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Goal and Scope

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The journal scope 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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PHYSICOCHEMICAL CONSTITUENTS AND SENSORY PROPERTIES OF ADLAI *(Coix lachryma jobi)*

Jerry James Dela Torre[1]

ABSTRACT

As a potential supplement to staple food, adlai (*Coix lachryma jobi*) was studied in terms of physicochemical constituents, steaming, glycemic index and sensory attributes. Glutinous adlai (Pulot variety) and Angelica rice were generally similar in terms of food composition but differed in crude protein and crude fat where the former contained more, as well as in total carbohydrates where it showed less. The cooking properties of adlai: Rice composite samples (100%: 0%, 75:25, 50:50, 25:75 and 0:100) were not significantly different in terms of water requirement and expansion except for the longer cooking time of pure adlai. As a steamed food, well-milled adlai produced a high glycemic index. Among selected consumers from Muñoz Science City, Nueva Ecija, Philippines plain rice was still favored in terms of overall liking. Next to plain rice, minimal adlai (Adlai:Rice = 25:75), was preferred for its taste, aroma and texture. Overall, the likes clearly outweighed the dislikes, with the latter pointing to hard mouth feel. As to the buying intent, the subjects were inclined to purchase the minimal adlai mix, as a second choice to plain rice. Overall, the results imply that consumer acceptability rests on gradual familiarity.

Keywords: Adlai, *Coix lachryma jobi*, glycemic index, physicochemical properties, sensory attributes

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INTRODUCTION

The Department of Agriculture (DA) has long promised for food sufficiency, where rice as a staple sits at the center of the program. Unlike the population and the consequential demand for rice which have grown steadily upwards, the rice production could not keep up while facing the troubles of weather disturbances, irrigation, land conversion, postharvest losses and market forces. Short of fully giving up the fight, the DA leadership has subsumed the rice sufficiency goals into a broader Food Staples Sufficiency Program (FSSP) which covers the complementary promotion of rice, corn, cassava, sweet potato and adlai (*Coix lachryma jobi*) as primary sources of dietary carbohydrates.

The preliminary field investigation showed that adlai is a promising supplement to rice as staple food. It grows naturally on marginal uplands without requiring the traditional land cultivation, irrigation, fertilizer and pest control demands of rice. The harvesting, threshing and milling are done manually. Adlai is consumed mostly in the vicinity where it is produced in some forms such as steamed or boiled grain and as a fermented drink.

Currently, there is very little information on the nutritional and physicochemical profile of adlai. If it reaches the mainstream consumers with a wider sensory preferences and health tolerances, will adlai be as acceptable as rice? Is it as filling and as loaded with a similar amount of energy? Is there a risk for allergy? Does it pose some risks for diabetics? Does it possess enough attributes for processing into other starch-based products?

In other words, the basic characterization of adlai in terms of the physicochemical, nutritional and sensory properties could pave the way for:

- Identification of the comparative advantages of the raw adlai over other carbohydrate food materials
- Identification and development of suitable processing techniques to harness the unique attributes of adlai
- Identification of finished products into which adlai can be processed
- Identification of the market segment that is profitably favorable for adlai processing ventures

These are some of the major compelling issues at the front gate of adlai mass production and commercialization. Hence, this study was in order.

Generally, this study intended to evaluate the potential of adlai as a supplement to rice which is the Filipino's staple food.

Specifically, the objectives were: (1) to determine the physicochemical properties of uncooked adlai grains; (2) to evaluate the cooking properties of adlai grains; and, (3) to determine the sensory attributes of cooked adlai grains.

Some Characterization Studies of Adlai

Adlai is apparently a practical carbohydrate alternative to the staple rice but there is no extensive study yet on its physicochemical and nutritional attributes. In 2011, there were unpublished reports citing the Food and Nutrition Research Institute (FNRI), Bureau of Agricultural Institute (BAI) and University of the Philippines Los Baños – Biotechnology Institute (UPLB-BIOTECH) for their various physicochemical studies on adlai grits, seeds, bran and flour, respectively, but based from some divergent data from these reports, some quarters claim that the adlai samples for these tests may not be properly segregated by distinct varieties.

During that early period, the number of varieties and their characteristics were not yet fully settled. As a wild grass-like plant, the coexistence of mixed varieties in the field is common. In the study Sensory Quality and Acceptability of Cupcake and Cookie Using Adlai Flour (Cereno, 2012), this mismatch of reference physicochemical properties was evident. In another study (Li & Corke, 1999), the variability of amylose content including other starchy traits (swelling power, pasting profile) from eight adlai accessions were considerably high.

Functional Foods

In the midst of growing health concerns, the advancement of food science and allied fields has ushered in the development of functional foods which contain elevated amounts of constituents such as dietary fiber, antioxidants, vitamins, micronutrients and others. For instance, bread could be further fortified with fiber with the addition of apple pectin while enriching it with antioxidants using phenolic extracts from apple, kiwi and blackcurrant (Sivam, Sun-Waterhouse, Waterhouse, Quek and Derera, 2011).

In the segment of staple food, the functional food advocates claim that the winning venture does not securely lie anymore in the products that are "mura" or cheap and "nakakabusog" or instantly filling. The health conscious population is growing and is willing to pay premium price for better nutrition. In the long term, both the supplier of nutritious foods and the health-driven consumers mutually benefit in a sustainably profitable market.

Gluten

Gluten content is a fundamental question for all things starchy, more so for a strange grain like adlai. Some grains are widely favored for consumption in granular form, like rice, while some are often processed as flour, like wheat, which find numerous transformations as baked products. Rice flour, unlike wheat, is naturally gluten-free and is highly digestible (Deis, 1997). On the other hand, wheat flour contains mostly gluten-forming monomeric gliadins and polymeric glutenins, constituting about 80 to 90% of the total flour proteins (Shewry, et.al 2002).

The presence of gluten is both favorable and otherwise, depending on circumstances. Gliadins and glutenins are key elements in the functional properties of gluten (Fermin, 2003). The former is responsible for viscosity in dough development while the latter provide strength and elasticity. These are key players also in maillard and caramelization reactions (Toufeili, 1999). However, gluten is unsuitable with the digestive mechanisms of some consumers, leading to celiac disease.

Celiac Disease

Celiac disease is an illness of the upper small intestine mucosa caused by an incompatible immune reaction to glutein fractions which are common constituents of wheat, barley and rye (Marsh, 1992). It probably remains obscure from public concern because the symptoms are not uniquely alarming compared to other chronic diseases. These symptoms are diarrhea, weight loss and deficiency in iron, folate, vitamin B12 and D (Woodward, 2007). In Europe and the United States, celiac disease afflicts 1 for every 100 to 200 of the populace (Cook, 2000).

So far, the main weapon against this disease is still a strict gluten-free meal (Niewinksy, 2008).

Glycemic Index

Glycemic index (GI), among other indicators, measures the increase of blood sugar caused by the intake of carbohydrates. In the case of rice, both amylose and dietary fiber content were found to be inversely proportional to the GI. This is very important for persons who are at risk with diabetes, obesity and colon disorders (Trinidad & Mallilin, 2011).

Product Development

In product development, the strategy of compensation is a widely effective recourse in material blending to address the issue of scarcity, cost, substantial content and sensory desirability. This same technique could be applied to resolve whatever strengths and weaknesses that may be found in adlai.

For instance, to achieve a better nutritional profile, as much as 40% germinated brown rice blend was found acceptable in terms of physiochemical and sensory properties of wheat-germinated brown rice bread.

Germinated brown rice is better than the non-germinated option because of the presence of gamma-aminobutryic acid (GABA) which is a nutritionally essential non-protein amino acid.

However, the use of brown rice flour as blending material generally results in adverse effects on the flavor profile and rheological properties of the bread such as loaf volume, crumb firmness and appearance (Charoenthaikij et.al 2010).

Locally, a research (Nagares, 2007) was done on the nutritional value, physicochemical properties and sensory acceptability of rice-corn composite. The study revealed the following:

- The addition of corn ie., Quality Protein Maize (QPM) increased the amount of protein, fat, fiber, ash, starch, amylose, lysine, tryptophan and dietary fiber content of the rice-corn composite;
- The greater the corn content resulted in increased gel consistency, hardness and height increase;
- All rice composites were acceptable in terms of color, odor, flavor, cohesiveness and tenderness;
- The 70:30 rice-corn ratio was the most acceptable in terms of flavor and overall quality.

This study also offers a potential window for the mainstream utilization of adlai as rice composite, if adlai alone is not as nutritious and appealing as rice. Across the country, adlai-based food products such as *sinukmani, champorado, maja blanca, polvoron, turones de adlai, chicha adlai,* puffed adlai, cookies, cupcake and breakfast cereal are getting popular through the various efforts of state universities and regional research centers of the Department of Agriculture in cooperation with the leading direction of the Bureau of Agricultural Research (BAR).Most of these are contained in popular documents such as recipes, newsletter, and annual reports and are yet to sink into the mainstream, peer-reviewed scientific journals.

METHODOLOGY

Procedure of Investigation

This study was comparative in nature. Adlai was characterized in terms of physicochemical, cooking and consumption as well as sensory attributes using rice as a reference material. Both adlai and rice (Angelica) were of glutinous variety (Figure 1). The procedure of investigation is shown in Figure 2.

(a) (b)

Figure 1. (a) Adlai from its raw form to its constituent parts (left most to right), (b) Adlai and rice samples

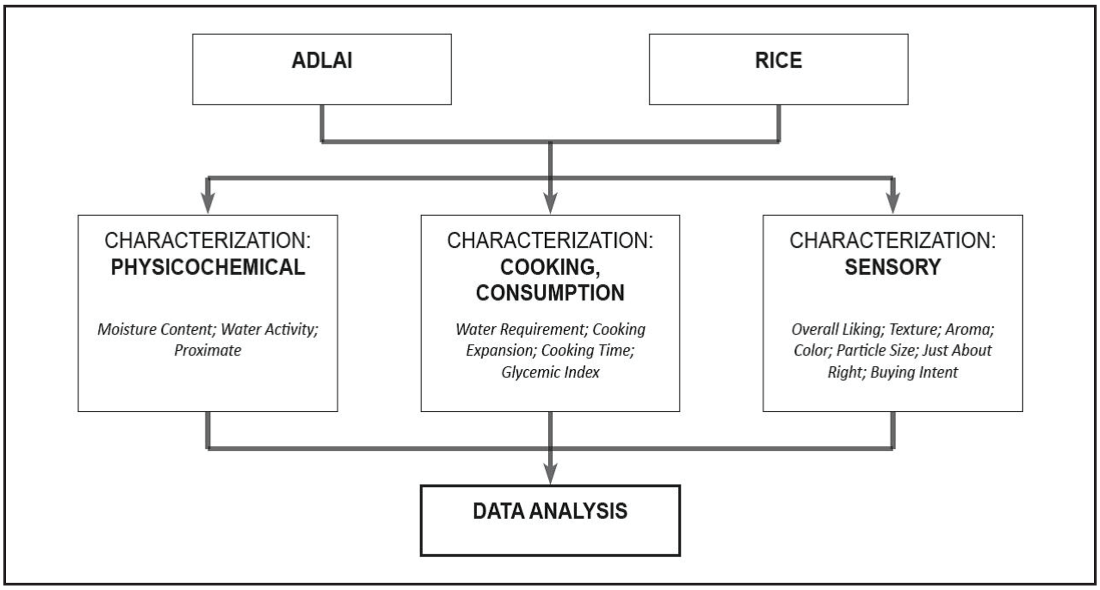

Figure 2. Procedure of Investigation

Physicochemical Properties of Adlai

The physicochemical properties of Aalai were measured in terms of the parameters and methods in Table 1 below. At least three replicates were done.

The water activity was measured using a digital water activity meter (Make: Rotronics, HC2-AW, SN 60750224; Output Range: 0 to 1 aw at 0 to 100% RH; Power: 9 VDC, Operating Temperature: -40 to 60 °C), shown in Figure 2.

The energy content, E, was computed from Equation 1 below.

$$E = (\text{crude fat})(9) + (\text{crude protein})(4) + (\text{total carbohydrates})(4) \qquad \text{Eq 1}$$

The total carbohydrate, Carb, was derived from the nitrogen-free extract calculation (Equation 2 below):

$$\text{Carb} = 100 - (\text{ash}) - (\text{moisture}) - (\text{crude fiber}) - (\text{crude protein}) \qquad \text{Eq 2}$$

All but the water activity were determined by the Regional Standards and Testing Laboratory (RSTL) of the Department of Science and Technology (DOST), Regional Office IV-A (CALABARZON) in Los Baños, Laguna. PHilMech provided the milled adlai and rice samples.

Cooking and Consumption Properties of Adlai

Well-milled adlai was boiled or steamed using a commercial rice cooker (Make: Camel SK50S, 500W, 1.5 L, 230V, 60Hz), as shown in Figure 3.

Water Requirement. The water requirement was initially based on the usual requirement of boiled or steamed rice. In addition to that reference, two more treatments were tried for adlai using plus and minus 25% volume. The suitability of the water volume was evaluated based on the texture doneness after cooking.

Cooking Time. The cooking time was based on the automatic warming or tempering onset of the rice cooker. The sensory evaluation was done 15 minutes after that signal. The food samples were considered good at a serving temperature of around 65 to 70 °C.

Table 1. Methods of characterization for the physicochemical properties of Adlai.

Parameter	Method
Water Activity	Equilibrium relative humidity correlation
Energy, g/100 g	By computation
Crude fiber, g/100 g	AOAC[a] Method 978.1
Ash, g/100 g	Gravimetric – AOAC, Method 923.03
Crude Protein, g/100 g	Semi-micro Kjeldahl
Total Carbohydrate, g/100g	By computation
Moisture Content, g/100 g	AOAC, Method 934.06
Crude Fat, g/100 g	Acid Hydrolysis
Calcium, mg/100 g	Microwave Digestion - AAS[b]
Sodium, mg/100 g	Microwave Digestion - AAS

[a] Association of Official Analytical Chemists
[b] Atomic Absorption Spectroscopy

Figure 2. Digital water activity meter

Figure 3. Test rice cooker

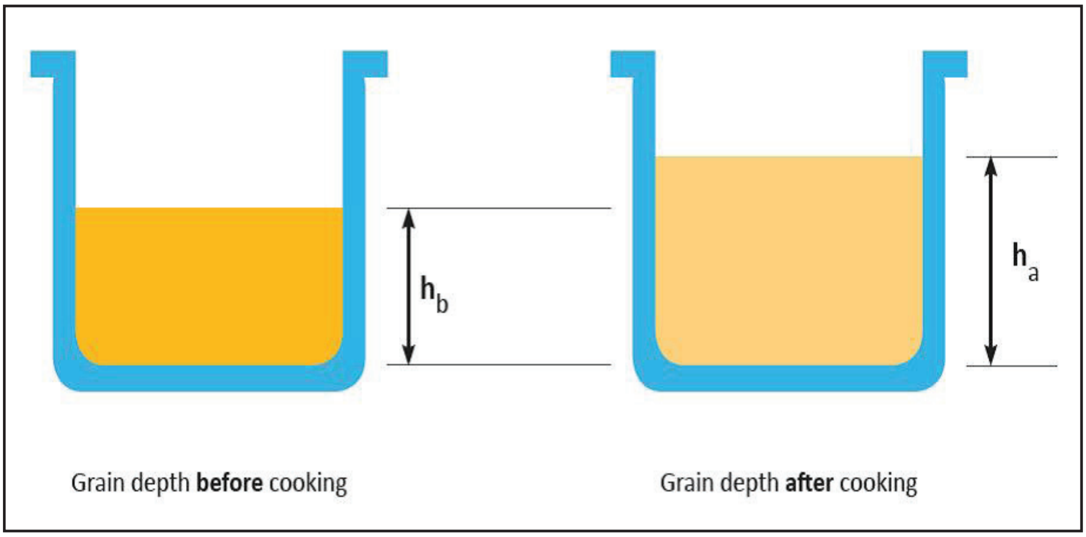

Figure 4. Cooking expansion

Cooking Expansion. The cooking expansion, Δh, was defined as the rise of the grains after cooking as illustrated in Figure 4 and Equation 3:

$$\Delta h=(h\_a- h\_b)/h\_b \quad x\ 100 \qquad \text{Eq 3}$$

Glycemic Index. The glycemic index of adlai was measured from 10 healthy subjects who were given each a serving containing 25g available carbohydrate after an overnight fast (10-12 hrs) and baseline blood glucose measurement. The change in the blood sugar due to the food sample was obtained by measuring glucose levels from finger-prick blood samples from each subject every 15 minutes during the first hour and every 30 minutes during the second hour. Test and reference food samples were given to the subjects three times on separate occasions. The corresponding glucose response of the subjects to these test and reference food samples were compared geometrically (incremental area under the curve or IAUC), while ignoring the baseline glucose at fasting level (Trinidad & Mallilin, 2011)

The glycemic index, GI, is thus computed as:

$$GI= \frac{IAUC_t}{IAUC_r}\ x\ 100 \qquad \text{Eq 4}$$

Where:

IAUCt = incremental area under the curve of the test food sample
IAUCr = incremental area under the curve of the reference food sample

The GI test in this paper was a commissioned work by the Food and Nutrition Research Institute (FNRI) of the Department of Science and Technology (DOST) for PHilMech. The latter likewise provided the adlai samples.

Sensory Attributes of Adlai

The acceptability of Adlai to potential consumers was studied by determining the following:

- Overall acceptability of the product
- Degree of liking on individual sensory attributes, and;
- Buying intent

Five samples representing different levels of Adlai: Rice mixture were evaluated. These are given in Table 2.

Table 2. Sample treatments for the sensory evaluation.

Sample	Adlai:Rice Mix, %		
1	100	:	0
2	75	:	25
3	50	:	50
4	25	:	75
5	0	:	100

One kilogram each of the five treatments was prepared. From each of these, approximately 30 g was served to the respondents in random order, one at a time. Samples were coded with alpha numeric tags to avoid bias. The raw Adlai:Rice samples were soaked (10 min) and gently stirred briefly in one liter potable water. About 500 ml of that wash water was expelled immediately after. An additional 1 liter of potable cooking water was added into the wet, pre-washed grains. Cooking was done using five identical commercial rice cookers until the automatic warming set point. The serving temperature was maintained at 65 to 70 °C. If not consumed within 3 hrs after cooking, the product is considered tale, hence, they were discarded from the evaluation.

The respondents were composed of 70 % women and 30 % men, whose age ranged from 16 to 50, as shown in Figure 6. The study was done at the Sensory Evaluation Laboratory, Department of Food Science and Technology, Central Luzon State University (CLSU) on July 24-26, 2013.

Respondents were recruited through random intercepts. Prior to tasting, the respondents were given purified water to cleanse their palate and to neutralize their taste buds. After tasting the product, they were asked about their likeability and perception of the samples.

The key performance indicators of the test samples in the questionnaire (were as follows):

- overall acceptability, 9-point hedonic scale (1-least liked; 9- most liked);
- product ratings on specific attributes such as color, aroma, flavor, mouth feel and after-taste; and,
- purchase intent.

RESULTS AND DISCUSSION

Physicochemical Constituents of Adlai

The physicochemical properties of glutinous adlai in comparison with glutinous rice are shown in Table 3. Adlai contained more energy (1%), crude protein (89%), crude fat (48%) and sodium (35%) than rice.

On the other hand, rice possessed greater crude fiber (33%), ash (32%) and total carbohydrates (7%) than adlai. For containing higher amounts of plant-based protein and fat than rice, adlai scores better in this respect as a staple food supplement.

Water Requirement

Several cooking trials were done for glutinous rice using the test rice cooker. Based from the texture of the cooked rice, the following grain to water ratios (kg rice : li of water) were subsequently tried for adlai: 1 : 1.125, 1 : 1.5 and 1 : 1.875.

Taste tests were done thereafter. Based on texture, 11 of 25 respondents favored the 1 : 1.5 ratio while most (14 of 25) preferred a little more water (1 : 1.875) to soften the adlai grains further.

However, for simplicity in practical application afterwards, the 1 : 1.5 ratio was chosen as the minimum water requirement for adlai. The fraction 0.875 is more difficult to convey to household consumers.

Cooking Time

The cooking time (Figure 5) was longer for pure adlai (50 ± 6 min) than rice, and as rice was increased into the mix, it became shorter, down to 32 ± 2 min for plain rice although only the former was significantly different from the group.

Cooking Expansion

Figure 6 shows that the grain expansion after cooking is directly proportional to the amount of glutinous rice in the mix. Glutinous rice expanded a little more than glutinous adlai although the difference was not significant. Adlai grains are bulkier and hence, porosity is greater. As adlai expands through the cooking process, the effect is not only manifested in the upward rise of the grain bed but also in the lateral filling up of void granular spaces.

Glycemic Index

The glycemic index (GI) of well-milled adlai (81 ± 6) was relatively high compared to some local carbohydrate food samples, as given in Figure 7 (FNRI, 2011). It is closely similar to the kutsinta (80 ± 6) and pandesal with five percent coconut flour (87 ± 6).

Table 3. Water activity, energy, proximate composition and selected mineral contents of rice and adlai.

Parameter	Rice [b]	Adlai c
Water Activity	0.8041 ± 0.0009	0.8056 ± 0.0008
Energy, g/100 g	356 ± 0.7	360 ± 0.3
Crude fiber, g/100 g	0.48 ± 0.04	0.36 ± 0.01
Ash, g/100 g	0.41 ± 0.04	0.31 ± 0.03
Crude Protein, g/100 g	6.22 ± 0	11.76 ± 0.51
Total Carbohydrates, g/100g	80.91 ± 0.17	75.48 ± 0.44
Moisture Content, g/100 g	11.99 ± 0.25	12.05 ± 0.03
Crude Fat, g/100 g	0.81 ± 0	1.20 ± 0
Calcium, mg/100 g	3.47 ± 0.25	3.44 ± 0.68
Sodium, mg/100 g	0.99 ± 0.21	1.34 ± 0.02

[a] Values are given with ± 2 SE
[b] Glutinous rice, Angelica, well-milled
[c] Glutinous Adlai, well-milled

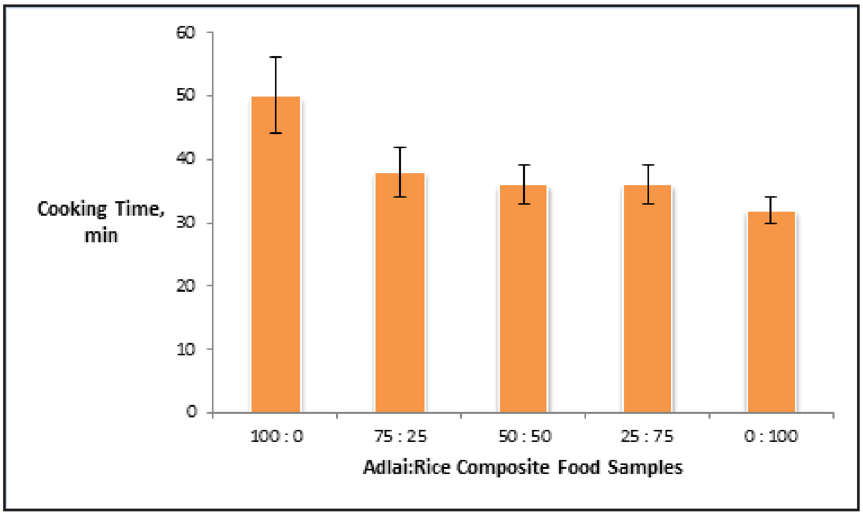

Figure 5. Cooking time, min, of adlai:Rice food samples. Error bars are ± 2 SE

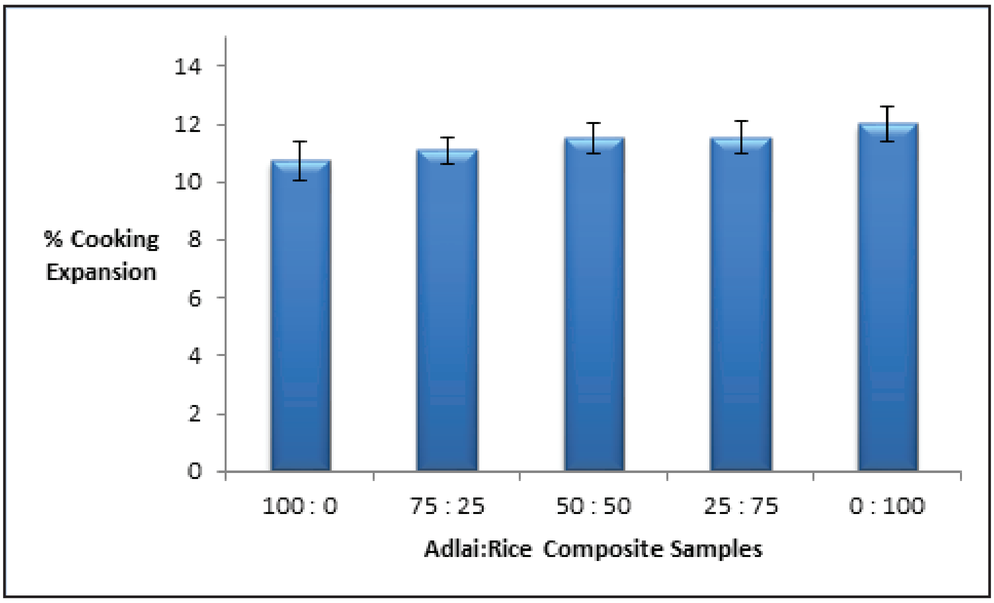

Figure 6. Cooking expansion, Δh (%), of adlai:rice food samples. Error bars are ± 2 SE

The rest of the reference food samples, apart from *kutsinta* and *pandesal*, are unprocessed rice of different varieties. Brown rice of the same variety has consistently exhibited a significantly lower spike in glucose levels among the subjects. The bran adds fiber into the grain, and the higher the dietary fiber and amylose contents, the lower the glycemic index in rice (Trinidad & Mallilin, 2011). Brown rice from Sinandomeng and IR64 have 5.25 and 6.25 more dietary fiber, respectively, compared to the well-milled counterparts. This fiber content was apparently enough to bring these varieties from high to low GI.

For adlai, the undermilled form with intact brown pericarp contains 2.78 more fiber. In other words, there is a bright prospect of making adlai more diabetic-friendly which is simply offering it as whole grain or undermilled food.

Overall Liking

Overall, steamed plain rice (mean = 7.80) was significantly ($p <0.05$) the most liked sample followed by the composite with minimal adlai (Adlai: Rice at 25:75%), as shown in Figure 8. The least liked was the pure adlai.

By further investigating the likes and dislikes, it was found that plain rice and minimal adlai mixture (adlai : rice = 25 : 75 %) were both liked for their aroma, taste and texture. For these two variants, likes clearly outweighed the dislikes. On the other hand, all but one of 50 respondents disliked the pure adlai for various reasons such as after-taste, stale-like taste (lasang-luma), dry, texture and hardness, color and appearance.

Degree of Liking for Specific Sensory Attributes

Across all five specific sensory attributes such as color, particle size, aroma, taste and mouth-feel (Figure 9), plain rice was the most liked, followed by the minimal adlai composite (adlai:rice = 25:75%). This means that the overall liking result in the previous section was a reasonable judgment among the subjects.

In terms of color, aroma and taste, the minimal adlai mixture (adlai:Rice = 25:75%) was not significantly different with the equal ratio composite (adlai:rice = 50:50%). This result supports the favorable prospect of adlai getting into the mainstream carbohydrate staple of Filipinos.

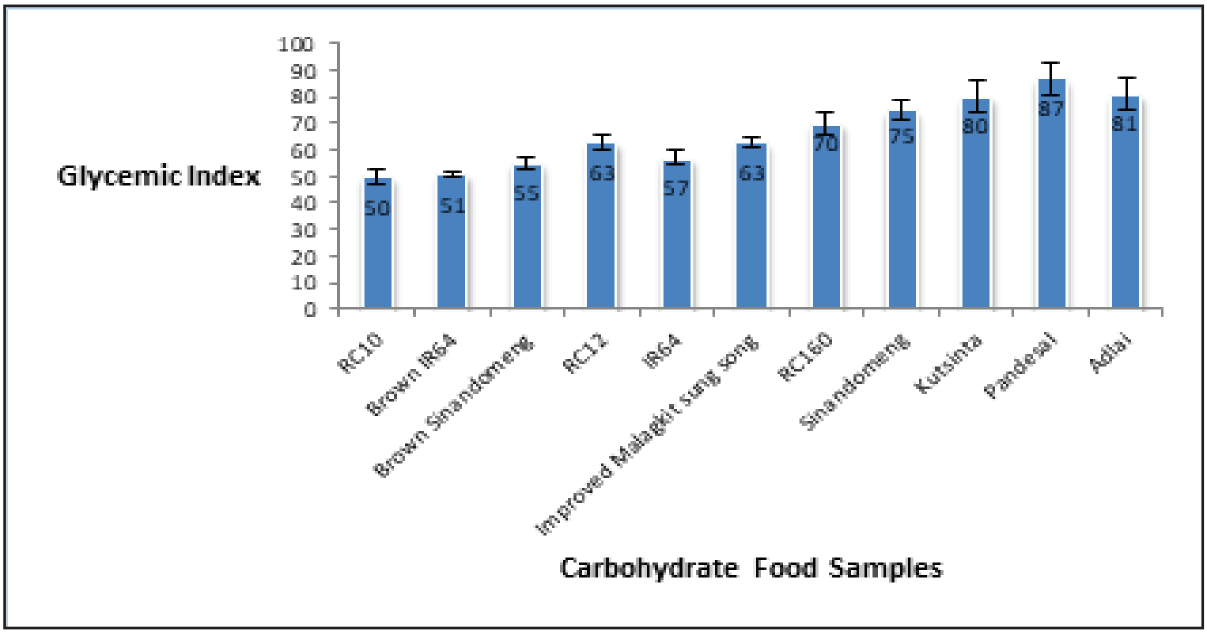

Figure 7. Glycemic index of adlai compared to some local carbohydrate food samples

A strong inclination to whiteness was also manifested in the color parameter, with plain rice (score = 7.92a) clearly separating itself from the other four mixtures. Anything containing adlai was perceived not significantly different with each other (score = 4.46b to 5.80b).

The particle size criterion reaffirmed the preference for the familiar. Plain rice was another strong favorite (7.82a). However, the subjects were able to distinguish and subsequently favor the minimal adlai mix (6.30b) over all the three other adlai:rice composites, the latter group being perceived as not significantly different (4.68cd to 5.40c) with each other. This suggests that adlai should be served in smaller grits, as close to the size of rice as possible, to gain better acceptability.

When the samples were judged by aroma, the next valuable insight aside from the obvious bias for plain rice, was that pure adlai has a strongly unique olfactory appeal (5.00c) that stands out over all the other mixtures regardless of the degree of dilution with rice (5.36bc to 6.00b).

In terms of taste, each mixture tended to illicit a linearly differing flavor (4.40d to 7.54a), with plain rice still getting the top choice.

The mouth-feel aspect showed a slight surprise from the usual order of preference. This time, the increased adlai ratio (adlai:rice = 75:25%) scored a third higher preference (4.92bc) instead of merely settling near the bottom

Buying Intent

The respondents expressed a strong loyalty to buying plain rice while stating the minimal adlai (adlai:rice = 25:75%) as their next purchase preference (Figure 10). The other mixtures were largely clustered on the neutral scale, which means the buying intent could be swayed either way. For adlai advocates, this should at least be consoling because at the very least, the respondents spared them of a strong outright rejection. As such, this is a challenge with a fair prospect of winning, perhaps by responding to the specific signals from the sensory evaluation, such as serving in smaller grit size, cooking to a softer texture or doneness, and so on.

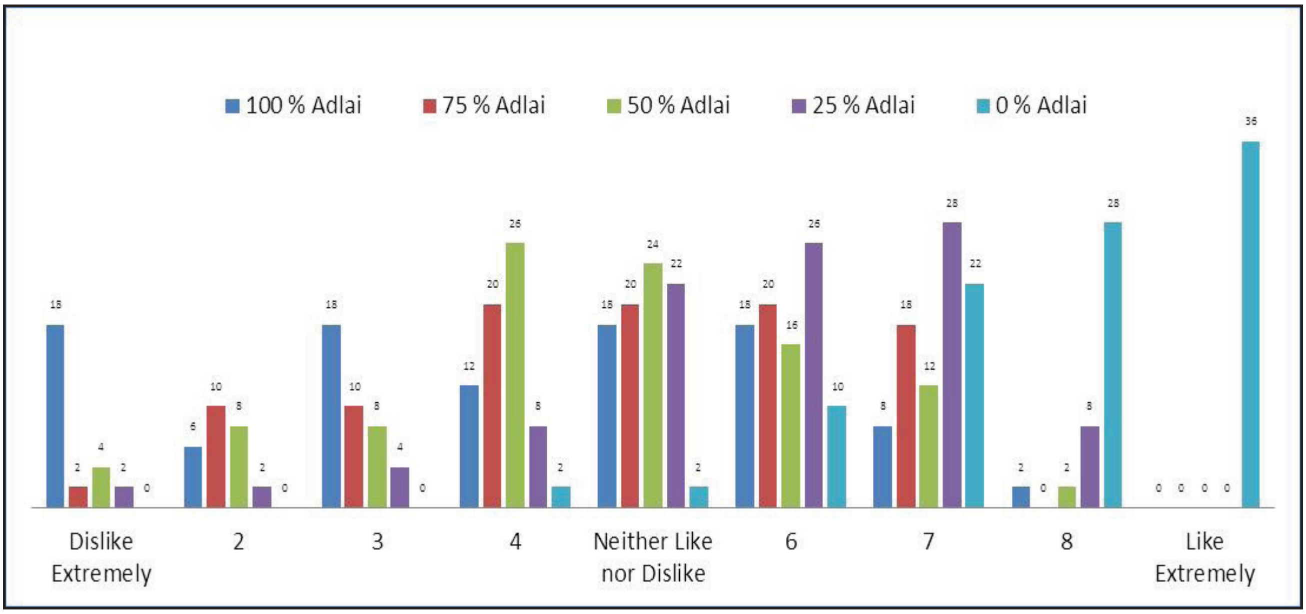

Figure 8. Overall liking scores for adlai-rice composite sample

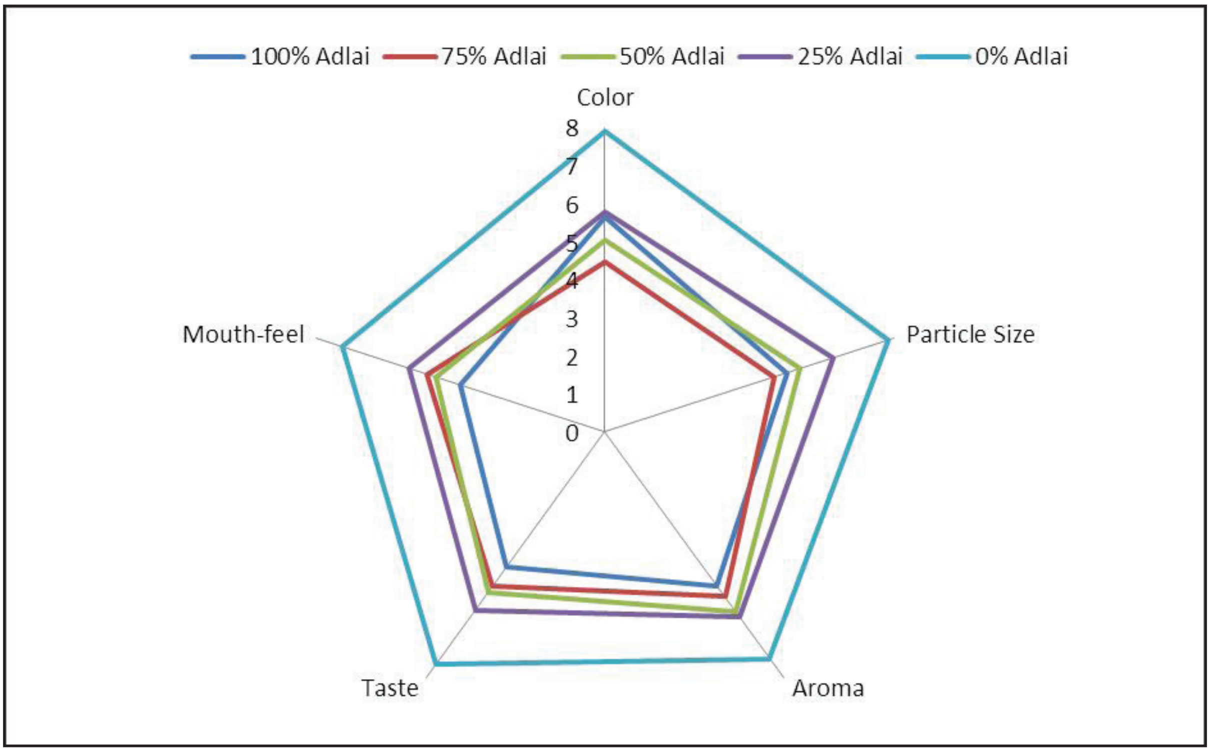

Figure 9. Degree of liking on specific sensory attributes for adlai-rice composite samples

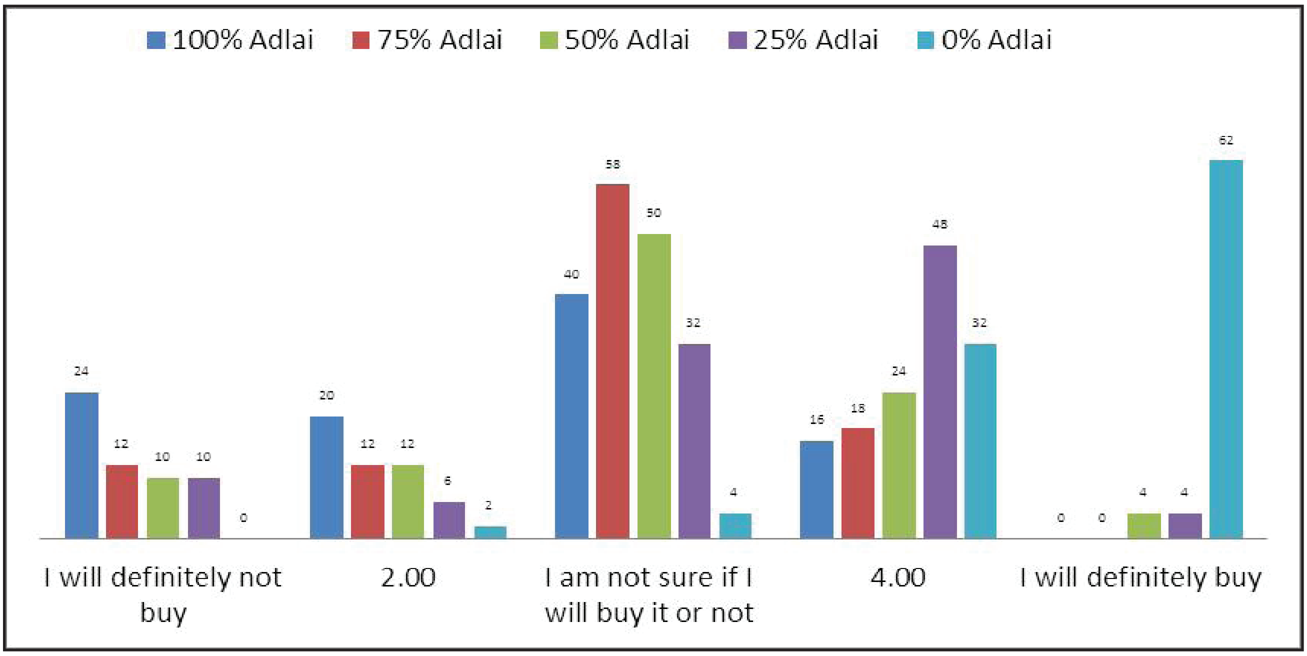

Figure 10. Buying intent of potential consumers for Adlai-Rice composite samples

It will not be a surprise if food scientists pose a reservation against the consumer's preference for color or specifically, whiteness because as indicated in the separate glycemic index test, the well-milled adlai, which was naturally rice-like in whiteness, suggests greater health risks for diabetics. The undermilled form of both rice and adlai contain a significantly greater amount of fiber, which prevents easy breakdown of complex carbohydrates into glucose.

Buying intent is largely governed by strong forces of economics such as supply and demand, marketing and others. Pricing alone may easily obliterate the logic of health and food science. Packaging adlai into a healthier version may be absorbed as part of marketing such that both economics and food science may collectively sway the potential consumers towards a favorable purchase.

CONCLUSIONS AND RECOMMENDATIONS

Adlai is a promising supplementary staple food crop in terms of its comparative advantage in a number of physicochemical constituents such as energy, crude protein and crude fat content. Adlai in undermilled form is also desirable owing to its higher availability of fiber.

The cooking properties of adlai are not entirely strange to rice. Where there are differences, blend options in product development have shown favorable complementary results. The consumer acceptability of adlai looks hinged on gradual familiarity.

Moreover, the following recommendations are offered:

1. Adlai should be continually promoted as a supplementary carbohydrate food.
2. The product stability of undermilled adlai should be investigated.
3. The development and promotion of adlai based products should be pursued and documented scientifically to settle variability issues and to ensure marketing claims rest on solid footing.

ACKNOWLEDGMENT

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ASSESSMENT OF *TRICHODERMA* SP. IN MANAGING *ASPERGILLUS FLAVUS* LINK GROWTH AND AFLATOXIN PRODUCTION IN CORN

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ABSTRACT

Pre-harvest infection of corn (*Zea mays*) by *Aspergillus flavus* creates a major food and feed safety problem worldwide. Many strains of *A. flavus* produce aflatoxins, which are potent carcinogens. Removing aflatoxin from corn once they are produced is impractical and expensive. Research is therefore needed to develop strategies designed to manage *A. flavus* infection and aflatoxin formation both in the field and during postharvest handling. One of the most promising tools to manage aflatoxin in food and feed is biological control of aflatoxigenic fungi using microbes. The potential of *Trichoderma* sp. (BT9) as effective biocontrol agents against *A. flavus* was determined in previous laboratory testing studies by Santiago et al., (2010). This showed a reduction in *A. flavus* infection and aflatoxin contamination when BT9 was applied in corn ear with husk. Hence, this study was conducted to validate the efficacy of *Trichoderma* BT9 strain in managing *A. flavus* growth and aflatoxin contamination in corn under field conditions.

Five farmers were selected as cooperators and sources of samples. Newly harvested corn were randomly selected from pile of each farmer and subjected to shelling and piling treatments. The *Trichoderma* sp. (BT9) was applied as a harvest treatment to corn. Toxigenic *A. flavus* was also inoculated as a conidial suspension (1x105 spores/ml) into corn. Percentage kernel infection and HPLC analyses were used to quantify *A. flavus* infection and aflatoxin contamination.

Field testing using the formulated BCA showed a reduction in *A. flavus* infection when BCA was applied on newly harvested corn with husk not immediately shelled and immediately dried. Likewise, a reduction in aflatoxin contamination was also observed in this treatment during the testing.

Keywords: *Aspergillus flavus, Trichoderma spp*., Aflatoxin, Biological control

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INTRODUCTION

Aflatoxins are a group of natural poisons known to cause liver damage and cancer in humans and animals. They are produced by certain species of fungi, *Aspergillus flavus* and *Aspergillus parasiticus*, while growing on suitable substrates under favorable conditions.

Studies show that homegrown corn is highly susceptible to aflatoxin contamination. A study conducted by Tiongson et al (2005) showed significant aflatoxin contamination in corn collected from Isabela, South Cotabato, Pangasinan, and Camarines Sur in 2004 and 2005, with 32% of the 172 samples having more than 50 ppb aflatoxin. Monitoring and surveillance studies conducted by Esteves et al (2008) also showed high aflatoxin incidence in corn during the September monitoring period in Villa Luna, Cauayan, Isabela. Aflatoxin was detected in 92% of the monitored lots, with levels averaging at 64 ppb. The maximum level recorded was 410 ppb. Current aflatoxin limit in products intended for human and animal consumption is 20 and 50 ppb, respectively.

Aflatoxin contamination in homegrown corn can compromise the safety of food and feed supplies. Corn is an important source of food and feed in the Philippines. About 18 % of corn produced in the country is consumed as staple in corn-eating regions while about 80% is processed into feeds. Hence, there is a need to control aflatoxin contamination in corn.

Aflatoxins are very stable compounds and once they are produced, they cannot be readily removed from contaminated commodities. Hence, the ideal strategy is to control the growth of aflatoxin-producing fungi. The method commonly used to control fungal growth is chemical treatment. However, the hazards posed by disease control chemicals to human health and the environment limit their application. Another effective method of controlling fungal growth is immediate drying to moisture levels that do not allow fungal growth. However, sundrying, which is the most commonly used method of drying corn, is unreliable during the wet season.

Hence, there has been increasing interest in developing alternative control strategies. Among these strategies is biological control, which is based on antagonistic action of one organism over another. The use of indigenous microorganisms as biocontrol agents offers a viable and sustainable alternative to chemicals for the control of seed borne and seed rot fungal pathogens. These microorganisms can be formulated, commercially-produced and applied to crops much like disease control chemicals (Quimio, 1997).

The most promising biocontrol agents belong to the genus *Trichoderma*. The genera Trichoderma is known to possess useful attributes for biological control. They are soil fungi that are active as mycoparasites and have been used as biological control agents because they attack a large variety of pathogenic fungi responsible for major crop diseases (Harman and Lumsden, 1990). Their effectiveness as biocontrol agents has been attributed to enzyme or antibiotic production and mycoparasitism.

Trichoderma spp. have been shown to have antagonistic effect on *A. flavus*. In experiments conducted by Thakur et al. (2003), *T. viride* and *T. harzianum* were highly antagonistic and were successful in competing with *A. flavus* in groundnuts. These *Trichoderma* spp. also inhibited *A. flavus* growth in the study conducted by Calistru and Mclean (1997). In-vitro assays conducted by Bermundo and Santiago (2000) demonstrated the antagonistic effect of *Trichoderma harzianum* on *A. flavus*. These studies show the potential of *Trichoderma spp* as biocontrol agents against *A. flavus.*

The potential of T*richoderma harzianum* (BT9) as effective biocontrol agents against *A. flavus* was determined in previous studies by Santiago et al., (2010). Laboratory testing showed a reduction in *A. flavus* infection when BT9 was applied in corn ear with husk. A reduction in aflatoxin contamination was also observed in this treatment. Field testing also showed a reduction in *A. flavus* infection when shelling was delayed and drying was on time when BT9 was applied during ear emergence and at harvest.

However, reduction of aflatoxin levels with BT9 treatments was not observed in the field trial, unlike in laboratory in-vivo testing where aflatoxin reduction was apparent.

This may be due to the fact that storage time was limited to one day unlike in laboratory in-vivo testing where aflatoxin level was determined after four weeks of storage. Longer storage period may be required to see the effect of BT9 treatment on aflatoxin level. Moreover, it is also possible that the high incidence of *A. flavus* growth observed in the field trial is non-aflatoxin strains. Further field studies should be conducted to determine if aflatoxin reduction can be achieved by applying BT9 at corn ear with husk after harvest. Hence, this project was conducted.

METHODOLOGY

Site Selection

This study was conducted in Cauayan City, Isabela province. Corn production in Isabela contributes about 13% to total corn production. Isabela also has a Types 3 climate. This means seasons are not very pronounced, relatively dry from November to April and wet during the rest of the year.

Treatment comparisons after harvest with the *Trichoderma* treated corn and farmer's practice were conducted during the wet season cropping from June to October 2015. Five farmer cooperators in study site were selected as source of corn samples. Farmer cooperators were selected based on willingness to introduce the technology to their farm. The corn was managed by the farmer cooperators according to their recommended cultural and management practices from seed sowing to harvesting.

Preparation of experimental unit

Newly harvested corn were randomly selected from pile of each farmer and subjected to different shelling and piling treatments. Nine different treatments were made. These were about 10 kilogram corn seeds (for treatment 1-5 including the T1 control) and 18 kilogram corn ear with husk (for treatment 6-9).

The *Trichoderma* sp. (BT9) was applied as a harvest treatment to corn.

Toxigenic *A. flavus* was also inoculated as a conidial suspension (1x105 spores/ml) into corn. Time lags were allowed before drying or shelling the treated corn seeds to enable the microorganisms to get established in the corn. Experimental treatments and components are as follows:

Treatments
T1: Shelled corn + dry immediately for 2 days (Control)
T2: Shelled corn + store for 3 days, then dry
T3: Shelled corn + *Trichoderma* (5g/200g; 25g/kg $1x10^5$ spores/mL)+ store for 3 days then dry
T4: Shelled corn + aflatoxigenic *Aspergillus flavus* (5ml/200g; $1x10^5$ spores/mL)+ store for 3 days then dry
T5: Shelled corn + *Trichoderma* + *A.flavus* + store for 3 days then dry
T6: Corn ear with husk + pile for 5 days then shell and dry
T7: Corn ear with husk + *Trichoderma* + pile for 5 days then shell and dry
T8: Corn ear with husk + *A.flavus* + pile for 5 days then shell and dry
T9: Corn ear with husk + *Trichoderma*+ *A.flavus* + pile for 5 days then shell and dry

The recommended practice to control aflatoxin formation in corn is the immediate and proper drying of seeds. This must be done within two days after harvest. This was applied in Treatment 1.

After drying, the treated and inoculated seeds were stored in net bags stacked in sacks in the laboratory. Samples were taken for microbial before storage and after 30 days of storage. About 500 grams of corn kernel sample were taken for plating. Percentage infection was determined five to seven days after seeding in PDA and AFPA plates. Likewise, physical quality and aflatoxin level was determined after one month of storage.

Assessment of kernel infection and isolation of A. flavus and BCA

Kernels were prepared for microbial analysis using the standard method of Pitt and Hocking (1997). One hundred randomly selected corn kernels from each sample were plated, 10 kernels per plate on two media namely: *Aspergillus flavus* and *Parasiticus Agar* (AFPA) as a selective medium and *Potato Dextrose Agar* (PDA) as a general medium.

All kernels were surface sterilized before plating by immersing for 3 minutes in 0.4% sodium hypochlorite solution followed by rinsing three times in sterile distilled water and blot drying. Culture plates were incubated for five to seven days at 28^{o}C. After incubation, incidence of infection by *A. flavus* and growth of *T. harzianum* and other fungi was recorded. As a selective medium, *A. flavus* can be identified on AFPA by the production of typical yellow to olive green spores and a bright orange reverse.

Aflatoxin analysis

Aflatoxin B1 level was determined following the Immunoaffinity Column-Liquid Chromatography Method with Pre-Column Derivatization. This method involves extraction of a 25-g sample with 70% aqueous methanol and cleanup with AflatestTM immunoaffinity column.

Statistical Analysis

Data from microbial, aflatoxin and physical analyses during field trial were analyzed using the ANOVA. Significant differences among means were determined using the Least Significant Differences at 5% level.

RESULTS AND DISCUSSION

Assessment of kernel infection and isolation of A. flavus and BCA

Kernel infection of *A. flavus* before storage was influenced by treatment. Growth of *A. flavus* was very evident in shelled corn samples that were not immediately dried. Infection in shelled corn sample in T1 is significantly lower compared to other treatments (T2, T3, T4 and T4). In BT9 treated T3, high incidence of *A. flavus* (66.4%) was noted and not significantly different to T4 and T5 but showed significant difference to T2 (99.2%) (Figure 1).

Moreover, no significant differences were noted in T2, T3, T4 and T5 after four weeks of storage. The high incidence of *A. flavus* might be influenced by the temporary storage at high moisture content (27.5%) for three days before finally sun drying the crop to 14% moisture content.

There was a significant reduction of *A. flavus* infection in *Trichoderma* treated corn with husk compared to non-*Trichoderma* treated samples (Figure 2). Incidence of *A. flavus* infection before storage in corn with husk is significantly lower in T7 and T9 (percent mean of 9.6, 10.8 and 11.2, respectively) compared to treatments T6 and T8.

Significant reduction in infection level was observed in treatments where BCA was applied on corn ear with husk, namely T7 and T9 which is comparable with the control T1 (9.6%). After a month of storage, T7 had significantly lower infection than the other treatments, except T9, which had similar infection level as T7 after four weeks of storage.

Likewise, the experiment demonstrated that the BCA used in this study meets several criteria essential for an effective biocontrol agent. One feature is that the biocontrol agent survived and colonized the corn kernels targeted by *A. flavus* as indicated by their growth from the seed planted in PDA (Figure 3). The co-cultivation of *A. flavus* and the isolate of *T. harzianum* in corn kernels satisfied another criterion in that the biological agent must be able to survive on kernels in storage.

The applied *T. harzianum* isolate grew on corn kernels when plated in the PDA, the part of the corn plant most commonly associated with the aflatoxin in causing harmful effects on animal and human health after four weeks of storage.

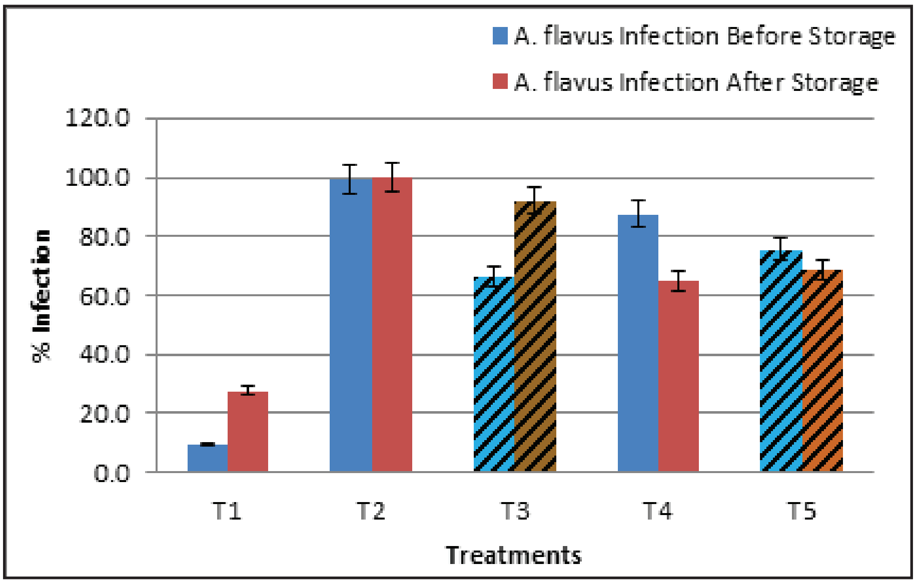

Figure 1. Percent mean A. flavus infection (n=5) of corn samples with delay in drying before storage and after 4 weeks of storage

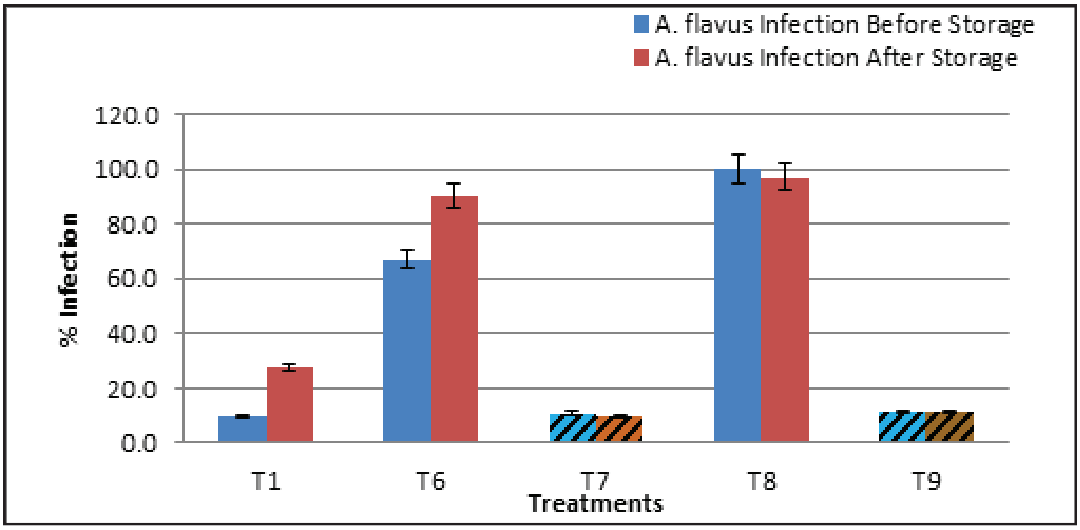

Figure 2. Percent mean A. flavus infection (n=5) in corn samples unshelled for 5 days and dried immediately after shelling before and after 4 weeks of storage

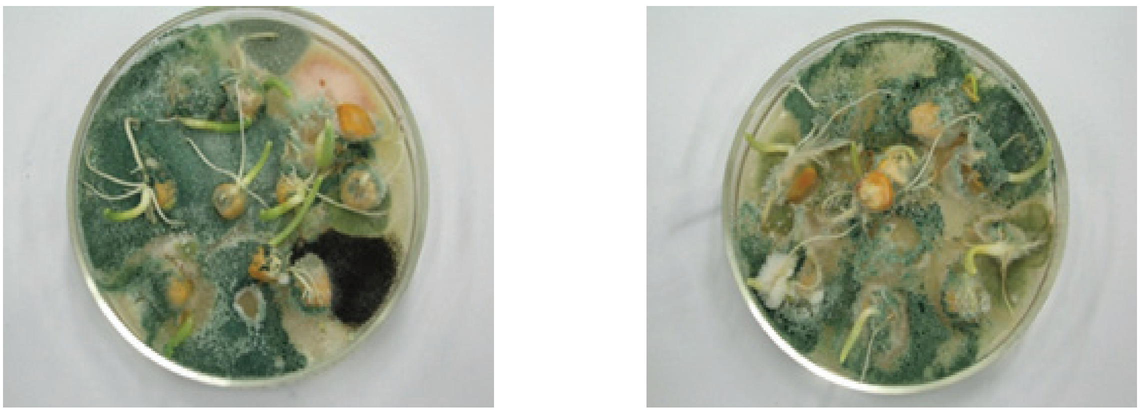

Figure 3. Growth of *T. harzianum* on corn kernels after storage.

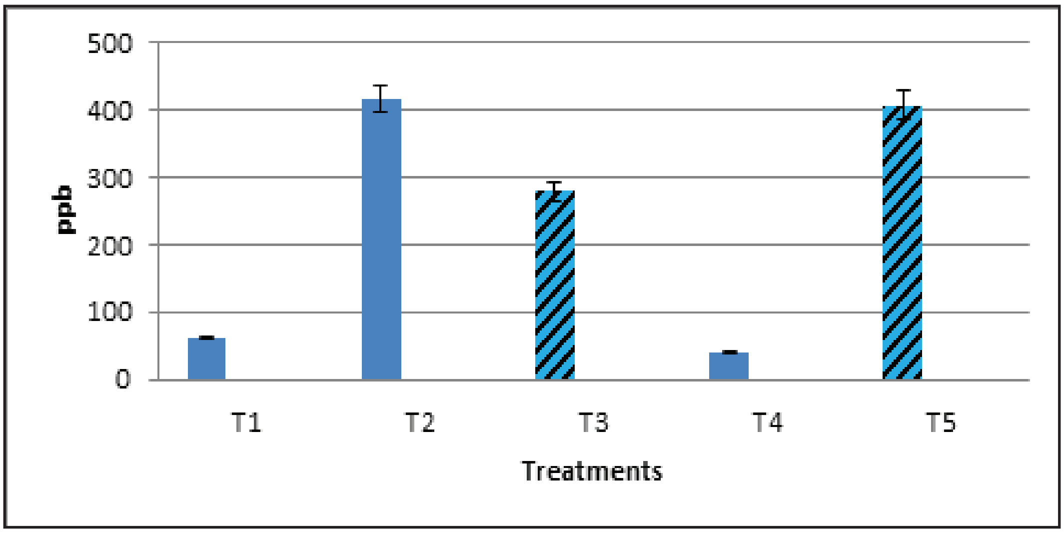

Figure 4. Mean aflatoxin concentrations in corn samples with delay in drying after 4 weeks of storage

Aflatoxin contamination in corn

Shelled corn samples treated with *Trichoderma* (BT9) alone (T3) and stacked for three days had significantly lower aflatoxin levels compared with those not treated with BT9 (T2) (Figure 4). However, shelled corn samples with *Trichoderma* and in combination with *A. flavus* (T5), T2 and T3 had significantly higher aflatoxin level compared with sample inoculated with *A. flavus* (T4). Aflatoxin production in samples of corn ears with husk was affected by treatment with *Trichoderma* (BT9) (Figure 5).

Samples of corn ear with husk treated with *Trichoderma* (T7) and in combination with BT9 and *A. flavus* (T9) had significantly lower aflatoxin levels than the untreated ones (T8). The mean aflatoxin level in T9 was 33 ppb and 84 ppb in T7 while 435 ppb in T8. Though, levels in T6 (32 ppb), T4 (39 ppb) and T1 (61 ppb) are not significantly different from T9 and T7.

Levels of aflatoxin were lower in samples of *Trichoderma*-treated corn ear with husk than *Trichoderma*-treated shelled corn. Likewise, samples of corn ear with husk not treated with *Trichoderma* had lower levels than shelled corn not treated with *Trichoderma*. These results show the protection provided by corn husk. This protection is enhanced by *Trichoderma* application. These results support the previous observation that corn husk provides protection from infection (Santiago et al, 2010). However, when shelled corn was inoculated with toxigenic *A. flavus* as in T4 and stacked for three days, the aflatoxin concentration was low and not significantly different with the control (T1) and BCA treated corn ear with husk samples (T7 and T9).

This result may be attributed to the antagonistic effect of the applied *A. flavus* in corn.

Physical Quality/Visible A. flavus Infection

Percentage mold damage and visible *A. flavus* growth on treatments with BCA (T7) and in combination with *A. flavus* (T9) that was not immediately shelled (corn cobs stored for five days) and immediately dried after shelling was significantly lower than in treatments where *A. flavus* (T8) was applied on corn husk (Figure 6). Likewise, percentage mold damage and visible *A. flavus* growth on treatment with BCA (T3) where the corn was immediately shelled and not immediately dried was not significant in treatments where BCA was not applied (T1 and T2) but significantly lower in treatment where *A. flavus* was applied (T4) (Figure 6).

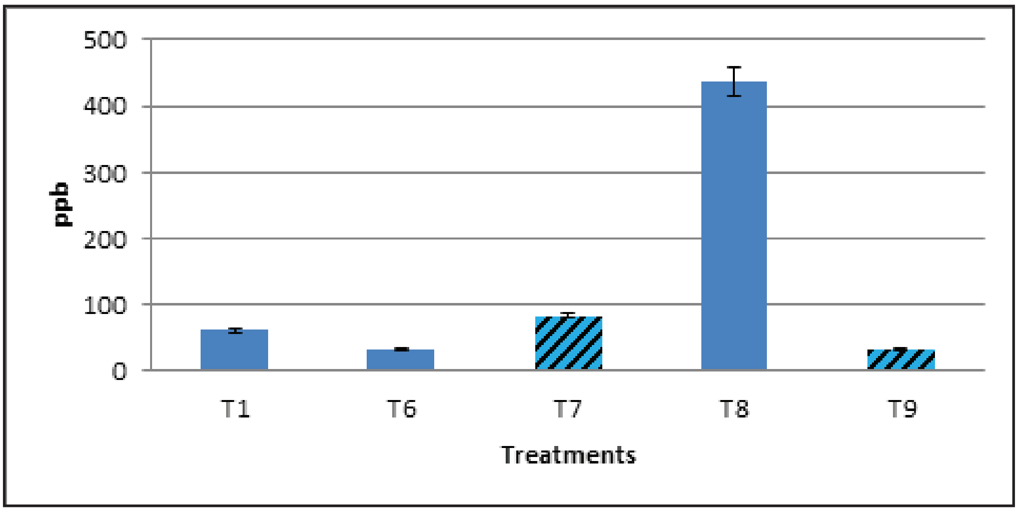

Figure 5. Mean aflatoxin concentrations (n=5) of treatments with shelling delay and no drying delay of untreated and BT9 treated corn

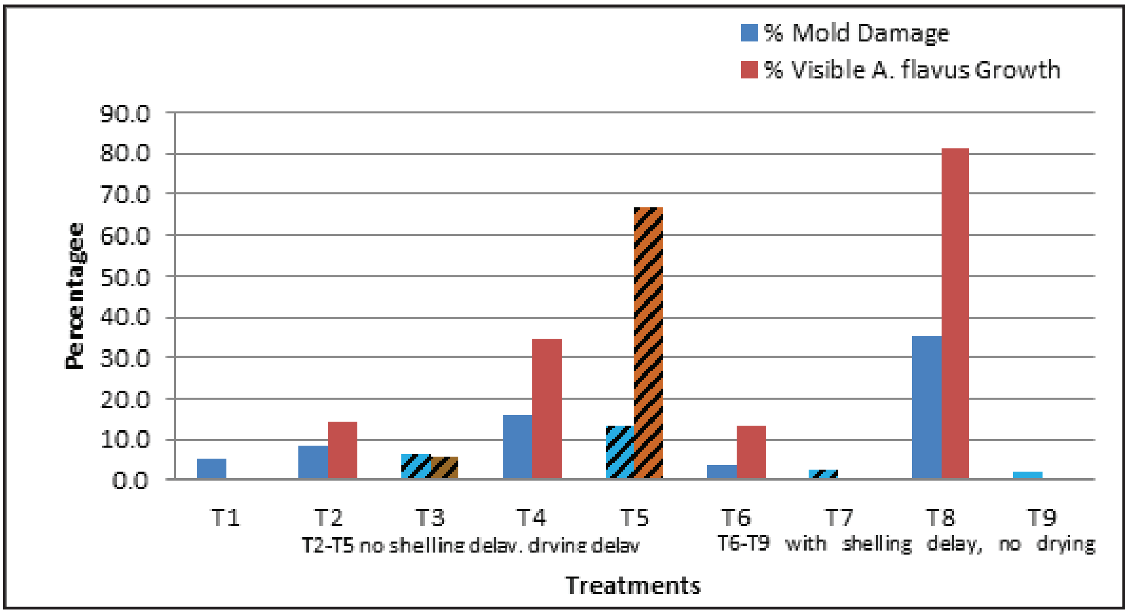

Figure 6. Percent mold damage and A. flavus infection in corn kernels after 4 weeks of storage

CONCLUSION AND RECOMMENDATIONS

Field testing showed a reduction of *A. flavus* infection when BCA was applied in corn ear with husk when shelling was delayed and drying was on time. When there was delay in shelling and immediate drying, BCA applied at harvest resulted in significantly lower *A. flavus* infection. Likewise, reduction of aflatoxin levels with BCA treatments was also observed.

Further studies regarding aflatoxin prevention and control should be conducted, particularly on biological control using atoxigenic *A. flavus* and an integrated approach consisting of pre-harvest and postharvest biological control agent (*Trichoderma sp.* BT9).

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HERMETIC STORAGE FOR PRESERVING QUALITY OF LIBERICA AND ROBUSTA COFFEE IN THE PHILIPPINES

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ABSTRACT

Storage trial of up to nine month duration was carried out to observe and compare the use of hermetic storage grain bags (HSGB) made of polyethylene plastic material with plastic woven polypropylene bags (PPB) for preserving dried (11-12.5%) green coffee. The trial was done under ambient condition of 23-31°C T and 74-90% RH. The parameters observed were moisture content (MC), color, fungal infection, Ochratoxin A (OTA), insect infestation, and sensory attributes (aroma, fragrance, acidity, flavor, body and aftertaste).

Results showed that the color of green coffee stored in HSGB and PPB had no significant difference, both for Liberica and Robusta. The MC of coffee beans stored in HSGB was lower than the beans stored in PPB.

Insect population increased with time in coffee bean stores at PPB while in HSGB, insects were either prevented or controlled. Fungal species producing ochratoxin were among those present in both Liberica and Robusta coffee however, OTA was detected only in Liberica'. The initial contamination levels of OTA in Liberica had no significant difference with the levels detected up to nine months storage.

Sensory attributes on the cupping qualities of green coffee beans can be preserved when stored in HSGB for as long as nine months while storage in PPB will preserve cupping qualities of coffee tor only four months.

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INTRODUCTION

The desirable sensory attributes of coffee depends in its storage conditions, hence technologies that can be used in preserving the quality of coffee and preventing losses during prolonged storage periods are important. In the Philippines, a large part of coffee produced is stored by farmers and traders in times of glut in supply while waiting for processing and/or better market price of coffee. However, prolonged storage of bagged green coffee beans in warm climates under ambient conditions, even when properly dried, is prone to insect infestation. Keeping coffee in containers where moisture may accumulate could result to bigger problems of microbial infection which can lead to production of mycotoxins, specifically, ochratoxin A (OTA). Mycotoxins are natural toxic substances produced by certain fungi and are hazardous to the health of man and animals.

Ochratoxin is the specific mycotoxin found in coffee. Grain temperature and moisture content are the critical factors which affect its production. The introduction of ochratoxin (OTA) limits for green coffee started way back in 1974, with individual countries setting limits at 5-20ppb for green coffee. Protecting coffee from deterioration and degradation of their organoleptic qualities in the tropics can also be a problem as prolonged storage could result to gradual loss of beans' taste and aroma, color and density (Aronson et al., 2005).

Current practice in the country involves the use of either jute sacks or polypropylene bags (PPB) to store green coffee. Both bags are permeable, hence, coffee is susceptible to insect attack and the loss of quality caused by the changing moisture content of the beans, as a result of the beans' interaction with ambient air.

Recent studies reported the use of hermetic technology in storing green coffee. Hermetic storage is a type of biogenerated modified atmosphere. It consists of the generation of an oxygen-depleted and carbon dioxide enriched interstitial atmosphere brought about by the respiration of the living organisms in the ecological system of a sealed storage (Navarro and Navarro, 2015).

GrainPro Coccoon is an example of hermetic storage technology which has been used in the successful storage of grains like paddy and corn with capacities varying from 200 tons to 5000 tons. The use of hermetic storage in preserving the qualities of coffee beans for five months using GrainPro Cocoons has been reported in Costa Rica (Aronson et al., 2005). India and Kenya likewise acknowledged the potential of sealed storage (Ministry of Agriculture and Rural Development, 2002) although the storages' atmospheric composition has not been properly documented. It is theorized that by holding properly dried coffee under hermetic conditions, moisture ingress that could lead to loss of beans' taste and aroma, color and density, mold infection and insect infestation could be prevented. The lethal hypoxic atmosphere formed could minimize several oxidative processes that would adversely affect the bean quality (Aronson et al., 2005) and kill microbial and insect pests. However, application of new technologies for coffee storage requires validation at local conditions with a broader scope of looking into the effects to organoleptic and sensory qualities.

In the current study, the application of hermetic storage for preserving dried (ll-12.5%m.c) green coffee bean was evaluated and compared with the conventional storage practice of local processors/farmers. Storage trials were conducted at the Cavite State University, Indang, Cavite where Robusta and Liberica coffee varieties are cultivated and grown.

METHODOLOGY

Preparation of coffee for storage

Dried coffee green beans from the farmers were purchased and immediately sorted and cleaned during processing to obtain good quality beans for storage. The dried green coffee bean above the safe level of MC was dried down to 11-12.5% moisture content using a laboratory dryer or by solar drying.

Storage treatments

Dried green coffee beans were immediately stored in the test bags (10kg capacity): the Hermetic Super Grain Bags (HSGB) made of polyethylene plastic material and Polypropylene bags (PPB). Four replicates were prepared for each treatment and were stored at ambient condition.

Storage and sampling periods:

The initial condition of coffee was established by analyzing three samples for each variety from three bags randomly selected from each lot at the start of the storage trial. Thereafter, succeeding samples were gathered every scheduled sampling months of storage to determine changes or deterioration of stored coffee.

Analyses of samples

Moisture content was measured immediately after collecting samples using a coffee moisture meter calibrated through oven method. Changes in color (lightness (L); negative values for green to positive values for red (a); and negative values for blue to positive values for yellow (b)) of coffee was measured by using the B-YK Gardner color guide. The change in color per replicate sample was based from the mean' readings of sub samples observed. The physical qualities which includes percentage of good beans, broken, small, insect damaged and impurities (stones, sticks) of the stored coffee beans was analyzed on sampling periods up to nine months.

Microbial infection was determined from thoroughly mixed replicate samples gathered per treatment. Ten (10) randomly selected green beans were directly plated in potato dextrose agar for observation. Assays were replicated three times. *Ochratoxin* contamination in coffee samples was analyzed using the Immunoaffinity Column (IAC)- Liquid CHromatograph (LC) Method (AOAC)

Table 1. The various parameters observed every sampling period.

Parameters	Schedule of sampling and analyses (months)
Changes in moisture content	0,2,3,4,6,9
Changes in color	0,2,4,6,9
Sensory evaluation	0,2,4,6,9
Microbial load	0,3,6,9
Ochratoxin	0,3,6,9
Insect and mites infestation	0,3,6,9
Physical Quality	0, 3,6,9

Insect and mites infestation were determined from each replicate using 500g sub-samples. Insects were collected from samples by sieving. All insects gathered (dead or alive) were sorted, counted, identified, properly mounted, and stored. Mites on the other hand were collected from coffee samples using the flotation method. Gathered mites were sorted according to morphological semblances, counted and identified.

Sensory Evaluation

Fifteen potential panelists were trained and screened using the coffee sensory evaluation scoring system used by the Specialty Coffee Association of America. Seven were left for the project. Five cupping sessions were made, each for Robusta and Liberica- green coffee beans.

The following basic coffee characteristics were evaluated:

1. Fragrance (dry): Sensation of gases released from freshly roasted and ground coffee as aromatic compounds are inhaled when sniffed. Sweetly floral or sweetly spicy.
2. Aroma (wet): Sensation of gases released from freshly brewed coffee.
3. Acidity: A taste sensation related to the presence of sweet-tasting compound which are created as acids in coffee, combine with sugars to increase the brews overall sweetness. Taste sensation experienced at the tip of the tongue.
4. Flavor: The vapors tasted when coffee is swal lowed.
5. Body: The sensation that denotes the level of substance in the coffee solution or brew
6 Aftertaste: Sensation of brewed coffee vapors as they are released in the mouth after swallowing during expectoration.

Statistical Analyses

Gathered data were subjected to one- way ANOVA. Statistical significance at 5% level was tested by comparing the F - test statistic.

RESULTS AND DISCUSSION

Moisture Content

Moisture content (MC) of the coffee beans fluctuated during storage perhaps because of the changes in the temperature and relative humidity of the storage room (Table 2). Nonetheless, the moisture content of coffee stored in hermetic bags (HSGB) is generally lower than the MC of beans in PPB for both varieties. There was no significant difference in the initial and final MCs of coffee beans stored in HSGB for both Robusta and Liberica varieties.

The sudden increase in the MC of Liberica on the four month of storage was due to a rat-damaged HSGB bag. On the other hand, the MC of coffee beans stored in PPB significantly increased after nine months. The coffee beans inside the PPB bags have greater interaction with the ambient air which may have caused the significant increase in the MC after nine months of storage. The permeable characteristic of polypropylene bags allowed the ingress of moisture and fluctuation in the MC of the coffee beans. HSGB or hermetic bag was effective in maintaining the MC levels of the green coffee beans.

Color

There was no significant difference in the color of the coffee beans, both in Liberica and Robusta varieties, whether stored in polypropylene bags (PPB) and in hermetic stored grain bags (HSGB) as analyzed in each sampling periods of 0,2,4,6 and 9 months. No significant change in color was observed from the start of the storage trial (0 month) up to the end of storage (9 months). Both Robusta and Liberica coffee can be stored in PPB- or HSGB- under ambient condition for 9:0 months without significantly affecting bean color.

Table 2. Moisture content of coffee beans stored for nine months in PPB and HSGB

Storage Time (months)	Liberica		Robusta	
	PPR	HSGB	PPB	HSGB
0	10.67 BC	10.67 B	9.62 C	9.62 C
2	10.85 B	10.67 B	10.49 AB	10.35 AB
3	10.27 D	10.21 B	10.56 A	10.50 A
4	11.24 A	15.27 A	10.27 A	10.26 AB
6	10.52 C	10.39 B	10.25 B	9.76 C 10.11 C
9	11.35 A	10.37 B	10.46 AB	9.76 C 10.11 C

Means having the same letter within a column is not statistically significant

Table 3. Color of Liberica and Robusta coffee beans in PPB and HSGB at different storage time.

Storage Time (months)	Liberica		Robusta	
	PPB	HSGB	PPB	HSGB
0	20.6254 AB	20.6254 A	19.3975 A	19.379 A
2	20.0512 B	20.1417 A	19.0942 A	19.235 A
4	21.4342 A	20.8329 A	18.8325 A	18.8883 A
6	20.7975 AB	21.2021 A	19.3054 A	19.2158 A
9	19.9600 B	20.4146 A	19.5642 A	18.4237 A

Means having the same letter within a column is not statistically significant

Insect Infestation

Coffee bean weevils were present in both Liberica and Robusta varieties at the start of the study. The-green coffee beans were purchased from coffee farmers and may have been infested at the farmers' storages. Coffee bean weevils, Araecerus fasciculatus (Anthribiidae: Coleoptera) is the most common pest of coffee in storage.

Liberica

The population of the coffee bean weevil stored in PP bags, increased with time (>2x) in the subsequent sampling periods of 3, 6 and 9 months (Table 5). At the end of storage, the population of coffee bean weevil was 75.25/500g sample.

On the other hand, coffee bean weevils were observed only at the sixth month samples, at a decreased number of 1.5/500g in the coffee beans stored in the hermetic bags.

This shows that hermetic storage works in preventing further increase in insect population already present before storage. The coffee bean weevil was shown to be successfully controlled at nine months.

Psocids and mites were observed on the third month sampling of Liberica beans but their presence was limited on the beans stored in PP bags only. This further demonstrates the effectiveness of the HSGB bags in controlling insect infestation. Anoxia, or lack of oxygen prevented the increase of insect population inside the hermetic bags.

Robusta

Three insect species and two mites species were observed in the Robusta variety during the study. Infestation of coffee bean weevil was already observed at the initial samples (0 month).

Aside from the coffee bean weevil and the psocids encountered in the Liberica variety, the corn-weevil, *Sitophilus zeamais* (Curculionidae: Goleoptera) and the mites species, *Suidasia pontifica* were also observed.

Population of coffee bean weevil also increased in the subsequent sampling periods (3, 6 and 9 months) in beans stored at PP bags. While coffee bean weevils were also observed in the initial samples that were stored in hermetic bags, its population was obviously controlled as shown in the following sampling periods.

The corn weevil present at the sixth month sampling period may have been present as an egg during the initial sampling and wasn't visible at that time. Nonetheless, the insect was not observed on the final sampling at nine months.

Except for the few psocids observed in HSGB on the sixth month sampling period, no other insects and mites were present in the hermetically stored Robusta coffee. Psocids were observed in coffee beans stored in PPB only in the third month of storage. Mites which could possibly impart smell in the stored beans were not observed in hermetically stored coffee beans.

Table 4. Insects and mites infestation in Liberica coffee beans stored for nine months in polypropylene bags (PPB) and hermetic super grain bags (HSGB).

Insect/Mite species	**Mean number of insects/mites per 500g sample (n=4)**						
	Storage Time (months)						
	0	**3**		**6**		**9**	
		PPB	HSGB	PPB	HSGB	PPB	HSGB
Insects							
Araecerus fasciculatus (coffee bean weevil)	2	14.0	0.00	35.00	1.50	75.25	0.00
Liposcelis bostrychophillus (psocid)	0	17.25	0.00	0.00	0.00	0.00	0.00
Mites							
Cheyletus mallaccencis	0	7.00	0.00	1.00	0.00	77.25	0.00

Table 5. Insects and mites infestation in Robusta coffee beans stored for nine months in polypropylene bags (PPB) and hermetic super grain bags (HSGB)

Insect/Mite species	**Mean number of insects/mites per 500g sample (n=4)**						
	Storage Time (months)						
	0	**3**		**6**		**9**	
		PPB	HSGB	PPB	HSGB	PPB	HSGB
Insects							
Araecerns fasciculatus	2	4.20	0.00	10.00	0.00	16.50	0.00
Sitophilns zeamais	0	0.00	0.00	0.00	0.50	0.00	0.00
Liposcelis bostrychophillus	0	39.50	0.00	0.00	0.25	0.00	0.00
Mites							
Cheyletus mallaccencis	0	3.50	0.00	41.50	0.00	76.50	0.00
Suidasia pontifica	0	0.00	0.00	0.00	0.00	1.50	0.00

Table 6. Percent infection of fungal species isolated from Liberica beans stored in polypropylene bags (PPB) and hermetic super grain bags (HSGB) for nine months.

Fungal Isolates	Microbial infection (%) at Different Storage Time						
	Omo.	3 mos.		6 mos.		9 mos.	
		PPB	HSGB	PPB	HSGB	PPB	HSGB
Aspergillus flavus	36.12	25	13.5	3	4	28	12
Aspergillus tamari	6.5	1	1	0	0	0	2
Aspergillus ochraceus	4	0	0	0	0	0	0
Aspergillus niger	96	48.5	46.25	100	94.5	100	100
Aspergillus japonicus	16	52	52.25	0	0	0	0
Aspergillus fumigatus	0	23.75	17	9.33	5.33	2	0
Aspergillus terreus	0	0	0	2	0	0	0
Fusarium proliferatum	2	0	0	0	0	0	0
Fusarium oxysporum	6.67	0	0	0	0	0	0
Fusarium semitectum	0	0	0	0	0	4	8.67
Mucor piriformis	0	0	0	0	0	0	2
Lasiodiplodia theobromae	14	0	0	0	0	00	0
Rhizopus microspores	14	0	0	0	0	0	0
Rhizopus stolonifer	0	0	0	0	0	22	0
Rhizopous pusilus	0	0	0	7.33	7.5	0	0
Trichoderma harzianum	4	0	0	0	0	0	0

Fungal Infection

A total of 16 fungal species were isolated from Liberica coffee beans and 18 from the Robusta coffee beans. The fungal species in Liberica and Robusta varieties belong to same six genera namely *Aspergillus, Fusarium, Mucor, Lasiodiplodia ,Rhizopus* and *Trichoderma.*

Of these, three species all belonging to genera *Aspergillus*, were reportedly producing ochratoxin (Abarca et al., 1994; Accensi et al., 2001, Alvindia and De Guzman 2016. These are *Aspergillus niger*, *Aspergillus ochraceous* and *Aspergillus carbonarius.* Microbial occurrence and levels of infection were similar in coffee stored in PPB and HSGB in both Liberica and Robusta varieties.

Ochratoxin (OTA)

The type of storage bag used has no effect on the OTA levels of the Liberica coffee. Liberica coffee was already contaminated with OTA at 12.45ppb at the beginning of the experiment. Moreover, levels of OTA at the succeeding sampling periods were not significantly different between those stored in HSGB or in PPB (Table 9). At nine months, OTA level in coffee beans stored in PPB was 10.50ppb while coffee stored in HSGB was 12.62ppb. Nonetheless, both levels were not statistically different with the initial OTA level and with the OTA contamination levels detected at three and six months of storage. The levels of Ochratoxin A detected are above the safe level of 5 ppb in roasted coffee beans and ground roasted coffee set by the Commission Regulation (EC) No 1881/2006.

The OTA was not detected in the initial samples of Robusta coffee beans nor in the subsequent samples analyzed for three, six and nine months stored in both bags.

A study reported by Alvindia and De Guzman (2016) showed that among the fungal species detected in the coffee beans during storage, *Aspergillus niger* and *Aspergillus ochraceous*, *Aspergillus carbonarius* and *Penicillium verrucolosum* were the ones producing ochratoxin in Liberica and Robusta variety.

Table 7. Percent infection of fungal species isolated from Robusta beans stored in PPB and HSGB for nine months.

Fungal Isolates	**% infection at Different Storage Time**						
	Omo.	**3 mos.**		**6 mos.**		**9 mos.**	
		PPB	HSGB	PPB	HSGB	PPB	HSGB
Aspergillus flavw	19.33	33	29.5	6	7.5	21.5	19
Aspergillus ochraceus	10	0	0	0	0	0	0
Aspergillus niger	97.75	97.33	86.5	79.5	25.25	82	84.5
Aspergillus tamari	8.67	6.25	5	5	0	5	5.33
Aspergillus japonicus	2	2	1	2.5	3.66	4	0
Aspergillus terreus	0	0	0	0	1.5	0	0
Fusarium verticolloides	6	0	0	0	0	0	0
Fusarium solani	28.5	0	0	0	0	0	0
Fusarium udum	35.5	0	0	0	0	0	0
Fusarium oxysporum	0	4.67	2.67	4-	12	0	10;5
Fusarium semitectum	0	19.5	16.5	0	0	0	0
Lasiodiplodia theobromae	0	2.5	1	2.5	7.25	0	0
Mucor piriformis	0	0	0	0	0	0	2
Mucor hiemalis	0	0	0	1	5.5	0	0
Mucor circinilloides	0	0	0	0	0	34	46
Penicillium citrinum	0	3.5	4	1	2	0	0
Penicillium brevicatum	6.33	0	0	0	0	0	0
Rhizopous pusilus	0	0	0	7.33	7.5	0	0

While the incidence of OTA in Liberica can be attributed to the above fungal species, it is also negated in the absence of OTA in the Robusta variety. In consideration of the three factors that must be present for the potential of mycotoxin production which are the substrate, the environment (moisture) and the microorganism, we can predict that the time needed for Liberica to dry made the difference. Liberica coffee, being larger in size than the Robusta coffee took longer time to dry making possible for the toxigenic fungi present in Liberica to produce OTA. Drying time for Liberica takes 10 to 29 days and only 8 to 14 days for Robusta (Regpala-era. 2009).

Robusta

There was no significant difference in the cupping qualities of the beans stored in HSGB and PPB from 0 month up to four months.

Significant differences were observed on the cupping session for the sixth month storage samples. The beans stored in HSGB showed greater values.in terms of fragrance and aroma than those stored in PPB. Beans stored in PPB showed less values or started to lose some fragrances and aroma. On the aftertaste, significant difference was also observed with greater values given to the hermetically stored beans than those stored in PPB. On the other hand, there were no significant differences in the acidity, flavor and body of beans stored in the two containers.

On the last cupping session (nine months storage) there were significant differences between coffee beans stored in HSGB and PPB. The green coffee beans stored in HSGB consistently showed greater values in terms of fragrance, aroma; acidity, flavour, body, and aftertaste than those beans that were stored in PPB.

Liberica

There was no significant difference in the cupping qualities of the beans stored in HSGB and PPB from 0 month up to four months.

Samples from the sixth month storage period showed significant differences in fragrance and aroma. The beans stored in HSGB showed greater values in terms of fragrance and aroma than those stored in PPB. Beans stored in PPB showed less values or started to lose some fragrances and aroma. On the other hand, there were no significant differences in the acidity, flavor, body and aftertaste of beans stored in the two containers.

On the last cupping session (nine months storage) there were significant differences between coffee beans stored in HSGB and PPB. The green coffee beans stored in HSGB consistently showed greater values in terms of fragrance, aroma; acidity, flavour, body, and aftertaste than those beans that were stored in PPB

CONCLUSION

Results showed that the MC of coffee beans in stored HSGB was significantly lower than the beans stored in PPB. The color of green coffee stored in HSGB and PPB has no significant difference, both for Liberica and Robusta.

Insect population increased with time in coffee- beans stored at PPB while in HSGB, insects were either prevented or controlled. Fungal species producing ochratoxin were among those present in both Liberica and Robusta coffee. However, OTA was detected only in Liberica. The initial contamination levels have no significant difference with the levels detected up to nine months of storage.

Sensory evaluation results showed that cupping qualities of green coffee beans can be preserved when stored in HSGB for as long as nine months while storage in PPB will preserve cupping qualities of coffee for only four months.

Table 8. Levels of Ochratoxin (OTA) contamination in Liberica and Robusta coffee beans stored in polypropylene bags (PPB) and hermetic super grain bags (HSGB).

Storage Time (months)	**OTA level (ppb)**			
	Liberica		**Robusta**	
	PPB	HSGB	PPB	HSGB
0	12:42a	12.42a	nd	-nd
3	11.87a	10.25a	nd	nd
6	10.25a	10.12a	nd	nd
9	10.50a	12.62a	nd	nd

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MANAGEMENT OF PRE AND POSTHARVEST DISEASES IN BULB ONIONS THROUGH *TRICHODERMA HARZIANUM RIFAI* UTILIZATION

Nelson C. Santiago[1], Benny P. Roderos[2] and Frances M. Gallema[3]

ABSTRACT

Rhizoctonia solani, Fusarium sp., *Sclerotium rolfsii, Aspergillus sp*. and *Penicillium sp*. are the soil-borne and seed-borne fungal pathogens infecting onions in the Philippines. These pathogens are commonly controlled using fungicides, but lose its effectiveness once misused and when pathogens gained resistance to the compound. In addition, fungicides pose hazards to human health and the environment. A potential alternative to fungicide is the use of *Trichoderma spp.* as biocontrol agents. *Trichoderma spp.* are known for their antagonistic effects against several fungal pathogens. This project aimed to establish a biological control method using *T. harzianum* for the management of soil-borne pathogens infecting onion and extending the storage life.

The influence of pre harvest application of formulated *T. harzianum* on bulb rot diseases and on the shelf life of onion cv. Super Pinoy was determined through field trials conducted from November 2013 to March 2014 in Bunol, Guimba, Nueva Ecija, and through storage study conducted from April 2014 to October 2014 at the Philippine Center for Postharvest Development and Mechanization (PHilMech), respectively.

Results revealed that application of *T. harzianum* resulted in lower disease incidence and severity as compared with no application similar to that of farmers' practice. Significant differences were observed on disease incidence and severity at 60 and 80 days after transplanting (DAT) between *T. harzianum* treated plots and farmers' practice. Likewise, yield and net income from plants treated with *T. harzianum* was higher compared to those using farmers' practice.

In storage, samples from the farmers' practice showed higher rotting percentage compared with the *T. harzianum* treated samples throughout the duration of the study.

Keywords: Onion, Pre and Postharvest Diseases, *Trichoderma harzianum*

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INTRODUCTION

Onion is one of the high value crops in the country. It has long been valued for its uses in agriculture and medicine. It generally comes in three varieties namely Red Creole, Yellow Granex and multiplier onion (Shallot). The Red varieties and Shallots (Tanduyong) are the most preferred varieties because it can be stored for a longer period. Other varieties can only be stored for a short period of time specifically the Yellow Granex.

A major problem with onion production is the damaging effect of fungi and bacteria, resulting in yield losses and shortening of shelf life of the bulb during storage. *S. rolfsii, Fusarium spp*., *R.solani*, *Phoma terrestris* and *Sclerotium cepivorum* are the principal soil-borne pathogens infecting onion crops in the Philippines. *Fusarium oxysporum*, *R. solani* and *S. rolfsii* cause bulb rot, which is the most important production and storage disease in onion. Bulb rot-causing pathogens attack the roots and lower parts of the bulb scales. Plants infected at seedling stage may be killed or severely stunted showing symptoms of nutritional deficiencies or drought stress. Infected plants produce unmarketable bulbs that are either shrivelled or undersized. Soil containing spores from the fungus or bacterium get washed or blown into the neck or base of the crop during the growing phase of the onion and cause disease when conditions are suitable during storage.

In order to minimize pre and postharvest bulb rot diseases of onion, an alternative strategy need to be developed. The use microbial product as biological control agent (BCA) against pathogens in onion offers alternative techniques which are environmentally safe. *Trichoderma* species are known for their antagonistic effects against several fungal pathogens.

Trichoderma is probably the most widely investigated fungal genus for biological control applications, as the species are easy to isolate and culture and can rapidly colonise a number of inexpensive substrates.

Trichoderma species are rarely pathogenic to higher plants and a number of *Trichoderma* isolates have been successfully used against a range of aerial and soil-borne plant pathogens (Whipps, 1997; Harman and Lumsden, 1990).

METHODOLOGY

Study 1. Efficacy of T. harzianum on bulb rots diseases development of onion

This study described the on-farm bulb rotting disease development through time between farmers' practice and *T. harzianum* treated onions. Trial was conducted in Brgy. Bunol, Guimba,Nueva Ecija. The treatments used were as follows:

T1 - Farmers' Practice: Onions weremanaged according to farmers' recommended cultural and management practices from transplanting to harvesting.

T2 - *Trichoderma* Treated: One kilogram per plot (30 m2) of the formulated *T. hazianum* was applied on the soil surface by broadcasting immediately after transplanting, 20 days after transplanting (DAT), 40 DAT, 60 DAT and 80 DAT.

Seedling Production

A 200 square meter seedbed was prepared for 800 g seeds for Red creole that produced enough transplants for 1,000 m^2 area. The area was prepared by thorough plowing and harrowing. The soil was levelled and pulverized to facilitate formation of beds (10 m x 0.70 m). Shallow furrows about 1 cm deep was made horizontally across the seedbed at 2-5 cm furrows. Seeds were distributed thinly and evenly in beds then covered lightly with the soil with rice hull ash and covered with rice straw for seven days. After a week, rice straw was removed to expose the seedlings in sunlight. Adequate soil moisture was maintained by irrigating the area every three to five days.

Land Preparation

Land preparation was carried out a month prior to onion transplanting. The land was plowed twice and harrowed thrice with a tractor-drawn implement. A total of 800m^2 lot was used in the study. The area was divided into two blocks to represent two treatments and nine plots measuring 6m x 5m. A crop cut of 1m x 1m from each plots were mark to represent nine replications. A two-meter distance between blocks and 0.5 meter between plots were allotted.

Transplanting

Onion seedlings were transplanted six weeks after sowing at a distance of 6 to 8 cm between transplants. Air plots were done for proper spacing of seedlings and to facilitate transplanting. Proper care and management was done in the seedlings to prevent damage from the basal portion of the plant. The field was irrigated prior to transplanting. Border plants were also planted around the experimental area to serve as barrier.

Crop Management

Both treatments were managed according to farmers' practice where the recommended protocols for weed and insect management were strictly followed.

Fertilizer application. Basal application was carried out 14 days after transplanting with the farmer-cooperator, application rate of two bags of Urea (46-0-0) and four bags of complete fertilizer (14-14-14) per hectare or approximately 10 grams of Urea and 20 grams of complete fertilizer per square meter were used. Side dressing was done with the same amount of inorganic fertilizer 50 days after transplanting.

Pest management. Insect pest population of the crop was monitored and identified for 20 to 80 DAT. For insect pest management, chemical insecticide (Brodan) was applied weekly using the recommended rate on both treatments. Incidence of disease was monitored from 20 to 80 DAT. The farmer-cooperator immediately sprayed chemical fungicide (Dithane) after every rainfall to farmers' practice plots.

Irrigation. Irrigation was done 10 times for the whole duration of onion production. Initial irrigation was done at transplanting and the last one was five days before harvesting

Weeding. For weed control management, the farmer-cooperator used Goal herbicides at 14 days after transplanting. Spot weeding was done two to three times depending on the growth of the weeds.

Study 2. Assessment on the Progress of Bulb Rot and Subsequent Losses in Storage

At physiological maturity, onion bulbs were harvested from a crop cut in each plot for the assessment on the progress of bulb rot and subsequent losses in storage. Onion bulbs were allowed to cure for a week in a ventilated area. After curing, onion bulbs were placed in Red mesh bags with a capacity of 20 kg. Onion samples were kept in the same room at PhilMech under the ambient temperature. Daily ambient storage temperature and relative humidity were recorded using digital Thermo-hygrometer. Sufficient air circulation was provided in storage the area to prevent heating build up from the bags.

Data Gathered for Study 1

Disease incidence (% DI). Disease incidence was determined by counting the number of both healthy and diseased onion plants within each square meter and the incidence obtained by using the formula below:

$$\%\text{Incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants within a square meter area}} \times 100$$

The disease incidence in the marked area was furthered assessed for disease severity (% DS).

Disease severity (% DS). The disease severit was scored following the symptoms on a 1 to 5 severity scale and determined by using the severity index formula (Devi and Marimuthu, 2011). Diseased plants were assessed by estimating the onion plant areas with affected or with symptoms to the rating scale (0 – no infection, 1 - <10%, 3 - 11-25%, 5 - 25-50%, 7 – 51-75% and 9 - > 75%).

$$\%Severity = \frac{\text{Sum of all disease rating}}{\text{Total number of rating x maximum disease rating}} \times 100$$

Yield (t/ha) of onion with varying treatments in each production areas

Percentage of Rotten Bulbs by Weight. Bulb rot was determined every month for six months. Bulbs that are rotten was segregated, weighted and computed in percentage using the formula indicated below.

$$\%\ Rotten\ bulbs = \frac{\text{Weight of sound bulbs – Weight of rotten bulbs}}{\text{Weight of sound bulbs}} \times 100$$

Statistical Analysis. All data obtained from the study was analyzed using the T-test.

RESULTS AND DISCUSSION

Study 1. Efficacy of T. harzianum on bulb rot diseases development on bulb onions

Onion seedlings recovered equally after transplanting and no obvious effect of early damping off or seedling rots on initial plant populations during the trial. Incidence and severity of pre-harvest diseases were noted and observed from 20 DAT until 80 DAT. Experimental results indicated that there were lesser disease incidence (Figure 1) and lower disease severity (Figure 2) observed in *T. harzianum* treated plots as compared to the farmers' practice.

The t-test performed on the results of the mean values of the disease incidence revealed that there was a significant difference between the two treatments for incidence at the latter part of the trial.

At 20 DAT, 2.45% and 2.41% disease incidence were noted for the farmers' practice and *T. harzianum* treated plots, respectively. The *T. harzianum* treated plots have lower disease incidence at 40 DAT with 4.11% as compared to the farmers' practice at 5.22%. However, t-test performed on the results of the mean values of the disease incidence and severity revealed that there was no significant difference between the two treatments during the 20 and 40 DAT periods (Figure 1 and 2).

On the other hand, significant difference were observed at 60 and 80 DAT with *T. harzianum* treated plots (6.65% and 8.19%) and farmers' practice (10.43% and 12.49%) (Figure 1) and with a percentage disease severity 0.90% and 2.90% for with *T. harzianum* and 7.64% and 8.22% for farmers practice (Figure 2.). Plots with *T. harzianum* consistently had lower disease incidence and severity possibly due to its high population recovery in the soil. These results are in agreement with Rapusas et al., (2009) who reported that percent disease incidence and severity of onion such as damping-off, anthracnose and basal plate rot was lesser in vesicular arbuscular mycorrhiza (VAM) + *Trichoderma* sp. (PhilRice isolate) treated plots at 3.4% and 7.6%, respectively, as compared to the other treatments. Moreover, highest percentage incidence and severity was observed on the farmers' practice plots at 72% and 32%, respectively. Similarly, Mclean (2001), found out that at low to moderate disease incidence of white rot pathogen, *Trichoderma* sp. (C-52) can reduce disease incidence and severity in onion.

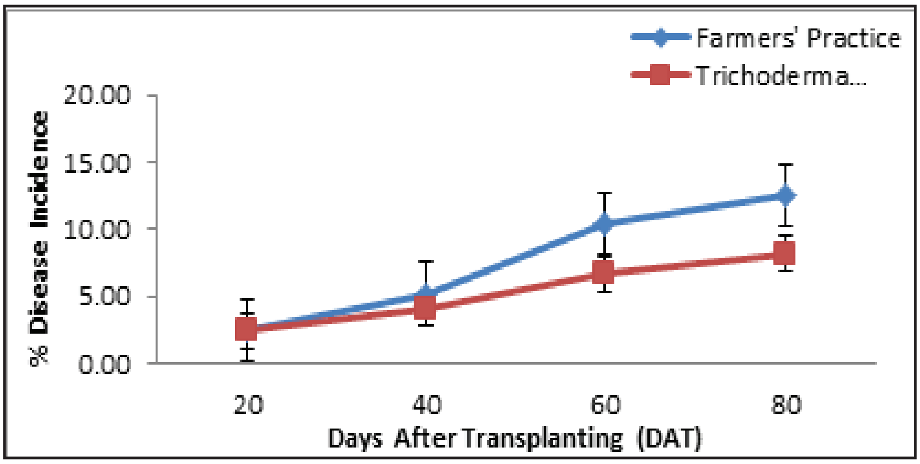

Figure 1. Disease incidence of onion bulb rots cv. Super Pinoy in Brgy. Bunol, Guimba, Nueva Ecija. Dry Season, 2014

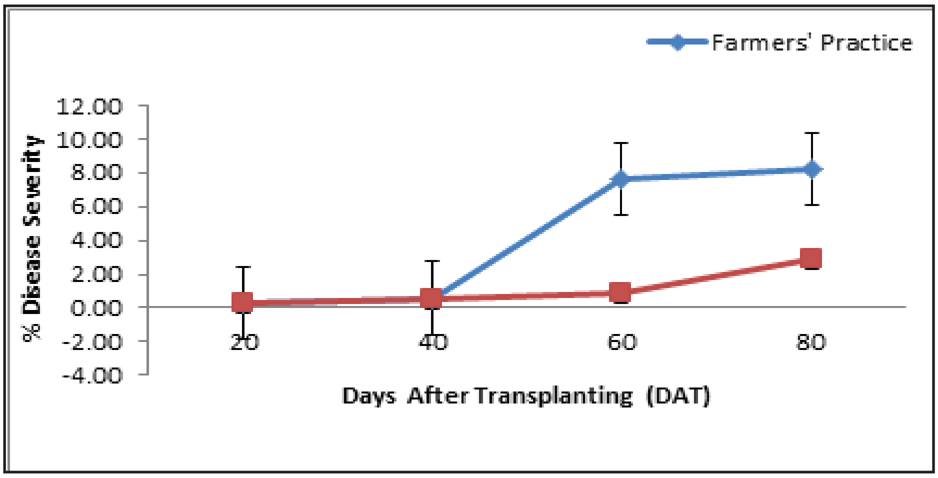

Figure 2. Disease severity of onion bulb rots cv. Super Pinoy in Brgy. Bunol, Guimba, Nueva Ecija. Dry Season, 2014

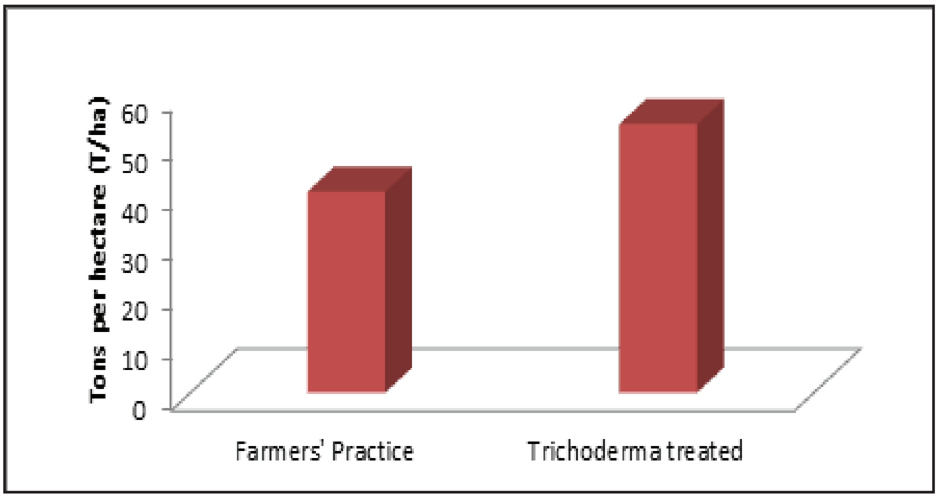

Figure 3. Yield of onion cv. Super Pinoy in Brgy. Bunol, Guimba, Nueva Ecija. Dry Season, 2014

Yield for Red creole cv. Super Pinoy obtained from *T. harzianum* treated plots was significantly higher at 53.8 t/ha compared to the farmers' practice plots at 40.3 t/ha (Figure 3). Likewise, the computed net income derived from *T. harzianum* treated plots was higher at Php 826,685 per hectare as compared to farmers' practice with Php 605,685 (Table 1). This results validated the data obtained by Rapusas et, al (2009) that the yield obtained from the VAM + *Trichoderma* sp. (PhilRice isolate) treated Red Creole onion plots has a yield advantage of 1 ton/ha with net returns increased by 35% compared with farmer's practice. Altamore et. al (1999), also reported that promotion of growth and yield by *Trichoderma sp.* maybe a result of increased root area, allowing the roots to explore larger volumes of soil to access nutrients.

The potential of *T. harzianum* as biological control agent on bulb rotting fungi was evident in this study for Red Creole cv Super Pinoy as reduction in disease incidence, disease severity and higher yield were observed consistently. This further confirmed the results of previous work and the general reproducibility of the biological control activity of *Trichoderma sp.* against bulb rotting fungi (Clarkson et al., 2004).

Shelf Life Under Ambient Condition (from study 1)

Figure 4 presents the percent bulb rot of samples subjected to production treatments and stored for six months. In general, samples from the farmers' practice exhibited higher rotting percentage compared to the *T. harzianum* treated samples throughout the duration of the study. The *T. harzianum* treated onion samples had lower percentage bulb rot at 28% compared to the farmers' practice at 43% after 6 months of storage.

The t-test performed on the results of the mean values of the bulb rot revealed that there was a significant difference ($P<0.05$) between the two treatments at 150 and 180 days of storage.

T. harzianum treatment apparently did not control bulb rot but it reduced the occurrence of the disease. The result of this study was better compared to the findings of Rapusas et al., (2009) who reported that 34% and 44% of rotten onion bulbs was observed on treatments dusted with *Trichoderma sp*. (CRSP isolate) and without treatments, respectively, while 53% was observed on the onion bulb samples dusted with fungicide after five months of storage.

Table 1. Net income derived from onion cv. Super Pinoy production in Bunol, Guimba, Nueva Ecija. Dry Season, 2014

TREATMENT	Yield (ton/ha)	Gross Income (P@P18.00/kg)	Prod cost (P)	Net Income (P)
Trichoderma treated	53.8	948,400	121,715	826,685
Farmers' Practice	40.3	725,400	119,715	605,685

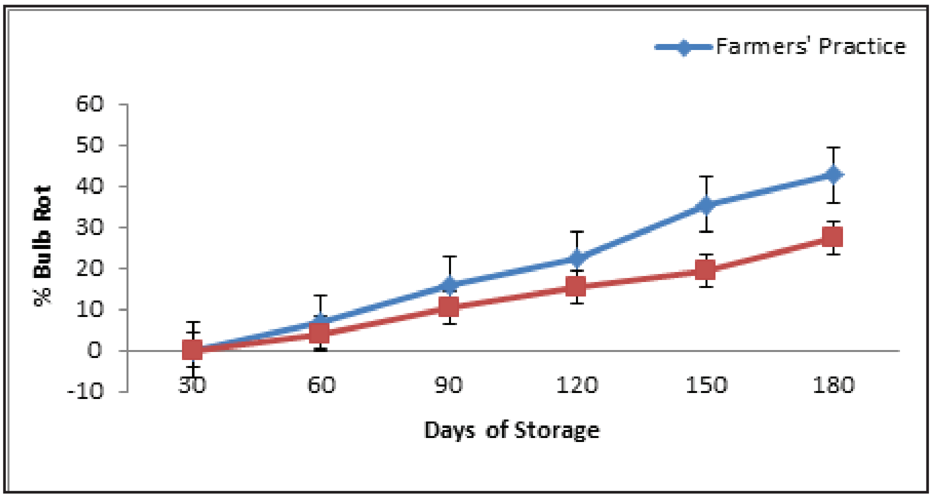

Figure 4. Bulb rotting losses in stored onion throughout the storage period, cv. Super Pinoy.

In addition, Jallorina et al. (2012), stated that bulb-rot during storage for six months at ambient temperature and at 300C with 0.03-0.04 m/s air velocity showed bulb rot intensities of 57% and 55%, respectively.

CONCLUSION AND RECOMMENDATIONS

The project proved that the formulated *T. hazianum* is one possible alternative for management options against soil-borne pathogens infecting onion soil-borne pathogens infecting onion which causes bulb rot.

To further evaluate the results, a more detailed mode of action studies of *T. hazianum* in high disease pressure field is recommended. Establish other methods of application of the *T. hazianum* such as adding of surfactant to this biocontrol agent to increase adhesiveness/retentiveness into the soil, leaf and bulb surfaces. Likewise, an integrated disease management program trials can be conducted to determine the effectiveness of a combination of treatments on disease incidence and severity.

Awareness on the biological control agent is very limited. Hence, farmers still resort to the use of chemical fungicides to address disease problems in their areas. Thus, it is important to create more awareness in the use and advantages of using *T. hazianum* as biological control agent.

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ASSESSMENT OF THE POSTHARVEST HANDLING SYSTEMS OF FRESH SWEET POTATO

Edgar D. Flores[1], Renita SM. Dela Cruz[2], Ma. Cecilia R. Antolin[3]

ABSTRACT

The study described and analyzed the postharvest handling systems of fresh sweet potato using primary data obtained from 350 sweet potato farmer-respondents. Actual loss assessments in major routes of sweet potato from farm to retail market were conducted. Major postharvest problems identified for sweet potato were noted with their potential technological interventions. Staggered harvesting was common in areas with smaller harvest and local market destinations (Albay and N. Samar) as compared to one-time or single harvesting in Tarlac and Bataan from which produce are destined to commercial markets. Postharvest system's loss in sweet potato ranged from 31.21 to 32.97% which was largely contributed by the inefficiency of existing harvesting methods. Harvesting loss due to uncollected and mechanically damaged roots ranged from 15.96 to 17.94% of marketable harvest. In terms of quality, sweet potato marketed from farm to the retail level was reduced from the scale of 4.89 to 3.85 in Bataan-Divisoria route and from 4.93 to 4.41 in Tarlac-Tanauan City route (5 as the highest and 1 as the lowest). Potential technology intervention to address observed problems in harvesting sweet potato roots was the introduction of mechanical root crop harvester to reduce losses and labor requirements. Available imported harvester which can simultaneously remove the vines and dig sweet potato roots can be localized to reduce its cost and adapt to local areas. The mechanical harvester for white potato can also be adapted and modified for sweet potato. Indigenous harvesters developed by farmers in Tarlac using mould board plows attached to tractors can also be further improved.

Keywords: Sweet potato, postharvest systems, losses, qualitative, quantitative, intervention

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INTRODUCTION

Sweet potato (*Ipomoea batatas l.*) is the seventh most important food crop in the world in which majority of world's production share is coming from China, followed by Nigeria and Uganda. Among the 82 developing countries, 40 countries consider sweet potato as the fifth most important food crop produced annually (Elameen et al., 2008, FAO 2014). On the ASEAN block, Philippines also entered the list with production share of 0.50% making the country as top 19 sweet potato producing country in the world (FAOSTAT, 2015).

Sweet potato is usually produced in sub-tropical and tropical countries by small farmers with limited land, labor, and capital (Claessens et al., 2009). It is usually planted in less productive soils with restricted supply of water. Despite these conditions, sweet potato contains more calories than any other major food crops like rice or wheat (Horton, 1988). The roots and leaves of sweet potato are both used for human and animal consumption as well as raw material for production of starch, organic acids, and alcoholic beverages (Woolfe, 1992). Fresh roots are also a good source of vitamins and minerals but less in protein and fats. Because of its nutritional value, sweet potato is becoming more important both in research and industrial applications (Bovell-Benjamin, 2007).

In the Philippines, sweet potato is one of the most important crops after rice and maize, in many areas. The crop is included as a priority among the root crops in the country. Currently, the Philippine government through the Department of Agriculture (DA) is advocating the production and consumption of sweet potato. It is believed that sweet potato plays a major role in realizing the country's goal towards food self-sufficiency. Sweet potatoes like any other crops are exposed to postharvest losses during harvesting, transportation from farm to market. These losses are mainly due to physical damage, weight reduction, sprouting, pests and diseases (Woolfe, 1992; Mtunda et al., 2001; Rees et al., 2001) and improper postharvest handling systems that lead to both qualitative and quantitative losses.

Freshly harvested sweet potato roots have high respiratory rate that releases both heat and moisture that would eventually soften its texture. Sweet potato is considered highly "perishable" commodity because once it is detached from the plant it can no longer be stored for a long period of time (Wagner et al., 1983; Mtunda et al., 2001; Rees et al., 2001).

Quantitative and qualitative loss of a product during the postharvest chain includes the change in the availability, edibility and freshness of the product that prevents its consumption (Troger et al., 2007). Both quantitative and qualitative losses of extremely variable magnitude occur during postharvest stages, from producers until its final delivery to the consumers. Furthermore, improper postharvest handling practices result in losses due to spoilage and deterioration in appearance, taste and nutritional value of the product before reaching the market. Such improper practices risk the marketability of the product, lower the prices and shorten the storage period of the products (Turan, 2008 as cited by Buyukbay et al., 2011).

The deterioration of quality and reduction in quantity of marketable produce would be transformed to economic loss and revenue on the part of the producers, lesser availability of marketable commodity on the consumer's side and lead to a higher price. Likewise, all the resources used in the production of crops will only be wasted (Kumar et al., 2006; Prusky 2011). It was reported that losses during harvest, preparation for market, transportation and marketing of fruits and vegetables vary from 15 to 50% (Ozcan, 2007; Nuevo and Apaga, 2010) and could be up to 65% due to either loss in fresh weight or root rot during storage (Kone,1 991). Postharvest losses have already been recognized as one of the reasons that reduce food supply to the increasing population. Though the focus of the government is more on increasing production to provide the need of the growing population, postharvest loss reduction is another area that leads to increase food availability.

Hence, this study was designed to assess the postharvest handling systems of sweet potato as basis for providing appropriate loss reduction technology to improve the handling system of fresh sweet potato.

Specifically, the study sought to determine and describe the postharvest handling systems of fresh sweet potato; assess the nature and magnitude of postharvest losses from farm to retail market level; determine the potential technology intervention that can reduce the magnitude of loss in the most problematic sweet potato postharvest operations; and determine the potential effects of the proposed intervention in improving the postharvest operation of fresh sweet potato.

METHODOLOGY

Study Sites and Data Collection

Study areas for identifying and describing the postharvest handling systems of fresh sweet potato were in Albay, Northern Samar, Bataan and Tarlac.

Data and information were collected through key informant interviews (KII), survey and focus group discussions (FGD). Interviews were done with selected respondents who are very much familiar, knowledgeable and immersed in the production and postharvest activities of sweet potato such as the farmer-leaders, key officials of Department of Agriculture (DA), Local Government Units (LGUs) and traders (i.e. wholesaler, retailers, viajeros, agents/middlemen).

Surveys and FGDs were conducted in top producing municipalities with each three top producing barangays. A minimum of 10 sweet potato farmers or 10% of the total farmers in each top producing barangay were gathered and interviewed using structured questionnaires.

Loss assessment studies were done in the provinces of Tarlac and Bataan where majority of crop is grown for commercial market. The assessment of postharvest losses (both qualitative and quantitative) began from farm to retail level, following three to four major routes, treating the routes as replicate for a given postharvest handling operation. The actual operations, practices and facilities used in handling the commodity were observed and noted. Ambient conditions such as temperature, relative humidity (RH), where the crops are exposed were also monitored.

The distance travelled, nature of the road network, the time required to harvest and transport the commodity from farm to market, losses due to mechanical, physical and physiological damage and weight loss due to moisture reduction were determined. The commodity handlers such as farmers, traders, wholesalers, and retailers were also interviewed to determine related information such as price and market quality standards.

Methods of Analysis

Qualitative losses. Visual quality rating (VQR) and quality profile (QP) were used in determining the quality loss.The evaluation of the losses in quality was performed at the determined points of the commodity flow. Five to 10% of the stocks were subjected to VQR. Samples in each container were labelled and rated by trained staff in every operation from farm to the final destination.

The VQR scales and description for sweet potato are summarized in Table 1. The average rating for the samples monitored is calculated using equation 1. The rating scale and descriptions were based on the quality standards set by BAFPS and validated with traders and retailers.

The degree, extent or description of the quality defects or damage, (e.g. bruises, compressions, rotting, etc.) were evaluated both with the pre-harvest and postharvest defects presented in Table 2.

$$VQR = \frac{(Wc)(Rc)+\ldots(Wc)(Rc)}{\text{(Total weight of the samples)}} \qquad (1)$$

Where: Wc = weight of the commodity per rating scale;
Rc = rating of the commodity

Table 1. Rating scale used in VQR of samples for sweet potato

Category	Description
5	0 to < 5 % of surface have skinning damage, < 35 % superficial pest damage, whole, fresh, firm, minimal cut damage,
4	5 to < 50 % of surface have skinning damage, with moderate cut damage,
3	> 50% of surface have skinning damage, > 35 % superficial pest damage, moderate bruising, with breakage
2	> 30% superficial damage; minimum level of edibility, shriveling, concealed weevil damage, < 20 % soft rot, > 1 inch sprouting
1	Non-marketable; non edible, skin browning, >20 % soft rot

Table 2. Quality traits used in describing QP of sweet potato

	Postharvest		
Pre-harvest defects	Mechanical damage	Pathological defects	Physiological defects
Wireworm damage	Bruises	Soft rot	Shrivelling
Weevil damage	Cut	Skin browning	Sprouting
Fertilizer damage	Skinning		

Quantitative losses. The measurements of quantitative losses are determined from weight differences of the initial and final weight of the whole stock produce. The following equations were used in the computation of loss at each handling point:

Harvesting loss (HL) – This is the harvested sweet potato roots that were damaged (cut) during harvesting and those left in the farm or under the soil uncollected during harvesting activity. HL can be computed using equation 2.

$$HL(\%) = \frac{(UCMh+CMhD)}{(UCMh+CMhD+CMh)} \times 100 \qquad (2)$$

Where UCMh is the uncollected marketable commodity during harvesting; CMh is the collected marketable commodity during harvesting and CMhD is the collected but damaged marketable commodity during harvesting.

Sorting loss (SL) – This refers to the marketable sweet potato roots that were accidentally sorted as non-marketable reject during sorting activity and calculated using equation 3.

$$SL(\%) = \frac{ASRs}{(SMCs+ASRs)} \times 100 \qquad (3)$$

Where ASRs is the accidentally-sorted commodity as reject during sorting; and SMCs is the sorted marketable commodity during sorting.

Non-marketable rejects (NR) – These refers to edible and non-edible rejects. Edible rejects are those sweet potato roots that are still edible but cannot be sold due to slight damage and low physical quality caused by pre-harvest-related defects (“gapang”) which are not acceptable based market standard. Non-edible rejects are non-edible sweet potato roots totally damaged by weevil (“ulalo” or “balitungeg”) and pre-harvest-related defects that cannot be accepted in the market standard. It is calculated using equation 4.

$$NR(\%) = \frac{NRs}{(SMCs+NRs)} \times 100 \qquad (4)$$

Where NRs is the sorted non-marketable commodity reject during sorting; and SMCs is the sorted marketable commodity during sorting.

Weight loss (WL) – loss that contributes to the reduction of weight or volume during the operations from harvesting up to the point of sale to the consumer and calculated using equation 5

$$WL\ (\%) = \frac{(IW-FW)}{IW} \times 100 \qquad (5)$$

Where WL is the weight loss in percent; initial weight (IW) and final weight (FW) are the sample weights before and after a period of observation, respectively. Period may refer to time or operation.

Data and information collected from the key informant interviews, surveys and FGDs were analyzed with the aid of Statistical Package for Social Sciences (SPSS). Qualitative and quantitative losses were analyzed and presented using mean values.

RESULTS AND DISCUSSION

Postharvest Handling Systems of Fresh Sweet Potato

Harvesting. Harvesting of sweet potato involves the cutting of the vines and then the digging of roots from the soil. Harvesting generally requires 30 to 50 laborers per hectare per day. Harvesting can be done in two ways: staggered and single harvesting. Single harvesting involves the harvesting of sweet potato farm in one batch where the vines are totally removed and the whole land is ploughed or dug. In staggered harvesting only marketable size roots are collected on the first three harvesting before the vines are finally removed and plowed at the fourth harvest; this type is usually done on areas where home consumption of sweet potato is common.

Table 3 shows the percentage of farmers practicing the two methods of harvesting. Albay and Northern Samar sweet potato farmers mainly use staggered harvesting at 90 and 95.45%, respectively, with small percentage practicing for single harvesting. Moreover, 50% of the farmers from these areas prioritize and retain their produce for home consumption. On the other hand, Bataan and Tarlac practice single harvesting

Table 3. Type of harvesting by sweet potato farmers, percent reporting, 2015

Type of harvesting provinces	**Albay,**	**Bataan,**	**Tarlac,**	**N. Samar,**	**All**
	n=110	**n=105**	**n=60**	**n=84**	**n=350**
Staggered	90.00	-	-	95.45	46.36
Single	10.00	100.00	100.00	4.55	53.64

Vine clearing. Vine clearing is the removal of sweet potato vines from the plants prior to soil digging (Figure 1). The labor requirement for vine clearing is estimated to be 10.5 person-days/ha. About 18.0 tons of fresh SP vines can be recovered per hectare.

Soil digging. Soil digging is exposing the roots from the soil through digging (Figure 2). This can be done by using any sharp or hard rod or stick; or by passing once or twice with single plow drawn by animal or two plows drawn by tractor (commonly done in single-type harvesting).

Field gathering. Feld gathering is the collection of exposed sweet potato roots and piling them at central location (Figure 3). Spacing of piles depends on the number of assigned laborers.

Sorting and grading. Sorting is the removal of rejects from the harvested roots while grading is classifying the collected roots according to the present market grade. This operation is done on the farm by laborers hired by the trader (Figure 4). Sweet potatoes are graded according to size through its diameter. Every market or provincial market has its own version of grading system.

Figure 1. Removal of sweet potato vines

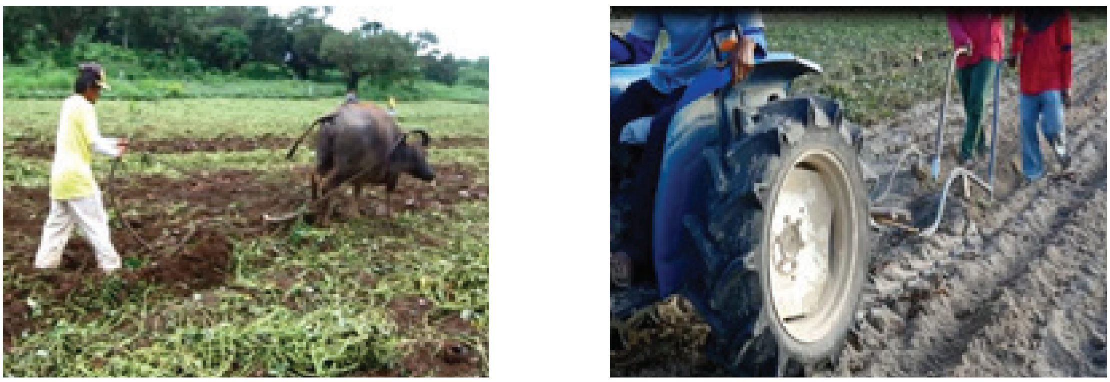

Figure 2. Soil digging of SP roots, with tractor (right) and with carabao (left)

In Albay ("primera", "segunda", "tersera" and "quarta"), Moncada and Paniqui (good, medium, small and "palito"), Concepcion-Tarlac ("primera", "segunda", "tertia" and "imut-imut"); and Bataan (good, medium, small and kalatong).The Philippines has a size classification standard for sweet potato based from PNS-BAFPS.

Comparing the sizes of grade set by the PNS and the farmer/trader's grading system showed that 1st tier (primera or good) are those roots classified as large (7.1 to 9cm dia) and extra-large (7 to 10cm dia) , 2nd tier (segunda or medium) are those roots classified as medium (5.1 to 7cm dia) , third tier (tersera or small) are those roots classified as small (3 to 5cm dia) and the fourth tier (imut-imut or kalatong) are those classified as very small by the PNS less than 3 cm diameter.

I***n-field Bagging.*** In farm, sweet potatoes are bagged or packed in sack before hauling (Figure 5). The weight of a bag of sweet potato varies per study sites. In Albay and Northern Samar, the weight of bag range from 50 kg to 75 kg. In Bataan and Tarlac, the usual weight of bag is 100 kg; with some farmers opting to have 50 kg per sack. Bagging is commonly shouldered by the trader.

In-field hauling/Transportation. Sweet potato is transported from farm to more accessible roads and to the intended market location. It usually involves land travel using trucks and jeeps (Figure 6). Farms that are not accessible to four-wheel transport, used carabao-drawn sled, single motorcycle, hand tractor, four wheel tractor drawn trailer and motorized bancas.

Figure 3. Field gathering of digged SP roots

Figure 4. Sorting of SP roots

Figure 5. In-field weighing and bagging of SP roots

Washing. Washing of sweet potato is done at the wholesale level (Figure 7). It is usually done within the vicinity of the warehouse. Washing is done twice. The first washing removes the soil from the surface by soaking and with the aid of both feet (with or without rubber boots) loosens the soil from roots. Water replacement is done after three sacks or when around 300 kg of sweet potato roots have been washed.

The second washing is done on concrete tanks (usually on warehouses that is distant from the intended market) or wooden slats. The roots are brushed manually to remove remaining dirt. Warehouses are either within the market such as in Tanuan Public Market and on case-to-case basis in Divisoria Public market.

Packaging. This operation is done at the wholesale level. Washed and graded sweet potato roots are usually packed in 10-kg capacity polyethylene (PET) bag before trading (Figure 8).

Marketing. Figure 9 illustrates the typical market flow and players involved in sweet potato market. Market flow number one is the most common and participated by farmer, "viajero", wholesaler and retailer.

This is very common when there is high volume of produce, a fast market phase and high volume of demand. Typical example of this flow is the Tarlac to Divisoria or Tarlac to Tanauan route.

Figure 6. In-field hauling of sweet potato

Figure 7. Washing of SP roots at the wholesale level

Figure 8. Packaging of SP roots using PET bag at the whole sale level

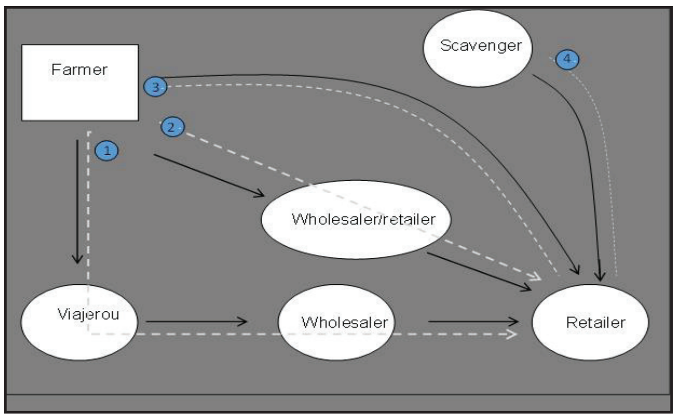

Figure 9. Typical flow and players involved in fresh sweet potato market

Market flow number two happens when the farmer or the wholesaler can afford to have trucking service. This flow was also observed in Tarlac where farmer can be wholesaler and at the same time retailer in Central Market. Market flow number three is where farmer directly transact to a retailer. This type is more common on markets of considerably lower volume that the roles of viajerou and wholesaler are not needed. Typical example of this was observed in Albay and N. Samar market.

Market flow number four is where scavengers or gleaners directly transact with retailer. This usually happens in provinces where there are wide farms of sweet potato like in the areas of Bataan and Tarlac. Gleaners collect left-over marketable produce for their own needs or for sale to retailers or on house-to-house basis.

Figure 10 shows the commodity flow/handling routes of Albay, Bataan, Tarlac and Northern Samar. Sweet potato roots from farm in Albay are commonly sold within the province (95 %) and in Naga City market (5%). Movement of sweet potato from farm to market is done through traders (60%) or by the farmers themselves (40%). Farms that are not directly accessible to four-wheel vehicles are also very common. Delivery to Naga is usually done through passenger bus.

Sweet potatoes from farm in Bataan are commonly sold to Metro Manila markets (94 %): Divisoria, Pasig, Balintawak, etc. Only 6% are sold to neighbouring towns within the province. Movement of produce from farm to market is done through traders (90%) or by the farmers themselves (10%). Delivery usually involves hired trucks that can haul 38 to 75 sacks (90 kg/sack).

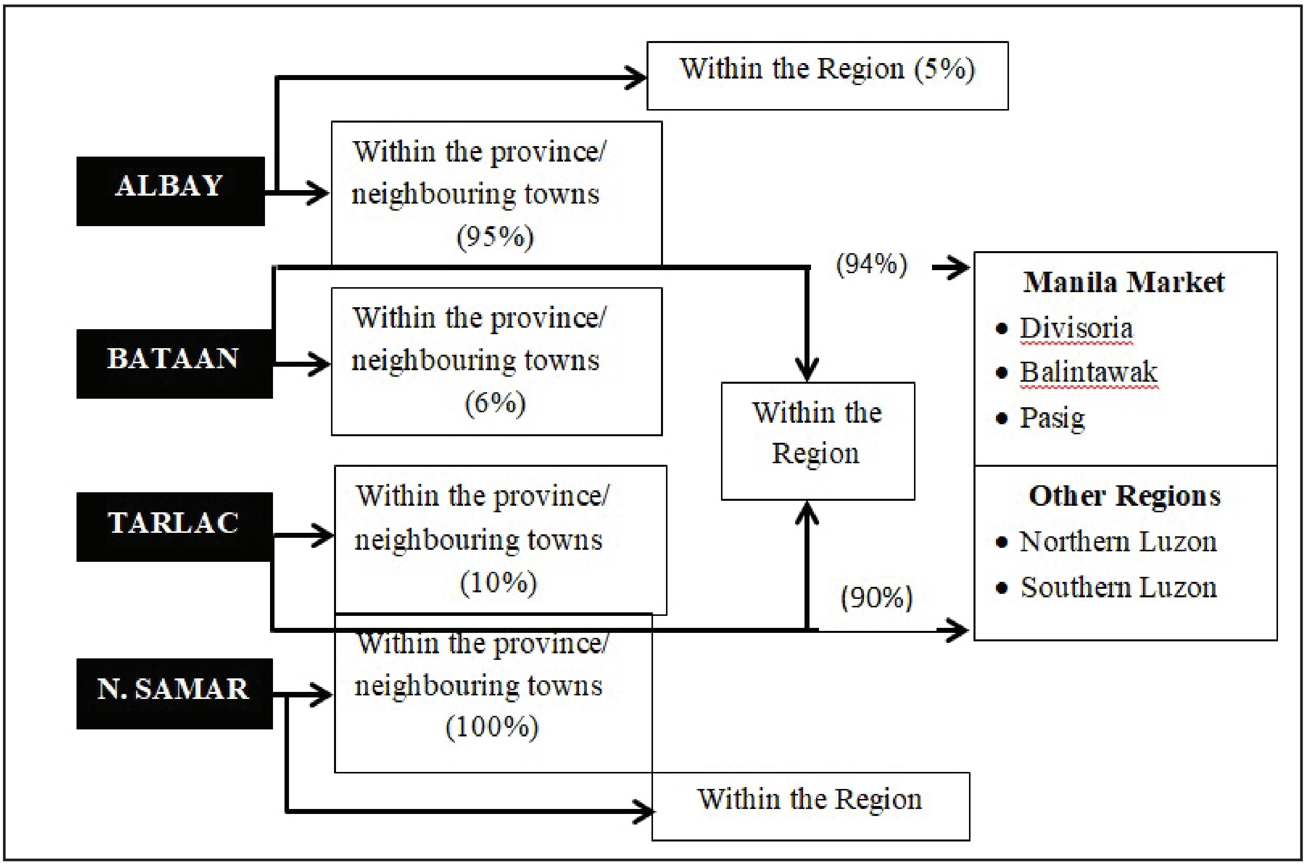

Figure 10. Commodity flow/handling route of sweet potato in Albay, Bataan, Tarlac and Northern Samar

Table 4. Average quantitative loss of sweet potato samples (% of total weight)

		Postharvest loss (%)			
Major Points	**Activities**	**Tarlac to Divisoria**	**Bataan to Tanauan**	**Ave(%)**	**Sources of Losses**
Farmer Level	Harvesting	17.94	15.96	16.95	Unharvested, cut
	In-field hauling	0.48	1.16	0.82	Physiological weight loss
Agent/Trader	Hauling, Transporting				Physiological weight loss
Wholesale Level	Cleaning, Re-bagging	5.97	1.89	3.93	Weight loss of peels, physiological weight loss
Retail Level	Marketing (1-7 DAH)	8.58	12.20	10.39	Physiological weight loss, rotten
TOTAL		**32.97**	**31.21**	**32.0**	

Sweet potatoes from the farm in Tarlac are commonly sold to Metro Manila markets (90 %): Divisoria, Pasig, Balintawak and Batangas (Tanauan market). The remaining 10% are sold to neighbouring towns. Movement of produce from farm to market is largely done through traders (70%) or by the farmers themselves (30%).

Delivery usually involves hired trucks or owned by traders that can haul 38 to 75 sacks of 90 kg. SP roots from farm in Northern Samar are consumed within the province. Majority of sweet potato produce is bound for home consumption. Small volumes (10 %) are sold to neighbouring towns. Movement of produce from farm to market is largely done through traders (90%) or by the farmers themselves (10%).

Postharvest Losses of Sweet potato

Quantitative losses. For loss assessment, two major market chains of sweet potato were studied. These were the routes from Bataan to Divisoria and Tarlac to Tanuan Public Market. Similar specific stages from harvesting to retail level for the two cases were documented. Table 4 shows the observed losses of marketed samples from Bataan and Tarlac on the seventh day in retailer level, for Bataan-Divisoria route and Tarlac-Tanauan City route, respectively.

Results revealed that the total postharvest system's loss ranged from 31.21 to 32.97% (average of 32.09%) from the farm to retail, seven days after harvest (7 DAH). This system's loss was mainly contributed by weight loss (moisture loss) from farm to the retail level. Across the routes evaluated, highest postharvest loss was observed at the retail level at the farmer-level during harvesting.

The observed total harvesting loss for Bataan and Tarlac were 15.96 and 17.94%, respectively. Harvesting loss accounts for the roots that were unharvested or uncollected and mechanically damaged (cuts, breaks) during harvesting.

As depicted in Table 5, Bataan has comparatively higher uncollected roots at 14.60% as compared to Tarlac (7.19 %). The potential contributing factors to the wide gap is the difference in soil type. Bataan has a sticky clay loam type, while Tarlac has a sandy loam type of soil.

In terms of the observed mechanical damaged during harvesting (basically the roots that were damaged by plow during harvesting), Bataan has lower mechanical damage at 1.36% than Tarlac (10.75%).

Differences might be due to the variation in harvesting practices and size of harvested sweet potato roots. Sweet potatoes in Tarlac had bigger sizes than Bataan which could be due to the soil type and crop management practices. It was observed that bigger sizes of roots were easily hit by the pointed tooth of the plow especially when the implement could not cut the soil deeper than the roots of the sweet potato plants.

Qualitative losses. The quality profile of sweet potato samples for Bataan to Divisoria and Tarlac to Tanuan City route are shown in Table 6.

For Bataan to Divisoria route, the observed final VQR rating (before the whole batch was marketed) decreased from the scale of 4.89 to 3.85.

Skinning of the samples was monitored in the farm and on the wholesale level Breakage of samples was also observed at the wholesale level Bruising was reported on the farm and trader level while shriveling of the samples was monitored on the fifth to seventh days at the retail level.

During the period, two or more sprouts appeared on almost half of the samples. Pathological defects however were not observed.

For Tarlac-Tanauan route, the observed final VQR (before the whole batch was marketed) decreased from 4.93 to 4.41. Skinning and bruising of the samples was monitored in the farm and on the wholesale. Breakage on samples was also observed at the wholesale level. This could be due to the mechanical damage during transport and washing.

Pathological defects were observed on the trader and wholesale levels. Soft rot was reported on the whole sale level while weevil infestation was observed on the trader level (just after the transportation).

Table 5. Harvesting loss in Bataan and Tarlac, percent of total weight

Factors	**Bataan**	**Tarlac**
Uncollected	14.60	7.19
mechanically damaged	1.36	10.75
Total Harvesting loss	15.96	17.94

Table 6. Visual quality rating (VQR) of fresh sweet potato from farm to retail level

Major route	**Farm level**	**Trader level**	**Wholesale**	**Retailer @ 1st day**	**1st 2-4 day stay**	**1st 5-7 day stay**
Bataan - Divisoria	4.89	4.80	4.80	4.64	4.61	3.85
Tarlac – Tanauan	4.93	4.72	4.50	4.50	4.47	4.41

* Scale: Scale of 1 has the lowest quality; 5 has the highest quality

Table 7. Problems or inefficiencies of postharvest handling systems of sweet potato and their potential solutions

Problems and constraints		Potential interventions	
Existing Practices	**Problems**	**Available Technologies**	**Potential Intervention**
Vine clearing is done manually by cutting and rolling the vines to one side of the field.	Removing the vines manually is time-consuming. The labor requirement for vine clearing was estimated to be 10 to 12 person days/ha	A tractor-drawn implement was initially developed by Phil Root Crop, VSU, Leyte but no news about its commercialization	Coordination with VSU to evaluate the status of the technology
Uprooting is done by using mouldboard plows dragged by an animal or by four-wheel tractor with one or two laborers guiding the handle of the plows to hit the rows expected with tubers	Uprooting/digging of tubers using tractor-drawn mouldboard plows with two laborers holding and guiding the direction of the plows requires 5 to 6 person-days/ha. Labor requirement is doubled to 10 to 12 person-days/ha if carabao-drawn mouldboard plow is used	There are imported and costly mechanical harvester which could do a single pass both the vine clearing and digging of tubers Combine digger/ vine chopper which could do a single pass both the cutting of vines and uprooting of tubers.	Imported harvester can be localized to reduce its cost and adapt to local areas The mechanical harvester used for white potato can also be adapted to SP with modification
	Losses due to uncollected and mechanically damaged roots ranged from 15.96 to 17.94%		Indigenous harvesters developed by farmers in Tarlac using two mouldboard plows attached to tractors can be further improved.
Sweet potato vines remove before harvesting are left in and burned when dried. The vines which are normally considered waste by farmers can be nutritious source of feed for animals.	About 18.0 tons of fresh sweet potato vines can be recovered per hectare which remains largely unutilized. Burning releases gases that damage our environment	It is reported that sweet potato vines can be used as good silage for feeding cattle or carabao. The leaves have high protein content and can therefore be used as a protein source for livestock (Ishida et al 2000).	A project proposal for (a) marketability and financial assessment of converting SP vines for animal feeds (SEPRD); (b) technical and environmental assessment of converting SP vines to animal fees is done by SEPRD-PhilMech

Problems and constraints of sweet potato and their potential interventions

In Albay, majority of sweet potato farmers expressed their concerns on the unavailability of new varieties and the lowering yield as a result of declining soil fertility. In Bataan, the common problem is infestation of round worm "gapang" that damages the skin of the sweet potato roots. In Tarlac, most of the reported problems are on the presence of "kulot" which render the crop unproductive. Labor insufficiency is also a major problem and contributing factor to delayed harvesting of sweet potato which in turn exposes the roots to higher pest infestation. Albay, Bataan and Northern Samar had all express the need for financial assistance in sweet potato production. Based from the results of survey and loss assessment conducted, the problems and constraints of postharvest handling system of sweet potato with their potential interventions were drawn and presented in Table 7.

CONCLUSION AND RECOMMENDATIONS

The study assessed the postharvest handling systems of sweet potato. Quantitative and qualitative losses at major postharvest handling points were determined. Problems and constraints in postharvest handling of sweet potato were identified and potential interventions were formulated.

Staggered harvesting was common in areas with smaller harvest and local market destinations (Albay and N. Samar) as compared to one-time or single harvesting in Tarlac and Bataan from which produce are destined to commercial markets.

Postharvest loss in sweet potato ranged from 31.21 to 32.97% which are largely contributed by the inefficiency of existing harvesting methods. With this concern, the harvesting operation of sweet potato can be mechanized using an efficient mechanical root crop harvester that can eventually reduce labor requirement and losses on uncollected roots. Available imported harvester which can simultaneously remove the vines and dig sweet potato roots can be localized to reduce its cost and adapt to local areas.

The mechanical harvester for white potato can also be adapted and modified for sweet potato. Indigenous harvesters developed by farmers in Tarlac using two mouldboard plows attached to tractors can also be further improved.

Overall, the results of this project would serve as guide for other researchers and concerned institutions in identifying problem areas for action and applied research. This can also guide the policy makers to provide measure and policies for loss reduction. Furthermore, this will enhance awareness on the need to provide appropriate assistance and/or technologies for the improvement of postharvest handling system of sweet potato.

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EVALUATING THE PERFORMANCE OF THE TWO-STAGE CORN DRYING AND PROCESSING SYSTEM IN THE PHILIPPINES

Hernaiz G. Malanon[1] & Renita SM. Dela Cruz[2]

ABSTRACT

The study aimed to evaluate the technical and socioeconomic performance of the two-stage corn drying and processing system (CDPS) in selected corn-producing provinces in the country to determine whether the objectives of the technology in reducing postharvest losses, improving corn grain quality, and increasing farmers' income could be realized. This was done to provide insights and lessons on how to sustain or improve operation of the facilities or recommend measures on how to enhance the overall implementation of projects related to CDPS. The study was carried out in Pangasinan, Agusan del Sur, Isabela and South Cotabato using formal survey, observation of CDPS operations, collection and analysis of corn samples, using the available records from the operators of CDPS and key informant interview to gather the needed data.

Results of the study showed that the establishment of CDPS is relevant in addressing the problems of high postharvest losses. With the CDPS, the incidence of high aflatoxin contamination (>50 ppb) and the incidence of broken and moldy grains were significantly lower compared to the traditional practice. The use of CDPS also resulted to lower postharvest losses at 5.3% and 6.2%, during the first and second cropping season, respectively.

Farmers who sold their produce to the operators of CDPS obtained additional profit ranging from Php 1,152.00 to Php 4,117.00 per hectare. The operation of large CDPS was not financially viable at average utilization levels of 20% of its rated capacity. Similarly, the operation of village-type CDPS was not financially viable although integrating the system with corn trading operation exhibited better financial indicators compared to CDPS operating as provider of custom shelling and drying services.

Keywords: Aflatoxin, Corn on cobs, Drying, Financial viability, Postharvest losses, Shelling Two-stage drying

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INTRODUCTION

In the Philippines, corn is the most important crop after rice. It is consumed by at least 14 million Filipinos and main source of livelihood for about 600,000 farm households. It also comprised 50% of livestock feed formulation (Department of Agriculture, 2013). However, the Philippine corn subsector had been hampered by insufficient and unsteady supply linked to low productivity and profitability, high risk in corn farming due to weather, pests and price fluctuations and huge quantitative and qualitative postharvest losses. The low profitability coupled with the high risks involved in corn farming are the major reasons why some farmers intermittently shift to other crops such as banana, cassava and other high value or cash crops.

As one of the reasons restricting corn supply, postharvest losses, particularly drying constitutes the largest losses in corn, accounting for 63.23% of the total losses from harvesting to transport/marketing (Salvador et al., 2012). Harvesting loss recorded 1.05%, accounting for about 14% of the total losses from harvesting to marketing. Meanwhile, shelling contributed 7.24% of total losses. It is important to note that there was higher quantitative loss obtained for areas that used dehusker-sheller compared to areas that used dedicated shelling facility. The study also revealed that poor quality corn is associated with delayed or prolonged postharvest operations while broken grains are caused by inefficient shelling machines and processing immature corn with high moisture content.

Aside from qualitative losses, failure to handle proper postproduction operation from harvest to storage of corn grains may result to high aflatoxin contamination. Aflatoxin is a naturally occurring toxin produced by a fungus called Aspergillus flavus. Moisture and heat stress predisposes aflatoxin growth. The inability of farmers and traders to promptly dry corn to a safe level of moisture content (13-14%) was identified to be the root cause of fast deterioration due to the presence of Aspergillus flavus (Tiongson, 1986). Paz (1996) noted that farmers from South Cotabato were penalized as high as 5% for the presence of molds and up to 17% for discolored grains.

The two-stage corn drying and processing system with corn-in-cob dryer, sheller and grain dryer components, had been developed to curb high postharvest losses and poor grain quality as a result of shelling corn with high moisture content. With the lingering challenge of globalization, the government is even more hard-pressed in putting up appropriate intervention to enhance the competitiveness of the corn subsector and the livestock/poultry industries that mainly depends on corn. The establishment of two-stage corn drying and processing systems (CDPS) in strategically located areas is part of the government's effort to address these concerns. With the provision of postharvest facilities such as the two-stage CDPS, corn farmers and other stakeholders of the corn industry are saved from incurring huge postharvest losses that includes quantitative and qualitative losses characterized by high aflatoxin contamination and incidence of broken and/or moldy grains. The establishment of two-stage CDPS has also been considered as a means to secure farmers' income by mitigating effects of adverse weather as harvest-shelling-drying periods often coincide with inclement weather in major corn-producing areas. Furthermore, this will improve market efficiency, as some unnecessary profits will be eliminated from the chain, resulting to more competitive prices.

Assessment of the two-stage CDPS was found necessary to provide important feedback to program implementers, operators to improve and sustain operations, and corn farmers to enhance adoption and utilization of the facilities. Moreover, the increasing and more active involvement of the private sector in putting up these kinds of facilities also pose some concerns whether it is still justifiable for the government to intervene in this aspect, or just leave this process entirely to the private sector or through Public Private Partnership (PPP).

The study aimed to evaluate the performance of adopting the two-stage CDPS. Specifically, it aimed to: (1) evaluate the performance of the two-stage CDPS in terms of maintaining corn quality and reducing postharvest losses; (2) determine the financial benefits derived by the farmer-users and operators of the two-stage CDPS, and; (3) identify the problems/constraints encountered by the farmer- users and operators of the two-stage CDPS.

METHODOLOGY

Project Framework

The DA-Corn Program identified the high postharvest losses and poor quality of corn as among the factors limiting productivity and profitability of corn growers and industry stakeholders. To solve the identified problems, necessary infrastructures such as the two-stage CDPS were established. This is a corn processing-marketing system earlier developed by the private sector (Mindanao Grains Corporation) that procures newly harvested corn-on-cobs (CoC) directly from the corn farmers, undertake CoC drying, shelling, grain drying, storing and marketing of premium quality corn.

The performance of the two-stage CDPS was investigated in terms of the changes in corn postharvest loss reduction and corn quality improvement, the benefits derived by the farmer-adopters and the operators of the facilities; the changes in the postproduction practices done by the corn farmers who adopted the facilities and corn traders, the problems encountered by the adopters and operators; and other adjustments essential in the adoption and sustainable operation/ management of the facilities. Results of the evaluation provide important insights and lessons in sustaining or improving two-stage CDPS operation and the overall program implementation.

Project Sites

The study was conducted in four corn-producing provinces (stratified according to climatic type, Corona's Classification) where the two-stage CDPS were initially established. The study areas included: Pangasinan (Type I); Agusan del Sur (Type II); Isabela (Type III); and South Cotabato (Type IV).

Respondents of the Study

The respondents included corn farmers who patronized the two-stage CDPS by selling their produce in CoC form to the CDPS operators and the other corn farmers who still practiced traditional system of postharvest operations, shelled and dried their grains before marketing. The total respondents composed of 120 farmers selling to operators of two-stage CDPS and 120 farmers practicing the traditional postharvest system.

Types of Data to be Collected and Method of Collection

Structured and unstructured questionnaires were employed in gathering data from corn farmers, traders and two-stage CDPS operators. Monitoring forms were also used to record day-to-day operations of the two-stage CDPS.

Primary data were collected through personal interview and observations of the processing centers' actual operations. The activities of the processing centers were monitored through records and other relevant documents. In addition, key informant interviews were done to supplement gathered information.

For qualitative loss measurement, aflatoxin and physical analyses of corn samples were undertaken. Samples were taken from the two-stage CDPS operators at different stages of postharvest operations: loading, shelling and after drying. Three kilograms were set aside for aflatoxin analysis while 250 grams were set aside for physical analysis. The same amount of samples were also obtained from farmers who practiced traditional method at each operation: before shelling, after shelling and after drying. Fresh or wet samples collected were dried immediately using laboratory dryer or solar dryer down to 14% m.c. prior to laboratory analysis.

Analytical Procedure

The information generated from the survey was analyzed and presented using descriptive statistics such as means, percentages and frequency distribution.

Aflatoxin analysis was undertaken by the Laboratory Services Division (LSD) of PHilMech using Natural Resources Institute, Thin-Layer Chromatography (NRI-TLC) method. Physical analysis was also done, comparing the outputs of grains processed by the CDPS facilities and grains passing through traditional practice of corn farmers using conventional corn shellers and solar or flatbed dryers. The parameters on broken and moldy grains that were affected by the corn sheller and mechanical dryer were considered in the analysis.

In assessing the performance of the two-stage CDPS in terms of postharvest loss reduction or grain quality improvement, t-test was used to compare the samples from the CDPS and samples from farmers who adopted traditional system of corn harvesting, shelling and drying.

To evaluate the financial benefits derived from the two-stage CDPS, partial budget analysis and capital budgeting analysis using the methods of payback period, net present value and internal rate of return were done.

Partial budget analysis was employed to determine the effect on income of farmers adopting the CDPS through selling corn on cobs compared with the traditional system of corn postharvest operations. The adoption of two-stage CPDS by farmers through selling corn on cobs to the operators of CDPS was considered a change in postproduction practice and was compared with the traditional postproduction system previously adopted or currently employed by other farmers. Sections within the partial budget include added returns and reduced costs (which increases the net financial gain from adoption of CDPS), as well as reduced returns and added costs (which decreases the net financial gain from adopting the technology).

Net effect was calculated to determine the financial gain or loss from adopting the services offered by the facility. The assumptions were based on actual data generated from the farm survey and technical coefficients derived from available data.

Capital budgeting analysis was used to determine the profitability of investing on CDPS from the viewpoint of the farmer adoptor. Profitability parameters used were benefit-cost ratio (BCR), net present value (NPV), payback period (PP) and internal rate of return (IRR). These were computed using the following formula:

PP = investment cost/discounted net income/yr

NPV = Σ discounted gross benefit
Σ discounted gross cost
>0 CDPS is financially viable
<0 CDPS not viable; retain traditional practice

BCR = Discounted benefit/ investment;
>1 the benefits outweigh the project's costs and should be considered
<1 the project's costs outweigh the benefits and should not be considered

$$IRR, 0 = NI_0 \; \frac{NI_1}{(1 + i)^1} + \frac{NI_2}{(1 + i)^2} + \frac{NI_3}{(1 + i)^3} + \frac{NI_n}{(1 + i)^n}$$

Where: NI = net income
i = discount rate
IRR > 10% is acceptable
IRR < 10 is not acceptable

RESULTS AND DISCUSSION

The Technology: The Two-Stage Corn Drying and Processing Systems

There are two types of corn drying and processing systems considered in the study: the larger CDPS with 200-metric ton ear corn dryer capacity and the village-type with 10-metric ton ear corn dryer capacity. The CDPS regardless of capacity, consists of the following components: (1) receiving section for ear corn, (2) ear corn dryers, (3) corn sheller, (4) grain dryers, (5) holding and bagging bin, (6) cob storage bin, (7) conveyor system, (8) cob-fed furnace, (9) control system, and (10) grain storage.

The ear corn dryer lowers the ear corn moisture down to 20% using a reversible airflow design. Reversible flow minimizes moisture gradient resulting to a uniform drying. A belt conveyor allows easy loading of ear corn into the drying chamber. The drying floor is inclined to facilitate unloading of pre-dried ear corn. A biomass furnace supplies clean hot air to the dryer through a vane axial blower at a superficial air velocity of 20m/min (65.6cft/min). The pre-dried ear corn is unloaded and conveyed to the corn sheller via another belt conveyor. Three belt conveyors are installed for the CoC dryer.

The first conveyor is a movable inclined conveyor with cleats to facilitate loading of CoC to the dryer. The second conveyor is a horizontal conveyor without cleats and used to convey pre-dried ear corn from the dryer to the third conveyor. The third conveyor is also an inclined conveyor with cleats but is not movable. Gear motors or speed reducers provide power to each conveyor.

Ear corn at 20% moisture is loaded at the top portion of the sheller through an inclined conveyor. It has a suction blower to remove light impurities from the shelled grain. It also has an oscillating sieve to separate corn cobs and other impurities from shelled grain. It is provided with a screw conveyor for the transfer of crushed cobs to the cob storage.

The shelled corn dryer is an LSU-type grain dryer and this is where the second-stage or final drying occurs. Drying air passes through inverted v-ducts arranged in alternating pattern. As the grain flows downward, it is exposed to alternate drying air and exhaust air resulting to a uniform drying. Grain is recirculated repeatedly inside the drying chamber until 14% moisture is reached. A biomass furnace using corn cobs or ricehull fuel supplies the heating requirement while two centrifugal blowers with single phase motors supply the airflow. The dryer operates at negative pressure to minimize dust inside the warehouse. It is also provided with dust collection system, maintenance ladder and catwalks for easy maintenance.

The biomass furnace is an indirect-fired type of furnace using fire tubes as heat exchanger. Corn cob or ricehull fuel is automatically fed into the burning chamber. Temperature is controlled by means of a temperature controller. Clean hot air passes in between the heat exchanger tubes while smoke and flue gas passes through the tubes and exits at the chimney. Refractory bricks with melting temperature of 1700o C is used as insulation material in the combustion chamber. It is also provided with fly ash scrubber for clean smoke emission. Ash is disposed mechanically to an ash bin.

Operation of Two-Stage CDPS

Procured wet ear corn (above 24% m.c.) are weighed and loaded into the CoC drying bin through the conveyor. Belt conveyor systems are employed to facilitate loading and unloading. During loading, underdeveloped/damaged pieces or rejects are manually discarded. The ear corn undergo first-stage drying for 8-10 hours, depending on the initial m.c. Upon reaching 20% m.c., the ear corn is ready for shelling. The pre-dried ear corn is conveyed to the sheller for the shelling process.

After shelling, the corn grain is conveyed into a recirculating batch-type dryer for final drying down to 14%. The crushed corn cobs are loaded into cob storage bin to be used as fuel for the furnace. Aside from corncobs, rice hull and wood are also used as fuel. All system components are operated through a centralized control panel.

Effect of Two-stage CDPS on Corn Quality

Aflatoxin analysis. Based on the summary of samples collected in two cropping seasons from four locations of CDPS, all samples collected from the corn processing facilities were of better quality in terms of aflatoxin content compared to samples taken from farmers doing conventional method of shelling and drying. There was no incidence of high aflatoxin level (≥50 ppb) on corn passing through the CDPS. Aflatoxin levels were all ≤ 20 ppb. On the other hand, the incidence of corn with aflatoxin level >50 ppb was found to be 43% of the samples taken from the corn produced following farmer's practice (Fig. 1). Results showed the advantage of CDPS in reducing the incidence of high aflatoxin levels from corn grains.

Physical analysis. In all areas, the corn processing facilities reduced the incidence of broken grains during the second season but there was no effect during the first season as the samples from two-stage CDPS and traditional system did not differ significantly during the period (Table 1).

Similarly, the incidence of moldy grains from two-stage CDPS and traditional system did not differ significantly during the first season but differed significantly during the second season (Table 2). The first season harvest generally fall during the drier months and harvested corn grains are generally drier compared to those harvested during the second cropping when the frequency of continuous rains are higher (Dela Cruz and Villota, 2014). Corn grains with high moisture content, higher than 18% w.b., were found to be susceptible to mechanical damage during shelling. Additionally, high moisture corn grains are susceptible to microorganism invasion causing mold growth (Paz et al., 1996).
The advantage of two-stage CDPS in reducing broken/cracked grains and moldy/discolored grains was more pronounced during the second cropping when harvested ear corn had higher moisture at harvest. It is implied that the adoption of two-stage CDPS would be advantageous in areas that are more frequented by rains during the harvesting season, for example, Agusan del Sur and South Cotabato.

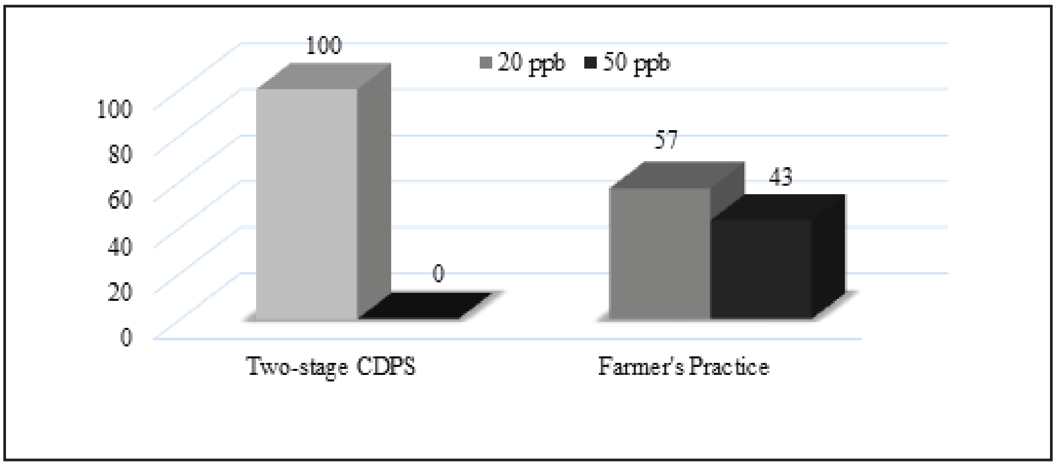

Figure.1 Incidence of aflatoxin in corn from two-stage CDPS and farmer's practice

Table 1. Percentage of broken/cracked grains of samples from selected two-stage CDPS

Location	First Cropping			Second Cropping		
	CDPS	Farmer's Practice	Diff.	CDPS	Farmer's Practice	Diff.
Agusan Sur	9.16	8.80	0.36ns	3.62	7.81	-4.20**
Isabela	-			3.32	4.43	-1.11*
So. Cotabato	3.96	4.66	-0.70ns	6.02	6.01	0.01ns
All areas	6.56	6.73	1.41ns	4.07	6.10	-2.03***

*** significant at 1%; ** significant at 5%; * significant at 10%; ns not significant

Table 2. Percentage moldy/discolored grains of samples from selected two-stage CDPS

Location	First Cropping			Second Cropping		
	CDPS	Traditional	Diff.	CDPS	Traditional	Diff.
Pangasinan	0.39	0.06	0.33ns	-	-	-
Agusan Sur	0.90	0.46	0.44ns	3.55	3.43	0.12ns
Isabela	0.08	0.45	-0.37ns	0.83	2.34	-1.51***
So. Cotabato	0.65	3.41	-2.76***	1.30	4.12	-2.82***
All areas	0.51	0.97	-0.46ns	1.63	3.09	-1.46***

*** significant at 1%; ** significant at 5%; * significant at 10%; ns not significant

Table 3. Percent of dried corn grains recovered from corn in cobs; selected CPTC locations

Location	First Cropping			Second Cropping		
	CDPS	Traditional	Diff.	CDPS	Traditional	Diff.
			%			
Pangasinan	56.0	50.0	6.0	-	-	-
Agusan del Sur	57.1	49.5	7.6	51.5	50.3	1.2
Isabela	56.0	51.5	4.5	61.0	52.0	9.0
South Cotabato	57.0	54.0	3.0	55.6	47.2	8.4
All	56.5	51.2	5.3	56.0	49.8	6.2

$$\text{* Grain output (\%)} = \frac{\text{Output (dried grains; 14\%m.c.)}}{\text{Input (fresh corn on cobs)}} \times 100$$

Effects of Two-Stage CDPS on Shelling and Drying Losses

The reduction of postharvest losses attributable to the two-stage CDPS was estimated by comparing the outputs of the system involving corn in cobs that were processed into dried corn grains. The outputs of the processing systems were expressed in terms of dried corn grains (14% m.c.) produced from known weight of fresh CoC.

During the first cropping season, the average dried corn recovered from two-stage CDPS was 56.5% compared to 51.2% from farmers who adopted traditional system (Table 4).

The difference of 5.3% reflects the percentage of loss reduced with the use of two-stage CDPS. The loss reduction was recorded at 6.2% during the second cropping season.

Table 4. Partial budget of selling CoC versus selling dried grains using the traditional system; average of two seasons

Item	Pangasinan	Isabela	Agusan del Sur	South Cotabato	Average
Returns (A)					
Added Returns	0	0	0	0	0
Total Added Returns	0	0	0	0	0
Reduced Costs					
• Shelling	1,645	1,542	1,824	1,221	1,558
• Drying	2,211	2,614	1,905	1,800	2,132
• Hauling & transport	1,201	1,254	1,030	3,239	1,682
• Packaging	670	550	530	620	592
• Miscellaneous	581	674	514	487	564
Total Reduced Costs	6,309	6,635	5,802	7,366	6,528
Total Added Returns & Reduced Costs	6,309	6,635	5,802	7,366	6,528
Costs (B)					
Added Costs					
• Dehusking	-	670	-	-	168
Total Added Costs	0	670	0	0	168
Reduced Returns					
• Reduced sales	4,377	1,848	1,938	6,214	3,594
Total Reduced Returns	4,377	1,848	1,938	6,214	3,594
Total Added Costs & Reduced Returns	4,377	2,518	1,938	6,214	3,762
Net Change (A-B)	1,932	4,117	3,864	1,152	2,766

Table 5. Financial analysis of two-stage CDPS with 200 metric ton ear corn dryer capacity

Item	Large-scale CDPS	
	Average Utilization*	High Utilization**
Investment	Php 26,000,000.00	Php 26,000,000.00
Facilities (Book value)	21,000,000.00	21,000,000.00
Working capital	5,000,000.00	5,000,000.00
Annual Procurement		
Vol. of procurement, kg ear corn	3,052,535	10,961,494
Price per kg of ear corn	Php 5.80	Php 5.55
Gross Sales		
Vol. processed corn grains, kg	1,678,894.25	6,028,821.7
Selling price per kg	Php 12.56	Php 12.86
Net Revenue	Php 3,382,208.78	Php 16,694,355.36
Less: Operating Costs		
Fixed costs[1]	Php 5,610,000.00	Php 5,610,000.00
Variable costs[2]	3,754,058.93	9,835,639.75
Total Operating Costs	Php 9,364,058.93	Php 15,445,639.75
Annual Net Income/Loss	*(Php 5,981,850.15)*	*Php 1,248,715.61*
Measures of Project Worth		
Net Present Value (NPV)	*(Php 32.90 million)*	*(Php 5.13 million)*
Internal Rate of Return (IRR)	*Not calculable*	*7.70%*
Benefit Cost Ratio (BCR)	*0.29*	*0.80*

* Average annual utilization of the four two-stage CDPS
** Highest utilization recorded by an operator of CDPS in South Cotabato
[1] Depreciation, repair and maintenance
[2] Procurement costs at Php 0.16/kg, processing costs at Php 0.50/kg, marketing costs at Php .39/kg and admin costs comprising the salaries, wages and other fringe benefits

Partial Budget Analysis of Selling Corn on Cobs versus the Traditional System of Shelling and Sundrying of Shelled Grains

In Pangasinan, selling corn on cobs to the operators of CDPS was more advantageous, generating higher profit than the traditional system. The costs averted from holding off postharvest activities outweighed the potential income generated should corn farmers perform shelling and drying before selling their produce. Selling corn on cobs benefits the small farmers who have no more cash to pay for the postharvest activities. The net effect was an additional Php 1,932 per hectare (Table 5). In Agusan del Sur, corn farmers who sold corn on cobs obtained additional Php 3,863 per hectare while in Isabela, the added profit was Php 4,117 per hectare. Compared to other areas, farmers in Isabela incurred additional cost of dehusking, estimated at Php 670.50 per hectare per season. From among the study areas, corn farmers in South Cotabato gained lowest although additional income amounting to Php 1,152.00 per hectare for both cropping seasons.

Based on the foregoing analysis, the financial advantage of adopting the CDPS by selling CoC depend largely on the prevailing prices adopted by the operators of the CDPS and grain buyers in specific area. CDPS operators that had just started to operate offered "promotional" prices to attract more farmers to sell their produce in CoC form. Since the primary concern of the CDPS operators was to acquire enough volume to warrant economies of scale operation, they need to offer higher prices to ensure procurement. This was even more evident in areas where dehusking is not done simultaneously during harvesting or selling corn on cobs is not yet widely practiced. In addition, there were still no private traders actively buying CoC which they could base their buying price. Conversely, earlier operators of CDPS started to offer relatively lower prices, from which the base price mostly depended on the price offered by private traders operating in the area.

Financial Analysis of Operating CDPS

The financial viability of investing and operating CDPS was determined based on the actual data from the previous operations of existing CDPS. Two scenarios were considered based on the utilization of two-stage CDPS: (1) the average annual utilization of the four CDPS; and (2) the highest volume procured recorded by an operator of the CDPS.

Based on the average annual utilization, average costs paid and prices received for grains sold by the four operators of two-stage CDPS, the revenues generated did not even cover the variable costs that include the administrative costs composed of salaries, wages and other fringe benefits (Table 6).

The facilities were not financially viable at current utilization level as the average volume procured was only 20% of the rated capacity of the two-stage CDPS.

Looking at the scenario when a two-stage CDPS attained the highest volume of procurement (Banga CDPS recorded 10.96 million kilogram corn on cob procurement in 2008), the operator of two-stage CDPS could potentially earned income but the financial indicators were not acceptable according to the usual measures of project worthiness.

Although financial analysis indicated low level of return on investments for the operation of CDPS, other social gains are not reflected in the analysis.

For the village-type of two-stage CDPS, adoption of the system integrated with corn trading operation exhibited more favorable indicators compared to CDPS operating as provider of custom shelling and drying services (Table 7). The toll rates charged by CDPS operators only covered the variable costs (administrative costs excluded) and certain part of fixed costs (no interest charges).

Comparison of Shelling and Drying Cost Between The Two-Stage CDPS and Traditional System

Adopting custom shelling and corn on cob/grain drying was costlier as the toll rates charged by CDPS operators offering custom drying-shelling was higher than the average cost incurred by farmers who practiced traditional method of shelling and then drying (Table 8). This suggests that the toll system did not offer profit advantage on the part of farmer-users as the costs were higher compared to the traditional system. The average shelling and drying costs reported by farmers ranged from Php 0.70-Php 1.09 per kilogram while the toll rates charged by CDPS operators during the same period ranged from Php 1.20-Php 1.40 per kilogram, a difference of Php 0.40 per kilogram additional cost.

This would be even higher in areas where harvesting-dehusking is not yet widely practiced, as farmers have to pay additional cost of dehusking. Moreover, if the costs charged by the 10 ton capacity two-stage CDPS (village-type CDPS) are adjusted assuming that the losses are the same for the two systems, farmers are incurring additional costs ranging from Php 0.24 to Php 0.85 per kg if they avail the custom shelling-drying services of the village-type CDPS. This explains why only few farmers availed the custom shelling-drying services of the village-type CPTCs. Corn farmers were better off selling their produce in CoC form or sell dried shelled grains by employing traditional shelling and drying method.

Table 6. Financial analysis of operating two-stage CDPS with 10 metric ton ear corn dryer capacity

Item	Type of Operation	
	Trading	*Tolling*
Investment	Php 4,628,307.00	Php 4,628,307.00
Facilities	3,628,307.00	3,628,307.00
Working capital	1,000,000.00	
Annual Procurement	Php 3,300,000.00	
Vol. of procurement, kg CoC	600,000	
Price per kg CoC	Php 5.50	
Gross Revenue	Php 4,521,600.00	Php 468,000.00
Vol. processed corn grains, kg	360,000	360,000
Selling price per kg	Php 12.56	
Net Revenue	Php 1,221,600.00	Php 468,000.00
Less: Operating Costs		
Fixed costs[1]	Php 312,284.53	Php 312,284.53
Variable costs[2]	273,600.00	273,600.00
Total Operating Costs	Php 585,884.53	Php 585,884.53
Annual Net Income/Loss	*Php 635,715.47*	*(Php 117,884.53)*
Measures of Project Worth		
Net Present Value (NPV)	*(Php 2.46 million)*	*(Php 7.59 million)*
Internal Rate of Return (IRR)	*5.83%*	*Not calculable*
Benefit Cost Ratio (BCR)	0.47	-

[1]Depreciation, repair and maintenance
[2]Variable cost at P0.76/kg

Farmers' Reasons for Selling or Not Selling CoC

The reasons of corn farmers for selling their produce in ear corn form are detailed in Table 9. Sixty one percent of the respondents mentioned convenience and fast disposal of produce. The widespread use of mobile phones facilitates product disposal as farmers can easily contact operators of CDPS during harvest through short messaging service. 21% of respondents pointed out the advantage of not spending cash to do the postharvest operations.

Farmers adopting the CDPS had a reduced cost of PhP6,528/ha (range: Php 5,802-Php 7,366) for not spending on shelling, drying, hauling, and other related postharvest supplies as shown in Table 5. Meanwhile, 20% of the respondents cited the reasonable price offered by CDPS operators, although this was only experienced by corn farmer-beneficiaries selling to CDPS operators that had just started operation. Moreover, 11% of the respondents sold ear corn as market agreement with CDPS. Other reason stated was the inclement weather during harvest while few respondents disclosed that they just wanted to try selling to the operators of CDPS.

The reasons given by farmers for not selling CoC despite the presence of CPTC in the area are shown in Table 10. Twenty six percent of non-beneficiaries were tied-up with traders because of credit-market arrangements.

The same number or respondents pointed out the lack of information about the CDPS existing in their area. Some corn farmers assumed that only those affiliated to cooperatives or associations are allowed to sell their produce at the CDPS. The fluctuating price offered by CDPS also deterred some farmers to sell their produce to the CDPS. Another complain was the presumed strict classification employed by CDPS. Seven percent of the respondents mentioned they have small volume of harvest and that they were less prioritized by the CDPS. Meanwhile, 6% declared they have shelling machines that can be displaced by the CDPS.

Based on the inventory of postharvest facilities in the province, there are about 2,000 units of multipurpose sheller-dehusker-threshers and corn shellers in Isabela. Although some of these facilities were located in areas with rice production, the change in corn postproduction practice will affect the owners of corn shellers who mainly utilize the facility to shell corn or the facility is situated in area where corn monoculture is practiced. Few farmers also stated that the CDPS cannot absorb all the produce of farmers during peak periods, others reported that weather was favorable when they harvested their crop, others do not want to pay additional cost of dehusking, few objected the non-cash and delayed payment and the distant location of their farms from the CDPS.

Table 7. Average shelling and drying costs (Php/kg) incurred by corn farmers

Location	Traditional System	Village-type CPTC	Difference
Pangasinan	0.82		
Agusan del Sur	1.00		
Isabela	1.09		
South Cotabato	0.70		
Range	*0.70-1.09*	*1.20-1.40*	*0.11-0.70*
Mean	*0.90*	*1.30*	*0.40*
Adjusted for Losses			
Range		*1.33-1.55*	*0.24-0.85*
Mean		*1.44*	*0.54*

Table 8. Farmers' reasons for selling corn on cobs, four maize-producing provinces, 2012

Reason	Percent Reporting* (N=120)
Convenience and fast disposal of produce	61
Avert cash needs to do postharvest Operations	21
Reasonable price	20
Credit marketing agreement	11
Inclement weather during harvest	7
Just wanted to try selling corn on cobs	3

* there are multiple responses

Table 9. Farmers' reasons for not selling corn on cobs

Reason	Percent Reporting* (N=120)
Credit-market tie-up with trader-financiers	26
Lack of information about CPTCs	26
Fluctuating/low prices	21
Strict classification employed by CPTCs	8
Small harvest	7
Owns dehusker-sheller	6
CPTCs cannot accommodate all farmers during peak periods	5
Good weather during period of harvest	4
Additional cost of dehusking	3
Delayed and non-cash payment	2
Distant location of farms from CPTC	2

CONCLUSION AND RECOMMENDATION

The study evaluated the technical and socioeconomic performance of the two-stage corn drying and processing system in selected corn-producing provinces in the country to determine whether the objectives of the program in reducing postharvest losses, improving corn grain quality and increasing farmer income were realized. Specifically, the study aimed to evaluate the performance of the CDPS in terms of maintaining corn quality and reducing postharvest losses, determine the financial benefits derived by the farmer-users and operators of the two-stage CDPS, and identify the issues that could hamper the adoption of the postharvest intervention.

Comparisons between CDPS operators/clients and corn farmers practicing the traditional method of postproduction operation in terms of postharvest losses and grain quality, costs and benefits were done. Corn samples from different postproduction systems collected at various stages of postproduction operations were analyzed for aflatoxin content and other quality parameters. The study composed of 120 adopters (CDPS clients) and 120 non-adopters (CDPS non-clients). Partial budget analysis was also undertaken to determine the financial advantage of selling CoC versus the conventional system of selling dried shelled grains. Financial analysis was also done to determine the financial performance of operating two-stage CDPS.

The two-stage CDPS was relevant in addressing the problems of high postharvest losses (qualitative and quantitative). With the CDPS, the incidence of high aflatoxin contamination (above 50ppb) was lower in both seasons. In addition, the incidences of broken and moldy grains were significantly lower during the second or wet season. Comparing the corn grain outputs of CDPS and farmers who employed traditional system, differences of 5.3% during the first season and 6.2% during the second season were noted. These represent the reduced postharvest losses with the use of CDPS.

The benefits ascribed to higher grain quality because of CDPS, had low monetary translation as most of the operators of the two-stage CDPS had no access to better markets that give price incentive for premium quality grains. Farmers who sold their produce to CDPS obtained additional profit ranging from Php 1,152.00 to Php 4,117.00 per hectare. With the CDPS, net farm income of farmers could increase by Php 2,766/ha-season.

At the operators' point of view, the large CDPS were not financially viable at average utilization levels. The actual utilization was only 20% of the rated capacity. On the other hand, the village-type CDPS integrated with corn trading operation exhibited better financial indicators compared to CDPS operating as provider of custom shelling and drying services. Operating the CDPS through tolling scheme was not viable, both from the standpoints of user and operator.

Village-type CDPS (with capacities depending on specific locations) can be provided in selected areas, with the necessary conditions, such as: (1) the facilities will be utilized as support to trading operation; (2) in areas where selling CoC is predominant; (3) in areas where shellers are inadequate, solar drying unreliable, mechanical drying is costly; (4) in areas with simultaneous planting/harvesting when facilities/labor is expected to be scarce during peak periods; (5) presence of market for premium quality corn; (6) village level CDPS must be linked to large CDPS for market assistance and accumulate enough volume to satisfy the volume requirement of commercial feed millers requiring premium quality corn grains, (7) inclusion of credit facility in the package; (8) promotion of the advantages of the technology. The two-stage CDPS should not be promoted in areas where corn is grown for only one cropping (as a rotational crop to rice) and where private sector practicing two-stage CDPS is already existing. The low utilization rate of CDPS which generally happen with one cropping season of corn, renders the operation of the facility not profitable.

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GUIDE TO CONTRIBUTORS

1. The authors should follow the given instructions for the papers to be published in the Asian Journal of Postharvest and Mechanization (AJPM).

2. Name of authors must not contain professional or academic titles. The surname should be the last part of the authors' name. Affiliation of the authors should contain name of the agency or university he/she belongs, address, and the country of the authors. Include e-mail addresses of the corresponding authors.

3. Papers for submission must be recent and has not been published or submitted for publication in any other journal.

4. The following are the components of the journal paper: Title, Authors, Abstract, Introduction, Methodology, Results and Discussion, Conclusion and Recommendations, and References.

5. Its scope is on postharvest and mechanization to include the following research, development and extension (RD&E) topics: Engineering Science, Agricultural Engineering, Biology (e.g. Physiology, Pathology, Entomology), Agricultural Food Chemistry and the Social Sciences (e.g. Extension, Development Communication, Economics, Sociology, Anthropology).

6. The minimum number of pages is 6 and the maxi mum is 12 pages.

7. The Introduction should include the rationale of the paper, objectives and the review of literature.

8. Submit the journal paper in A4 size bond paper, 12 font size, Times New Roman.

9. The journal adopts a two-column format for text except for pictures, tables, graphs, flowcharts.

   The margins are set as follows:
   - Top = 1” (25.4 mm)
   - Bottom = 1”
   - Inside = 1.5” (38.1 mm)
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10. All paragraphs must be indented. All paragraphs must be left justified.

11. Use only three levels of headings especially in the discussion of results.

12. For Level 1 headings, use small caps and center.

13. For Level 2 headings, italize and left justify.

14. For Level 3 headings, indent, italize and place a period. The body of the level-3 section immediately follows in the same paragraph.

15. Figures and tables must be centered, spanning across both columns, if needed. Place tables or figures that take up more than 1 column either at the top or at the bottom of the page.

16. Graphics should have adequate resolution. Images should be clear. Colors used must contrast well. Labels should be readable.

17. Figures must be numbered using Arabic numerals. Figure captions must be in 9 pt regular font. Captions of a single line must be centered whereas multi-line captions must be justified . Place captions of figures at the bottom of the figures.

18. Tables must be numbered using uppercase Roman numerals. Captions with table numbers must be placed above the tables.

19. Place equations flush-left with the text margin. Equations are centered and numbered consecutively starting from 1 as follows:

$$\mathrm{E}(F) = \mathrm{E}(0) + \sum_i \left(\frac{\delta \mathrm{E}(F)}{\delta F_i} \right)_0 F_i \qquad (1)$$

20. Authors should follow instructions, otherwise their papers will be returned for reformatting prior to the peer review.

21. Examples of different reference categories are shown below:

• *Book*

Fawcett, S. E., L.M. Elram, and J. A. Ogden. 2007. Supply Chain Management from Vision to Implementation. New Jersey: Pearson Education Inc. 530 pp.

• *Book portion*

Schuber, S. 1995. Proton release by roots. In: Singh BB, Mengel, K. Editors. Physiology and Biochemistry of Plants. New Delhi: Panama Publishing Corp. pp. 97-119

• *Journal*

Siemens, M.C and D.E. Wilkins. 2006. Effect of residue management methods on no-till drill performance. Applied Engineering in Agricul ture. 22(1): 51-60.

• *Theses and Dissertation*

Rodeo, AJ. 2009. Low temperature conditioning to alleviate chilling injury in mango (*Mangifera indica* L. Cv. Carabao fruit (BS Thesis) College, Laguna, Philippines: University of the Philippines Los Banos.

• *Paper from a Proceedings*

M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, 2000, paper 11.3.4, p. 109.

• *Website*

Scofield, A. Undated. Vietnam: Silent Global Coffee Power. Retrieved on August 4, 2007 from http://www.ineedcoffee.com/02/04/vietnam/

• *Standard*

Agricultural Machinery Testing and Evaluation Center (AMTEC). 2003. Philippine Agricultural Engineering Standards. Volume 1. 2003. PAES 124:2002 Agricultural Machinery – Walking-type Agricultural Tractor – Specifications Part 3: Special Type (Float-Assist Tiller). College, Laguna, Philippines: University of the Philippines Los Banos (UPLB). p.8

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