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Characterization of Philippine Rice – a Case of Mixed Rice Variety

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This study presented variabilities in physico-chemical and microbial qualities of raw and resulting ready-to-eat (RTE) cooked rice prepared by a cook-chill processing system utilizing commercially available Philippine rice, marketed under the trade name *Super Angelica*. Significant variations (p < 0.05) in raw rice physical qualities were established based on the results of the grading and classification evaluation system described by the Philippine National Standards–Bureau of Agriculture and Fisheries Standards PNS/BAFS 290:2019 and amylose content. Likewise, variations in trends of texture cooked rice qualities were established in the resulting microwaved reheated chilled RTE rice stored up to 7 d in terms of hardness, cohesiveness, and adhesiveness. The pH values and microbial quality of reheated cooked rice were significantly affected by processing and storage conditions. The study recommended the strict implementation of the National Food Authority (NFA) Circular OCS-2018-J-0 that limits the classification of local commercial rice into four categories – namely, regular, well-milled, premium, and special – as an official replacement to the current use of market trade or fancy names for rice supplies. Likewise, the study cited the need for drafting a national regulation that will eventually reflect the actual cultivar names of rice being marketed in the country to avoid the rumbling of commercial rice.

Keywords: cook-chill processing system, fancy rice trade name *Super Angelica*, mixed rice variety, RTE cooked rice

INTRODUCTION

Rice (*Oryza sativa* L.) remains the main staple food in the Philippines with a total demand of 14.46 million metric tons based on the report of the Department of Agriculture in 2020 (DA 2020). Local consumers traditionally purchase low to intermediate amylose content table rice marketed under well-known local trade names like *Sinandomeng*, *Dinorado*, *Milagrosa*, *Super Angelica*, and *Wag-wag* (Macalalad *et al.* 2019). Filipinos prefer low to intermediate amylose content table eating rice that has long grain, mostly head rice, white, aromatic, and soft texture when cooked, as described by Juliano (2007). However, the different commercially available Philippine rice cultivars under the same fancy trade names are mainly too variable in quality due to the lack of guidelines and standards of quality parameters that are marketed based on the arbitrary use of popular trade names (Macalalad *et al.* 2019; Mataia *et al.* 2020).

Rice cultivars are generally mixed at various stages of harvest and post-harvest activities (Cuevas *et al.* 2016). The classification of the cultivar of rice grains by millers and traders remains through subjective visual inspection rather than the actual cultivar of rice, leading to unrestricted mixing of rice varieties (Cuevas *et al.* 2016; Macalalad *et al.* 2019). Other cited reasons for mixing rice cultivars include the practice of combining

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harvested rice from small land parcels, rice cultivars with lower grain quality having been blended and priced lower, and minimizing rice wastage by mixing different cultivar grains before disposal (Cuevas *et al.* 2016; Macalalad *et al.* 2019; Mataia *et al.* 2020).

The demand for controlled-quality rice cultivars is increasing due to changes in consumer preferences and strong quality control requirements by the market (Lapitan *et al.* 2007). Rice marketed under a single local trade name containing mixed rice cultivars has very variable qualities in terms of physicochemical parameters, morphological characteristics, and cooking properties of cooked rice for household and industrial use (Abera *et al.* 2021; Yadav *et al.* 2014). The marketing of commercial ready-to-eat (RTE) rice – particularly those prepared by cook-chill processing system, a method that involves cooking and rapidly chilling food products to extend the shelf life of cooked rice while maintaining their quality – is becoming more intolerant of substandard raw materials control and inconsistent quality parameters in cooked products, which would consequently fail to meet customer requirements (Abera *et al.* 2021; GPPB 2022; Syafutri *et al.* 2016). This study aimed to present the variabilities in physico-chemical and microbial qualities of raw and resulting RTE cooked rice prepared by a cook-chill processing system utilizing commercially available mixed rice variety marketed under one of the popular raw materials for table rice, with the trade name *Super Angelica.*

MATERIALS AND METHODS

Super Angelica Rice

The study utilized *Super Angelica* as the representative of a common local trade name of rice to present quality variations in the physico-chemical and microbial characteristics of commercially available mixed rice cultivars in the Philippine local market. A listing of common and popular trade names of raw milled rice in the local market was initially done through a review of related published and grey literature. *Super Angelica* was selected among the common and popular trade names used as raw material for table rice (Juliano 2007; Tuaño *et al.* 2016).

The study employed Google Search to identify major retailers of local *Super Angelica* raw milled rice in Metro Manila. Keywords used include "rice retailer," "rice seller," "rice market," "rice dealer," "rice supplier," "*Super Angelica*," and "Metro Manila market." The top four major retailers of *Super Angelica* raw milled rice in Metro Manila were selected, following the criteria of local *Super Angelica* raw milled rice material marketed within Metro Manila, Philippines. Rice retailers that were eliminated from consideration included those dealing in imported rice resources, retailing other fancy rice trade names, and those outside the Metro Manila Market.

Twenty-five (25) kg milled rice samples with a local trade name *Super Angelica* were then procured from four rice retailers in Metro Manila, Philippines – particularly from Marikina, Mandaluyong, Quezon City, and Parañaque. *Super Angelica* samples were stored in their original woven polypropylene packaging material at 27 ± 3 °C in the Food Product Development Laboratory at the College of Home Economics of the University of the Philippines Diliman until further evaluation. All raw rice samples were used and analyzed within 1 mo of purchase.

Raw Rice Physico-chemical Characterization

Quality and grading classification. The study utilized the defective analysis method recommended in grains – grading and classification – paddy and milled rice (PNS/BAFS 290:2019) for quality and grading classification of test raw milled rice samples. Representative primary samples, *i.e.* 1-kg rice sub-portions from sacks containing each of the test milled rice procured from various market sources, were prepared by compounding *Super Angelica* rice from the top, middle, and bottom portions from each of the rice packaging materials, as adopted from combined protocols by Kamara *et al.* (2015) and PAES 207:2000 (2000). Six 50-g sub-portions were eventually separated from each of the representative samples for the subsequent grading analysis shown in Figure 1. The parameters included in the quality grading were percentage head rice; broken rice; brewer's rice; damaged kernel, discolored kernel, chalky, red kernel, immature kernel, and foreign matter (PNS/BAFS 2019).

For the first three working samples, 10 whole grains were pre-selected in each working sample lot to establish the subtotal average length dimension of head rice using a vernier caliper as a measuring instrument. Based on the total average length dimension of the head rice, broken grains were measured as greater than 25% but less than 75% of the total average length of head rice, and brewer's rice was measured as equal or less than 25% of the total average length of head rice, as described by PNS/BAFS (2019). The determination of the total percentage of quality parameters on a by-weight basis (%head rice, %broken rice, and percent brewers) was based on Equation 1 (NFA 2022):

$$\text{\% Quality parameter} = \frac{\text{Weight of kernel per working sample (g)}}{\text{Weight of working sample (50 g)}} \times 100 \qquad (1)$$

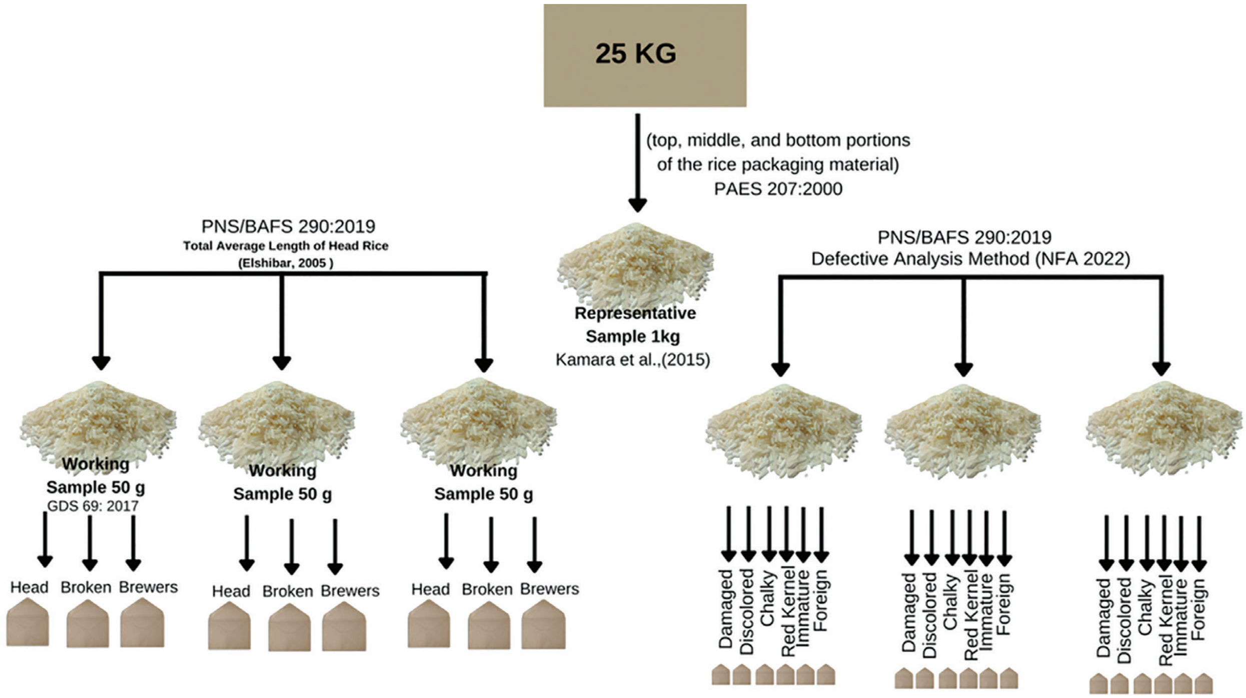


Figure 1. Sampling method prior to grading analysis adapted from the combined protocols by Elbashir (2005), GDS 69: 2017, Kamara *et al.* (2015), NFA (2022), PAES 207:2000, and PNS/BAFS (2019).

For the remaining three working samples, defective parameters were analyzed including damaged, discolored, chalky, red kernels, immature kernels, and foreign matter, as described in Appendix I. An individual kernel was inspected using a forceps and magnifying glass for the presence of the mentioned defectives criteria and was segregated into its defective kernel category. For kernels with multiple defects, the categorization priority order from highest to lowest of defect classification is as follows: damaged – discolored – chalky – immature kernel – red kernel (NFA 2022). Each grouping of defective kernels was segregated, and the percentage of defective parameters was calculated based on weight using Equation 1 (NFA 2022). Grades were determined based on criteria provided by PNS/BAFS (2019). The overall grade of milled rice is determined by the lowest grading among all the grade factors, in accordance with the guidelines stated in PNS/BAFS (2019).

Moisture content. The moisture content of *Super Angelica* raw rice from different market locations was measured using a rapid moisture analyzer (Ohaus, United States).

Amylose content. The apparent amylose content of milled rice samples was determined using the iodine-colorimetric method specified in ISO-6647-1-2015 (ISO 2015). The test rice samples were sent to the Philippine Rice Research Institute, Los Baños, Laguna, Philippines, and were stored in polyethylene ziplock resealable bags. The classification of amylose content for *Super Angelica* rice samples was based on PNS/BAFS (2019).

Cook-Chill Processing of RTE Rice

The cook-chill processing system utilized in the study was done at a 10-kg production level. Test rice samples were washed twice with water using a ratio of 1:3 (raw rice to washing water), and excess water was drained for a minimum of 2 min, following the method described by Li *et al.* (2019). The freshly washed and fully drained raw rice, with a cooking water ratio of 1:1.5, underwent steam cooking at a temperature of 100 °C for 1 h, adopting the combined procedures by Hasbullah *et al.* (2017) and Maleki *et al.* (2020).

After cooking, the newly cooked rice was placed in metal bowls and rapidly cooled in a chiller until it reached a temperature below 30 °C, as adopted from the work of Yu *et al.* (2009). The cooled rice samples were then packed and sealed in rice trays measuring 4 cm x 15 cm x 19 cm, containing 170 g of cooked rice, in an air-conditioned room at a temperature below 30 °C, as modified from the methods of Auksornsi and Songsermpong (2016) and Yu *et al.* (2009). RTE cooked rice was stored at a temperature below 4 °C for more than five storage days to assess the physicochemical and microbial qualities (Yu *et al.* 2009).

Physico-chemical Characterization of Microwaved Reheated RTE Cooked Rice

The cook-chill processing system allows five days of chilled storage based on the Codex Alimentarius Commission (CAC 1993), but the monitoring done in the study was beyond 5 d to observe the characteristics at the end of the declared acceptable shelf life of cooked rice. The test RTE cooked rice samples stored at a chilled temperature of < 4 °C for 1–7 d of storage were subjected to microwave reheating using a commercial microwave oven with dual touchpads (Sharp) operating at a power level of 1800 W for a duration of 60 s.

pH. The pH values were determined using the PH60 premium digital pocket pH meter (Apera Instruments). Microwaved RTE cooked rice samples were prepared using a 1:5 rice-to-distilled-water ratio.

Color. Color measurements of the microwaved reheated RTE rice samples for each day of storage were determined using ColorFlex EZ port forward dual-beam benchtop spectrophotometer (Hunter Associates Laboratory, Inc). In the CIELab color scale, L* = 0 (black), L* = 100 (white); –a* (green), +a* (red); and –b* (blue) and +b* (yellow) values were recorded. The color difference (*ΔE*) between the color of the first day of chilled storage and the seventh day of chilled storage per market location was calculated using Equation 2 (Federici *et al.* 2021):

$$\Delta E = \sqrt{(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2} \qquad (2)$$

where L_1*, a_1*, and b_1* were the color values of the seventh-day microwave-reheated RTE-cooked rice sample, whereas L_0*, a_0*, and b_0* were the color values of the first day of storage of microwave-reheated RTE cooked rice samples.

Texture profile analysis. The texture profile of the microwaved reheated RTE cooked rice samples was analyzed at the Department of Science and Technology Laboratory in Taguig, National Capital Region. The texture profiles of the test cooked rice samples were determined using Texturometer Model #TA Plus (LLOYD Instruments) at a test speed of 0.1 m/s through a compression plate probe with a load cell of 0.05 N to compress the rice kernel to 90% deformation.

Microbial Analyses of RTE Cooked Rice

The total plate count (TPC) and yeast and mold count (YMC) of the chilled stored and microwaved reheated RTE rice were assessed based on the procedures described in the Bacteriological Analytical Manual (USFDA 2001) and were presented in CFU/g.

Statistical Analysis and Interpretation

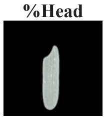
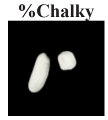
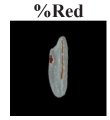
The results for each parameter were presented as mean values ± standard deviation. Mean differences were analyzed using one-way analysis of variance (ANOVA), except for the pH of microwaved (RTE) cooked rice, which was subjected to two-way ANOVA. The significance of the difference among means was determined by Duncan's multiple range test ($p < 0.05$) using SPSS software version 26 (SPSS Inc., Chicago, IL). Trends of the texture parameters during storage were analyzed by generating a scatter plot, fitting a line equation, and determining the coefficient of determination (R^2). The interpretation of the R^2 value was based on the descriptors provided by Saura (2018).

RESULTS AND DISCUSSION

Super Angelica Physico-chemical Quality and Grading Classification

Table 1 presents the quality and grading classification for *Super Angelica* rice supplies procured from four test retailers in Metro Manila, Philippines based on the PNS/

Table 1. Defective analysis results based on PNS/BAFS 290:2019 (Grains – Grading and Classification) of various *Super Angelica* fancy rice supplies marketed from various location in Metro Manila, Philippines.

Market location of rice	%Head 	%Broken 	%Brewer 	%Damaged 	%Discolored 	%Chalky 	%Red 	%Foreign 	Final grade**
Quezon City	78.07 ± 0.75[a]	21.94 ± 0.75[d]	0.17 ± 0.02[b]	5.24 ± 0.42[b]	0.39 ± 0.04[d]	0.59 ± 0.11[c]	0.08 ± 0.01[c]	0.00 ± 0.00[a]	5
Mandaluyong	66.97 ± 0.66[b]	33.03 ± 0.66[c]	0.25 ± 0.07[ab]	6.13 ± 0.19[b]	1.48 ± 0.16[a]	0.12 ± 0.02[d]	0.19 ± 0.03[b]	0.02 ± 0.00[a]	5
Marikina	60.55 ± 0.93[c]	39.45 ± 0.93[b]	0.37 ± 0.11[a]	4.93 ± 0.43[b]	1.14 ± 0.06[b]	1.94 ± 0.30[b]	0.25 ± 0.03[a]	0.02 ± 0.03[a]	5
Parañaque	49.98 ± 0.85[d]	50.02 ± 0.85[a]	0.27 ± 0.06[ab]	12.81 ± 0.74[a]	0.88 ± 0.14[c]	2.98 ± 0.27[a]	0.00 ± 0.00[d]	0.00 ± 0.00[a]	5

[a, b, c, d] Mean values of three trials ± standard deviation followed by the same letter(s) within the same column are not significantly different at 5% significance level

Entry values per parameter are color-coded based on PNS/BAFS 290:2019 (Grains – Grading and Classification): Premium, Grade 1, Grade 2, Grade 3, Grade 4, and Grade 5

*PNS/BAFS (Philippine National Standards–Bureau of Agriculture and Fisheries Standards) 290:2019 (Grains – Grading and Classification): grading entry for immature kernel parameter was evaluated; however, no immature kernel was graded for all the samples, resulting a Premium rating; grading for immature kernel was not presented in the table since no immature kernel was found from the four market locations of raw rice

**Grade of milled rice that exceeds the maximum limit or falls short of the minimum grade requirement for any grade factor or parameter of a given grade shall be given the next lower grade; the final grade level of rice was carried by the lowest grading from any grade factor based on PNS/BAFS (2019)

BAFS (2019). The test rice samples were rated premium grade for chalkiness, immature kernel, red kernel, and foreign matter parameters. Chalky center, red kernels, and foreign matter parameters were graded premium in the test rice samples, whereas no immature kernels were found – indicating high quality in terms of chalkiness, immature kernel, red kernel, and foreign matter, which positively contributes to the visual appearance of the cooked rice (Badi 2013; Xia *et al.* 2021).

Quality parameters such as brewer's rice, discolored rice, head rice, and broken rice were rated Grades 1–4 invariably for the test rice samples. The significant variability ($p < 0.05$) observed in head, broken, and brewer parameters were related to length dimensions. It has been reported that different cultivars having the same sizes could be a reason for mixing rice cultivars (Juliano 2010). The development of discolored kernels is due to high-temperature stress, and an increase in moisture content that may result in microbial activities and other chemical changes during storage, therefore, could not be associated with the reason for mixing of rice cultivars (Haydon 2016; Shad 2020).

The final grade of *Super Angelica* rice procured from four market locations was Grade 5, determined by the lowest grading among all the parameters evaluated – including damaged kernel percentage – and head rice and broken rice in at least two retail locations. The overall grade of milled rice is determined by the lowest grading among all the grade factors, following the guidelines stipulated in PNS/BAFS (2019). Damaged grains may be caused by insects, mold, water, and heat damage, which could develop off-odor and poor physical appearance, leading to low market value of rice (Badi 2013; Hossain *et al.* 2016).

Moisture Content

The mean moisture content of *Super Angelica* rice from three market locations (Mandaluyong, Marikina, Paranaque) conforms to the set value of ≤ 14%, as specified by PNS/BAFS (2019), whereas *Super Angelica* rice from Quezon City obtained a 14.12% moisture content exceeding the moisture requirement (Table 2). Moisture content with a set value of ≤ 14% is ideal for the prevention of grain deterioration, fungal infection, and pest infestations (PNS/BAFS 141:2019). However, rice exceeding 14% moisture content is not considered safe for storage (IRRI 2013). This shows the importance of maintaining the optimum ≤ 14% moisture content to allow 3 mo of storage (IRRI 2013; Mohd Ramli *et al.* 2021). Although not all procurement sites conform to the standard moisture content, this parameter cannot be used to directly indicate the commercial mixing of rice since this is caused by post-harvest storage handling (IRRI 2013).

Amylose Content

The amylose content of *Super Angelica* rice from different test rice retailers in Metro Manila ranged from 15.52–25.90%, as indicated in Table 3. Among the market locations, *Super Angelica* rice from Mandaluyong, Marikina, and Parañaque had an intermediate amylose content classification, whereas the test rice sample from Quezon City was classified as having low amylose content. The variation in amylose contents among the

Table 2. Moisture content of various *Super Angelica* fancy rice supplies marketed from various locations in Metro Manila, Philippines.

Market location	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean ± SD (%)
1. Quezon City	14.32	14.17	14.03	14.12	13.97	14.12 ± 0.14[a]
2. Mandaluyong	13.29	12.98	13.54	13.04	13.2	13.21 ± 0.22[c]
3. Marikina	13.35	13.43	13.15	13.19	13.2	13.26 ± 0.12[c]
4. Parañaque	13.81	13.41	13.77	13.85	13.8	13.73 ± 0.18[b]

[a, b, c] Mean values of five trials ± standard deviation followed by the same letter(s) within the same column are not significantly different at 5% significance level

Table 3. Amylose content* of various *Super Angelica* fancy rice supplies marketed from various locations in Metro Manila, Philippines.

Market location	Trial 1	Trial 2	Mean ± SD (%)	Amylose content classification*
1. Quezon City	16.02	15.02	15.52 ± 0.71[b]	Low
2. Mandaluyong	22.21	22.67	22.44 ± 0.33[a]	Intermediate
3. Marikina	22.33	22.36	22.35 ± 0.02[a]	Intermediate
4. Parañaque**	24.90		24.90 ± 0.00	Intermediate

[a, b] Mean values of two trials ± standard deviation followed by the same letter(s) within the same column are not significantly different at 5% significance level
*Amylose content classification based on PNS/BAFS 290:2019 (Grains – Grading and Classification – Paddy and Milled Rice)
**Amylose content of *Super Angelica* fancy rice from Parañaque was only evaluated for one trial

test rice samples could be attributed to several factors – including the rice cultivar types, diverse environmental conditions at the planting sites, harvest timing, grain storage conditions, and traditional mixing practices by millers and traders (Abera *et al.* 2021; Suryana *et al.* 2022). The results of the study indicated that the amylose content types of the test rice samples are generally low to intermediate range, conforming with the preference of local consumers for table-eating rice with a moderately tender to soft texture when cooked, as described by Felix *et al.* (2007) and Juliano (2010). Previous literature discussed the significant influence of amylose content levels in milled rice on the texture properties of cooked rice varying with different rice cultivars (Yu *et al.* 2009). The test rice samples exhibited amylose content levels ranging from low to intermediate, indicating variability that could potentially be attributed to the commercial practice of mixing rice cultivars.

Physico-chemical Qualities of Microwaved Reheated RTE Cooked Rice

pH. The pH values of microwaved reheated RTE cooked rice from four market locations ranged from 6.2–6.83 during the chilled storage period (Table 4). The two-way ANOVA showed that market location and storage days interaction had no significant effect on the pH level of microwaved reheated RTE cooked rice during chilled storage at temperatures below 4 °C. However, there was a significant difference detected between the pH values of rice samples and different market locations. Generally, cooked rice has a pH range of 6.2–6.8 (slightly acidic) (Moulavi *et al.* 2022). The pH of test microwaved reheated RTE cooked rice samples tended to be stable at the usual pH levels of cooked rice 6.2– 6.8 due to chilled temperature storage that inhibits microbial growth, which prevents the potential production of acids resulting from microbial activities (Nugrahanto *et al.* 2018).

Color. Figure 2 shows the color properties of microwaved reheated RTE cooked rice using *Super Angelica* raw rice supplies from market locations Quezon City, Mandaluyong, and Marikina for seven days under chilled storage. The statistical analysis showed that the storage duration significantly ($p < 0.05$) influences some of the L*, a*, and b* color values of microwaved reheated RTE cooked rice. The color properties of RTE cooked rice samples were all in the second quadrant of the a* and b* plane CIELab color space, with a Pantone value of 7534 C (Figure 2). L* values ranging from 79–82.54 were considered relatively high, indicating a lighter or brighter color of microwaved reheated RTE cooked rice samples, as described on the color scale by Bhuvaneswari *et al.* (2020). Previous literature reported that Asian consumers preferred cooked rice with a high degree of whiteness due to the visual appeal (Goodwin *et al.* 1992; Köten *et al.* 2020; Mundo and Juliano 1981).

ΔE values were calculated to determine the color difference of reheated RTE cooked rice from the first day to the seventh day of chilled storage. It has been reported that ΔE was used in the industry to measure the deviation of the color of a product and to establish allowable tolerance limits (Karma 2020). The calculated ΔE values ranged from 0.76–2.85. Test market locations that exhibited significant changes in L* values also obtained higher ΔE values, indicating that lightness value has a greater impact on the calculation of ΔE values for RTE cooked rice, whereas it may not be as relevant for a* and b* values. The perceivable changes in color observed during the seven-day storage period, as indicated by the calculated ΔE values, were found to be significant in the Quezon City test rice location only, based on the scale provided by Karma (2020). However, the Pantone values across different raw rice supply locations for 7-d storage remained the same for all samples, indicating a consistent color appearance based on the Pantone color system (Howard 2012). The color changes of RTE cooked rice in this study may have been the result of the combination effects of different cultivars, as well as the duration of storage of each of the component cultivars or as a mixed cultivar (Köten *et al.* 2020; Bett-Garber *et al.* 2011).

Table 4. pH level of microwaved reheated RTE cooked rice using *Super Angelica* raw rice marketed from various locations in Metro Manila, Philippines during chilled storage.

Market location	Storage days			
	1	2	4	7
Quezon City	6.62 ± 0.07^{az}	6.83 ± 0.13^{az}	6.66 ± 0.05^{az}	6.51 ± 0.23^{az}
Mandaluyong	6.23 ± 0.03^{bz}	6.24 ± 0.10^{bz}	6.20 ± 0.03^{bz}	6.38 ± 0.25^{bz}
Marikina	6.62 ± 0.31^{az}	6.74 ± 0.13^{az}	6.76 ± 0.08^{az}	6.75 ± 0.09^{az}

[a, b] Mean values of three trials ± standard deviation followed by the same letter(s) within the same column are not significantly different at 5% significance level
[z] Mean values of three trials ± standard deviation followed by the same letter(s) within the same row are not significantly different at 5% significance level

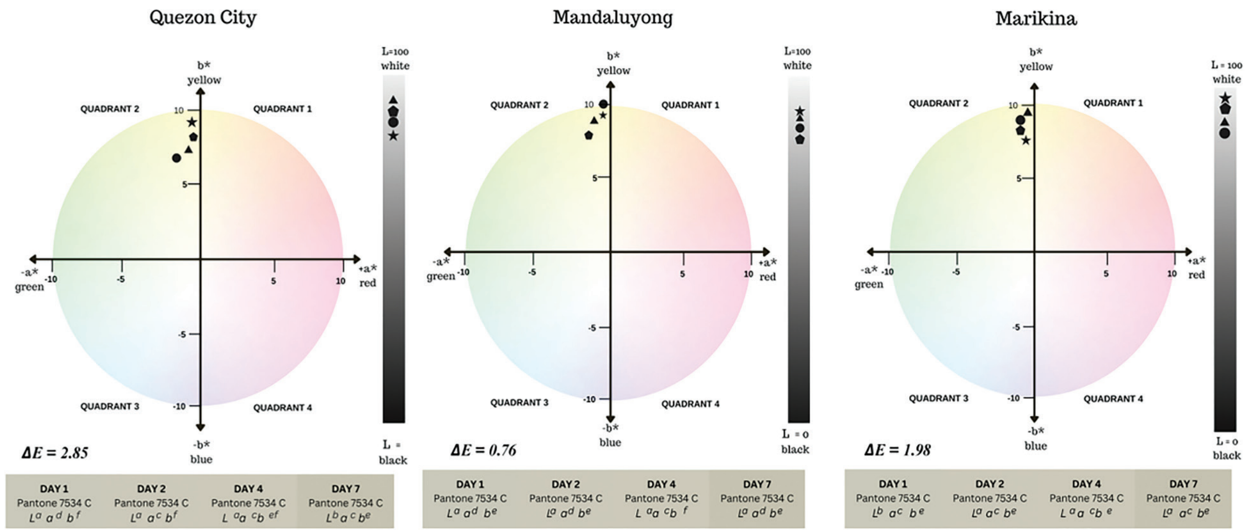


Figure 2. Color properties of microwaved reheated RTE cooked rice using *Super Angelica* raw rice marketed from three locations in Metro Manila, Philippines during 7 d of chilled storage.

[a, b] Same superscript letters within L^* values for storage days 1, 2, 4, and 7 per market location are not significantly different at a 5% significance level

[c, d] Same superscript letters within a^* values for storage days 1, 2, 4, and 7 per market location are not significantly different at a 5% significance level

[e, f] Same superscript letters within b^* values for storage days 1, 2, 4, and 7 per market location are not significantly different at a 5% significance level

a*, b*, and L* graphs: Day 1●, Day 2▲, Day 4 ⬟, and Day 7 ★ for respective color scales of microwaved reheated stored chilled RTE cooked rice

Texture profile. The texture of cooked rice is one of the most important factors influencing consumer preferences (Custodio *et al.* 2019). In general, Southeast Asians tended to prefer a softer and stickier (adhesive) texture of cooked rice that corresponds to low or intermediate amylose content (Custodio *et al.* 2019; Calingacion *et al.* 2014). Trend analysis of texture parameters including hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness of the microwaved reheated RTE cooked rice during storage were shown in Appendix II. Raw rice materials of processed RTE cooked rice sourced from Marikina showed a strong decrease in hardness and a strong increase in cohesion with storage while samples from Quezon City and Mandaluyong became more adhesive during storage. The amylose content of rice was previously correlated with the retrogradation behavior of rice starch during cooking and cooling processes, which – in turn – affect the textural properties of the cooked rice (Yu *et al.* 2009). It has been reported that differences in texture profiles of cooked rice during storage are associated with different amylose content levels of rice samples due to varying rice cultivars (Yadav *et al.* 2014; Yu *et al.* 2009). Therefore, variability in the trends of texture qualities of microwaved reheated RTE cooked rice during 7 d of chilled storage – using raw milled rice under the trade name *Super Angelica* sourced from various market locations – can be attributed to the differences in amylose content levels of the tested raw rice samples, which may possibly result from the commercial mixing of rice cultivars (Yadav *et al.* 2014; Yu *et al.* 2009).

Microbial Analyses of Microwaved Reheated RTE Cooked Rice

The TPC values of chilled (non-microwaved) RTE cooked rice were < 1.0×10^1 to 2.3×10^3 CFU/g, whereas the microwaved reheated RTE cooked rice during 7 d of chilled storage ranged between < 1.0×10^1 to 9.8×10^2 CFU/g. The microbial count of both chilled and microwaved reheated RTE cooked rice, stored for 7 d, was found to be within the acceptable limit specified by CFS (2014). TPC values exceeding 10^5 are considered unsatisfactory, based on the guidelines of CFS (2014). The results show that microwave heating of RTE cooked rice for 60 s reduced the total microbial counts of the reheated rice by 1–2 log CFU/g, as indicated in Appendix III (i and iii). Previous literature reported the effectiveness of microwave reheating in destroying microorganisms and inactivating enzymes, particularly psychotropic microorganisms that may survive under chilled conditions (Auksornsri and Songsermpong 2016).

The YMC for both microwaved and chilled stored (non-microwaved) samples consistently remained at 1.0×10^1 CFU/g for 7 d of monitoring in market locations in Quezon City, Mandaluyong, and Marikina – showing no significant difference (Appendix IV). The YMC values for chilled and microwaved RTE cooked rice samples obtained from four market locations were found to be within the acceptable limit range specified by the European Union (EU 2012). In a study conducted by Auksornsri and Songsermpong (2016), it was observed that the YMC of microwave RTE meal remained below 5 x 10^2 CFU/g throughout the 7-d storage period, showing that the chilled storage conditions at < 4 °C effectively inhibited the growth of yeast and molds.

CONCLUSION

The study presented variabilities in physico-chemical and microbial qualities of raw and resulting processed RTE cooked rice prepared by a cook-chill processing system utilizing commercial mixed rice variety marketed under a single trade name *Super Angelica*. Significant variations ($p < 0.05$) in raw rice were established in the results of PNS/BAFS (2019) grading and classification parameters – particularly in length measurements of head rice, broken rice, brewers, and the degree of kernel damage. Variations in grain dimensions may be explained by the mixing of rice at the level of millers-traders since high-head rice recovery is associated with competitive pricing (Mataia *et al.* 2020). Another parameter that resulted in high variation ($p < 0.05$) in the raw rice grading under PNS/BAFS (2019) grading and classification was discoloration, which, however, could not be used to justify the commercial raw rice mixing since this parameter is more associated with high moisture and temperature that may result in microbial activities, as well as other chemical changes during storage and other post-harvest parameters conditions (Shad 2020). Significant variations ($p < 0.05$) of moisture content established in this study also cannot be used to indicate the rumbling of rice because this parameter is associated with post-harvest storage handling of the rice supplies (IRRI 2013).

The amylose content of test rice samples ranged from low to intermediate levels showing variability, possibly resulting from the commercial rumbling practice. The color changes of microwaved reheated RTE cooked rice in this study could be attributed to the combination effects of different cultivars, as well as the duration of storage of each of the component cultivars or as a mixed cultivar (Yadav *et al.* 2014). Similarly, trend analysis of texture that can be directly attributed to the amylose content of microwaved reheated cooked chilled RTE rice indicated significance in terms of hardness, cohesiveness, and adhesiveness. Although pH values and microbial quality were included in the physical and microbial qualities of RTE cooked rice, these parameters were not identified as factors affected by the mixing of rice because these were considered significantly controlled by the processing and storage conditions of the RTE rice.

In summary, the study was able to present variabilities in raw rice grain quality dimensions and color and texture quality parameters of microwaved RTE cooked rice. These quality parameters can be linked directly to the commercial practice of mixing raw milled rice samples used as raw materials in the production of RTE rice products through the cook-chill processing system. Given this conclusion, raw rice cultivar control is very necessary for the standardization of the final cooking quality of resultant cooked rice products. It is, therefore, pertinent that strict quality control be placed in the marketing of commercial rice supplies in the Philippines – whether for family use or more significantly – for industrial use that requires more stringent observation of quality standards. The study recommends the strict implementation of NFA (National Food Authority) Circular OCS-2018-J-01 that limits the classification of local rice into four categories – namely, regular milled rice, well-milled rice, premium grade rice, and special rice – as a replacement for the use of current market trade or fancy names to prevent marketing of milled rice based on grain appearance. However, the study also looks forward to the drafting of national regulations that will eventually reflect the actual cultivar name of the rice being marketed in the country to address or prevent the practice of mixing rice nationally.

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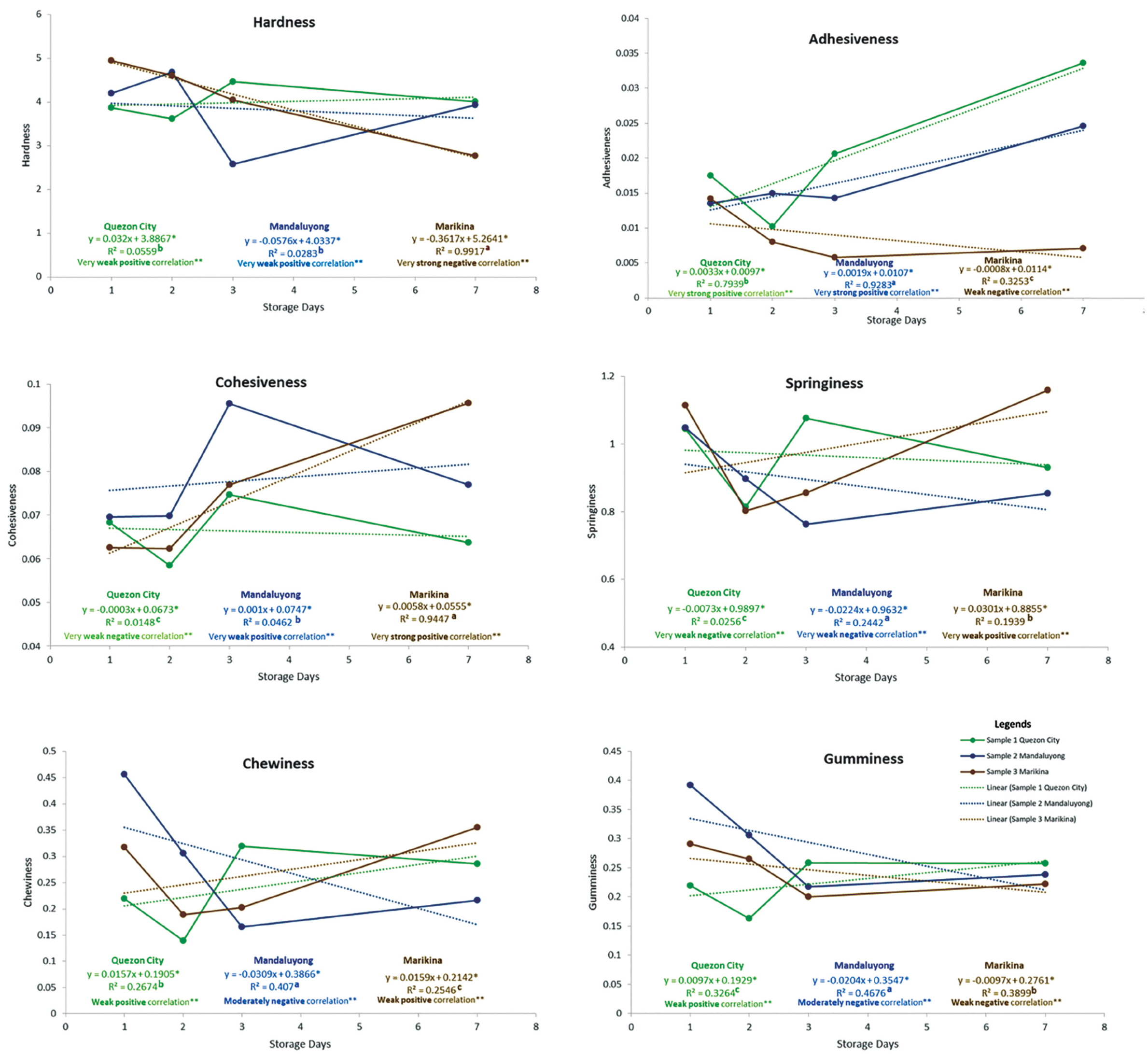
APPENDICES

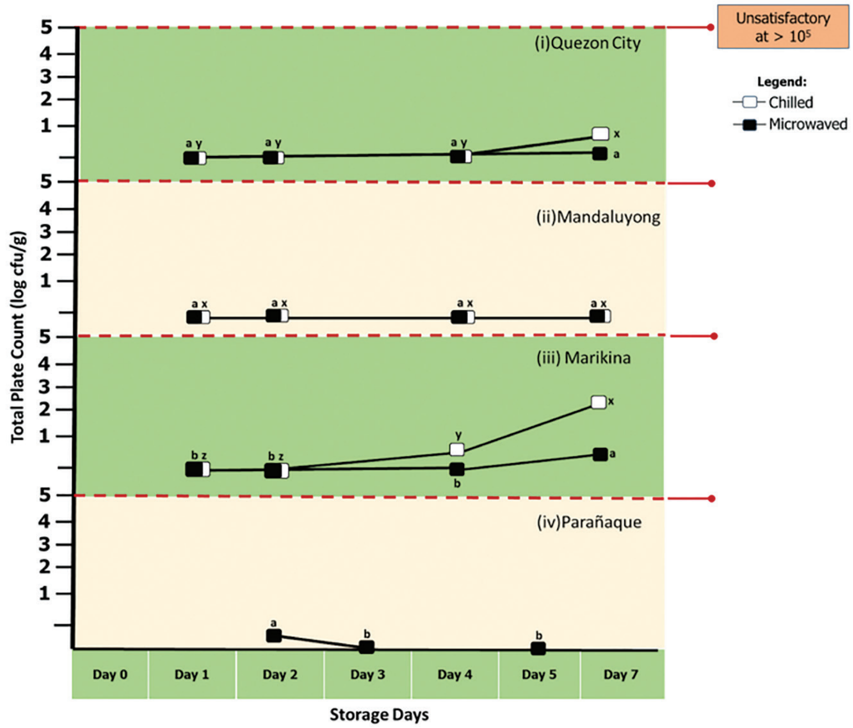
Appendix I. Rice defectives parameters (PNS/BAFS 2019).

Defective parameter	Quality parameter description [extracted from PNS/BAFS (2019)]
%Damaged	Grains that are obviously damaged by insects, water, diseases, and/or any other means seen by the naked eye
%Discolored	Kernels that have changed their original color as a result of heating and other means, or known as yellow kernels or fermented kernels
%Chalky	The chalky kernel is identified as the kernels, whole or broken, 50% or more of which is similar to the color of white chalk
%Red Kernels	Kernels that have red bran covering, wholly or partly
%Immature Kernel	Head rice or broken kernels that are light green and chalky with soft texture
%Foreign Matter	Foreign matters are all matters other than whole or broken rice kernels such as [a] foreign seeds, husks, bran, and [b] sand or dust



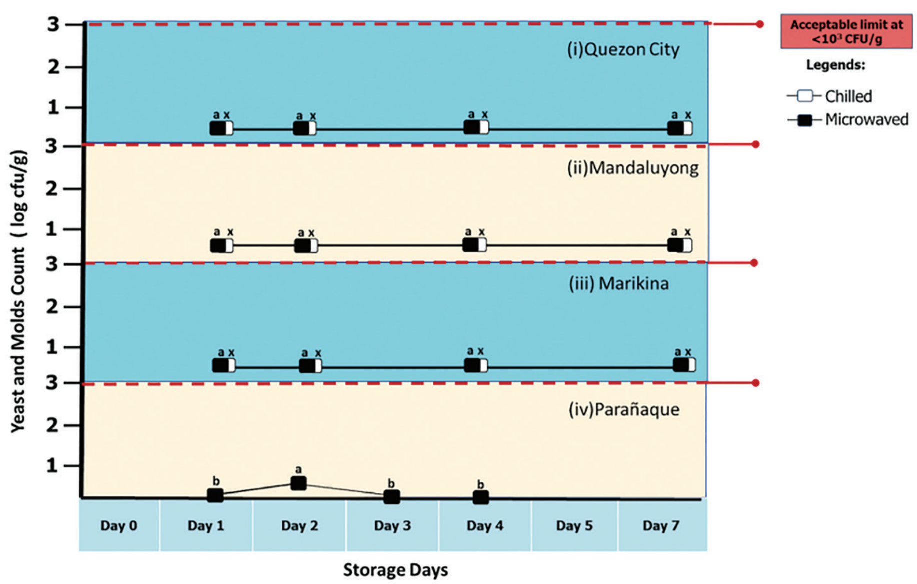
Appendix II. Trend analysis of TPA results based on the line equation* and descriptors** for R^2 of microwaved reheated RTE cooked rice using *Super Angelica* local trade name rice supplies marketed from various location in Metro Manila Philippines during seven days of chilled storage.

[a, b, c] R^2 of market location followed by the same letter indicate no significant difference at 5% significance level per texture parameter
*The best-fit line equation was obtained from three trials conducted for each of the texture parameters
**The descriptors for coefficient of determination (R^2) were based on the study of Saura (2018)



Appendix III. Total plate count (log CFU/g) of chilled (non-microwaved) and microwaved RTE cooked rice using Super Angelica raw rice marketed from various location in Metro Manila, Philippines during 7 d of chilled storage.

[a, b] Same letter(s) indicate no significant difference for microwaved RTE cooked rice at 5% significance level per market location
[x, y, z] Same letter(s) indicate no significant difference for chilled (non-microwaved) cooked rice at 5% significance level per market location



Appendix IV. Yeasts and molds count (log CFU/g) of chilled (non-microwaved) and microwaved RTE cooked rice using *Super Angelica* raw rice marketed from various location in Metro Manila, Philippines during 7 d of chilled storage.

[a, b] Same letter(s) indicate no significant difference for microwaved RTE cooked rice at 5% significance level per market location
[x] Same letter(s) indicates no significant difference for chilled (non-microwaved) cooked rice at 5% significance level per market location