# 2015 National Rice R&D Highlights

## Rice Chemistry and Food Science Division

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

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# RICE CHEMISTRY AND FOOD SCIENCE DIVISION

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## Executive Summary

The Division implemented 2 projects: 1) Grain Quality (GQ) Assessment of Rice Lines and Varieties, and 2) Nutrition, Health, and Wellness Potential of Philippine Rice and Rice-Based Crops.

Project 1 aims to identify promising rice lines for entry into the National Cooperative Test. Advancement of the GQ assessment methods is also a way to upgrade capacity and fast-track varietal screening. Current development in analytical assessment of quality characteristics of rice and the demand for reliable data by heightened breeding activities further necessitate an immediate updating of grain quality techniques. In addition, total antioxidant capacities and composition of local rice-based crops was evaluated. This is to aid in the production of high quality foodstuffs from rice-growing areas and in consumer selection of products for health maintenance and disease prevention.

From grain quality evaluation study under project 1, out of the 32 Direct Seeded General Yield Trial (DSR-GYT) entries of 2014WS, 26 had good milling recovery, are long and slender and had Intermediate amylose content (AC) indicating that the samples are tender to very tender when cooked. Most of the 72 samples evaluated from Long Term Organic Fertilizer (LTOF) passed the standard for milling potential, except for two (2) samples. Crude protein content ranged from 6.0 to 9.6%. All samples had Intermediate AC and High Intermediate gelatinization temperature (GT). Forty-two (42) NSIC Rc222 Mutant entries evaluated for physicochemical properties were observed to be on the upper limit of protein content ranging from 8.8 to 10.7%. AC were mostly high with hard gel consistency (GC) value which may produce slightly tender to hard cooked rice. Half of the aromatic entries had very good grain quality score having high milling recovery; and AC were low to intermediate, thus are expected to have tender cooked rice grains. Glutinous rice entries have excellent grain quality with high milling recovery and waxy to very low AC characteristic of glutinous rices. Pigmented glutinous rice entries have waxy to very low AC, except for two entries.

Based on the study on cooked rice spoilage, results revealed that after 18 hours of standing at ambient temperature, high amount of microbial load and presence of slightly perceptible to perceptible off-odor was observed in varieties with low to intermediate AC - low to intermediate GT such as Koshihikari, NSIC Rc140, Rc160, Rc142, and Rc158. On the other hand, IR64, NSIC Rc340, PSB Rc10 (high AC - low to intermediate GT), and PSB 72H still had higher sensory index (>1.8) even at 24 hours standing.

Preliminary findings from the study on Visible-Near-Infrared Spectroscopy for Rapid Assessment of Grain Quality of Philippine Rice showed that analysis and modeling of the entire sample set showed good prediction models for crude protein. Prediction models for amylose contents needed to be further refined and validated. The Gelatinization Temperature models, in the meantime, were unstable, which would require further validation. The performance statistics showed that in terms of accuracy in prediction, floured rice has the best while rough rice has the least statistical results among the four forms of rice.

For the second project, local rice-based crops were evaluated for their total antioxidant capacities and composition. A total of 21 vegetables harvested from PhilRice CES, Bulacan, Nueva Ecija and Mt. Province were used as test samples for antioxidant analyses. Of the 17 hydrophilic extracts of the raw vegetable samples assayed for total phenolic content (TPC), jute had the highest concentration (31.78mg GAE/g dry weight), while Mt. Province Squash had the lowest (1.08mg GAE/g) (Table 2). Jute likewise contained the highest TPC in fresh weight basis (850mg GAE/100g). In raw form, the following had the highest TPC in fresh weight basis: jute>chili pepper (Mt. Province)>oyster mushroom>spinach>taro tuber.

## I. Grain Quality Assessment of Rice Lines and Varieties

*EH Bandonill*

Grain quality (GQ) evaluation is the final trial that rice lines undergo after meeting standards for yield, disease and insect resistance, agronomic and other traits. Study 1 of this project covers GQ evaluation of rice lines before they are elevated in the advance stages of the National Cooperative Test (NCT). Its purpose is to select promising entries to expedite the screening, thereby reducing cost and maximizing resources.

The ultimate objective of the GQ project is to enhance breeding efficiency for grain quality, ensure availability of cooked rice with longer shelf-life for consumers, and develop prediction models of milled rice for rapid grain quality analysis. For Study 1, it covers GQ evaluation of rice lines before they are elevated in the advance stages of the National Cooperative Test (NCT to select promising entries to expedite the screening, thereby reducing cost and maximizing resources. Study 2 tries to determine the causes of cooked rice spoilage in the Philippine setting and determine the best storage and reheating practices that will extend the shelf life while keeping the quality of cooked rice, while Study 3 wants to know the form of rice samples (grain, brown, milled or flour) that can efficienly predict crude protein, gelatinization temperature, and apparent amylose content of milled rice, and some color parameters of the CIEL*a*b* from optical absorbance data, as well as identify the spectral pre-treatments and wavelength ranges that should be used for maximum effectiveness of the predictions.

**Centralized grain quality screening**
*GG Corpuz, CT Estonilo, RP Tubera, JD Adriano, JMC Avila, and MJC Ablaza*

Grain quality evaluation (GQE) plays an important role in the rice breeding program of PhilRice. Aside from yield, resistance to pests and diseases, and agro-morphologic characteristics, grain quality is also influenced by genotype. The physical appearance of milled rice is important to the consumer, which in turn makes it essential to the marketer and the miller as well. Grain length and shape are among the primary rice quality criteria that breeders consider when developing new varieties for release. Preference for grain shape may vary from one group to another, but a higher value is assigned for slender shapes and a lower value for medium and bold shapes. On the other hand, the presence of chalk in the rice grain has been described as a defect that affects milling, marketing and storage properties.

Early generation and pre-NCT lines must therefore be evaluated and screened for grain quality to trim down the number of lines advanced for further trials, thus reducing cost and maximizing resources. Furthermore, early generation screening may also allow the identification of entries with properties suited for special purposes.

This year, one thousand three hundred thirteen (1,313) entries from 2014 wet season and 2015 dry season under the Plant Breeding and Biotechnology and Agronomy, Soils and Plant Physiology Divisions were screened for grain quality.

Samples for the 2014 Wet Season was composed of Direct-Seeded General Yield Trial (DSR-GYT), Direct-Seeded Preliminary Yield Trial (DSR-PYT), Long Term Organic Fertilizer (LTOF), Direct-Seeded Preliminary Observation Nursery (DSR-ON), Rainfed Elite Lines, Rainfed Favorable vs Drought, Special Purpose Seed Increase (SPSI), Rainfed Submergence (SUB), Irrigated Lowland – Ultra Early Maturing (IL-UEM), Preliminary Yield Trial (PYT-R), Preliminary Yield Trial for Special Purpose Rice (PYT-SP), and NSIC Rc222 Mutant. Samples for 2015 Dry Season were from Hybrid Group, SPSI, IL-DSR, PYT-R, PYT-SP, DSR-PYT, DSR-GYT, Rainfed IVC, Rainfed – Multi Environment Trial (MET), Rainfed – Traditional Varieties (TRV), and Rainfed Submergence (SUB). Additional samples from LTOF were monitored for spoilage using the laboratory sensory panel.

**Highlights:**

- From 32 Direct Seeded General Yield Trial (DSR-GYT) entries in 2014 WS, 26 had good milling recovery. PR38856-2-5-1-3-B, PR39150-3-2-2-3-1-B, PR37801-16-3-3-1-3-1-B, PR38869-17-1-3-1-B had Poor brown rice recovery but with

Grade 1 to Premium milled and head rice recoveries. Twenty (20) entries had acceptable % chalky grains. Most of the samples were long and slender and had Intermediate amylose content (AC) indicating that the samples are tender to very tender when cooked. Four samples including NSIC Rc240 had high AC indicating poor eating quality.

- Out of the 24 Direct Seeded Preliminary Yield Trial (DSR-PYT) samples, all 24 had excellent milling recovery except for PR41225-6-1-B-B. Two (2) entries, PR39628-17-2-1-1-B and PR39573-12-2-1-1-1-B-B had Premium % chalky grains, while 8 other grains were considered as Grade 1. Most of the samples were long and slender and had Low to Intermediate AC, indicating that these samples had good eating quality.

- From the 53 Direct Seeded Preliminary Observation Nursery (DSR-ON) assessed, 17 entries had very good grain quality score having Premium to Grade 1 milled rice and head rice, Grade 1 to Grade 2 chalky grains, long and slender or intermediate grain dimension and Low to Intermediate AC. Twenty-eight of the samples had good grain quality score while the remaining eight (8) samples had poor grain quality having high amount of chalky grains and high amylose content.

- Most of the 72 samples evaluated from Long Term Organic Fertilizer (LTOF) passed the standard for milling potential, except for two (2) samples. Crude protein content ranged from 6.0 to 9.6%. All samples had Intermediate AC and High Intermediate gelatinization temperature (GT).

- From the 59 Rainfed Elite Lines assessed, majority of the samples have excellent grain quality with high milling recovery, medium and intermediate to long and slender grains. Most of the samples had intermediate AC, thus are expected to have tender cooked rice grains.

- The crude protein content of 8 Rainfed Submergence rice samples were assessed which ranged from 7.1 to 9.1% and with high AC.

- Out of the 77 Irrigated Lowland – Ultra Early Maturing lines assessed, 47 samples had excellent grain quality having high milling recovery, low amount of chalky grains, and with low to intermediate AC which suggests that these samples have tender cooked rice. Eleven (11) samples with very good grain quality have low percent chalky grains, low to intermediate

AC, and acceptable milling recovery, while ten (10) entries with good grain quality may either have good milling recovery, low amount of chalky grains or intermediate AC. The remaining four (4) entries with poor grain quality have low milling recovery, high amount of chalky grains and high AC. These samples are expected to have hard cooked rice grains.

- Forty-two (42) NSIC Rc222 Mutant entries evaluated for physicochemical properties were observed to be on the upper limit of protein content ranging from 8.8 to 10.7%. AC were mostly high with hard gel consistency (GC) value which may produce slightly tender to hard cooked rice. GT of samples were generally intermediate.

- Special Purpose had 20 aromatic, 6 glutinous, 12 pigmented glutinous, 23 pigmented, and fourteen Iron/Zinc-dense rice entries. Half of the aromatic entries had very good grain quality score having high milling recovery; and AC were low to intermediate, thus are expected to have tender cooked rice grains. Glutinous rice entries have excellent grain quality with high milling recovery and waxy to very low AC characteristic of glutinous rices. Pigmented glutinous rice entries have waxy to very low AC, except for two entries. DPPH assay showed 20.0 to 71.1 antioxidant scavenging capacity while the anthocyanin content ranged from 4.3 to 106.0mg/kg. Pigmented rice lines had 44.6 to 78.2 antioxidant scavenging activity and 2.9 to 352.5mg/kg anthocyanin content.

- From the 2015 Dry Season samples, Special Purpose group had 43 aromatic, 9 glutinous, 11 pigmented glutinous, and 28 pigmented non-glutinous rice entries. Generally, entries from the special purpose group had poor milling recovery particularly for head rice. Aromatic rice samples had low to intermediate AC, thus are expected to have tender cooked rice grains. Only one glutinous rice entry was classified as waxy with the rest having very low AC. Pigmented glutinous samples had very low amylose content while anthocyanin content ranged from 20.5 to 683.0 and antioxidant scavenging activity of 46.2 to 91.9mg/kg. Pigmented non-glutinous rice lines had 2.4 to 521.4 antioxidant scavenging activity and 22.1 to 75.6mg/kg anthocyanin content.

- Entries from the hybrid group were evaluated for AC and GT. One entry (PR33878H) had very low amylose, ten entries had low amylose, and 41 entries had intermediate AC indicating that these samples will have very tender to tender cooked rice grains. The remaining 22 entries were classified as having high AC. Alkali spreading value of all the samples ranged from 2.7 to 7.0.

- From the 41 Direct Seeded Preliminary Observation Nursery (DSR-ON) assessed, 5 entries had very good grain quality having Premium to Grade 1 milled rice and head rice, Premium to Grade 1 chalky grains, long and slender or intermediate grain dimension and Low to Intermediate AC.

- Only two of the 14 entries from Preliminary Yield Trial (PYT-R) had very good grain quality which passed the standards for milling potential, with Grade 1 to Grade 2 chalky grains and low to intermediate AC. High chalkiness was observed among PYT-R samples while AC ranged from 10.6 to 20.2 indicating very tender to tender cooked rice grains.

- Nine samples from Preliminary Yield Trial for Special Purpose Rice (PYT-SP) obtained very good grain quality score. Milling recovery was high particularly for brown rice and total milled rice and per cent chalky grains was acceptable. AC of non-glutinous samples ranged from 12.0 to 19.5, while glutinous rice samples were all classified as waxy.

- Six entries from Direct-Seeded Rice (PYT & GYT) group obtained good grain quality score having acceptable milling recovery, Grade 1 to Grade 2 per cent chalky grains, and low to intermediate AC. Generally, entries had very low head rice recovery.

- Eighteen LTOF samples were submitted for spoilage monitoring. Samples were cooked and kept at room temperature up to 21h and evaluated every 3 hours starting from 12h. Samples were assessed for odor, texture and color in reference to the characteristics of acceptable cooked rice. Panelists rated the samples using the following scores: 3 for very acceptable, 2 for acceptable and 1 for not acceptable. At 12h, no sample was perceived to have off-odor. At 15h, LTOF-01 and LTOF-10 had very low sensory index (SI) of 1.5 and 1.2, respectively. At 18h, five more samples exhibited perceptible off-odor with SI ranging from 1.3 to 1.8. At 21h, all the samples were considered spoiled having SI of 1.8 and below. Only LTOF-11 remained acceptable to the panelists at 21h.

**Factors affecting rice spoilage and optimum cold storage treatment of cooked rice**
*EH Bandonill, GG Corpuz, MJC Ablaza, and OC Soco*

Filipinos regularly eat boiled rice three times a day where most of the consuming population belongs to the class below poverty line and depends highly on white rice for their cheap source of carohydrates and protein. To save on fuel cost, cooking rice once in the morning enough for the whole day's consumption is a common practice. In the absence of a refrigerator,cooked rice is usually kept at ambient temperature. This practice does not hasten rice retrogradation unlike refrigeration. In several instances however, food poisoning caused by the consumption of unrefrigerated cooked rice have been reported. Homemakers have also noted that cooked rice spoils easily during hot weather and when cooking a particular rice variety.The issue of rice spoilage has been raised but the specific causes have not been identified. The presence of Bacillus cereus, a Gram-positive bacteria is often associated with rice spoilage which can cause foodborne illness where its toxin can be fatal in some cases.

Meanwhile, some private companies are also getting interested in knowing the optimum cold storage and reheating practicesfor cooked rice since most of their ready-to-eat rice meals are stored under refrigerated or chilled temperatures. To improve the stability of cooked rice and disseminate information to interested groups/clients, it is important to investigate the best processing techniques that will not only extend the shelf life but also maintain the quality of cooked rice. In the advent of rice conservation and to help in the attainment of rice sufficiency in the country, it is important to keep rice, raw or cooked, safe for consumption even for an extended period. The results of the study will provide not only valuable information on possible causes of cooked rice spoilage and its prevention but may also save lives of the rice consuming public.

The effect of amylose content and gelatinization temperature combination on the spoilage rate of cooked rice was studied using rice samples representing the different AC-GT types. In addition, the contribution of rice ageing, amount of cooked rice per batch, periodic reheating, different storage temperatures and reheating practices, in hastening/retarding cooked rice spoilage was investigated using IR64and NSIC Rc160 varieties. The physicochemical properties, proximate composition, microbial load, sensory properties and sensory index (SI) of samples were determined.

**Highlights:**

- Under the AC-GT effect, after 18h standing, high microbial load and presence of slightly perceptible to perceptible off-odor was observed in varieties with low to intermediate AC - low to intermediate GT such as Koshihikari, NSIC Rc140, NSIC

Rc160, NSIC Rc142, and NSIC Rc158. On the other hand, IR64, NSIC Rc340, PSB Rc10 (high AC - low to intermediate GT), and PSB 72H still had >1.8 or higher sensory index even at 24 hours standing (Table 1).

- For ageing effect, the moisture content of raw rice samples ranged from 10.1 to 11.6% and increased to 57.3 to 62.5% after cooking. Raw rice samples had 0.57 to 0.75% crude ash and decreased to 0.17 to 0.32% after cooking. Crude protein content (6.8 to 8.5%) remained at a normal level even after cooking. The amylose content of IR64 (intermediate AC) and NSIC Rc160 (low AC) remained the same over the three harvest seasons (14DS, 14WS,15 DS).

- Generally, IR64 had lower microbial load compared to NSIC Rc160. In the sensory evaluation at 0h, 15h, 18h, 21h and 24 hours, IR64 (14WS) had the lowest spoilage index at 21h while NSIC Rc160 (15DS) had 1.6 sensory index as early as 15h showing that freshly harvested samples is more prone to spoilage than aged sample (Table 2).

- As to the effect of cooked rice amount, off-odor was perceived in cooked IR64.500g at 21h unlike IR64.300g which remained acceptable at SI of 2.4. At 24h, a slight off-odor was perceived in IR64.300g samples lowering its SI to 1.7 (Table 3).

- Drastic change in the quality of cooked rice was observed in NSIC Rc160 sample. As early as 15H, sensory index was 1.7 indicating that the samples were already spoiled. Although similar in SI values, it was observed that NSIC Rc160 cooked at 500g has stronger off-odor compared with sample cooked at 300g.

- These results indicated that cooking greater amounts of rice has higher tendency to spoil, among the samples tested. Validation of these findings may be conducted using other rice varieties and other cooking amounts.

- As to the influence of periodic reheating, data on sensory index showed that reheating cooked IR64 at 6 hour interval has extended its SI from 24 to 42h and from 30 to 42h for NSIC Rc160 (Table 4).

- The effect of storage temperature and reheating showed that SI of cooked IR64 remained acceptable after 24h at room temperature with sensory index of 2.1 (Table 5). Storing cooked rice samples at refrigerated temperatures retarded its spoilage. Moreover, refrigerated cooked rice reheated through steaming was more preferred by panelists. Reheated samples were observed to be more cohesive and moist than unreheated samples.

- At Day 1, cooked NSIC Rc160 sample was observed to have perceptible off-odor and was rated as almost unacceptable with SI of 1.9. As with IR64, panelists preferred the cooked rice quality of reheated over unreheated cooked rice samples.

- Refrigerated cooked IR64 and NSIC Rc160 had acceptable SI, both for unreheated and reheated, until Day 4, however with decreasing trend. These results indicated that storing cooked rice samples in refrigerated temperatures can retard the spoilage rate and reheating makes rice comparable with freshly cooked rice quality.

**Table 1.** Spoilage index of rice varieties with different AC-GT type.

| Rice Variety | AC-GT | Sensory Index (SI) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0h | 12h | 15h | 18h | 21h | 24h |
| *Set I* | | | | | | | |
| NSIC Rc15 | W-L | 2.8 | 2.3 | 2.3 | 2.2 | 2.2 | **1.8** |
| Koshihikari | L-L | 2.7 | 2.8 | 2.7 | **1.7** | 2.1 | **1.3** |
| NSIC Rc160 | L-L | 2.8 | 2.8 | 2.8 | **1.9** | **1.6** | **1.3** |
| IR64 | I-I | 2.7 | 2.8 | 2.7 | 2.7 | 2.2 | 2.0 |
| NSIC Rc140 | I-I | 2.7 | 2.5 | 2.4 | **1.5** | **1.7** | **1.3** |
| PSB Rc72H | I-L | 2.7 | 2.8 | 2.7 | 2.6 | 2.4 | 2.5 |
| PSB Rc10 | H-I | 2.4 | 2.6 | 2.5 | 2.4 | 2.2 | 2.2 |
| NSIC Rc340 | H-L | 2.7 | 2.5 | 2.5 | 2.5 | 2.2 | 2.2 |
| *Set II* | | | | | | | |
| NSIC Rc21 | W-L | 3.0 | 3.0 | 2.8 | 2.3 | **1.8** | **1.2** |
| IMS2 | W-L | 3.0 | 3.0 | 2.8 | 2.7 | 2.4 | **1.3** |
| NSIC Rc170 | L-L | 2.8 | 2.7 | 2.7 | 2.4 | **1.5** | **1.2** |
| NSIC Rc142 | I-I | 2.8 | 2.3 | 2.4 | **1.8** | **1.4** | **1.2** |
| NSIC Rc158 | I-I | 3.0 | 2.8 | 2.6 | **1.7** | **1.4** | **1.3** |
| NSIC Rc106 | I-L | 2.8 | 2.6 | 2.5 | 2.3 | **1.5** | **1.3** |
| PSB Rc282 | H-I | 2.8 | 2.6 | 2.6 | 2.4 | **1.8** | **1.8** |
| PSB Rc44 | H-L | 2.6 | 2.3 | 2.1 | 1.9 | 1.9 | **1.2** |

Note: Samples were considered spoiled when sensory index reached 1.8 (Bruckner 2010).

**Table 2.** Spoilage index of rice varieties harvested at different seasons.

| Harvest Season | Sensory Index (SI) | | | | |
|---|---|---|---|---|---|
| | 0h | 15h | 18h | 21h | 24h |
| *IR64* | | | | | |
| 2014 DS | 3.0 | 2.9 | 2.8 | 2.1 | **1.7** |
| 2014 WS | 3.0 | 2.9 | 2.2 | **1.6** | **1.6** |
| 2015 DS | 3.0 | 2.9 | 2.9 | 2.5 | **1.7** |
| *NSIC Rc160* | | | | | |
| 2014 DS | 3.0 | 2.6 | **1.3** | **1.3** | **1.3** |
| 2014 WS | 3.0 | 2.4 | **1.8** | **1.4** | **1.3** |
| 2015 DS | 3.0 | **1.6** | **1.3** | **1.3** | **1.3** |

Note: The samples were considered spoiled when sensory index reached 1.8 (Bruckner 2010).

**Table 3.** Spoilage index of rice varieties with different cooking amount.

| Rice Variety | Sensory Index (SI) | | | | |
|---|---|---|---|---|---|
| | 0h | 15h | 18h | 21h | 24h |
| *IR64* | | | | | |
| 300g | 3.0 | 2.9 | 2.9 | 2.4 | **1.7** |
| 500g | 3.0 | 2.9 | 2.0 | **1.7** | **1.4** |
| *NSIC Rc160* | | | | | |
| 300g | 3.0 | **1.7** | **1.3** | **1.3** | **1.3** |
| 500g | 3.0 | **1.7** | **1.3** | **1.3** | **1.3** |

*The samples were considered spoiled when sensory index reached 1.8 (method from Bruckner, 2010).

**Table 4.** Spoilage index of reheated and unreheated rice samples.

| Rice Variety | Sensory Index (SI) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0h | 12h | 18h | 24h | 30h | 36h | 42h |
| *IR64* | | | | | | | |
| Without Reheating | 3.0 | 2.9 | 2.2 | **1.4** | **1.2** | **0.0** | **0.0** |
| With Reheating | | 2.9 | 2.8 | 2.8 | 2.7 | 2.3 | 2.2 |
| *NSIC Rc160* | | | | | | | |
| Without Reheating | 3.0 | 2.9 | 2.6 | 2.3 | **1.8** | **1.7** | **1.3** |
| With Reheating | | 2.9 | 2.9 | 2.7 | 2.8 | 2.2 | 2.2 |

**The samples were considered spoiled when sensory index reached 1.8 (method from Bruckner, 2010).*

**Table 5.** Spoilage index of rice varieties stored at different storage temperatures.

| Rice Variety | Sensory Index (SI) | | | | |
|---|---|---|---|---|---|
| | Day 0 | Day 1 | Day 2 | Day 3 | Day 4 |
| *IR64* | | | | | |
| Room | 3.0 | **2.1** | | | |
| Ref.Unreheated | | 2.8 | 2.5 | 2.5 | 2.4 |
| Ref. Microwave | | 2.9 | 2.4 | 2.7 | 2.6 |
| Ref. Steam | | 2.8 | 2.4 | 2.8 | 2.6 |
| *NSIC Rc160* | | | | | |
| Room | 3.0 | **1.9** | | | |
| Ref.Unreheated | | 2.6 | 2.4 | 2.3 | 2.1 |
| Ref. Microwave | | 2.8 | 2.7 | 2.6 | 2.5 |
| Ref. Steam | | 2.7 | 2.7 | 2.5 | 2.5 |

*The samples were considered spoiled when sensory index reached 1.8 (method from Bruckner, 2010).

**Visible-near-infrared spectroscopy for rapid assessment of grain quality of Philippine rice**

*JG Tallada, EH Bandonill, HM Corpuz, GG Corpuz, MA Ramos, LH Lopez Jr., NRL Sevilla*

The Rice Chemistry and Food Science Division receives approximately 1,500 early and advance rice lines for grain quality evaluation from breeders every harvest season. On top of this, the NCT requires measurement of grain properties of a great number of samples. Compounded to this is the desire for some studies within PhilRice to measure grain properties to take advantage of availability of grain samples, or to add more insight on the effects of the study parameters on grain quality, for example, nitrogen fertilization on grain protein contents. Evaluation for grain quality requires measurement of a number of physicochemical parameters that includes moisture, crude protein, apparent amylose contents, gel consistency, gelatinization temperature, whiteness, test weight, grain dimensions, amongst others. Quantification of most of these require chemical preparations that are not only quite hazardous to health and safety, but are long, tedious and very prone to errors. In addition, cost of consumables, such as chemicals and laboratory supplies contribute to the expense for analysis.

Visible-near-infrared spectroscopy is a rapid non-destructive technique that has the capability to simultaneously estimate a number of physical and chemical properties non-destructively from the samples with minimal or no sample preparations (e.g. drying and grinding). This technology would offer great advantages of high sample throughput, lower costs of analysis, greater time efficiency, and safety to the researcher and to the environment.

The main goal of this study is to develop prediction models for crude protein, gelatinization temperature and apparent amylose contents of milled rice, and some color parameters of the CIEL*a*b* from optical absorbance data collected from grain, brown rice, milled rice, and rice flour samples. Specifically, we want to know the form of rice samples (grain, brown, milled or flour) that can efficiently predict the target parameters. We also want to know the spectral pre-treatments and wavelength ranges that should be used for maximum accuracy of the predictions.

**Highlights:**

- The laboratory analysis results were still partial since the DS 2014 constituent analysis for crude protein were needed to be re-analyzed. All analysis for this sample set are expected to be completed on January 2016. Analysis for the WS 2014 has been completed. Chromometric parameters for CIEL*a*b* were also measured. Recently in December, additional samples from the NCT were analyzed and added to the sample set of this study.

- The Foss Food and Feed Analyzer 6500 of IPB, UPLB had a significant damage in its sample transport system and has to be repaired. In most part of 2015 the instrument was under repair as a component part had to be imported from the originating country. In the meantime, the CvSUInGaAs-based NIR instrument was used to obtain alternative absorbance data in the range 950 to 1650nm.

- Preliminary analysis and modeling of the entire sample set showed good prediction models for crude protein (Table 6 and Figure 1). Prediction models for amylose contents needed to be further refined and validated (Table 7). The Gelatinization Temperature models, in the meantime, were unstable, which would require further validation.

- Validation of the analysis procedures is being done to ascertain the relative errors that are realized for each of the constituents. This has marked effects on the accuracy of the model predictions.

- The performance statistics showed that in terms of accuracy in prediction, floured rice has the best while rough rice has the least statistical results among the four forms of rice.

- Further analysis and removal of possible outliers are needed for amylose contents specifically for the waxy parts.

**Table 6.** Summary of performance statistics for different spectral pre-treatments and forms (BR, FR, MR, RR) for 950-1650 nm wavelength range for crude protein (ncalibration= 90, nvalidation= 45).

| | Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| **BR** | | | | | | | | | | | | | |
| None | 12 | 0.913 | 0.348 | 0.350 | 3.42 | 0.964 | 0.224 | 0.225 | 5.31 | 0.929 | 0.336 | 0.323 | 3.63 |
| SNV | 13 | 0.932 | 0.307 | 0.309 | 3.87 | 0.977 | 0.177 | 0.178 | 6.73 | 0.942 | 0.305 | 0.301 | 4.00 |
| SNV + 1D | 12 | 0.811 | 0.512 | 0.515 | 2.33 | 0.972 | 0.198 | 0.199 | 6.01 | 0.807 | 0.525 | 0.531 | 2.33 |

BR- Brown Rice

| | Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| **FR** | | | | | | | | | | | | | |
| None | 12 | 0.941 | 0.287 | 0.289 | 4.15 | 0.970 | 0.204 | 0.205 | 5.83 | 0.946 | 0.278 | 0.281 | 4.39 |
| SNV | 12 | 0.951 | 0.260 | 0.261 | 4.58 | 0.978 | 0.174 | 0.175 | 6.86 | 0.951 | 0.267 | 0.269 | 4.57 |
| SNV + 1D | 12 | 0.845 | 0.464 | 0.467 | 2.56 | 0.989 | 0.126 | 0.126 | 9.47 | 0.731 | 0.632 | 0.638 | 1.93 |

FR - Flour

| | Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| **MR** | | | | | | | | | | | | | |
| None | 12 | 0.921 | 0.331 | 0.332 | 3.6 | 0.964 | 0.223 | 0.224 | 5.34 | 0.926 | 0.325 | 0.329 | 3.76 |
| SNV | 12 | 0.937 | 0.295 | 0.297 | 4.03 | 0.973 | 0.195 | 0.196 | 6.11 | 0.922 | 0.334 | 0.338 | 3.66 |
| SNV + 1D | 13 | 0.873 | 0.423 | 0.426 | 2.81 | 0.988 | 0.131 | 0.131 | 9.12 | 0.901 | 0.380 | 0.383 | 3.22 |

MR – Milled Rice

| | Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| **RR** | | | | | | | | | | | | | |
| None | 13 | 0.862 | 0.44 | 0.442 | 2.71 | 0.950 | 0.263 | 0.264 | 4.53 | 0.821 | 0.552 | 0.547 | 2.21 |
| SNV | 13 | 0.873 | 0.420 | 0.422 | 2.84 | 0.964 | 0.222 | 0.224 | 5.35 | 0.882 | 0.438 | 0.436 | 2.79 |
| SNV + 1D | 14 | 0.698 | 0.647 | 0.650 | 1.84 | 0.992 | 0.105 | 0.105 | 11.37 | 0.769 | 0.605 | 0.608 | 2.02 |

RR – Rough Rice

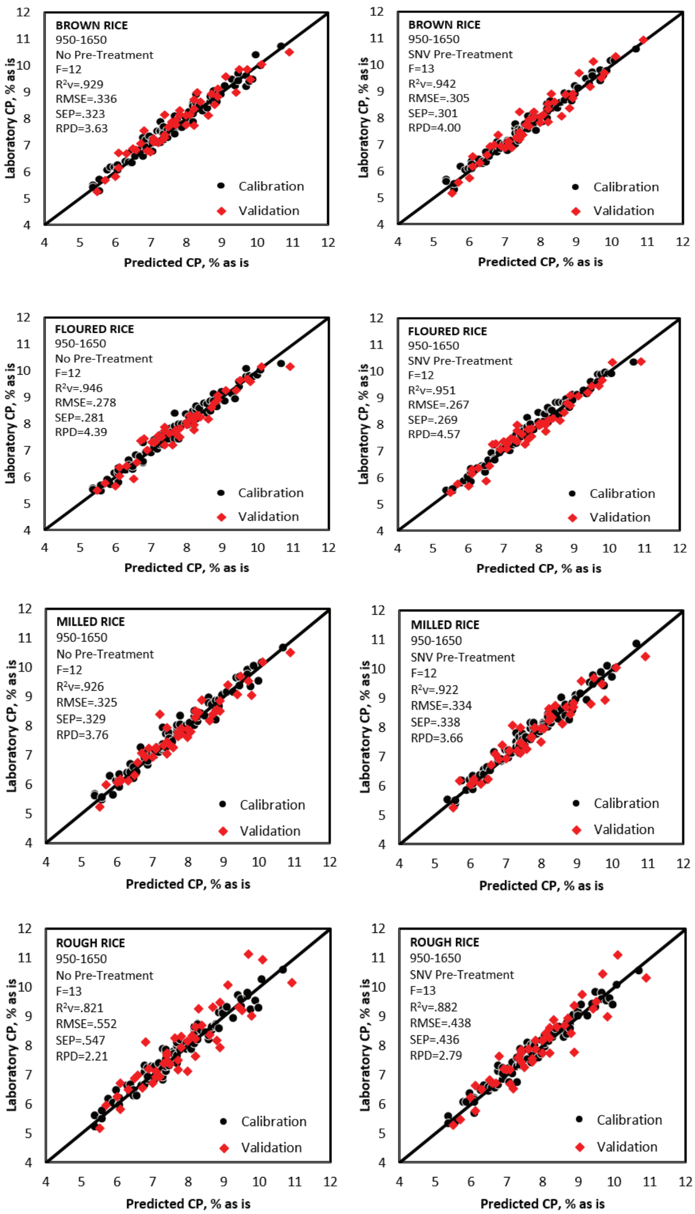


**Figure 1.** Scatterplots for prediction models for Crude Protein on a 950-1650 wavelength range of the four forms of rice.

**Table 7.** Summary of performance statistics for different spectral pre-treatments and forms (BR, FR, MR, RR) for 950-1650 nm wavelength range for Amylose Content (ncalibration= 90, nvalidation= 45).

| Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| 13 | 0.563 | 2.836 | 2.883 | 1.49 | 0.894 | 1.369 | 1.379 | 3.12 | 0.534 | 2.885 | 2.328 | 1.48 |
| 12 | 0.532 | 2.989 | 3.011 | 1.43 | 0.887 | 1.415 | 1.425 | 3.02 | 0.583 | 2.711 | 2.718 | 1.58 |
| 12 | 0.190 | 4.204 | 4.231 | 1.02 | 0.909 | 1.273 | 1.282 | 3.36 | 0.216 | 3.717 | 3.752 | 1.15 |

| Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| 11 | 0.813 | 1.833 | 1.846 | 2.33 | 0.912 | 1.249 | 1.258 | 3.42 | 0.533 | 2.844 | 2.880 | 1.50 |
| 10 | 0.808 | 1.853 | 1.866 | 2.30 | 0.904 | 1.307 | 1.317 | 3.27 | 0.577 | 2.703 | 2.738 | 1.58 |
| 10 | 0.659 | 2.467 | 2.484 | 1.73 | 0.944 | 0.999 | 1.006 | 4.28 | 0.418 | 3.240 | 3.264 | 1.32 |

| Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| 13 | 0.579 | 2.842 | 2.863 | 1.50 | 0.907 | 1.283 | 1.292 | 3.33 | 0.506 | 3.019 | 2.959 | 1.41 |
| 12 | 0.571 | 2.873 | 2.894 | 1.49 | 0.880 | 1.457 | 1.467 | 2.93 | 0.511 | 3.139 | 2.953 | 1.36 |
| 13 | 0.168 | 4.186 | 4.216 | 1.02 | 0.973 | 0.690 | 0.695 | 6.19 | 0.209 | 4.042 | 4.032 | 1.06 |

| Cross-validation | | | | | Calibration | | | | Validation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fcv | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD | Rsq | RMSE | SDE | RPD |
| 12 | 0.871 | 1.526 | 1.537 | 2.8 | 0.949 | 0.950 | 0.957 | 4.50 | 0.867 | 1.777 | 1.731 | 2.4 |
| 11 | 0.865 | 1.563 | 1.574 | 2.73 | 0.950 | 0.943 | 0.950 | 4.53 | 0.872 | 1.716 | 1.679 | 2.49 |
| 12 | 0.722 | 2.232 | 2.249 | 1.91 | 0.992 | 0.374 | 0.377 | 11.42 | 0.803 | 1.922 | 1.883 | 2.22 |

## II. Nutrition, Health, and Wellness Potential of Philippine Rice and Rice-Based Crops

This project aims to develop and validate methods of analyses for secondary metabolites and elemental composition in rice to enhance analytical capability of the division.

### Antioxidant Capacity and Antioxidant Components of Rice-Based Crops in the Philippines

*RVManaois, JEI Zapater, AVMorales*

Plants are known rich sources of biologically active compounds, mainly antioxidants, known to lower risks of life-threatening diseases, such as diabetes, cardiovascular diseases, and various forms of cancer. The Philippines has a wide array of plant foods, which could be tapped for health promotion and disease prevention and for the production of functional foods and nutraceuticals. Some of these foodstuffs are those that can be cultivated in rice farming areas. Such practice of planting of various crops in between rice cropping seasons is a key feature of agricultural integration and diversification currently being advocated by PhilRice. This study aims to evaluate the different local rice-based crops for their total antioxidant capacities and composition. Data generated from this study will aid in the production of high quality foodstuffs from rice growing areas and in consumer selection of products for health maintenance and disease prevention. Additionally, it would provide information on several factors that favor the maximum production of antioxidants in local foodstuffs.

**Highlights:**

- Rice-based crop samples were procured from the Palayamanan Plus farms in PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija (16) and San Rafael, Bulacan (1). Likewise, samples were collected from Bontoc, Mt. Province (4), Mt. Province (Table 8).The edible parts of the vegetables were washed thoroughly and a portion of each was subjected to cooking by boiling in unsalted water for 3 min for leafy vegetables, 4 min for legumes; and 5 min for okra and root crop and tuber samples. The raw and cooked samples were oven dried at 40ºC for at least 16hr, powdered, and stored prior to antioxidant extraction and analysis.

- Hydrophilic extraction was carried out using 85% methanol. Of the 17 hydrophilic extracts of the raw vegetable samples assayed for total phenolic content (TPC), jute had the highest concentration (31.78 mg GAE/gdry weight), while Mt. Province Squash had the lowest (1.08 mg GAE/g) (Table 2). Jute likewise contained the highest TPC in fresh weight basis (850 mg GAE/100 g). In raw form, the following had the highest TPC in fresh weight basis: jute>chili pepper (Mt. Province)>oyster mushroom>spinach>taro tuber.

- Table 10 shows the concentrations of total phenolic compounds in the hydrophilic extracts of the cooked (boiled) vegetable samples. The TPC ranged from 0.97 to 21.08 mg GAE/g dry weight, with eggplant containing the highest (Table 3). Chili pepper had the highest TPC in fresh weight basis (268.90 mg GAE/100 g) among the assayed cooked samples, followed by jute, cowpea (Sumilang), water spinach, and string beans.

- Cooking reduced the TPC of most rice-based crops by as much as 73% (Tables 9 & 10). Studies show that cooking, specifically boiling or blanching, significantly reduces the phenolic contents of rice-based crops (Azizah et al., 2009, Sultana et al., 2007, Kettawan et al., 2011) due to the breakdown of antioxidants, leaching into cooking water, oxidation by polyphenol oxidase, and isomerization (Ahmed and Ali, 2013, Takenaka et al., 2006). Water spinach (1.92 mg GAE/g DW and 14.26 mg GAE/100g FW) and squash (Mt. Province) (0.21 mg GAE/g DW and 2.51 mg GAE/100g FW), however, showed slight increases. Heat processing generally cause degradation in food components, including phenolics, as what was observed in sweet potato (Padda and Picha, 2008), brassica vegetables (Sikora et al., 2012), and legumes (Xu and Chang, 2008, Barroga et al. 1985). Conversely, increase in phenolic content in certain foods (e.g. corn) were also noted (Song et al., 2013, Dewanto et al., 2002). The said increase could be due to the release of phytochemicals, such as ferulic acid, from the matrix due to heat.

- The antioxidant capacity of the hydrophilic extracts were evaluated using the DPPH radical scavenging activity assay. The results are presented in Table 11. The five raw rice-based crops displaying the highest DPPH radical scavenging activity among the samples, expressed as fresh weight basis, were jute, taro (tuber), water spinach, chili pepper and spinach. Dry weight antioxidant capacities were in highest in the following samples: jute>eggplant>water spinach>taro (tuber)>okra.

- Table 12 shows that the cooked rice-based vegetables with the strongest DPPH antioxidant potential, in fresh weight basis, were jute, chili, sweet potato, water spinach and cowpea. Generally, antioxidant capacities decreased after heat processing, similar to those reported by other researchers (Kettawan et al., 2011, Tanongkankit et al., 2010, Oboh, 2005, Yamaguchi et al., 2001). As much as 92% (milky mushroom) of antioxidant capacity was lost after processing. Leaching of water soluble antioxidants, heat-induced degradation of components, and solid losses during processes are among the possible causes of the decreased antioxidant capacities in cooked samples (Xu and Change, 2007). On the contrary, improvement in antioxidant capacities was observed notably in sweet potato and chili pepper. It can be noted that phenolic content of these crops decreased after processing. This indicates that compounds other the phenolics that also exhibit high antioxidant activities were liberated or produced during the heating process.

- The TPC of the samples assayed generally corresponded to their DPPH radical scavenging activities, as shown by the positive correlations, particularly in raw forms (r=0.95, FW; r=0.92, DW). Cooked forms showed a less apparent trend.

**Table 8.** Rice-based crops procured for use in the experiment.

| Sample name | Tagalog Common Name | Scientific Name | Variety/ Description | Source |
|---|---|---|---|---|
| *Vegetables* | | | | |
| Bitter gourd, fruit | Ampalaya | *Momordica charantia* | Farmer's variety | Sagada, Mt. Province |
| Bottle gourd, fruit | Upo | *Lagenaria siceraria* | Farmer's variety | San Rafael, Bulacan |
| Chili pepper, fruit | Siling labuyo | *Capsicum frutescens* | Farmer's variety | Bontoc, Mt. Province |
| Eggplant, fruit | Talong | *Solanum melongena* | Morena | Muñoz, Nueva Ecija |
| Okra, fruit | Okra | *Abelmoschus esculentus* | Smooth Green | -do- |
| Squash, fruit | Kalabasa | *Cucurbita maxima* | Farmer's variety | -do- |
| Squash, fruit | Kalabasa | *Cucurbita maxima* | Gracia F1 | -do- |
| Squash, fruit | Kalabasa | *Cucurbita maxima* | Suprema | -do- |
| Oyster mushroom | Kabute | *Pleurotus florida* | | -do- |
| Milky mushroom | Kabute | *Calocybe indica* | | -do- |
| *Leafy vegetables* | | | | |
| Spinach | Alugbati | *Amaranthus viridis* | Green Amaranth | Muñoz, Nueva Ecija |
| Chinese cabbage | Petsay | *Brassica rapa* | Pavito F1 | -do- |
| Jute | Saluyot | *Corchorus olitorious* | Farmer's variety | -do- |
| Mustard | Mustasa | *Brassica juncea* | Monteverde | -do- |
| Water spinach | Upland Kangkong | *Ipomoea aquatica* | Tsina LP | -do- |
| *Pulses and legumes* | | | | |
| Cowpea, fruit | Sitaw na turo | *Vigna unguiculata* | Sumilang | Muñoz,Nueva Ecija |
| Cowpea, fruit | Sitaw na turo | *Vigna unguiculata* | Farmer's variety | -do- |
| String Bean, fruit | Sitaw na haba | *Vigna unguiculata* | Negrostar | -do- |
| *Rootcrops and tubers* | | | | |
| Sweet Potato, tuber | Kamote | *Ipomoea batatas* | Farmer's variety (Orange fleshed) | Sagada, Mt. Province |
| Taro, tuber and stalk | Gabi | *Colocasia esculenta* | Farmer's variety | Muñoz, Nueva Ecija |

**Table 9.** Total phenolic content of raw rice-based crops.

| Sample | Total Phenolic Content[1] | |
|---|---|---|
| | mg GAE/100g FW[2] | mg GAE/g DW[2] |
| Bitter gourd (Mt. Province) | 29.15 ± 0.93[ij] | 4.25 ± 0.23[fg] |
| Chili pepper (Mt. Province) | 286.21 ± 7.51[b] | 10.32 ± 0.27[c] |
| Eggplant | * | 22.52 ± 1.80[b] |
| Okra | 58.95 ± 1.75[fg] | 5.66 ± 0.04[de] |
| Squash (Mt. Province) | 27.75 ± 0.66[ij] | 1.08 ± 0.02[j] |
| Squash (Gracia F1) | 45.03 ± 1.22[gh] | 2.10 ± 0.02[ij] |
| Milky mushroom | 18.42 ± 0.49[j] | 2.14 ± 0.09[ij] |
| Oyster mushroom | 158.28 ± 16.76[c] | 3.13 ± 0.18[ghi] |
| Chinese cabbage | 89.48 ± 4.35[e] | 9.57 ± 0.46[c] |
| Spinach | 123.40 ± 2.21[d] | 6.79 ± 0.06[d] |
| Jute | 850.08 ± 9.32[a] | 31.78 ± 0.02[a] |
| Water spinach | 42.31 ± 0.46[hi] | 3.95 ± 0.12[fgh] |
| Cowpea (Sumilang) | 85.61 ± 3.02[e] | 6.29 ± 0.30[d] |
| String Beans | 60.41 ± 2.54[f] | 5.61 ± 0.15[de] |
| Sweet Potato (Mt. Province) | 112.44 ± 2.84[d] | 3.43 ± 0.13[fgh] |
| Taro, tuber | 113.10 ± 10.06[d] | 4.63 ± 0.33[ef] |
| Taro, stalk | 24.01 ± 0.56[j] | 2.85 ± 0.07[hi] |

**No sample available*
*[1]Mean of 3 replications ± SD. Mean values in the same column with the same letter are not significantly different at p=0.05.*
*[2] FW – fresh weight, DW – dry weight*

**Table 10.** Total phenolic content of cooked rice-based crops.

| Sample | Total Phenolic Content[1] | |
|---|---|---|
| | mg GAE/100g FW[2] | mg GAE/g DW[2] |
| Chili (Mt. Province) | 268.90 ± 3.27[a] | 10.27 ± 0.12[b] |
| Eggplant | * | 21.08 ± 1.30[a] |
| Okra | * | 4.28 ± 0.12[f] |
| Squash (Mt. Province) | 30.26 ± 0.16[f] | 1.29 ± 0.03[h] |
| Oyster mushroom | 10.11 ± 1.76[h] | 1.07 ± 0.12[h] |
| Milky mushroom | 4.89 ± 0.25[i] | 0.97 ± 0.03[h] |
| Chinese cabbage | 12.36 ± 0.98[hi] | 2.57 ± 0.17[g] |
| Jute | 130.76 ± 4.75[b] | 8.43 ± 0.31[c] |
| Water spinach | 56.57 ± 0.84[d] | 5.87 ± 0.16[d] |
| Cowpea (Sumilang) | 67.01 ± 6.11[c] | 5.36 ± 0.28[de] |
| String beans | 43.17 ± 2.38[e] | 4.47 ± 0.28[ef] |
| Sweet potato (Mt. Province) | * | 3.07 ± 0.55[g] |
| Taro, stalk | 19.22 ± 0.94[g] | 2.78 ± 0.08[g] |

**No sample available*
*[1]Mean of 3 replications ± SD. Mean values in the same column with the same letter are not significantly different at p=0.05.*
*[2]FW – fresh weight, DW – dry weight*

**Table 11.** DPPH radical scavenging activity of raw rice-based crops expressed in Trolox equivalents (TE).

| Rice-based crop | DPPH radical scavenging activity[1] | |
|---|---|---|
| | μmol TE/100g FW[2] | μmol TE/g sample DW[2] |
| Bitter gourd (Mt. Province) | 42.60 ± 2.82[h] | 6.42 ± 0.31[i] |
| Chili (Mt. Province) | 645.42 ± 21.20[d] | 21.96 ± 0.79[g] |
| Eggplant | * | 169.66 ± 1.41[b] |
| Okra | 390.84 ± 12.11[e] | 37.56 ± 1.40[e] |
| Squash (Gracia F1) | 33.19 ± 1.91[h] | 1.60 ± 0.13[i] |
| Chinese cabbage | 284.62 ± 8.41[fg] | 28.31 ± 0.82[f] |
| Jute | 4,613.52 ± 72.94[a] | 175.06 ± 0.32[a] |
| Spinach | 396.76 ± 22.45[e] | 22.00 ± 1.14[g] |
| Water spinach | 757.03 ± 80.70[c] | 69.45 ± 5.41[c] |
| Milky mushroom | 26.92 ± 1.93[h] | 3.05 ± 0.28[ij] |
| Oyster mushroom | 250.67 ± 19.55[g] | 4.90 ± 0.56[ij] |
| Cowpea (Sumilang) | 344.22 ± 20.60[ef] | 24.43 ± 1.82[fg] |
| String beans | 263.72 ± 21.37[fg] | 26.22 ± 2.08[fg] |
| Sweet potato (Mt. Province) | 212.60 ± 13.79[g] | 6.22 ± 0.35[i] |
| Taro, tuber | 1,059.28 ± 33.04[b] | 43.77 ± 0.52[d] |
| Taro, stalk | 87.98 ± 5.76[h] | 10.89 ± 0.72[h] |

**No sample available*
*[1]Mean of 3 replications ± SD. Mean values in the same column with the same letter are not significantly different at p=0.05.*
*[2] FW – fresh weight, DW – dry weight*

**Table 12.** DPPH radical scavenging activity of cooked rice-based crops expressed in Trolox equivalents (TE).

| Sample | DPPH radical scavenging activity[1] | |
|---|---|---|
| | µmol TE/100g FW[2] | µmol TE/g sample DW[2] |
| Bitter gourd | 48.19 ± 2.12[d] | 8.61 ± 0.24[e] |
| Chili pepper | 777.90 ± 17.97[a] | 28.59 ± 0.71[c] |
| Eggplant | * | 92.78 ± 0.56[a] |
| Okra | * | 23.30 ± 1.52[d] |
| Milky mushroom | 2.12 ± 0.24[d] | 0.43 ± 0.05 |
| Chinese cabbage | 48.03 ± 4.86[d] | 9.99 ± 0.74[e] |
| Jute | 807.30 ± 39.65[a] | 52.04 ± 2.46[b] |
| Water spinach | 539.89 ± 33.71[b] | 56.02 ± 4.14[b] |
| Cowpea (Sumilang) | 348.34 ± 20.97[c] | 27.90 ± 0.64[c] |
| Sweet potato | 745.15 ± 62.82[a] | 22.62 ± 2.58[d] |
| Taro, stalk | 75.85 ± 5.74[s] | 11.38 ± 0.54[e] |

**No sample available*
*[1]Mean of 3 replications ± SD. Mean values in the same column with the same letter are not significantly different at p=0.05.*
*[2]FW – fresh weight, DW – dry weight*

## Abbreviations and acronymns

ABA – Abscicic acid
Ac – anther culture
AC – amylose content
AESA – Agro-ecosystems Analysis
AEW – agricultural extension workers
AG – anaerobic germination
AIS – Agricultural Information System
ANOVA – analysis of variance
AON – advance observation nursery
AT – agricultural technologist
AYT – advanced yield trial
BCA – biological control agent
BLB – bacterial leaf blight
BLS – bacterial leaf streak
BPH – brown planthopper
Bo - boron
BR – brown rice
BSWM – Bureau of Soils and Water Management
Ca - Calcium
CARP – Comprehensive Agrarian Reform Program
cav – cavan, usually 50 kg
CBFM – community-based forestry management
CLSU – Central Luzon State University
cm – centimeter
CMS – cystoplasmic male sterile
CP – protein content
CRH – carbonized rice hull
CTRHC – continuous-type rice hull carbonizer
CT – conventional tillage
Cu – copper
DA – Department of Agriculture
DA-RFU – Department of Agriculture-Regional Field Units
DAE – days after emergence
DAS – days after seeding
DAT – days after transplanting
DBMS – database management system
DDTK – disease diagnostic tool kit
DENR – Department of Environment and Natural Resources
DH L– double haploid lines
DRR – drought recovery rate
DS – dry season
DSA -  diversity and stress adaptation
DSR – direct seeded rice
DUST – distinctness, uniformity and stability trial
DWSR – direct wet-seeded rice
EGS – early generation screening
EH – early heading
EMBI – effective microorganism-based inoculant
EPI – early panicle initiation
ET – early tillering
FAO – Food and Agriculture Organization
Fe – Iron
FFA – free fatty acid
FFP – farmer's fertilizer practice
FFS – farmers' field school
FGD – focus group discussion
FI – farmer innovator
FSSP – Food Staples Self-sufficiency Plan
g – gram
GAS – golden apple snail
GC – gel consistency
GIS – geographic information system
GHG – greenhouse gas
GLH – green leafhopper
GPS – global positioning system
GQ – grain quality
GUI – graphical user interface
GWS – genomwide selection
GYT – general yield trial
h – hour
ha – hectare
HIP - high inorganic phosphate
HPL – hybrid parental line
I - intermediate
ICIS – International Crop Information System
ICT – information and communication technology
IMO – indigenous microorganism
IF – inorganic fertilizer
INGER - International Network for Genetic Evaluation of Rice
IP – insect pest
IPDTK – insect pest diagnostic tool kit
IPM – Integrated Pest Management
IRRI – International Rice Research Institute
IVC – in vitro culture
IVM – in vitro mutagenesis
IWM – integrated weed management
JICA – Japan International Cooperation Agency
K – potassium
kg – kilogram
KP – knowledge product
KSL – knowledge sharing and learning
LCC – leaf color chart
LDIS – low-cost drip irrigation system
LeD – leaf drying
LeR – leaf rolling
lpa – low phytic acid
LGU – local government unit

LSTD – location specific technology development
m – meter
MAS – marker-assisted selection
MAT – Multi-Adaption Trial
MC – moisture content
MDDST – modified dry direct seeding technique
MET – multi-environment trial
MFE – male fertile environment
MLM – mixed-effects linear model
Mg – magnesium
Mn – Manganese
MDDST – Modified Dry Direct Seeding Technique
MOET – minus one element technique
MR – moderately resistant
MRT – Mobile Rice TeknoKlinik
MSE – male-sterile environment
MT – minimum tillage
$mtha^{-1}$ - metric ton per hectare
MYT – multi-location yield trials
N – nitrogen
NAFC – National Agricultural and Fishery Council
NBS – narrow brown spot
NCT – National Cooperative Testing
NFA – National Food Authority
NGO – non-government organization
NE – natural enemies
NIL – near isogenic line
NM – Nutrient Manager
NOPT – Nutrient Omission Plot Technique
NR – new reagent
NSIC – National Seed Industry Council
NSQCS – National Seed Quality Control Services
OF – organic fertilizer
OFT – on-farm trial
OM – organic matter
ON – observational nursery
OPAg – Office of Provincial Agriculturist
OpAPA – Open Academy for Philippine Agriculture
P – phosphorus
PA – phytic acid
PCR – Polymerase chain reaction
PDW – plant dry weight
PF – participating farmer
PFS – PalayCheck field school
PhilRice – Philippine Rice Research Institute
PhilSCAT – Philippine-Sino Center for Agricultural Technology
PHilMech – Philippine Center for Postharvest Development and Mechanization
PCA – principal component analysis
PI – panicle initiation
PN – pedigree nursery
PRKB – Pinoy Rice Knowledge Bank
PTD – participatory technology development
PYT – preliminary yield trial
QTL – quantitative trait loci
R - resistant
RBB – rice black bug
RCBD – randomized complete block design
RDI – regulated deficit irrigation
RF – rainfed
RP – resource person
RPM – revolution per minute
RQCS – Rice Quality Classification Software
RS4D – Rice Science for Development
RSO – rice sufficiency officer
RFL – Rainfed lowland
RTV – rice tungro virus
RTWG – Rice Technical Working Group
S – sulfur
SACLOB – Sealed Storage Enclosure for Rice Seeds
SALT – Sloping Agricultural Land Technology
SB – sheath blight
SFR – small farm reservoir
SME – small-medium enterprise
SMS – short message service
SN – source nursery
SSNM – site-specific nutrient management
SSR – simple sequence repeat
STK – soil test kit
STR – sequence tandem repeat
SV – seedling vigor
t – ton
TCN – testcross nursery
TCP – technical cooperation project
TGMS – thermo-sensitive genetic male sterile
TN – testcross nursery
TOT – training of trainers
TPR – transplanted rice
TRV – traditional variety
TSS – total soluble solid
UEM – ultra-early maturing
UPLB – University of the Philippines Los Baños
VSU – Visayas State University
WBPH – white-backed planthopper
WEPP – water erosion prediction project
WHC – water holding capacity
WHO – World Health Organization
WS – wet season
WT – weed tolerance
YA – yield advantage
Zn – zinc
ZT – zero tillage

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