefit - cost ratio	1.84
Return on Investment (ROI), %	116.43
Net present value @ 12% , Php	110,530
Breakeven volume of onion, kg/season	4,050
Breakeven selling price of onion, Php/kg	29.00

CONCLUSION AND RECOMMENDATIONS

The developed near-ambient temperature storage system can be used to store and extend the shelf life of bulb onion. Based on the evaluation, the near-ambient temperature storage system could store bulb onions in bags for 18 weeks (4.5 months) and 16 weeks in bulk storage with uniform weight reduction in all locations of the storage bin.

The optimum storage duration for bulb onion which gave the highest profit of around Php267.00/bag (Php10.68/kg) was determined at 16 weeks of storage period. The optimum storage duration is negatively influenced by the rate of losses and positively affected by increasing price of bulb onion through time from the time of harvest. Within 16 to 21 weeks of storage, profit can still be realized.

However, beyond 22 weeks; where the cost outweighs the revenue, a negative benefit will be realized. Financial analysis showed favorable results from the viewpoints of technology users.

Adoption of near-ambient storage system suggests that the farmer-owners will realize a positive benefit mainly from increased price of onion after four months storage and eventually recover the investment in just one cropping season.

Findings from this study would directly benefit bulb onion farmers by providing them alternative storage system suited on the volume they handle and some flexibility in the disposal of their produce. A more extensive pilot testing of the technology using solar panel as source of energyis recommended not only to validate its technical performance and financial benefits but to demonstrate and create awareness of the presence of an alternative storage technology.

ACKNOWLEDGMENT

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ADDRESSING CLIMATE-RELATED RISKS THROUGH RICE COMBINE HARVESTERS: EVIDENCE FROM ISABELA, PHILIPPINES

Hernaiz G. Malanon[1] and Zenaida M. Sumalde[2]

ABSTRACT

This study assessed the potential of rice combine harvester in addressing climate-related risks brought by tropical cyclones that constrains rice farmers during harvest operations in Isabela, Philippines. Although the number of tropical cyclones that affected the province has been declining, the frequency of stronger/ more destructive typhoons is increasing. Annually, rice farmers in Isabela incurred an average of Php158.71 million (US$ 3.17 million) value of crop damages, qualitative losses and additional costs due to tropical cyclones during harvest. The use of RCH potentially reduces exposure of rice farmers to tropical cyclones by 36 to 76 percent. In Isabela alone, the reduced exposure of rice farmers to climate hazards during harvest generate savings amounting to Php 46.62 (US$ 0.93 million) per year through reduced crop damages, averted grain qualitative losses and avoided additional cost of harvesting lodged crop.

Keywords: Rice combine harvester, Climate-related risks, Tropical cyclone

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INTRODUCTION

Climate-related risks are major sources of production risks in agriculture. In the Philippines, agriculture particularly the rice sub-sector often accounts for bulk of total damages attributed to tropical cyclones. Crop damages include the physical losses due to flooding and shattered grains caused by strong winds. Other losses are in the form of diminished grain quality due to submerged crops and delayed postharvest activities. These forms of losses result in reduction in output and lower price of farmers' produce.

With climate hazards such as tropical cyclones projected to intensify or become more unpredictable, adaptation mechanisms are needed to safeguard the produce and income of farmers. The unfavorable impacts of climate change necessitate adaptation in addition to mitigation (IPCC, 2007). Some adaptation measures being applied in Philippine agriculture include the use of stress-tolerant and early maturing varieties, expansion of irrigation facilities, crop diversification, crop relocation, intensification of planted area, migration to other areas, crop insurance and adjustment in cropping calendar.

While shifting the cropping calendar is possible for some crops, it is not commonly applicable for rice because of the limitation on the availability of irrigation water and the need to synchronize planting activities in order to avert pest infestation and avoid problem on farm access. Because of these constraints, rice farmers have to deal with inclement weather which normally coincides with harvest periods.

While mechanization technologies were primarily developed to improve labor and land productivity, other benefits in terms of reducing the exposure and vulnerability of rice farmers to climate hazards are not well documented. This study aims to evaluate the potential of rice combine harvester as an adaptation mechanism to address climate-related risks.

METHODOLOGY

Locale of the Study

The study covered Isabela, the second top rice producing province in the Philippines and one of the areas with high risk to typhoons (PAGASA). In addition, adoption rates for mechanization technologies in the province are found to be among the highest nationwide (PHilMech).

Research and Sampling Design

The study employed both qualitative and quantitative methods of design and analysis. The total number of sample respondents was determined using the formula:

$$n = \frac{Z^2PQ}{D^2}$$

Where Z is confidence level of 90% (standard deviation of 1.645); P is estimated prevalence of farmers in the project area (in %), that is, the proportion of the target population with a given characteristic (rice farmers); Q is $1-P$; D is margin of error at 5%.

Data Collection and Research Instrument

Data were collected through personal interview of 230 randomly selected rice farmers that adopted and not adopted rice combine harvester in major rice producing municipalities of Isabela. Farm survey was done in 2018 although data collected includes 2017 cropping period. Interview of 30 rice combine harvester, thresher operators and key informants in 24 rice producing areas, actual field observations and secondary data collection were also done to supplement collected data. Key informants included the Provincial Agriculture staff particularly the Postharvest Facility (PHF) Coordinators, Municipal Agriculture Officers (MAOs) and barangay officials in charge of the agriculture sector. Agro-climatic data on rainfall and typhoons were requested from PAGASA provincial Agro-Met Station. Moreover, inventory of mechanization technologies was taken from PHilMech database.

Analytical Procedure

Data were encoded, tabulated and analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics such as percentage, frequency distribution, cross tabulation and measures of central tendency.

To assess the climate-related risks that affect rice farmers during and after harvest, the formula of risk as defined by the Intergovernmental Panel on Climate Change (IPCC) was used:

Risk = Hazard x Exposure x Vulnerability

where:

Hazard was assessed in terms of the probability of occurrence of typhoons and during period of rice harvest. The study used historical data from PAGASA Isabela State University (ISU) AgroMet Station. The probability of occurrence was calculated by determining the number of tropical cyclones that hit the province per month when farmers are harvesting their crops.

Exposure was based on cropping calendar of rice farmers

Vulnerability or consequence of tropical cyclone and prolonged rainfall hazards based on the actual experiences of rice farmers based on farm survey was determined in terms of the following:

- Volume of damaged crop/losses, in kg/ha
- Increase in harvesting costs due to crop lodging, in Php/ha
- Price penalty/discount due to grain quality degradation as a result of flooding or delayed harvesting-threshing operations, in Php

Climate-Related Hazards, Exposure and Vulnerability of Rice Farmers to Hazards during and after Harvest

Assessment of risks from natural hazards involves calculation of probability of hazard occurrence and the level of potential losses based on exposure and vulnerability. This is consistent with IPCC framework which defines risk as a function of hazard, exposure and vulnerability.

While the probability of hazard occurrence can be easily quantified using a common unit of measure, the exposure and vulnerability are often assessed using multi-dimensional approaches. The study postulated that one of the roles of mechanization is to reduce the exposure of rice farmers to climate hazards that are detrimental to rice crop during and after harvest. Exposure as defined by the IPCC refers to the presence of people and assets in areas subject to the occurrence of natural hazards. Following the method used by Bouwer (2012), exposure was factored in to the probability of hazard occurrence to determine how it affects the likelihood of hazard occurrence.

The study likewise adopts the definition of vulnerability by United Nations Disaster Relief Organization (UNDRO, 1991) which is the degree of loss resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage). This definition framed vulnerability as the impact or consequence expressed as probability or percentage. Following this definition, crop damages or losses incurred by rice farmers caused by climate hazards indicate the vulnerability of farmers to such events.

RESULTS AND DISCUSSION

Tropical Cyclone Hazard

The Philippines has been regarded as the most vulnerable country in the world in terms of tropical cyclones as more tropical depressions, storms and typhoons are entering the Philippine Area of Responsibility (PAR) than anywhere else in the world. With an average of 20 tropical cyclones developed per year, more than 40% are making landfall in the country. The peak of typhoon season is from July through October, when nearly 70% of all typhoons are formed (PAGASA).

In Isabela, 89 tropical cyclones affected the province from 2001 to 2017, with high frequency of tropical cyclones occurred from 2004 to 2009 (Figure 1). From 2001 to 2010, 61 tropical cyclones were experienced compared to 26 tropical cyclones in 2011 to 2017. The frequency of tropical cyclones declined by more than 50% between the two periods.

Of the total tropical cyclones that affected the province, more than 60% occurred during the period of rice harvest. Meanwhile, all three tropical cyclones in 2001 and 2002 occurred before crop maturity while all typhoons recorded in 2007, 2013, 2014 and 2017 emerged during harvesting stage.

Tropical cyclones that occurred during the time of harvest were only observed during the rainy season that covered the months of August, September, October and November. The highest frequency of tropical cyclone occurrences was recorded in 2006, 2008 and 2009 while there were no typhoon occurring in 2001 and 2002 (Figure 2). It is important to note that for the period 2001-2008, tropical cyclones were experienced during the month of November but since 2009, there was no typhoons recorded during this month. There was also a decreasing trend in the number of tropical cyclones from 2009 to 2018.

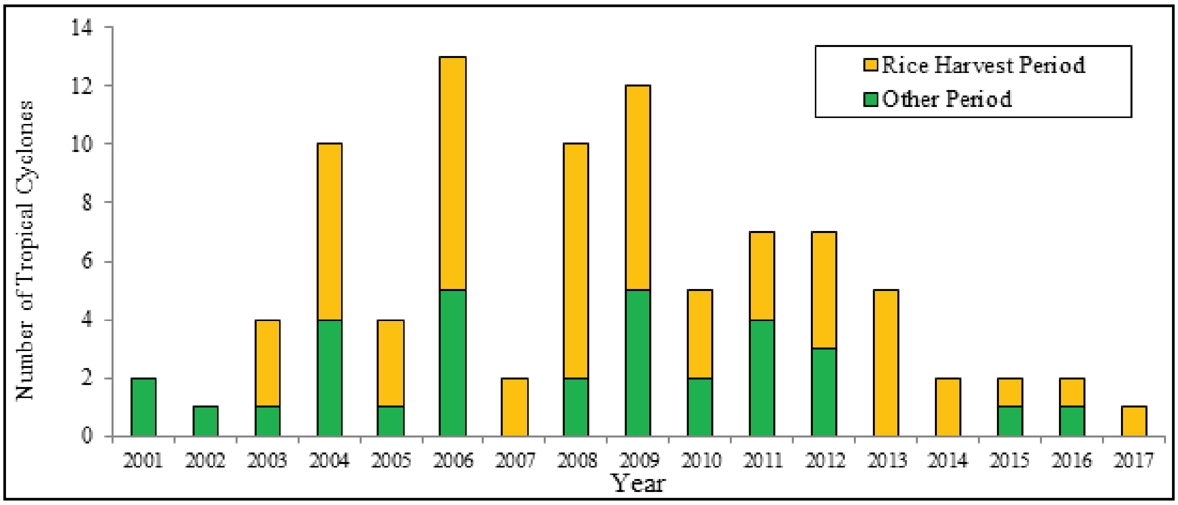

Figure 1. Frequency of tropical cyclones that affected Isabela, Philippines, 2001-2017

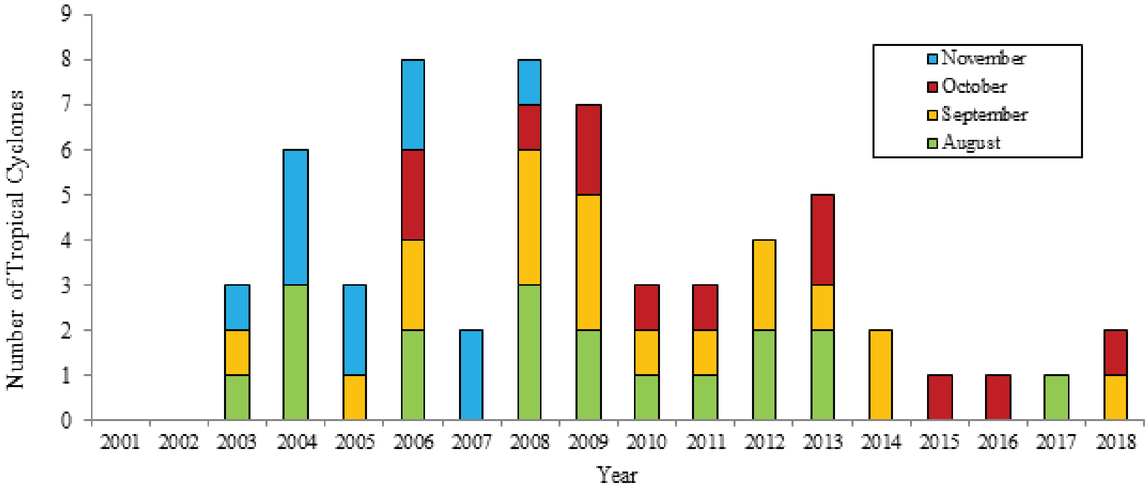

Figure 2. Frequency of tropical cyclones that affected Isabela during period of rice harvest, 2001-2018

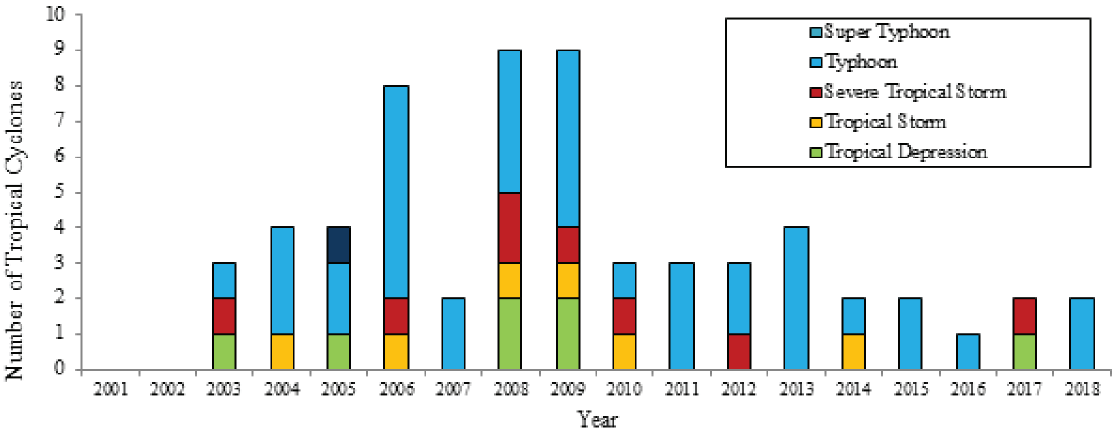

Figure 3. Number of tropical cyclones based on strength of the associated winds, rice harvest period, Isabela, Philippines, 2001-2018

The number of tropical cyclones that occurred during the time of harvest according to strength/magnitude is exhibited in Figure 3. This was based on the tropical cyclone classification according to the strength of the associated winds as adopted by PAGASA as of 2015:

1. Tropical Depression (TD) - a tropical cy clone with maximum sustained winds of up to 61 kilometers per hour (kph) or less than 33 nautical miles per hour (knots);
2. Tropical Storm (TS) - a tropical cyclone with maximum wind speed of 62 to 88 kph or 34 - 47 knots;
3. Severe Tropical Storm (STS) - a tropical cyclone with maximum wind speed of 89 to 117kph or 48 - 63 knots;
4. Typhoon (TY) - a tropical cyclone with maximum wind speed of 118 to 220kph or 64 - 120 knots; and
5. Super Typhoon (STY) - a tropical cyclone with maximum wind speed exceeding 220kph or more than 120 knots.

Typhoons made up more than 60% of the total number of tropical cyclones that traversed the province since 2001. While the frequency of tropical cyclone occurrences was declining, the number of stronger and more destructive typhoons has been more evident during the later period. This is consistent with most findings indicating that typhoons are getting stronger and more destructive although the frequencies of occurrences are declining.

Probability of Tropical Cyclone Occurrences

Based on the average life history or longevity of typhoons or range of rice maturity period (number of days at late maturity minus number of days at early maturity), the likelihood of tropical cyclone occurrences for the period 2001-2018 was calculated. This was determined by the number of tropical cyclone occurrences in a month over the total number of possible tropical cyclones that potentially affect rice crop at maturity ready for harvest. The average probability of tropical cyclone occurrence during the wet season was 0.17 during the period 2001-2010 and declined to 0.10 for the period 2011-2018 (Table 1). In general, there was a considerable decline in the probability of tropical cyclones occurrences during the months of August, September and November.

Exposure of Rice Farmers to Tropical Cyclone Hazard

For the period 2011-2018, the average rice area harvested in the province for two cropping seasons was 281,330 hectares. Hectarage for the wet season accounted for 49% of the total harvested area and consequently lower volume of production, comprising only 47% of the total annual production (Table 2).

Based from PSA data, the variability in area harvested and production for the wet season were higher than the dry season. The huge variability of production during the wet season may be explained by the more frequent tropical cyclone occurrences during the months of August to November when the rice crops are at the reproductive to maturity stages. The low rice production in 2018, 2011, 2016 and 2015 indicated the occurrences of strong typhoons that curtailed production during those periods.

Table 1. Probability of tropical cyclone occurrence during period of rice harvest, wet season, Isabela, Philippines, 2001-2018

MONTH	PERIOD		
	2001-2010	2011-2018	2001-2018
August	0.2000	0.1250	0.1667
September	0.1833	0.1458	0.1667
October	0.1000	0.1250	0.1111
November	0.1833	0.0000	0.1018
Mean	*0.1667*	*0.0990*	*0.1366*

Table 2. Hectarage and volume of rice production, Isabela, Philippines, 2011-2018

YEAR	AREA HARVESTED (HA)			PRODUCTION (MT)		
	Dry Season	Wet Season	Annual	Dry Season	Wet Season	Annual
2011	138,634	134,398	273,032	598,904	469,371	1,068,275
2012	141,384	141,765	283,149	614,450	602,085	1,216,535
2013	141,397	145,221	286,618	600,300	649,573	1,249,873
2014	144,969	141,350	286,319	639,597	638,026	1,277,623
2015	147,458	135,445	282,903	668,315	588,075	1,256,390
2016	145,243	132,758	278,001	668,596	554,129	1,222,725
2017	145,430	133,861	279,291	691,868	593,817	1,285,685
2018	146,411	134,915	281,326	703,800	484,784	1,188,584
Mean	*143,866*	*137,464*	*281,330*	*648,229*	*572,483*	*1,220,711*
Percentage	*51*	*49*	*100*	*53*	*47*	*100*
CV, %	*2.11*	*3.35*	*1.61*	*6.32*	*11.53*	*5.70*

Source: Philippine Statistics Authority

Effect of Cropping Calendar on Exposure of Rice Farmers to Tropical Cyclones

During the wet season, majority of the farmers have high exposure to tropical cyclones since 64% of rice farmers harvest their crops during the month of October and 26% harvest in September when the probability of tropical cyclone occurrence were high. Adjusting the probability of hazard occurrence and exposure of rice farmers based on the harvest period, the weighted average probability of tropical cyclone hazard and exposure during the wet season was 0.1267 for the 2011 to 2018 period (Table 3). Based on the average rice area harvested during the season, more than 17,400 hectares were exposed to tropical cyclones every year.

Vulnerability of Rice Farmers to Tropical Cyclones during Harvest

Quantitative losses

While there was a decreasing trend in the frequency of typhoons that devastated the province, the volume of crop damages exhibited an increasing trend (Figure 5). Typhoon Ompong which occurred in 2018 recorded the largest amount of rice crop damage estimated at 138,574.46 metric tons of paddy at different stages of crop development. Crop damages were incurred due to strong winds that caused grain shattering and crop lodging. Other losses were in the form of submerged crop as a consequence of flooding. On the average, 11,603.27 metric tons of paddy was lost due to tropical storms and typhoons every year.

Table 3. Probability of occurrence and exposure of rice farmers to tropical cyclones, Isabela, Philippines

MONTH OF HARVEST	PERCENT EXPOSURE	PROBABILITY OF TROPICAL CYCLONE OCCURRENCE x EXPOSURE		
		2001-2018	2001-2010	2011-2018
August	7	0.0117	0.0140	0.0088
September	26	0.0433	0.0477	0.0379
October	64	0.0711	0.0640	0.0800
November	3	0.0031	0.0055	0.0000
Weighted Mean		*0.1292*	*0.1312*	*0.1267*

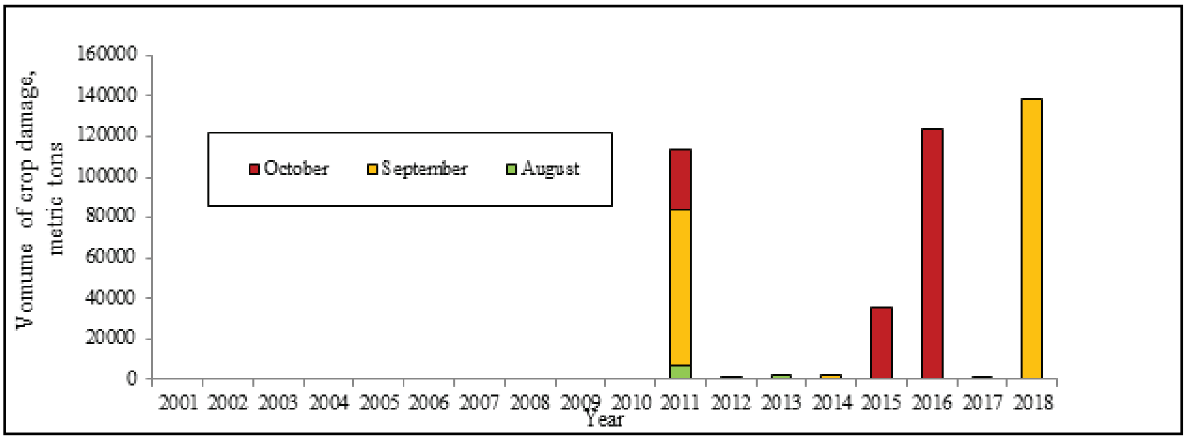

Figure 4. Volume of total rice crop damages attributed to tropical cyclones, Isabela, Philippines, 2001-2018

For the period 2011-2018, rice farmers in Isabela incurred rice crop damages amounting to Php 44,002.00 to Php 635.74 million for rice ready for harvest (Table 4). Highest value of crop damages was incurred during the month of September. On the average, crop damage at maturity accounted for 21% of total crop damages due to tropical cyclones.

From farm survey, the average volume of crop damage reported by rice farmers did not differ per hectare but differs significantly based on a per farm basis as the average farm holding of RCH adopters are significantly higher. RCH adopters reported an average of 725 kilogram per hectare during occurrences of typhoons. On the other hand, the non-adopters incurred higher losses at 844 kilograms per hectare (Table 5).

Qualitative losses

In addition to the quantitative losses due to tropical cyclones reported by farmers, qualitative losses are also incurred by rice farmers. These include value of grains with degraded quality as manifested by discoloration and also the shrinkage allowances charged by traders because of high moisture contents for wet and/or immature grains. These losses are caused by harvesting too early or too late due to inclement weather, delayed harvesting-threshing operations and submerged crop due to flooding. About 39% of the interviewed farmers reported to have experienced grain quality deterioration due to tropical cyclones. Based on these assumptions, farmers in Isabela suffer rice qualitative losses with monetary value of Php31.12 million to Php93.07 million per year (Table 6).

Table 4. Value of rice crop damages at maturity stage attributed to tropical cyclones, Isabela, Philippines, 2011-2018

YEAR	**MONTH**			
	Aug	**Sep**	**Oct**	***MEAN (Php)***
2011	22,899,927.00	263,920,103.00	103,104,763.00	129,974,897.00
2012	44,002.00	0	0	14,667.00
2013	7,936,476.00	0	0	2,645,492.00
2014	0	13,115,322.00	0	4,371,774.00
2015	0	0	111,979,524.00	37,326,508.00
2016	0	0	432,077,319.00	144,025,773.00
2017	4,260,590.00	0	0	1,420,197.00
2018	0	635,742,444.00	0	211,914,148.00
Mean, Php	*4,392,612.00*	*114,097,233.00*	*80,895,201.00*	*66,461,682.00*

Source of data: Office of the Provincial Agriculturist, Isabela

Table 5. Comparison of crop damages incurred due to tropical cyclones during period of rice harvest, by rice combine harvester adoption, 230 farmer respondents, Isabela, Philippines, 2018

ITEM	**ADOPTER *(n=190)***	**NON-ADOPTER *(n=40)***	**MEAN *(t-test)***	**DIFF. ALL *(n=230)***
Per Hectare, kg	725.50	844.27	118.77^{ns}	744.47
Per Farm, kg	3,876.06	1,191.42	$2,684.64^{**}$	3,383.88

**Significant at 5% (P = .025)
ns Not Significant at 10% level (P >.100)

Table 6. Rice qualitative losses at harvest due to tropical cyclones, Isabela, Philippines, 2018

PARTICULAR	RANGE	MEAN
Total area affected[1],	ha	6,792
Total volume of losses[2],kg		28,288,680
Price discount, %	6-18	13
Price discount[3], Php/kg	1.10-3.29	2.38
Value of qualitative losses, Php	*31,117,548.00-93,069,757.00*	*67,327,058.00*

[1]Based on 137,464 ha (wet season) *x* 39% *x* 0.1267 probability of typhoon occurrence *x* exposure
[2]At 4,165 kg ha^{-1} average yield, dry basis
[3]At Php18.30/kg, average price dry paddy and 13% price reduction

Table 7. Additional harvesting-threshing costs due to crop lodging attributed to tropical cyclones, Isabela, Philippines, 2018

PARTICULAR	RANGE	MEAN
Added cost, %	33-67	49
Added cost ha^{-1}, Php[1]	2,409.00-4,891.00	3,577.00
Total area affected[2], ha		6,967
Total additional cost, Php	*16,783,503.00-34,075,597.00*	*24,920,959.00*

[1] At Php 7,300.00 ha^{-1} average harvesting-threshing cost
[2] Based on 137,464 ha (wet season) *x* 40% *x* 0.1267 probability of tropical cyclone occurrence *x* exposure

Added cost of harvesting lodged crop

Other cost constitutes the additional charges of laborers in harvesting lodged crop. Based on the average harvesting-threshing cost, additional cost of Php3,577.00 was incurred by farmers per hectare during occurrences of typhoons. About 40% of the farmers experienced bearing additional cost of harvesting due to crop lodging. Considering the total area affected, additional cost amounting to Php24.92 million was incurred per year (Table 7).

Effects of RCH Adoption in Reducing the Exposure of Rice Farmers to Tropical Cyclones

The probability of tropical cyclone exposure of rice farmers to tropical cyclones was adjusted to reflect the harvest period by adopters and non-adopters of rice combine harvesters. Because the two groups of farmers follow different cropping calendar due to availability of irrigation water, their exposure to tropical cyclones also differ. In general, the average probability of exposure of RCH adopters was lower than the non-adopters (Table 8). This was explained by the significant number of farmers who extended their harvest period to November when there was no recorded tropical cyclone during the period.

To determine the effect of using RCH on the exposure of rice farmers to tropical cyclones, the capacity of RCH and traditional method of harvesting and threshing were compared.

On the average, harvesting to threshing time per hectare was reduced by 76% by using RCH. Considering that PAGASA generally issues typhoon advisory three days before a tropical cyclone make landfall, rice farmers have more time to harvest their crops to avoid potential crop damage and other consequences.

Table 8. Probability of occurrence and exposure of rice farmers to tropical cyclone hazard, by RCH adoption, wet season, Isabela, Philippines

PERIOD	PROBABILITY OF OCCURRENCE x EXPOSURE		
	ADOPTER	NON-ADOPTER	ALL
2001-2018	0.1261	0.1438	0.1292
2001-2010	0.1227	0.1736	0.1312
2011-2018	0.1304	0.1064	0.1267

Table 9. Effect of using RCH in reducing exposure of rice farmers to tropical cyclones, Isabela, Philippines

ITEM	MANUAL HARVESTING/ MECH’L THRESHING	RICE COMBINE HARVESTER	CHANGE
Harvesting-threshing time			
Harvesting, hr/ha	8.5	2.8	
Threshing, hr/ha	3.5	-	
Total harvesting-threshing time, hr/ha	*12.00*	*2.8*	*(76%)*
Capacity of laborers/facilities[1], ha			
Harvesting-threshing	*14,062*	*19,200*	*(36%)*

[1]All laborers and facilities are employed for three days before typhoon occurrence (4,694 rice threshers, 90,000 farm laborers – harvesters and 1,600 RCH)

Assuming that all laborers and facilities were employed for three days before occurrence of tropical cyclone, the number of hectares that can be harvested before the arrival of typhoon was estimated to determine the difference of the two methods.

Result showed that harvesting and threshing takes 36% less time with the use of RCH compared to the traditional method. This means that using RCH reduces exposure of rice farmers to tropical storms by 36% (Table 9).

Using the reduction in the exposure of rice farmers to tropical cyclones with the use of RCH, the probability of occurrence and exposure of rice farmers to tropical cyclones declines to 0.0835 for RCH adopters (Table 10).

Averted crop damage, qualitative losses and additional costs

The reduced exposure of rice farmers to tropical cyclones resulted in savings from averted crop damage amounting to Php29.81 million per year (Table 11). In addition, the value of qualitative losses due to grain deterioration was estimated at Php10.95 million while the savings from prevented additional cost of harvesting was Php5.85 million. At 90% adoption, the total savings from averted crop damage, qualitative losses and additional costs amounted to Php46.62 million per year.

Table 10. Probability of occurrence and exposure of rice farmers to tropical cyclone hazard with the use of RCH, wet season, Isabela, Philippines

PERIOD	**ADOPTER**	**NON-ADOPTER**
2001-2018	0.1261	0.1438
2001-2010	0.1227	0.1736
2011-2018	0.0835	0.1064

Table 11. Economic benefits through averted rice crop damage and costs due to tropical cyclones, 90% RCH adoption, Isabela, Philippines, 2018

ITEM	**MANUAL HARVESTING/ MECH'L THRESHING *(A)***	**RICE COMBINE HARVESTER *(B)***	**INCREMENT *(A-B)***
Quantitative loss			
Volume/ha, kg	844.00	725.00	
Prob. *x* Exposure	0.1064	0.0835	
Total damage/ha	89.80	60.54	
Total damage[1], kg	4,999,517	3,370,299	
Sub-total, Php	91,491,166.00	61,676,479.00	
Reduced quantitative losses, Php			*29,814,687.00*
Qualitative loss			
Volume[2], kg/yr	200,960,684	200,960,684	
Prob. [x] Exposure	0.1064	0.0835	
Price discount[3], Php/kg	2.38	2.38	
Sub-total, Php	50,889,676.00	39,936,917.00	
Reduced qualitative losses, Php			*10,952,759.00*
Increased cost due to lodged crop			
Additional cost, %	57%	33%	
Harvesting cost/ha,	5,901.00	8,698.00	
Additional cost/ha	3,363.57	2 ,870.34	
No. of ha. affected	49,487	49,487	
Prob. *x* Exposure	0.1064	0.0835	
Sub-total, Php	17,710,612.00	11,860,726.00	
Avoided cost, Php			*5,849,886.00*
TOTAL, Php			*46,617,332.00*

[1] At 137,464 ha (wet season) *x* 90% adoption *x* 45% affected *x* probability of typhoon occurrence *x* exposure *x* Php18.30/kg, average price dry paddy

[2] Based on 137,464 ha (wet season) *x* 90% adoption *x* 39% *x* probability of typhoon occurrence *x* exposure

[3] At Php18.30/kg dry paddy

[4] Based on 137,464 ha (wet season) *x* 90% adoption *x* 40% *x* probability of typhoon occurrence *x* exposure

CONCLUSION AND RECOMMENDATIONS

Rice farmers in Isabela, Philippines have been frequently exposed to climate-related risks caused by tropical cyclones as indicated by huge amount of crop damages and losses during occurrences of these events. As part of adaptation mechanism, the use of rice combine harvester potentially reduces the exposure of rice farmers to tropical cyclones by 36% and this contributes in safeguarding their produce and income.

Results of this study further substantiate the need to accelerate adoption of rice combine harvesters in major rice production areas of the country, especially in regions that are categorized as highly at risk to tropical cyclones. The amounts of crop damages or losses are likely to be higher in these areas; hence, potential benefits from introducing adaptation measures are expected to be enormous.

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POSTHARVEST INTERVENTIONS ON ROBUSTA GREEN COFFEE BEANS IN SELECTED COFFEE PRODUCING PROVINCES OF THE PHILIPPINES

Rodelio G. Idago[1], Ma. Cecilia R. Antolin[2] and Renita SM. Dela Cruz[3]

ABSTRACT

This study aimed to assess the Robusta green coffee bean (GCB) value chain and recommend postharvest interventions in selected coffee producing provinces of the Philippines. Value chains were mapped out by tracing method with information obtained through focus group discussions and key informant interviews in 12 major coffee producing provinces. Postproduction practices were identified through observations of actual postharvest practices and survey of 118 coffee farmers in pilot study sites. Differences in postharvest losses between actual and with postharvest interventions were analyzed using t-test. Quality parameters were measured using the three-tiered grading system that is generally applied for Robusta coffee: 1) moisture content; 2) triage or extent of physical defects; and 3) cup test. Results revealed that current postharvest loss was 17.33% while quality grade score barely passed grade 3. Postharvest technology interventions piloted under coffee farmers cooperatives were coffee depulpers, hullers and coffee dryers. With the use of the postharvest interventions postharvest loss was significantly ($P<0.01$) reduced to 4.95% while quality grade improved to grade 2 passing the three-tiered grading system. The study recommends that the postharvest interventions be strategically applied by specific value chain actors as follows: 1) Coffee depulper and coffee dryer to be used by individual coffee farmers as they perform the depulping and drying operations; 2) Hullers, on the other hand can be strategically situated and operated by the coffee farmers cooperative for economies of scale and for pooling of the limited volume produced by individual farmers. The set of postharvest facilities should be operated as a package of postharvest technology to attain the highest possible loss reduction and quality improvement. The result of the study can be a valued information for program planners, project implementers aiming to improve the Robusta GCB value chain and to potential technology adopters engaged in GCB production and processing.

Keywords: Coffee dryer, Dehuller, Depulper, Green coffee bean, Postharvest losses

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INTRODUCTION

The Philippines used to be one of the top 10 producers and exporters of coffee in the 1970s but problems related to unstable world market price of coffee beans, quota restrictions and high cost of production reduced the once booming domestic coffee industry into almost backyard type of production (Agrimag, 2018). The local coffee industry which is strongly participated by smallholder producers cultivating Robusta collapsed in the 1990s, following the end of the International Coffee Agreement and the 2001 coffee crisis (Bamber, et al., 2017).

The Philippine Statistics Authority (2018) reported that production of dried coffee berries of all varieties had gone down from 2012 to 2016 at an average annual rate of 6.2 %, from 88,940 MT to 68,820 MT . The country's production of green coffee bean in 2014 was about 37,727 MT while domestic consumption was about 132,000 MT making the Philippines a net importer of coffee.

Consequently, the Philippines had an average annual sufficiency ratio of only 49% (PSA, 2014). Because of the steady drop in the local production, the imports is continuously increasing with the rising demand due to the growing number of specialty coffee shops and foreign coffee brands that are now operating in the country (Philippine Coffee Industry Roadmap; 2017-2022).

There are four major varieties of coffee grown in the Philippines: Robusta, Arabica, Excelsa and Liberica. Of all the coffee varieties, Robusta coffee registered the highest production at 47,300 MT or a share of 68.7 % (PSA 2018). Arabica coffee followed with 16,760 MT, Excelsa coffee with 4,270 MT, and Liberica coffee with 500 MT (PSA; 2018).

While declining production, high importation, low yield, backyard scale of production becomes the notable characteristics of the Philippine coffee industry, the surge in demand both in the domestic and international market and its potential economic opportunities prompted the Philippine government to revitalize the once dying industry (Bamber et al.; 2017).

The Department of Agriculture (DA) identified coffee as among the priority crops to be developed in the next 10 years. Under the Coffee Development Program which was initiated in 2015, is a roadmap with a grand plan that aims to make the Philippine coffee industry self-sufficient characterized by increased income among the different levels of supply chain players, and getting a significant share in the export markets, especially for specialty coffee products.

Under the coffee development program the provision of postharvest facilities was identified as one of the critical interventions that must be provided in major coffee producing areas (DA-Coffee Roadmap, 2017-2022). Similarly, Bamber et al. (2017) identified the crude postharvest methods as one of the major limitations that needs to be addressed by the industry to improve its value chain. The postharvest methods and technology used play a critical role in the value chain as it directly influences the quality of GCB which is the base material required by processors in the production of specialty and instant coffee.

This study aimed to assess the Robusta GCB value chain and recommend postharvest interventions in selected coffee producing provinces of the Philippines. Specifically, it sought to: map out the market channels and identify the chain actors involved in the Robusta GCB value chain; identify and analyze the values added by various stakeholders in various market channels; identify the constraints specifically in the production of GCB, and; pilot test the identified postharvest technology interventions.

METHODOLOGY

Conceptual Framework

The study employed the Value Chain Analysis (VCA) framework to identify the activities of the different actors in the Robusta GCB value chain and determine specific areas in the field of postharvest that needs improvement and technological interventions. Value chain is the sequential set of primary and support activities that an enterprise performs to turn inputs into value added outputs for its external consumers.

As developed by Michael E. Porter (1985), it is a connected series of interdependent organizations, resources and knowledge streams involved in the creation and delivery of value to end customers (AsiaDHRRA, 2008). Adapting the VCA model of AsiaDHRRA (2008), the model is comprised of the following analytical entry points- the flows of product, information and payment, and the enabling environment (Figure 1).

The study confined its analysis on the value chain of Robusta GCB from the production, postproduction and marketing with the processors of GCB as the last point of value chain.

Value chain mapping

The coffee value chain was mapped out through tracing method with details established through focus group discussions (FGD), participation to regional and national coffee fora and key informants interview (KII) in 12 coffee producing provinces which include Cavite, Davao, Compostela Valley, Quezon, Batangas, Sultan Kudarat, Iloilo, Bulacan, Bataan, Surigao, Nueva Vizcaya and Aurora. KII was also conducted in the Nestle central processing plant located in Cagayan de Oro, Philippines.

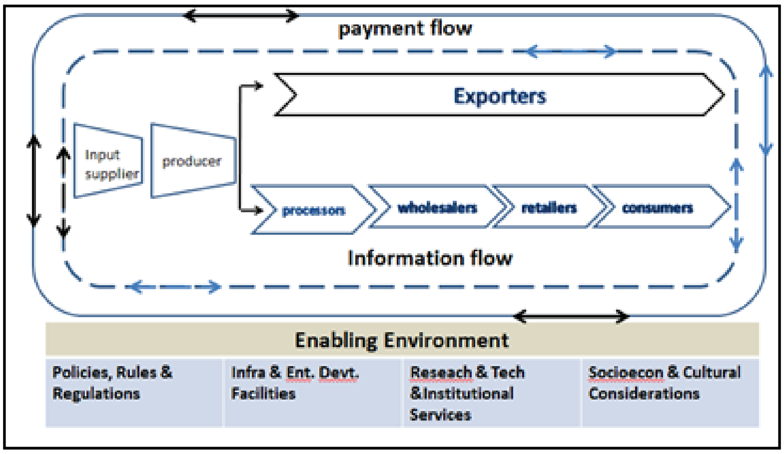

Figure 1. The Value Chain Analysis model (Adapted from AsiaDHRRA, 2008).

Type and Source of Data

Primary and secondary data were used in the study. Primary data include information on postharvest operations, practices and tools applied, average volume of production, marketing, value chain participants and their activities, etc. which were obtained using survey, focus group discussion (FGD) and key informant interviews (KII).

Data on the performance of current postharvest operations were obtained through actual observations and measurement of technical parameters such as capacity, postharvest losses and quality parameters. Secondary data include information on production, consumption, quality and grading system, etc. which were obtained from Philippine Statistics Authority (PSA), Department of Agriculture, Department of Science and Technology (DOST), Department of Trade and Industry (DTI), Philippine National Standard (PNS), Nestle, and attendance to various fora participated by stakeholders of the coffee industry.

Time and Place of Study

The study was conducted in 2013 to 2014 in the provinces of Kalinga and Aurora. These provinces were identified as pilot sites based on the pre-identified criteria of the study such as: the province should be one of the major producers of Robusta coffee; with strong participation of local specialty coffee processors; under the OTOP (one-town-one-product) program of the DOST; with favourable peace and order situation, among others.

Also the recommendations of Nestle and other coffee stakeholders were considered in the selection of the project sites.

Selection and Sampling of Respondents

The respondents were selected based on their participation in the value chain. Farmer respondents represent about 30% of the coffee farmers operating in the pilot sites or equivalent to 118 coffee farmers, which include both members and non-members of the project co-operators. Barangay trader and miller respondents represent all the barangay traders and millers operating in the study area. Municipal traders include the major traders operating in the study area identified through chain-referral and tracing method. Nestle buying station respondents include the buying stations operating in the province. Local coffee processors and coffee shop operator respondents are those that are operating in the study area and were licensed by DTI and supported by DOST under their OTOP program.

Postharvest practices of Robusta coffee farmers and its performance

The postharvest practices of the Robusta coffee farmers were determined by actual observations of postproduction operations covering harvesting, pulping, drying, storing, hulling and marketing. The performance of major postproduction operations were evaluated and served as benchmark in the identification and design of appropriate postharvest interventions in the production of Robusta GCB.

The quantitative performance of the current postproduction practices was evaluated using percentages of physical defects, specifically broken beans from the operations in depulping and dehulling using the following formula:

Percentage broken beans from depulping (%PBp)

Broken beans refer to fragment of coffee of which the size is less than three-fourths of the whole bean (PNS-BAFPS; 2012). Depulping is the operation in the wet processing of coffee which removes the pulp (exocarp) and as much as possible the mucilage (meso carp) through mechanical means (PNS-BAFPS; 2015). Percentage broken beans after depulping PBp (%) was computed using the formula:

$$PBp\ (\%) = \frac{PBp}{TWp} x100$$

where:

PBp (%) = broken beans, in percentage
PBp = weight of broken beans, in grams
TWp = total weight of depulped beans, in grams

Percentage broken beans from hulling (PBh%)

Dehulling is a primary processing step that separate the dried pericarp (in dry method) or the dried parchment and silver skin (in wet method) from the green coffee beans (PNS-BAFS;2015). Broken beans from hulling refers to dried parchment coffee or dried coffee cherries that are broken during dehulling. Percentage broken beans from dehulling (%PBh)was computed using the formula:

$$PBh\ (\%) = \frac{Bbh}{TWh} x100$$

where:

Bh (%)= broken beans, in percentage
Bbh = weight of broken beans, in grams
TWp = total weight of dehulled beans, in grams

The performance of the postproduction practices using qualitative parameters was evaluated using the three-tiered grading system: 1) moisture content; 2) triage and 3) cupping.

Moisture content (MC). MC is the first level of quality control that must be passed by the GCB to be accepted by buyers and processors.

The recommended moisture content for GCB for storage and eventual roasting is 11%. The moisture content was measured by the use of a moisture meter.

Triage. Triage is the second level of quality grading system which analyses GCB based on the extent of physical defects and impurities. Physical defects and impurities include foreign body, admixture, black beans, cherry/undehulled, stinker beans, husk fragment, parchment fragment, broken bean, moldy bean, immature bean and insect-damaged bean. The result of the triage determines the coffee grade (CG) which is computed using the formula:

$$CG = \frac{\Sigma\ Df}{\Sigma\ GCB} \ x\ 100$$

where:

CG = coffee grade which is determined as follows:
Grade 1 = coffee beans having or less than 8% triage
Grade 2 = coffee beans having more than 8% but not more than 12% triage
Grade 3 =coffee beans having more than 12% but not more than 16% triage
Σ Df = total count of physical defects and impurities
Σ GCB = total count of GCB samples

Cupping. Cupping is the last tier of grading and quality control system. This is performed by a trained cupper that examines the cupping quality and profile of GCB. Trained cuppers from Nestle who are assigned in satellite buying stations conducted the cupping of GCB samples submitted for quality analysis.

In the procurement of GCB, particularly by Nestle, the GCB must pass all the three grading systems prior to purchase. Price premium is given to GCB with higher quality grade.

Identification and piloting of postharvest intervention for GCB

Based on the result of value chain and the performance of current postproduction practices, the study identified specific areas that required interventions. In the identification of postharvest interventions major considerations were given into the specific actors that perform the specific operations and the volume of produce they are handling.

For example, if the source of inefficiency is the farmers current practice and tools, the design intervention must be appropriate to the farmer's level of operation and production. In addition, the study also recognized that the design of the intervention must be viewed as a series of operations operating as a system and therefore the design intervention must be properly matched to attain improvement in productivity and efficiency.

The work of Idago et al., (2011) on the design of postharvest system interventions on Arabica coffee provided the basis in the identification and matching of postharvest interventions for Robusta coffee. To assess the performance of the postharvest intervention, it was piloted in the provinces of Aurora and Kalinga under two coffee farmers cooperatives engaged in trading and processing of Robusta coffee.

Analyses of Data

Descriptive analysis was used to analyse the farm profile and postproduction practices of farmer respondents.

On the other hand, t-test was used to determine if there is significant differences between traditional and with postharvest interventions in terms of quality and physical parameters. The SPSS software was used to perform analysis of the data.

RESULTS AND DISCUSSION

Value chain of Robusta GCB

The value chain of Robusta coffee can be grouped into two major market channels: 1) the local processors market channel that produces roasted ground coffee and gets an estimated 15% share of the total GCB production (Figure 3); and 2) the Nestle market channel that produces instant soluble coffee getting 85% share of the local GCB production through its buying stations strategically distributed nationwide (Figure 4). Figures 3 and 4 also illustrate the flow of product, information and payment.

Robusta coffee value chain actors and their roles

The value chain actors and their roles are presented in Figure 2. The value chain actors and their specific roles and activities were the following:

1. **Input supplier** – supplies seedlings, fertilizers and other farm inputs, farm tools and equipment.

2. **Coffee farmers** – manage the farm, perform harvesting, pulping, drying and hulling to produce the GCB.

3. **Coffee farmers cooperative** – procures coffee in the form of GCB, dried berry or parchment coffee from farmers and provide other services to farmer members;

4. **Barangay traders/miller** – traders and also operating as millers in the barangays and typically operating a coffee huller for custom servicing. In some cases provide credit paid through "charge-to-crop" arrangement.

5. **Municipal trader/assemblers/miller** – operates buying stations and buys coffee from barangay traders and walk-in farmers. Others operate a huller for custom servicing.

6. Local processors/roasters - engaged in processing specialty "gourmet" coffee and invested in processing facilities such as roaster, grinder and packaging equip ment.

7. Nestle - procures about 85% of the total GCB production and sources out its deficit from other countries such as Vietnam, Malaysia and Indonesia. Operates satellite buying stations strategically situated in major coffee growing areas and imposes a 3-tiered quality control and grading system: i. moisture content; ii. triage; and iii. Cupping.

8. Other processors - value chain players including Café Puro, Blend 45, Kopiko, SanMig coffee and other processors of instant coffee.

9. Coffee shops – retails coffee in various preparations: black coffee, espresso, cappuccino, café latte, etc. and acquires raw material from other traders.

10. Institutional market – retails and wholesales GCB, processed coffee and instant coffee.

11. Consumers - the last actor of the value chain, buys roasted ground, instant, ready to drink preparations from coffee shops, supermarkets and retailers.

12. Other stakeholders – indirectly involved in the production of coffee but provides the necessary enabling environment such as infrastructure, research, credit, technologies, etc., comprising of government, non-government and private institutions.

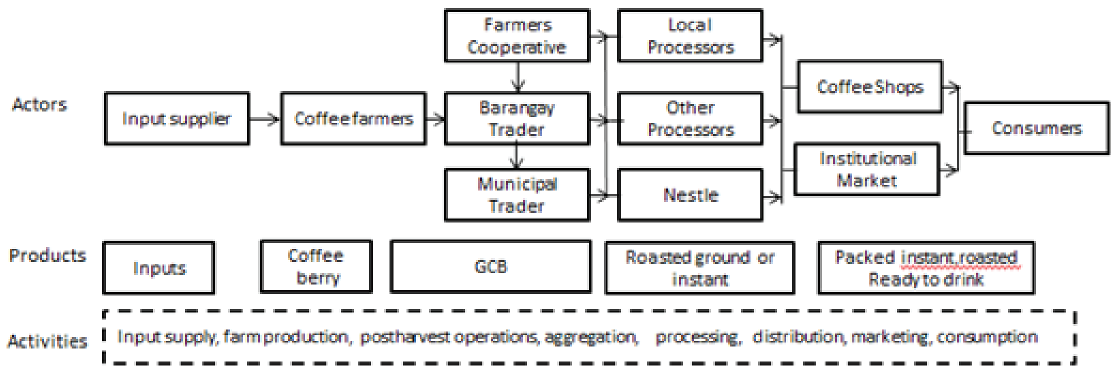

Figure 2. The coffee value chain actors and their roles.

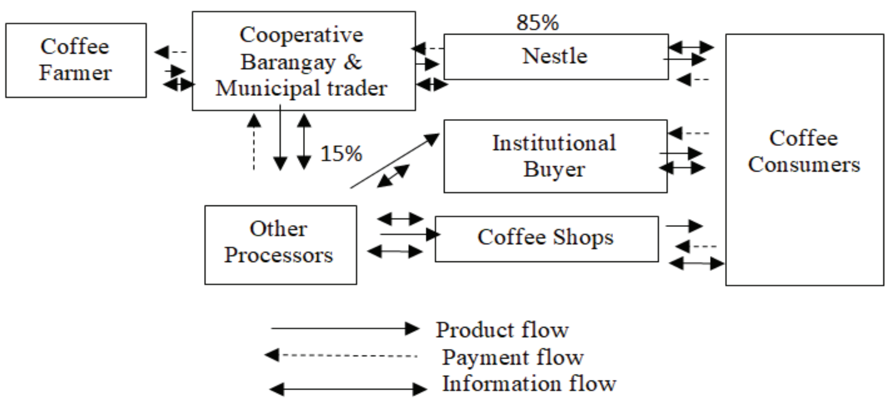

Figure 3. Local processors market channel

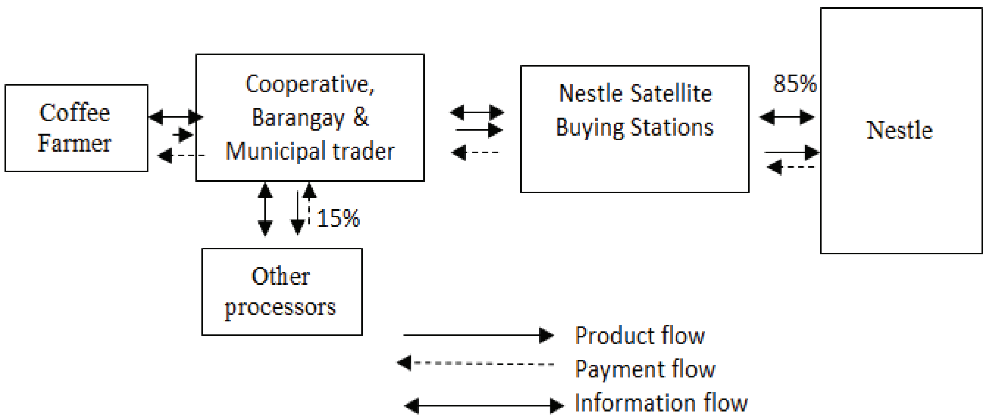

Figure 4. Nestle market channel

Cost and income structure

The cost and income structure highlighted the costs and net income shares of the value chain actors and at the same time provided a picture of the distribution of gain among the value chain actors. Adapting the work of Lantican et al. (2011), net income is the profit earned after deducting all the expenses of each actor from the total value of the final product at the end user of GCB. The study considered two market channels , the Kalinga-Tuguegarao-Manila market channel and the Aurora-Cavite market channel. These market channels were selected by the study as they are the major existing market channels in the pilot sites where the project cooperators were mainstreamed.

For Aurora–Cavite market channel, the distribution of gross margin was dominated by the coffee farmers at 53.19% followed by barangay trader at 39.72% (Table 1). Consistently the farmers and the barangay trader had the highest cost shares at 42.55% and 32.98%, and income shares of 10.64% and 6.75%, respectively (Table 2).

For Kalinga-Tuguegarao- Manila market channel, the distribution of gross margin was concentrated at the coffee farmers at 79.79% followed by municipal/city trader and barangay trader at 14.89% and 5.32%, respectively (Table 3). Gross margin share was computed as the percentage share received by the actor based on the highest price of GCB which is P94, for example the gross margin share of 79.79% received by the farmers was computed as the ratio of P75 and P94 expressed in percentage. In terms of costs share farmers also incurred the highest share at 62.93% and consistently had the highest net income share at 16.86% (Table 4).

In light of the value chain presented for all the market channels, primary processing operations (harvesting, drying, hulling, sorting) contributed about three-quarter on the average of the cost in the production of GCB. While farmers got the highest cost share, they still had the highest net income share by performing harvesting, drying and hulling before selling the GCB to the next supply chain player. This further suggested that providing them the opportunity to process their produce to GCB they reaped the highest profit despite their backyard level of production.

Table 1. Gross marketing margin shares, selling price and buying price of the different chain actors in Aurora–Cavite (Nestle Buying Station) market channel with GCB as final product. 2012.

Value chain actors	Selling price (Php/kg)	Gross margin		Share (%)
		Buying price (Php/kg)	Amount (Php/kg)	
Coffee Farmers	50	--	--	53.19
Barangay Trader	87.34	50	37.34	39.72
Trader/miller	94	87.34	6.66	7.09
Nestle	--	94	--	---

Table 2. Cost and net income shares of the different chain actors in Aurora–Cavite (Nestle Buying Station) market channel with GCB as final product; 2012.

Value chain actors	Farmers	Value Chain Actors		Total
		Brgy Trader	Trader/Miller	
Costs (Php/kg)	40 Production, harvesting, others	31 Drying, hulling, trucking, labor, others	5 Sorting, trucking, others	76
Net income (Php/kg)	10	6.34	1.66	18
Cost share, %	42.55	32.98	5.32	80.85
Net income share, %	10.64	6.75	1.76	19.15
Total	***51.77***	***38.65***	***9.57***	***100***

Table 3. Selling price, buying price and gross marketing margin shares of the different chain actors in Kalinga –Tuguegarao City (Nestle Buying Station) market channel with GCB as final product. 2012.

Value chain actors	Selling price (Php/kg)	Gross margin		Share (%)
		Buying price (Php/kg)	Amount (Php/kg)	
Coffee Farmers	50	--	--	79.79
Barangay Trader	80	75	5	5.32
Municipal/City Trader	94	80	14	14.89
Nestle Buying Station	--	94	--	---

Table 4. Cost and net income shares of the different chain actors in the Kalinga–Tuguegarao City (Nestle Buying Station) market channel with GCB as final product. 2012.

	Value Chain Actors			
	Farmers	Brgy Trader	Municipal Trader	Total
Costs (Php/kg)	59.15 Production ,harvesting, drying,hulling, delivery	3.2 Transportation, others	6.48 Delivery and marketing , others	68.84
Net income (Php/kg)	15.85	1.8	7.52	25.17
Cost share, %	62.93	3.40	6.89	73.22
Net income share, %	16.86	1.91	8.0	26.77

Existing Postharvest Practices and their Limitations

The information from this section were obtained through survey and actual observations and measurement of data on postproduction on-farm. Samples for physical analysis were collected from representative farms.

Harvesting. Farmers harvested their coffee manually either by priming (43%) or stripping method (57%). While priming, which is picking only the ripe berries, is the best method other farmers practiced stripping. Physical analysis of coffee berries harvested by stripping method revealed that about half (51%) is still unripe (Table 5). This practice resulted to low quality GCB. In terms of average production, a typical farmer produces 110 kg of GCB per season.

Depulping. This operation in the wet processing of coffee removes the pulp (exocarp) and most of the mucilage (mesocarp) through mechanical means (PNS-BAFPS ;2015). Some farmers (6%) applied the “pulped natural” process which removes the coffee pulp prior to drying. Coffee pulp is about 44% of the coffee berry hence removing the pulp significantly shortened drying time. While depulping facilitated drying, it produced about 10 percent broken (Table 6). This was due to the crude design of the wooden depulper that used common wood nail (Figure 5) in the depulping mechanism that resulted to breakage or mechanical damage in coffee bean. A wooden depulper has depulping efficiency of 72% and an average capacity of 45 kg/hr. Depulping efficiency is the ratio of the total weight of depulped coffee collected at the depulper outlets to the total coffee berry input, expressed in percentage. In areas that practiced pulped natural method 44% of the farmers used the wooden pulper while others used the mortar and pestle which was the same tool used for dehulling.

Drying. Majority of the farmers (94%) practiced the “dry method” which directly dries the coffee berries. This was in contrast to the wet method where depulping and fermentation were practiced prior to drying. The wet method or wet process is commonly applied in Arabica variety. Sundrying (78%) was done using underlays such as tarpaulin, plastic nets, and sacks usually touching the soil in the absence of a concrete pavement. Some farmers used the “tapahan” or improvised direct-fired dryer (Figure 4).

This drying practice produced low quality GCB due to excessive smoke which was later absorbed by the dried bean. In the absence of moisture meter, farmers estimated the dryness of coffee through feel method or approximated from the sound of bean inside the dried berry while shaking. This method of estimating the MC however, was not reliable as attested by several experiences of barangay traders when their GCB were rejected for purchase due to underdrying (MC>11%) .

Table 5. Physical analysis of coffee berries harvested by stripping method. 2013.

Description	Farm 1	Farm 2	Farm 3	Average	Percentage
Ripe	76	95	80	83.67	27.89
Unripe	140	153	170	154.33	51.44
Physiologically mature	75	40	40	51.67	17.22
Overripe	6	7	7	6.67	2.22
Dried berry	3	5	3	3.67	1.22

Table 6. Percentage broken of coffee beans depulped using wooden pulper. 2013.

Parameters	Farm 1	Farm 2	Farm 3	Average
Initial weight (grams)	500	500	500	500
Wt. of broken (grams)	50	50	55	51.67
Percent broken	10	10	11	10.33

Storing. More than half (60%) of the farmers stored their coffee in the form of dried berries in polyethylene sacks. They practiced storage for a number of reasons such as for home consumption and in anticipation of higher price. For those farmer respondents that practiced storage, they identified problems such as molded berries (3%) and insect damage (8%).

Hulling. Hulling is a primary process that separates the dried pericarp (in dry method) or the dried parchment and silver skin (in wet method) from the green coffee beans (PNS-BAFPS 2015).

Majority of the farmers (74%) hulled their coffee berries using the traditional huller or "kiskisan" (Figure 7). Coffee were normally disposed by farmers in the form of GCB. Hullers were typically operated by barangay and municipal traders that procured and traded coffee with other supply chain players, generally with players engaged in coffee processing. Aside from coffee, these hullers were also used for corn and palay as part of custom servicing. Mechanical huller incurred about 4% broken (Table 7) and in some cases went as high as 32% due to poor machine maintenance and undertrained operators.

In remote areas where huller was not available or practically inaccessible because of their location, farmers dehulled their coffee by pounding method with the use of the traditional mortar and pestle (Figure 6).Coffee dehulled using this method incurred about 7% broken beans (Table 8). Broken beans was a major form of defect when coffee is graded.

Figure 5. Pulping using wooden pulper

Figure 6. Improvised direct-fired or "tapahan"

Figure 7. Dehulling using mechanized dehuller.

Figure 8. Dehulling using pounding method

Table 7. Extent of broken and unhulled beans dehulled in existing hullers; 2013.

Defects (%)	Huller 1	Huller 2	Huller 3	Huller 4	Average
Broken beans (%)	5.00	3.00	4.00	5.00	4.25
Unhulled (%)	2.70	2.00	1.00	0.00	1.42

Table 8. Extent of broken beans dehulled using the traditional pounding method; 2013.

Parameters	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Average
Initial wt (g)	500	500	500	500	500	500
Broken bean (g)	40	35	30	32	35	34
Broken beans(%)	8	7	6	6	7	7

Sorting/grading. This operation is normally performed by traders which are the last value chain actors prior to processors that process the GCB. Hence, coffee bean must meet the quality standards imposed by Nestle and other local processors.

Quality Profile of GCB Under the Existing Postharvest Practices

Triage. GCB produced from sample farms were analysed using the triage or grading system practiced by Nestle and majority of the local traders.

The results suggested that GCB produced under the existing postharvest practices had the following major defects which included black beans and broken beans (Table 9).

These defects has profound influence on the quality of GCB. Black beans was a result of unripe or immature beans resulting from stripping method. Broken beans, on the other hand, was attributable to the method of depulping and dehulling. Without further sorting to remove these defects, only GCB from Farm 1 barely passed quality grade 3. Nestle only buys grade 3 or better.

Table 9. Physical analysis or triage of GCB produced from traditional harvesting, drying and hulling using the Nestle triage system; 2013.

Types of defect* (%)	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Ave. (%)
Foreign body	0	0	0	1.5	0	0.30
Black beans	10	6	31	23.33	23	18.66
Cherry/undehulled	0	5.30	0	0	0	1.06
Husk fragment	0	1.7	0	0.22	0.33	0.45
Broken bean	6	5.30	17.33	11.33	13.89	10.77
Insect damaged Bean	0.33	2.8	0	0.23	0.23	0.72
TOTAL	**16.33**	**21.10**	**48.33**	**36.61**	**37.45**	**31.96**

*based on NESTLE triage system
Grade 1 = coffee beans having or less than 8% triage
Grade 2 = coffee beans having more than 8% but not more than 12% triage
Grade 3 = coffee beans having more than 12% but not more than 16% triage

Table 10. Cupping result from different drying methods evaluated by Nestle buying station in Cavite; 2013.

Drying Methods	Cup Taste	Result
Sundrying, drying pavement, (2 weeks)	Low medium fermented Rating: 7.3*	Rejected
Sundrying, drying pavement,	Low fermented Rating: 7.2	Accepted
Smoke drying	Rejected**	Rejected

*Rating above 7.2 is not acceptable
** Not tested for cupping and immediately rejected because of smoky odour

Design of the Postharvest Interventions

Based on the aforementioned results of the current postharvest performance, the postharvest interventions were designed to address the inefficiencies in the operations of coffee pulping, drying and dehulling. Prior to the selection of facilities, factors considered were: 1) average production per farmer 2) coffee physical attributes 3) activities or roles of value chain participants 4) quality grading standard 5) access to electricity or power on-site.

Parallel to the identified inefficiencies, the postharvest facility interventions were coffee depulper (Figure 7), coffee dryer (Figure 8) steel huller (Figure 9) and moisture meter (Figure 10). The technical descriptions of these postharvest facilities are as follows:

1. Coffee depulper

Breast plate = Steel bib type
Cap.= 120kg/hr (manual operation); 300kg/hr motorized 6hp gasoling engine
Separation efficiency: >90%

Figure 9. Steel-bib coffee depulper

2. All-weather-solar dryer (AWSD)

Dimension: 2m x 7m
Capacity: 120-150 kg per batch
Material frame: wood or bamboo whichever is available in the area
Cover: UV stabilized plastic with 4 mil thickness
Source of heat: solar

Figure 10. All-weather solar dryer

3. Dehuller

Steel huller: "Engelber design"
Capacity = 360 kg/hr
Prime mover = 80hp diesel engine
Uses fluted steel for hulling

Figure 11. Steel huller

4. Moisture meter

Non-destructive type
For parchment coffee and GCB
Digital
Multi-grain moisture meter
Manufacturer : Nano Device Inc.

Figure 12. Moisture meter

The postharvest interventions were piloted in Mananig Multi-Purpose Cooperative in Kalinga Province and Dipaculao Coffee Producers Cooperative in Aurora Province from 2013-2014 and until 2016 to include enterprise development, technology promotion and commercialization.

These cooperatives were selected based on the criteria set by the study such as: 1) the cooperative must be active for the last five years and registered under the Cooperative Development Authority (CDA); 2) with existing trading and processing operation; 3) supported and recommended by DA, DTI and DOST; 4) with good track record; 5) willing to cooperate, among others. Prior to the piloting, project co-operators were provided trainings on the technical operation, maintenance and management of the postharvest system interventions.

Operation of the Postharvest Intervention

The set of postharvest interventions were operated as a system covering a series of operations from depulping, drying and dehulling. Newly harvested coffee berries were depulped using steel bib depulper to produce the fresh parchment coffee. Fresh parchment coffee were dried in the AWSD which took three to seven days on the average to dry from approximately 60% to 11% MC.

The method of process used was modified dry process or pulped natural method. To determine if the optimum MC was already attained after drying, the moisture meter was used to accurately measure MC. Dried parchment coffee were then temporarily stored in sacks for future hulling. For longer storage the practice was to store coffee either in dried berry or dried parchment coffee rather in GCB form to preserve the quality.

Coffee seeds can be stored in airtight polyethylene bag for two years at a temperature and relative humidity of 15C and 41%, respectively (Mitchell, 1988). The bulk of the GCB produced were delivered and sold to Nestle buying stations while a fraction (about 5%) was retained for their production of roasted ground coffee. These cooperatives had their own branding which is strongly supported by the DTI in terms of product development and marketing. The postharvest system was operated by the two project cooperators for about two years to cover two seasons.

Improvements as a results of Postharvest Intervention

Reduction in broken beans. Using the steel bib coffee depulper, percent broken beans from depulping was significantly ($P<0.01$) reduced by 6.10%. Likewise, the use of coffee huller significantly ($P<0.01$) reduced broken beans by 3 %. This translated to postharvest loss reduction of 9.10% bringing the current postharvest loss down to 4.95%. In terms of triage the GCB was upgraded from grade 3 to grade 2

Cupping quality. GCB samples produced with postharvest interventions were submitted to Nestle for cupping. Result of cup test revealed that coffee dried from AWSD, both in parchment and whole dried berry form, passed the cupping test of Nestle (Table 12). This can be attributed to immediate drying of the coffee berries that prevented overfermentation. Elevated drying bed also prevented the coffee from touching the soil that caused earthy flavour. The use of AWSD during sunny days reduced drying time from seven to five days during rainy days or seven to three days during sunny days with the aid of the depulper. During intermittent rain, the combination of AWSD and pulper reduced drying time from 14 days to six days, that contributed to better quality GCB.

Table 11. Comparison of quality indicators between with intervention and traditional practices for pulping and hulling; 2014.

ITEM	PRACTICE		MEAN DIFF
	With Intervention	Traditional	
Percent broken (pulping)	0.70	6.80	(6.10)**
Percent broken (hulling)	4.25	7.25	(3.00)**

**significant at 1% level of significance

Table 12. Cup tasting result of GCB produced with postharvest intervention conducted by Nestle buying station in Cavite; 2014.

Drying Methods	Cup Taste*	Result
AWSD whole berry	Low grassy Rating: 7.2	Accepted
AWSD depulped berry	Low fermented Rating: 7.2	Accepted

*Rating above 7.2 is not acceptable

CONCLUSION AND RECOMMENDATION

Employing VCA framework, the study revealed that the potential value of Robusta GCB was not attained because of poor postharvest practices and lack of appropriate postharvest facilities for depulping, drying and dehulling. Majority of the farmers dried their coffee by sundrying, a form of drying that was unreliable as harvesting coincided during the rainy months. Prolonged drying period due to intermittent rain resulted to over fermentation that produced GCB with poor quality due to high acidity.

Farmers without access to concreted pavement dried their coffee using net underlays but touching the soil. This practice produced coffee with earthy flavour. Earthy flavour and high acidity are quality deteriorations that manifest when coffee is subjected to cup testing and eventually results to rejection. Farmers that depulped their coffee to facilitate dying incurred losses from broken beans due to the crude design of improvised wooden depulper. Remote areas that still practiced the traditional pounding method produced GCB with high percentage of broken beans which is the basic raw material input for processors of instant and specialty coffee.

To address these inefficiencies, postharvest interventions comprising of coffee depulper, all-weather-solar dryer, dehuller and moisture meter was introduced and piloted in two coffee farmers cooperative engaged in trading and processing GCB. The results revealed that adoption of the postharvest system intervention significantly ($P<0.01$) reduced postharvest loss by 12.38%. Likewise, the use of the intervention improved GCB quality grade from grade 3 to grade 2. Cupping quality was also improved due to reduction in drying time and better handling, passing the stringent quality control and grading system of Nestle.

The results of the study suggest that the value chain of Robusta coffee can be enhanced due to availability of better quality GCB for processors of instant and specialty coffee. The provision of postharvest facilities can be an effective intervention to step up the performance of the Robusta GCB value chain. For further study, the sustainability of how these interventions will be made available and mainstreamed in the Robusta GCB value chain should be investigated. This will be valued information for researchers, program planners and project implementers in crafting interventions that aim to revitalize the Philippine coffee industry.

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EFFECT OF GAMMA IRRADIATION ON THE PHYSICO-CHEMICAL QUALITIES OF STORED BROWN RICE

Ma. Cristina B. Gragasin[1] , Ofero A. Capariño[2], Sheryll May M. Villota[3], and Zenaida C. De Guzman[4]

ABSTRACT

Rice is considered as one of the staple foods of the Filipinos. With the recent consumer preference to eat healthy foods, demand for brown rice or unpolished whole grain rice is increasing because of its nutritive value. However, brown rice contains high oil content that shortens its shelf-life and making the grains rancid because of the formation of free fatty acids causing rancidity and spoilage. Likewise, the eating qualities of brown rice change with time due to hardening of starch molecules. This makes it unattractive for eating. A suitable and cost-effective treatment to preserve the physico-chemical qualities of brown rice is needed to assure acceptability in terms of eating quality both in the local and international markets.The efficacy of irradiation treatment in preserving the qualities of brown rice was investigated in the present study in terms of its physical and chemical qualities. Low amylose brown rice produced from two weeks and eight weeks old paddy packed in polyethylene and super bags exposed to radiation treatments of 0.5 kGy and 1.0 kGy were used as experimental samples.The physico-chemical properties like moisture content, water activity and color were not affected. However, other chemical properties such as amylose content and gel consistency were slightly affected. Amylose content (AC) is affected by age of paddy and irradiation. Higher AC was observed in brown rice produced from 8 weeks old paddy and in non-irradiated samples.

Although there was gradual increase in moisture content with time, no significant increase or change in water activity with storage period, regardless of treatments was observed. However, water activity of brown rice from eight weeks old paddy was higher compared with those from two weeks old paddy. Gel consistency was affected by irradiation. Higher gel consistency was observed upon irradiation resulting to softer gel texture. On the other hand, color in terms of lightness, redness and yellowness was not affected by irradiation, age of paddy and packaging materials. Therefore, gamma irradiation retained/enhanced the eating qualities of stored brown rice and is an effective treatment in maintaining the eating quality of stored brown rice for several months. Maintaining the physico-chemical properties of brown rice will increase its utilization, thus, it will contribute to the staples sufficiency program of the Department of Agriculture since brown rice consumption has been identified as one of the identified strategy.

Keywords: Brown rice, Gamma irradiation, Amylose

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INTRODUCTION

Rice is considered as one of the main staple foods of the Filipinos. With the recent consumer preference to eat healthy and nutritious foods, demand for brown rice or unpolished whole grain rice is increasing. Brown rice is produced by removing husk or hull using mortar and pestle or rubber roll sheller. Brown rice still retains its nutrient-rich bran and germ. It has a mild nutty flavour, chewable and more nutritious than white rice. Brown rice requires longer cooking time or more difficult to cook than well-milled white rice and has harder texture due to the presence of fiber in the bran thus making slower absorption of liquid into the kernel.

At most, brown rice has a shelf-life of only about three to four months which could only be extended if packed with special packaging or processing (Garcia, et al., 2013). In their study, Garcia, et al., 2013 proved that combination of saturated steaming and fluidized bed drying extends the shelf-life of brown rice for up to six months. In many countries, freezing or refrigeration and the use of air-tight containers under nitrogen atmosphere condition have been applied with varying degrees of success.

However, these methods have several disadvantages with regards to their application such as reduction in the quality and prohibitive cost of treatments which add to the cost of processed brown rice. With problem on storage, producing brown rice at big volume without readily available market is too risky on the part of producers and sellers.

A suitable and cost-effective treatment to preserve the quality and extend the shelf-life of brown rice is needed to assure its steady supply both in the local and international markets. Irradiation is an effective non-thermal process to preserve food products. Roy (1997) reported that at irradiation dose of 10kGy, the nutritional quality of the food is generally unaffected. Many studies have shown that bacterial pathogens in food products are inactivated by irradiation (Follett, 2004; Ahmed, 2001). Thus, irradiation treatment can improve the microbiological safety and shelf-life of a number of food items. It is cost-effective compared with other treatments as reported by USDA (2004) as shown in Table 1.

However, no local studies have been conducted on the effect of irradiation in maintaining the quality while extending the shelf-life of brown rice. Thus, it is the aim of this project to investigate the efficacy of irradiation technology on preserving the physical and chemical, qualities of brown rice. The widespread consumption of brown rice could positively affect both the supply and demand of rice in the country. High milling recovery of brown rice is mainly due to the non-removal of the bran part which reported to contain essential nutrients.

Thus, the eventual adoption of irradiation treatment to preserve the qualities of brown rice can be one enabling mechanism to collectively achieve and sustain the rice sufficiency in the country.

Table 1. Cost of treatments to maintain the qualities of agricultural commodities.

Treatments	Cost (US$/ton)
Hot water	197.50
Vapor heat treatment	158-197.50
Cold treatment	36.34-474
Controlled atmosphere	39.50-474
Irradiation	19.75-39.50

METHODOLOGY

Preparation of experimental samples

Brown rice of RC 160 and SL 7 varieties having low amylose content were used as experimental samples. Rice varieties of low amylose content were selected as experimental materials because they are best for brown rice production due to their soft texture.

Freshly hulled brown rice of RC 160 variety were procured from PhilRice which were produced from 2 weeks and 8 weeks old paddy to determine the effect of the age of paddy on brown rice quality. SL 7 paddy was procured from a trader. The 2 weeks and 8 weeks old SL 7 paddies were dehulled using PHilMech Compact Rice Huller. The produced brown rice samples were packed in polyethylene bags (PE) and superbag (SB, hermetic bag provided by Grain Pro Corp.) at 1kg/bag.

Irradiation Treatment and Experimental Design

Brown rice produced both from the 2-week old and 8-week old paddy were subjected to gamma irradiation at doses of 0.5 and 1.0 kGy at Cobalt Radiation Facility, PNRI, Diliman, Quezon City. These irradiation doses were based on the study conducted by de Guzman, et al. (1996) where they found that irradiation dose of 1.0 kGy was sufficient for decontamination of brown rice from molds and yeasts with no significant effects on its physico-chemical and nutritional properties.

The 240 packs of brown rice were packed each in polyethylene and Super Bag at 1kg/pack or a total of 480 packs comprised the whole set-up. Each 10 packs were placed in ordinary plastic sacks prior to irradiation treatment. Two sacks containing 10 packs of brown rice each were placed inside the tote box, a metallic box having the dimensions of 50 x 70 x 90 cm. These tote boxes served as container of brown rice samples during irradiation treatment.

Tote boxes that contain the brown rice samples were carried by conveyor belt to the irradiation treatment chamber. A total of 48 sacks were irradiated (24 sacks per age of paddy) for two doses (0.5 and 1.0 kGy) using Co-60 as radiation source having an activity of 80.23 kCi. Chemical dosimeters were strategically placed inside the tote boxes to monitor the minimum and maximum absorbed radiation doses (figure 1). Non-irradiated brown rice served as control samples.

Immediately after irradiation treatment, all samples were brought back to PHilMech, Nueva Ecija and stored under ambient condition (26 ± 1°C). The temperature and relative humidity in the storage room were monitored.

Sampling Design

Irradiated and non-irradiated brown rice samples were sampled on a monthly basis starting from the beginning of storage until eight months to determine the effect of irradiation on the physico properties. The experimental design is shown in Table 2.

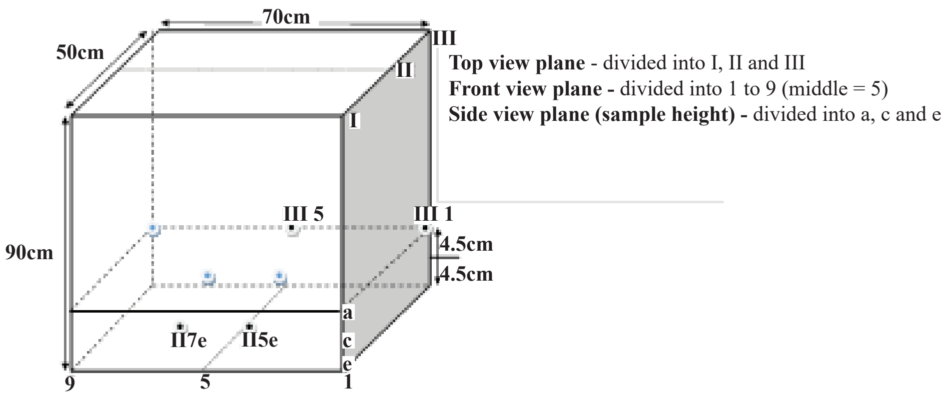

Figure 1. Position of dosimeters in the tote box for dose mapping and actual irradiation of brown rice.

Table 2. Experimental Design

Experiment No.	Treatment/Irradiation Dose (kGy)	Age of Experimental Stock (Weeks)	Type of Packaging	Storage Period (Months)
1	0.5	2	Regular plastic	8
2	0.5	2	Superbag	8
3	0.5	8	Regular plastic	8
4	0.5	8	Superbag	8
5	1	2	Regular plastic	8
6	1	2	Superbag	8
7	1	8	Regular plastic	8
8	1	8	Superbag	8
9	Control or Non-irradiated	2	Regular plastic	8
10	Control or Non-irradiated	2	Superbag	8
11	Control or Non-irradiated	8	Regular plastic	8
12	Control or Non-irradiated	8	Superbag	8

Physico-chemical evaluation of brown rice samples

Samples of both irradiated and non-irradiated stored brown rice withdrawn on monthly interval starting from zero time until eight months of storage were subjected to quality analyses using standard procedures. Water activity (Aw) was measured using water activity meter (Rotronic HygroPalm 23-AW-A).

Color was determined by color scales L*, a* and b* using Color meter (SPECTROMASTER 565/45, Erichsen,Inc., Germany). Gel consistency was determined following the method of Cagampang, G. B., et al. (1973). Determination of amylose content followed the method described by Juliano, et al. (2012).

Statistical Analysis

All analyses were done in three replications. Data were analysed statistically by analysis of variance and comparison among means at 95% confidence level.

RESULTS AND DISCUSSION

Moisture content

The moisture content (MC) of irradiated and non-irradiated stored brown rice (SL 7 & RC 160) packed in PE and SB packaging materials are shown in Figure 2. The moisture content of stored brown rice regardless of variety was between 8-11% which are within the tolerable limit of not more than 12% for safe storage of rice. Fluctuations in values were observed but to a very minimal extent. The moisture levels in all treatments were not affected by irradiation treatments, age of paddy and packaging materials. Increased in MC was more evident in SL7 rice variety but not significant.

Water activity

The water activity (Aw) of irradiated and non-irradiated brown rice (SL 7& RC 160) from two weeks and eight weeks old paddy packed in PE and SB stored at different storage times are shown in figure 3. The water activity of brown rice from both two-week and eight-week old paddy did not change much until eight months in all treatments.

However , water activity detected in brown rice from 8 weeks old paddy were higher compared with those obtained from two weeks old paddy even at the start of storage but no changes was observed until the end of storage period. Irradiation treatment did not affect the Aw in stored brown rice.

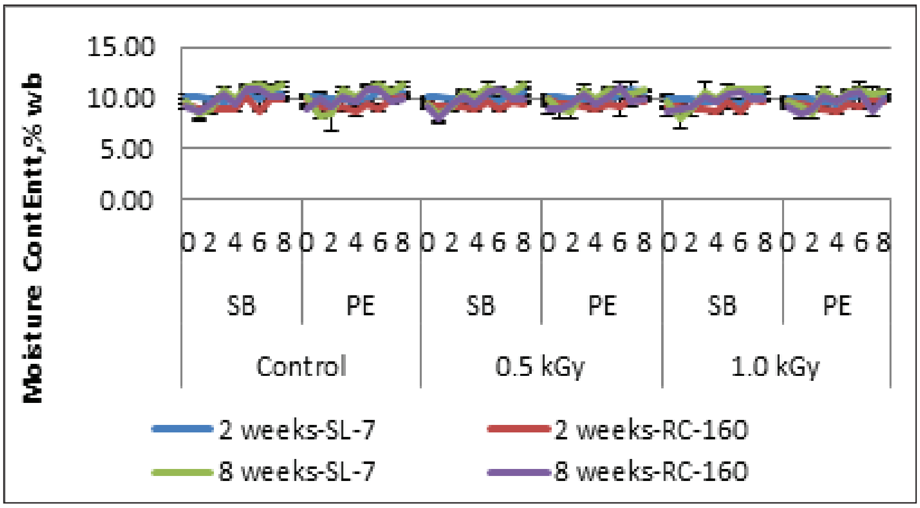

Figure 2. Moisture content (%) of irradiated and non-irradiated brown rice (SL 7& RC 160) from Lot 1 (two weeks old paddy) & 2 (eight week old paddy) packed in PE and SB stored at different times.

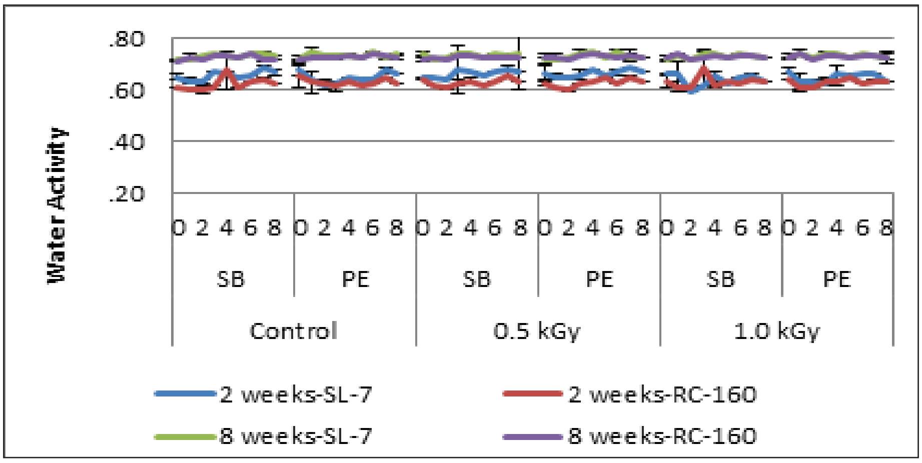

Figure 3. Water activity of irradiated and non-irradiated brown rice (SL 7& RC 160) from two weeks old & eight weeks old paddy packed in PE and SB stored at different times.

Amylose content

The amylose content (AC) of irradiated and non-irradiated stored brown rice from two-week and eight-week old paddy packed in PE and SB are shown in Figure 4. AC of brown rice of both varieties SL 7 and RC 160 both from two-week and eight-week old paddy increased continuously until five months. Thus declined slowly onwards until eight months within the low AC category.

Higher AC values were measured from eight-week old paddy compared to two-week old paddy indicating that the age of paddy from where the brown rice was produced affected the AC an indication of hardening of the starchy component with aging. Nevertheless, it was observed in the study, that the AC values of brown rice were still within the range of low AC category.

The AC values measured in irradiated samples from eight-week old paddy were lower compared with non-irradiated. Radiation dose of 1.0 kGy, provided slightly lower AC than non-irradiated brown rice. Therefore, the AC content was affected by the age of paddy and radiation treatment. There are reports that gamma irradiation reduced the AC in the cultivars with low and intermediate AC due to degradation of amylose fraction by gamma irradiation.

These results are in agreement with those of Wani, et al (2014) as cited by Mir, et al (2015). AC at the dose of 2.9 to 12 kGy provided significant changed in AC values (Wu, et al., 2002 as cited by Arvanitoyannis, 2010).

The present study used a maximum irradiation dose of 1 kGy only and this dose provided the same observation with the former study to some extent.

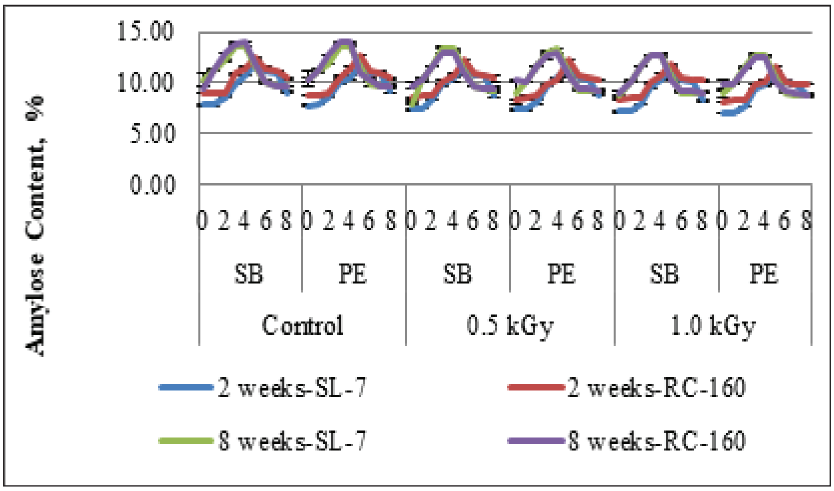

Figure 4. Amylose content (%) on irradiated and non-irradiated brown rice from two weeks old paddy & eight weeks old paddy packed in PE and SB in progress of storage period

Gel consistency

Gel consistency measures the tendency of the cooked rice to harden upon cooling. Figure 5 shows the gel consistency of irradiated and non-irradiated brown rice (RC 160 & SL 7) from two-week and eight-week old paddies packed in PE and SB in progress of storage period. The gel consistency (GC) of brown rice was affected by radiation treatment.

This was evident with higher GC values in irradiated brown rice compared with non-irradiated of both varieties. GC values in non-irradiated brown rice samples fell within 40-60mm which is categorized as medium gel.

On the other hand, GC in irradiated brown rice were within the range of 61-100mm which are categorized under soft gel thereby characterized with softer texture. GC tend to increase at 1.0 kGy than at 0.5 kGy indicating the effect of higher dose of radiation. The texture of irradiated brown rice was affected by gamma irradiation treatment.

This was evident with higher GC values on irradiated brown rice compared with non-irradiated irradiated rice was reported to be softer by Sirisoontaralak and Noomhorm, (2005). Chen, et al., 2014 also reported that irradiation decreased the hardness of brown rice.

Color

The L values of irradiated and non-irradiated SL-7 brown rice variety from two weeks old paddy packed in PE and SB stored at different storage period are shown in Figure 6. L color reflects the lightness or whiteness of the sample's color. The L values increased gradually from zero up to three months but remained almost steady onwards up to eight months. No significant differences in whiteness color were observed between irradiated and non-irradiated brown rice. The age of paddy also did not give significant effect on the L values. These data indicate that the whiteness of brown rice remained almost the same throughout the storage period of eight months except for 0.5kGy treated SL7 from eight-week old paddy packed in SB, stored for seven months.

Color a value measures the redness of the samples. Results showed higher a values, though insignificant, in brown rice from two-week old paddy compared with that from eight-week old paddy (figure 7). Irradiation at 0.5 kGy and 1 kGy did not affect the redness of samples.

Color b value measures the yellowness of the sample. No significant changed on the b values were observed in all samples (ig.8).

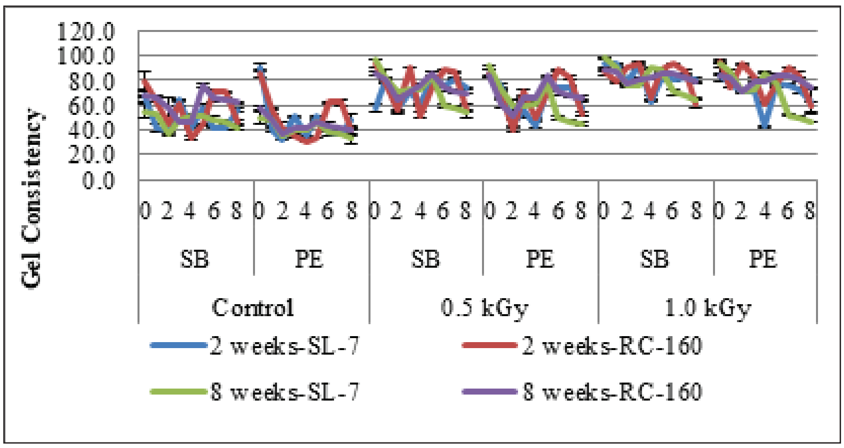

Figure 5. Gel Consistency on irradiated and non-irradiated brown from two weeks old paddy & 8 weeks old paddy packed in PE and SB in progress of storage period.

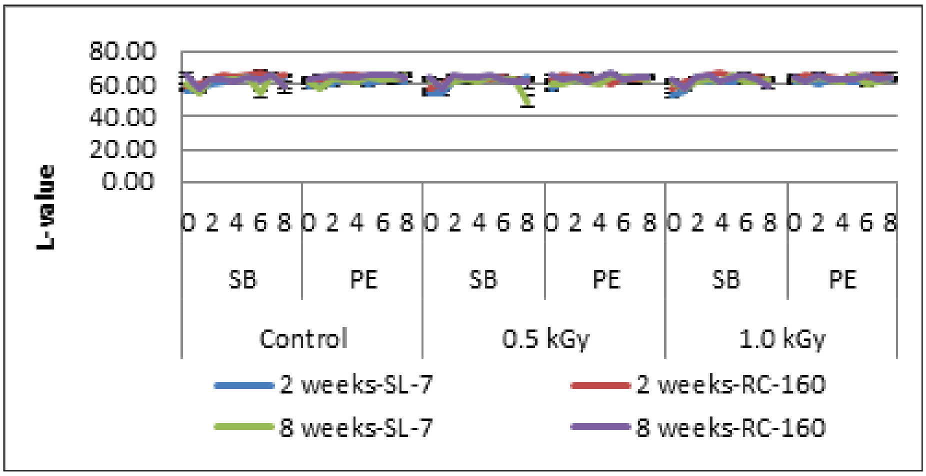

Figure 6. *L values* of irradiated and non-irradiated SL-7 brown rice variety from two weeks old and eight weeks old paddy packed in PE and SB stored at different storage period.

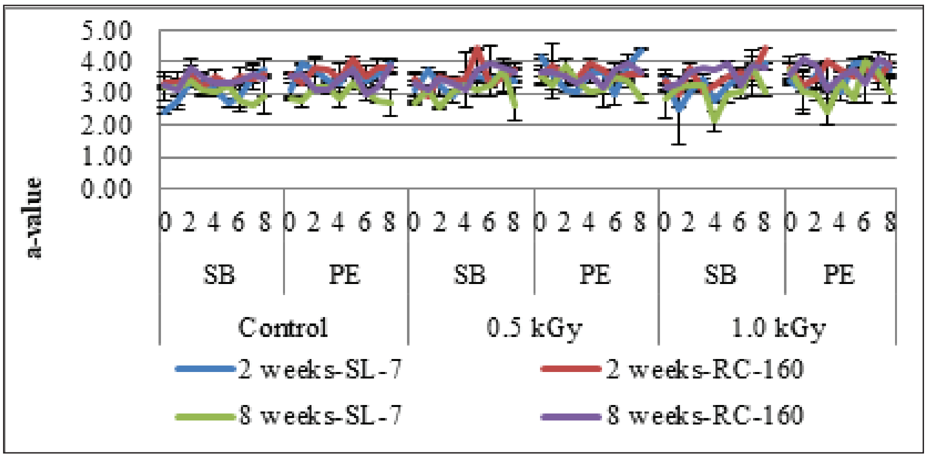

Figure 7. *a values* of irradiated and non-irradiated SL-7 brown rice variety from 2 weeks old and eight weeks old paddy packed in PE and SB stored at different storage period.

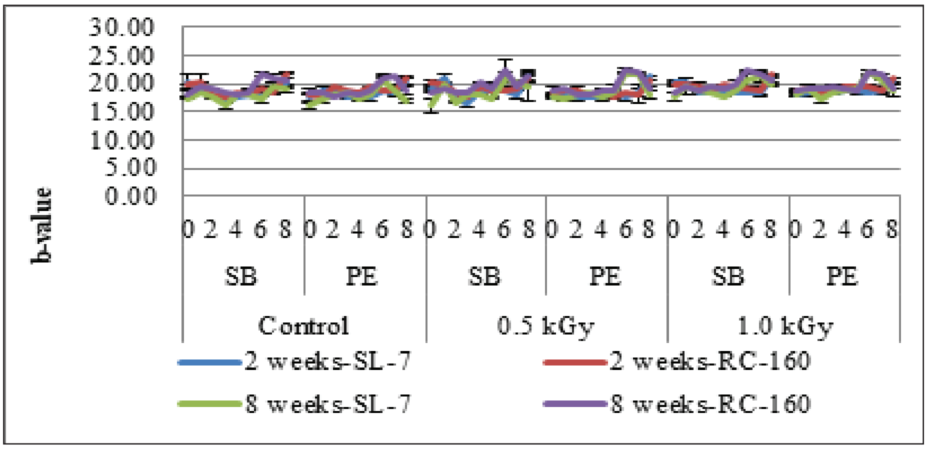

Figure 8. *Color b* of irradiated and non-irradiated SL-7 brown rice variety from two weeks old and eight weeks old paddy packed in PE and SB stored at different storage period.

CONCLUSION AND RECOMMENDATION

Gamma irradiation reduced the amylose content and increased the gel consistency values of stored brown rice to some extent, thus retained/improved the eating qualities of brown rice stored up to eight months. The treatment did not cause hardening of starch molecules of brown rice making it more palatable. A field trial experiment is recommended to generate more concrete information and to determine its technical and financial requirements on a semi-commercial scale operation.

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