Technical paper

Quality and Safety of Cambodian Rice

Sopheap EK¹, Sao SETKA¹, An MITHONA¹, Thor SEIHA¹, Kong THONG¹ and Kyoko SAIO^{2*}

¹*Grain Quality, Research and Extension Division, Faculty of Agro-Industry, Royal University of Agriculture (RUA)
Dangkor Khan, Phnom Penh, Cambodia*

²*Aikoku Gakuen Junior College 5-7-1 Nishikoiwa, Edogawa-ku, Tokyo 133-8585, Japan*

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While the quality and safety of rice, which is Cambodia's staple food, are recently attracting attention, the actual situation in Cambodia has not been researched or surveyed. In this work, 72 samples comprising 4 rice varieties, Neang Minh, Phka Khnei, Somali and Phka Rumduol, were collected from 3 shops in each of 6 local open markets of Phnom Penh and were analyzed. As physical measurements, grain moisture, grain weight and grain dimension were measured, and a grain scanner was used to measure: (1) whole and broken grains; (2) chalky, red and damaged grains; (3) level of accepted/defected grains; (4) level of mature grains; (5) glutinous grains; and (6) water-soaked cracked grains. In terms of biological measurements, the number of insects and the number and identification of bacteria and fungi were analyzed. The results showed that by variety, Somali and Phka Rumduol were generally higher in quality than Neang Minh and Phka Khnei. With respect to markets, some lacked good storage and selling conditions for some rice varieties. This market survey in Cambodia revealed that serious technical problems and challenges regarding quality and safety remain.

Keywords: Cambodia rice variety, market survey, Phnom Penh, physical and biological characteristics, grain scanner, Cambodia national standard

Introduction

Agriculture in Cambodia has been playing an important role in supporting economic growth and developing the rural economy (Royal Government of Cambodia, 2014). Rice cultivation covered 5 million hectares in 2013, accounting for about 68 % of the total arable land (MAFF, Cambodia, 2013). Agriculture related to rice cultivation employed about 49 % of the total labour force in 2013 and contributed about 28.6 % to the GDP in 2015 (MAFF, Cambodia, 2016). Rice is a staple food in Cambodia and accounts for at least 65 % of the energy intake in the diet of most Cambodians (Maltsoglou *et al*, 2010), who have a daily average consumption of 462 g/person (paddy, uncooked weight) (Seila Sar *et al*, 2012). The Cambodian government introduced a policy to promote paddy production and rice exports, setting a target of 4 million tons of paddy surplus and 1 million tons of milled rice exports by the end of 2015 (Royal Government of Cambodia, 2015). The policy also

recommended 10 rice varieties for export. However, realization of the export target is not likely. Large amounts of freshly harvested paddy have been unofficially exported to neighbouring countries. Paddy exported to Thailand and Vietnam is milled and distributed locally and/or exported to other countries as milled rice. This represents a huge lost opportunity for Cambodian rice farmers, millers and traders to add value to their product, export directly, and create employment locally.

In Cambodia, rice is transported as paddy (with hull), de-hulled and milled by millers located near the consumption area, and sold in local markets. The technical and hygienic conditions of millers and markets are not always sufficient. Rice in Phnom Penh markets includes products from the surrounding provinces and also from faraway places like Battambang, Takeo and/or other provinces.

In spite of growing concern for food security and safety in

*To whom correspondence should be addressed.

E-mail: k.saio@zb.cyberhome.ne.jp

Cambodia, there are almost no data on the safety and quality of Cambodian rice. Since 2015, the authors have discussed and studied the current status of rice quality in milling operations and market conditions, the effects of these treatments on the physicochemical properties of rice, the microbial contamination on grains in markets and possible solutions for controlling grain quality. Furthermore, the authors surveyed quality grade and biological qualities of rice samples marketed in 2016–2017.

Material and Methods

1. Material Milled rice samples of the 4 leading varieties, Phka Rumduol, Phka Khnei, Somali and Neang Minh (milled rice) were randomly collected from 3 shops in each of 6 markets (CKM, COM, DM, OM, RRPM and SMM; market names are abbreviated) in Phnom Penh on January 17, 2017. The selected 4 varieties are all Indica type, long grain and non-glutinous rice with aroma (the degree of aroma among varieties differs). The samples were stored separately in ordinary polyethylene film bags and kept at 5–10 °C in a refrigerator until analysis.

2. Methods

2.1 Subsampling In order to collect the amount required for assays from large quantity samples, machine sample divider (Satake Sample Divider TS-L) was used.

2.2 Measurement of 1,000 grain weight A sample of 100 grains was counted out, weighed and multiplied by 10.

2.3 Measurement of moisture content Moisture content was measured by a moisture meter (Kett PM 650).

2.4 Measurement of grain grade and physical quality

2.4.1 Rice grain grade To take measurements, 2 g (about 100 grains) of rice were placed on the tray of the grain scanner (Satake RSQI10A), and the shape and color of each individual grain, including images and graphs were recorded. Statistical data for the all samples were also displayed with histograms and average values. Specifically, white rice L was selected and clicked in the manual of the grain scanner (from brown rice S/M, brown rice L, brown rice Pb (parboiled), white rice S/M, white rice L, white rice Pb and other grains). Then, the Cambodian standard (from among Thai, India 1 and 2 and Cambodian) was selected. The length and width of grains were mechanically measured using 100 grains of whole rice while eliminating broken grains on the screen of the scanner. The rate of glutinous (waxy) grains and maturity level based on the parameter (following the calibration curves for white Indica rice) were also measured. In the measurement of accepts and defects, the acceptable grains and defective grains were differentiated after the Cambodian Standard was applied to determine the conditions of each quality grade. Here, Cambodian standard white rice long grain class 1 (over 6.6 mm) was classified into A, B and 5 other steps by the components (% of whole, large broken and small broken), contaminations (% of paddy seeds and other items), abnormal

seeds (% of damaged, red, red streak, chalky and yellow) and milling degree (extra, good and normal) for grain grade elements. The standard also classified length and width of a grain into C0 (over 7 mm), C1 (6.6–7.0 mm), C2 (6.2–6.6 mm) and C3 (5.4–6.2 mm) for whole grains and head rice BL (3–5.54 mm) and BS (0–3 mm) for broken grains.

2.4.2 Water-soaked cracked grain percentage A laboratory dish was filled with water, and 100 grains (about 2 g) were put into the dish. Changes in the grains were observed. Grains in which cracks formed at the ventral side were considered to be water-soaked cracked rice. The percentage of water-soaked cracked grains was calculated out of 100 grains.

2.5 Judgment of stored-product insects (major, primary pests) About 100 g of sample rice grains are kept at 28–30 °C for 2–6 months in vessels covered with cotton gauze. The appearance of harmful insects was recorded.

2.6 Bacteria and fungi counts Colony counts of aerobic bacteria were conducted on 4 rice varieties collected from 3 retailers in each of 6 local markets in Phnom Penh.

2.6.1 Counting and identification of bacteria Visible cell counts were determined by the plate count method and reported as CFU/mL (Asao, 2015). For the isolation and identification of visible bacteria cells, 72 samples of rice are diluted 10^5 times and isolation was conducted by the plate count method with standard agar (15–20 mL) held at 35 ± 1 °C for 48 ± 3 h (Asao, 2015).

2.6.2 Fungi detection Grains of rice were washed well and put on filter paper on a plate. After completely coagulating the agar (potato dextrose agar) on the plate, 4–5 washed grains were placed on the agar medium. The plate was kept at 20–25 °C for 10 days and examined for the growth of colonies around the grains. The ratio of the grains on which fungi grew and did not grow was determined (Morozumi, 2015). Identification of the species of fungi was done by color and comparisons to photographs.

2.7 Data analysis Most data analyses were done using descriptive statistics. Analysis of variance (ANOVA) was performed in Excel. For analyzing data, both quantitative and qualitative methods were used. For quantitative techniques, descriptive and analytical statistics such as charts, tables, graphs, frequency, percentage, mean, analysis of variance, and other appropriate methods such as preference ranking and indexing were used.

Results and Discussion

1. 1,000 grain weight

Comparison of the 1,000 grain weight for each variety in each market is shown in Fig. 1. Neang Minh (13.67 ± 0.40 g, NM) and Phka Khnei (13.51 ± 0.57 g, PK) had almost similar grain weight. Somali (18.81 ± 0.23 g, S) had the highest grain weight followed by Phka Rumduol (17.56 ± 2.46 g, PR) having considerable variation among markets.

Fig. 1. Weight of 1,000 grains

Table 1. Measurement of moisture content

Market	Neang Minh		Phka Khnei		Somali		Phka Rumdoul	
	% moisture	SD	% moisture	SD	% moisture	SD	% moisture	SD
CKM	11.12	0.33	12.49	0.20	11.03	0.28	12.69	1.30
COM	11.68	0.13	11.72	0.29	11.47	0.57	12.64	1.05
DM	12.80	0.25	12.10	0.62	12.89	0.53	11.39	0.86
OM	13.07	0.25	12.49	0.29	12.61	0.95	12.14	1.23
RRPM	13.49	0.32	12.20	0.46	12.51	0.89	11.22	0.69
SMM	11.39	0.47	12.38	0.38	11.56	0.32	12.96	1.17
Average	12.26	0.29	12.23	0.37	12.01	0.59	12.17	1.05

Fig. 2-1. Length of a grain

Fig. 2-2. Width of a grain

2. *Moisture content* Grain moisture content is shown in Table 1. All varieties were found to have almost similar percentages ranging from $12.01 \pm 0.59\%$ to $12.26 \pm 0.29\%$. However, differences were observed among markets. Neang Minh had the highest moisture content in RRPM ($13.49 \pm 0.32\%$) and lowest in CKM ($11.12 \pm 0.33\%$), and Phka Khnei was highest in OM and CKM ($12.49 \pm 0.29\%$ and $12.49 \pm 0.20\%$). Further, moisture content of Somali was highest in DM ($12.89 \pm 0.53\%$) and lowest in CKM market ($11.03 \pm 0.28\%$), and Phka Rumduol was highest in SMM ($12.96 \pm 1.17\%$) and lowest in RRPM ($11.22 \pm 0.69\%$).

3. *Grain length and width* In the comparison of grain length for each variety in each market (Fig. 2-1), Phka Rumduol (PR) was longest and Somali (S), Phka Khnei (PK) and Neang Minh (NM) followed with low variation among markets. For Phka Rumduol, grain length at COM, RRPM,

CKM, SMM, DM and OM was 7.31 ± 0.24 mm, 7.04 ± 0.14 mm, 7.19 ± 0.14 mm, 7.12 ± 0.21 mm, 7.11 ± 0.08 mm and 7.10 ± 0.22 mm, respectively. Grain width of each variety in each market showed no marked differences among varieties (Fig. 2-2), which is in contrast with the findings for grain length. Variation among markets was low but grain width of Somali at CKM was markedly high. These results suggest that variety characteristics are displayed more clearly in grain length than in grain width.

4 Rice quality grade

4.1 *Whole grain and broken grain* The Cambodian government proposed the Cambodian standard (Institute Standards Cambodia, 2016), which classifies whole grains into C0 (over 7.0 mm), C1 (6.6–7.0 mm), C2 (6.2–6.6 mm), C3 (5.4–6.2 mm) and broken grains into head rice (whole), broken L (3–5.54 mm) and broken S (0–3 mm).

Table 2-1. Quality grade of whole grains based on Cambodian standard

Variety	Market	Whole Grain								(%) of Total Whole grain	SD
		(%) Whole Grain C0(Over 7.0 mm)	SD	(%) Whole Grain C1(6.6–7.0 mm)	SD	(%) Whole Grain C2(6.2–6.6 mm)	SD	(%) Whole Grain C3(5.4–6.2 mm)	SD		
Neang Minh	CKM	5.00	2.87	9.91	6.24	8.36	3.99	11.26	2.54	34.52	11.39
	COM	7.28	5.90	8.09	5.73	6.17	2.25	6.39	2.74	27.92	12.14
	DM	5.77	1.26	9.43	4.44	8.12	2.47	3.89	0.59	27.21	8.40
	OM	2.46	2.23	1.99	1.61	4.22	1.81	4.32	1.28	12.99	4.01
	RRPM	2.68	1.29	2.69	2.28	4.36	2.85	4.60	3.47	14.32	8.32
	SMM	12.29	4.00	11.56	3.59	7.12	1.01	7.56	2.60	38.52	8.73
	Overall	5.91	2.92	7.28	3.98	6.39	2.40	6.34	2.20	25.91	8.83
Phka Khnei	CKM	21.10	19.03	12.70	1.44	7.84	2.61	6.46	2.82	48.10	16.65
	COM	17.19	2.54	18.74	3.19	22.76	2.54	16.30	3.53	74.99	2.33
	DM	8.30	2.46	6.73	3.71	7.12	2.52	6.06	0.47	28.21	8.00
	OM	12.10	8.42	12.08	9.41	9.96	4.85	6.12	1.96	40.26	21.27
	RRPM	11.21	2.17	12.47	5.10	10.79	1.83	7.06	2.81	41.52	5.78
	SMM	4.39	2.70	4.30	4.10	7.31	2.34	22.83	3.30	38.83	10.75
	Overall	12.38	6.22	11.17	4.49	10.96	2.78	10.80	2.48	45.32	10.80
Somali	CKM	32.96	7.26	17.04	6.52	9.62	3.36	6.51	1.28	66.13	12.41
	COM	46.50	27.50	12.48	4.52	6.39	2.38	5.36	2.22	70.72	19.22
	DM	43.23	8.66	14.50	1.90	9.54	2.77	5.58	1.37	72.86	5.30
	OM	39.24	2.91	11.81	1.74	7.12	1.85	4.61	0.80	62.79	6.00
	RRPM	46.93	11.91	16.92	5.51	9.09	3.32	5.44	2.92	78.39	8.58
	SMM	49.32	15.26	12.93	3.58	6.52	2.68	4.32	1.04	73.10	9.97
	Overall	45.05	13.25	13.73	3.45	7.73	2.60	5.06	1.67	71.57	9.81
Phka Rumduol	CKM	37.74	24.14	9.32	5.97	4.10	1.76	4.09	2.54	55.26	29.88
	COM	50.56	18.96	13.60	5.54	7.14	2.57	5.14	4.27	76.44	17.26
	DM	51.88	4.61	16.93	2.83	8.83	2.52	4.66	1.11	82.30	8.50
	OM	44.63	14.69	12.70	4.82	6.17	2.24	4.18	1.50	67.68	19.03
	RRPM	53.19	5.81	18.69	4.77	10.22	3.57	5.90	1.75	88.00	4.86
	SMM	34.02	16.95	12.48	5.76	5.78	2.29	4.09	1.21	56.37	17.36
	Overall	46.86	12.21	14.88	4.74	7.63	2.64	4.79	1.97	74.16	13.40

Table 2-1 shows the percentage of whole grains following the classification. This illustrates that the percentage of whole grains (C_0 , >7.0 mm) was markedly high for Somali (71.57 ± 9.81 %) and for Phka Rumduol (74.16 ± 13.40 %) with moderate variation among the 6 markets. The percentages of whole grains in C_1 , C_2 and C_3 were not markedly different also with moderate variation among the 6 markets. The whole grain percentage of Phka Rumduol and Somali was higher than the national standard (≥ 60 % for extra white rice) at 71.00 % and 70.66 %, respectively, which means that grains of these two varieties are ranked in the top grade of processing in the classification mill standard (100 % A) of Cambodia.

Table 2-2 shows the percentage of broken grains in each classification. This illustrates that the percentage of broken rice (BL + BS) for Neang Minh (74.09 ± 8.83 %) and Phka Khnei (54.68 ± 10.80 %) was significantly higher than for Phka Rumduol and Somali (25.84 ± 13.40 % and 28.43 ± 9.81 %, respectively) with moderate variation among the 6 markets. The percentage of head grains was higher for Phka Rumduol and Somali than for Neang Minh and Phka Khnei.

4.2 Chalky, red and damaged grains Table 3 showed the percentage of chalky, red and damaged grain in each variety and market. Chalky grains (26.87 ± 11.49 %) were frequently found, but red grains (0.41 ± 0.39 %) were few and damaged

Table 2-2. Quality grade of broken grains based on Cambodian standard

Variety	Market	Broken rice						(% of) Total Broken rice	SD
		Head rice	SD	(% of) Broken BL(3–5.54 mm)	SD	(% of) Broken BS(0–3 mm>=)	SD		
Neang Minh	CKM	3.74	0.95	41.96	4.92	19.78	8.45	65.48	11.39
	COM	5.23	1.40	49.20	12.63	17.64	5.22	72.08	12.14
	DM	7.64	2.02	38.57	4.44	26.58	8.03	72.79	8.40
	OM	2.93	1.08	52.61	5.93	31.47	1.87	87.01	4.01
	RRPM	2.42	1.2	56.92	3.95	26.33	11.23	85.68	8.32
	SMM	7.26	1.52	36.87	4.73	17.36	6.46	61.48	8.73
	Overall	4.87	1.36	46.02	6.10	23.19	6.88	74.09	8.83
Phka Khnei	CKM	4.73	2.33	35.53	9.70	11.63	7.71	51.90	16.65
	COM	4.98	1.29	19.28	2.49	0.76	0.51	25.01	2.33
	DM	4.50	0.77	49.09	8.69	18.20	2.44	71.79	8.00
	OM	6.04	2.31	43.33	17.73	10.37	5.70	59.74	21.27
	RRPM	4.72	0.97	40.29	7.67	13.47	4.85	58.48	5.78
	SMM	6.47	1.90	40.84	11.26	13.86	12.66	61.17	10.75
	Overall	5.24	1.60	38.06	9.59	11.38	5.64	54.68	10.80
Somali	CKM	5.28	2.08	23.69	7.51	4.90	5.64	33.87	12.41
	COM	4.89	0.84	19.11	12.42	5.28	7.27	29.28	19.22
	DM	13.68	2.57	12.22	3.44	1.24	0.74	27.14	5.30
	OM	18.51	3.36	14.21	1.99	4.49	2.36	37.21	6.00
	RRPM	10.86	4.30	9.40	4.06	1.36	1.58	21.61	8.58
	SMM	4.61	0.62	20.56	9.30	1.73	0.84	26.90	9.97
	Overall	10.51	2.34	15.10	6.24	2.82	2.56	28.43	9.81
Phka Rumduol	CKM	5.08	1.17	24.10	16.64	15.57	13.26	44.74	29.88
	COM	6.82	2.87	13.64	11.68	3.09	4.22	23.56	17.26
	DM	7.00	2.10	9.38	6.96	1.32	1.79	17.70	8.50
	OM	9.06	1.18	15.91	10.68	7.36	8.84	32.32	19.03
	RRPM	6.60	3.12	4.80	1.63	0.60	0.47	12.00	4.86
	SMM	8.07	1.37	25.10	10.83	10.47	9.11	43.63	17.36
	Overall	7.51	2.13	13.77	8.35	4.57	4.89	25.84	13.40

grains ($4.15 \pm 1.72\%$) were less than the 10 % level. The percentage of chalky and damaged grains for Neang Minh ($45.59 \pm 10.20\%$ and $7.21 \pm 2.69\%$, respectively) for Phka Khnei ($31.26 \pm 14.34\%$ and $4.50 \pm 2.04\%$, respectively) were higher than for Phka Rumduol ($11.87 \pm 8.80\%$ and $4.00 \pm 1.70\%$, respectively) and Somali ($18.78 \pm 12.60\%$ and $0.89 \pm 0.46\%$, respectively) with moderate variation among the 6 markets, similar to the results of measurement of broken grains.

The findings of chalky, red and damaged grains can be compared to the Cambodia Standard (for extra white rice and white rice long grain, class 1). According to the Cambodian standard, the percentage of chalky grains was too high. A

comparison of chalky grains values taken by a grain scanner and by classical judgment should be conducted. The percentage of damaged grains (including immature grains) was also high. The percentage of red grains was within the standard.

4.3 Glutinous rice grains Fig. 3 shows the percentage of glutinous (waxy) rice grains in each variety from each market. The percentage for Neang Minh ($4.16 \pm 1.49\%$, NM) and for Phka Khnei ($1.66 \pm 1.27\%$, PK) was higher and that for Phka Rumduol and Somali ($0.70 \pm 1.36\%$, PR and $0.59 \pm 0.74\%$, S, respectively) with moderate variation among the 6 markets.

Differentiation between glutinous and chalky grains appears to be a subtle distinction by use of a grain scanner.

Table 3. Percentage of chalky, red and damage grains

Variety	Market	Chalky	SD	Red	SD	Damaged and immature	SD
Neang Minh	CKM	49.620	8.790	1.140	1.053	4.160	1.607
	COM	46.110	12.066	0.420	0.259	10.770	2.069
	DM	56.730	4.541	0.700	0.957	11.430	4.259
	OM	51.260	9.210	0.960	0.566	5.780	2.171
	RRPM	16.470	17.032	0.320	0.376	1.020	1.140
	SMM	53.320	9.535	0.370	0.200	10.130	4.891
	Overall	45.585	10.196	0.652	0.568	7.215	2.690
Phka Khnei	CKM	31.030	12.137	0.310	0.176	3.390	3.053
	COM	7.360	1.536	0.290	0.162	4.030	1.620
	DM	52.070	15.546	0.190	0.190	5.070	1.050
	OM	28.130	13.777	0.280	0.222	5.300	2.043
	RRPM	28.770	16.185	0.880	1.596	3.200	1.605
	SMM	40.210	26.846	0.560	0.490	6.010	2.859
	Overall	31.262	14.338	0.418	0.473	4.500	2.038
Somali	CKM	21.310	9.576	0.360	0.588	0.280	0.161
	COM	19.280	17.045	0.370	0.308	3.080	0.764
	DM	20.000	11.094	0.090	0.093	0.180	0.088
	OM	23.160	18.874	0.120	0.164	0.210	0.094
	RRPM	17.930	15.872	0.100	0.132	0.170	0.097
	SMM	10.990	3.166	0.200	0.141	1.450	1.531
	Overall	18.778	12.604	0.207	0.238	0.895	0.456
Phka Rumdoul	CKM	15.630	11.797	0.170	0.166	3.000	1.301
	COM	9.640	8.714	0.620	0.640	2.980	2.173
	DM	10.090	8.941	0.120	0.109	4.780	1.256
	OM	12.710	7.978	0.760	0.621	4.760	1.685
	RRPM	8.180	4.508	0.110	0.093	3.420	2.105
	SMM	14.960	10.887	0.270	0.122	5.070	1.697
	Overall	11.868	8.804	0.342	0.292	4.002	1.703
Total		26.873	11.485	0.405	0.393	4.153	1.722

Fig. 3. Percentage of glutinous grains

Using the panel of the scanner, chalky grains were selected to have a Length of 5.2~999 mm, L^* 0~75, Chalky Area Ratio 0.5~1, while glutinous grain had Length 5.2~999 mm, L^* 75~100. Thus, glutinous grains are whiter (non-translucent)

than chalky grains.

On the other hand, Cambodia rice (as well as rice from South-East Asia) has wide differentiations in properties, ranging from glutinous to non-glutinous (Nakagahra *et al.*, 1986). The varieties used in this experiment were identified by variety name. However, many commercial rice crops in the Cambodian markets are a mixed variety. Further investigation is necessary to clarify whether the relatively high percentage of glutinous grains for Neang Minh and for Phka Khnei was either due to their specialty of variety or due to mixing with other glutinous varieties. Measurement by iodine staining should be done in order to compare both methods in the experiments using new crops.

4.4 Rate of accepted and defect grains As shown in Table 4, although there was considerable variation among markets, the factor of variety seemed to be a much more important factor. The comparison of accepted and defect grain percentage

Table 4. Accepted and defected grain from different markets in Cambodia

Variety	Market	Accepted		Defected	
		%	SD	%	SD
Neang Minh	CKM	40,11	6,63	59,89	6,63
	COM	40,64	11,51	59,36	11,51
	DM	34,71	5,07	65,29	5,07
	OM	40,58	9,43	59,42	9,43
	RRPM	41,31	16,15	58,69	19,23
	SMM	37,66	10,15	62,34	10,15
	Overall	39.17	11.49	60.83	10.34
Phka Khnei	CKM	62,37	13,48	37,63	13,48
	COM	74,87	3,05	25,13	3,05
	DM	39,79	14,03	60,21	14,03
	OM	62,34	14,16	37,66	14,16
	RRPM	62,59	15,41	37,41	15,41
	SMM	42,69	22,00	57,31	22,00
	Overall	57.44	13.69	42.56	13.69
Somali	CKM	71,80	9,14	28,19	9,14
	COM	72,93	19,83	27,07	19,83
	DM	74,98	11,66	25,02	11,66
	OM	72,47	18,53	27,53	18,53
	RRPM	77,36	16,07	22,64	16,07
	SMM	83,52	2,95	16,48	2,95
	Overall	75.51	13.03	24.49	13.03
Phka Rumduol	CKM	78,80	11,80	21,20	11,80
	COM	83,56	11,47	16,44	11,47
	DM	82,30	7,88	17,70	7,88
	OM	79,13	8,70	20,87	8,70
	RRPM	84,11	4,51	15,89	4,51
	SMM	75,60	13,40	24,40	13,40
	Overall	80.58	9.63	19.42	9.63

for each variety for each market showed that the acceptance ratio was very high for Phka Rumduol ($80.58 \pm 9.63\%$) compared to Somali ($75.51 \pm 13.03\%$), and both had a low percentage of defect grains ($19.42 \pm 9.63\%$ and $24.49 \pm 13.03\%$, respectively). On the other hand, the percentage of accepted grains for Neang Minh and Phka Khnei ($39.17 \pm 11.49\%$ and $57.44 \pm 13.69\%$, respectively) was low, while the percentage of defect grains for Neang Minh and Phka Khnei ($60.83 \pm 10.34\%$ and $42.56 \pm 13.69\%$, respectively) was high. This shows that Phka Rumduol and Somali were generally of better quality than Neang Minh and Phka Khnei.

4.5 Grain maturity The percentage of grain maturity depends on the weather of the flowering season. January to February in 2017 had more rainy days than in a usual year. The percentage of grain maturity was measured using a calibration curve in the grain scanner which was set previously based on white long rice samples with differentiated maturity. As shown

in Fig. 4, the comparison of grain maturity level (%) of each variety from each market showed the lowest for Neang Minh ($62 \pm 10.57\%$) while other rice varieties such as Phka Khnei ($85 \pm 6.56\%$), Phka Rumduol ($92 \pm 7.63\%$) and Somali ($97.23 \pm 3.20\%$) were higher. Phka Rumduol and Somali, which were shown to have good quality, were also high in maturity level.

4-5 Water-soaked cracked grains Based on the comparison of percentage of water-soaked cracked grains for each variety from each market (Fig. 5), the percentage was less than 1.2%. The percentage for Neang Minh ($0.92 \pm 0.24\%$, NM) and for Phka Khnei ($0.92 \pm 0.24\%$, PK) was slightly higher and that for Phka Rumduol and Somali ($0.57 \pm 0.44\%$, PR and $0.47 \pm 0.33\%$, S, respectively), with moderate variation among the 6 markets. The values seem to be insignificant for long grains. Previous papers (Lloyd *et al.*, 1999, Siebenmorgen *et al.*, 1998) reported that factors such as environmental relative humidity and temperature, moisture content during

Fig. 4. Percentage of matured grains

Fig. 5. Percentage of water-soak cracked grains

Fig. 6. Counted numbers of stored-product insect

drying, and stresses during milling can cause cracks.

5 Stored-product insects Fig. 6 shows the numbers of insects counted after storing the grains as described in the methods above. Insect counts were the highest for Neang Minh ($42.35 \pm 30.19\%$, NM) and the lowest for Somali ($14.44 \pm 17.61\%$, S) with considerable variation among markets. Market SMM had the lowest percentage ($3.42 \pm 3.06\%$) and was clearly lower than for other markets. The markedly lower value in SMM may suggest that good environment factors in the market can reduce insect growth.

6. Bacteria and fungi counts at different markets

6.1 Visible cell count in standard agar Fig. 7 shows the total plate counts for 4 rice varieties collected in different markets. Counts of samples were almost all less than

$5.000 \log_{10}$ CFU/mL. When considering variations among markets, Phka Rumduol (PR) had the lowest bacteria detection ($2.677 \log_{10}$ CFU/mL at COM). On the other hand, high levels of bacteria were detected for Neang Minh (NM, $5.350 \log_{10}$ CFU/mL at DKM) and Phka Khnei (PK, $5.026 \log_{10}$ CPF/mL at RRPM).

6.2 Isolation and identification of coliform bacteria in rice Coliform bacteria were not detected from any rice samples from retailers at 6 different local markets in Phnom Penh. Since no coliform bacteria were found, there are no data to report.

6.3 Fungi species As shown in Table 5, the results showed that microorganisms were not identified in many rice samples collected from the 6 markets, but the presence of fungi species were detected in some samples. The fungi detected in samples

Fig. 7. Visible cell counts in standard agar

Table 5. Detected numbers of fungi

Sample name	Somali (n=18)	Phka Khnei (n=18)	Phka Rumdul (n=18)	Neang Minh (n=18)	Number detected fungi (n=72)	%
RRPM	-	-	-	-	0	0
ORM	-	-	-	-	0	0
DKM	-	<i>Aspergillus flavus</i>	-	<i>Aspergillus ochraceus</i>	2	67
CKDM	-	-	-	-	0	0
SMM	-	-	-	-	0	0
COM	-	-	-	<i>Penicillium islandicum</i>	1	33
Total					3	

of Phka Khnei and Neang Minh from two markets DKM (n=2) and COM (n=1) were defined as *Aspergillus flavus*, *Aspergillus ochraceus*, and *Penicillium islandicum*. The results also showed that rice samples at COM had lower amounts of fungi (33 %) compared to those in at DKM (67 %).

The Cambodian Government is now considering how to reduce foodborne disease and how to improve public health by introducing food safety standards and market regulation into food industries. However, more effort is still required. The detection and identification of fungi will be continued in the market surveys in 2017–2018.

7. Conclusion Rice is a staple food and the most important cereal for human consumption in some areas of Asia. Different rice varieties and conditions during distribution result in physical, biological and chemical characteristics that vary significantly. This is potentially important in Cambodia, where rice is the major source of carbohydrate intake in the diet, which has many unique attributes, including ease of digestion, and mild flavor. Rice has played a mainstay role in the food culture and is important for the food security of the rural population.

In this work, quality characteristics of 4 Cambodian rice

varieties collected from 6 local markets in Phnom Penh were analyzed. The overall results showed that two rice varieties, Phka Rumdul and Somali, had rather high quality, while Neang Minh was considered to have low quality. All rice varieties analyzed in this paper were ranked as grade B according to the Cambodian Standard. Thus, serious technical problems and challenges remain to improve quality. There is a need to make further advances in the quality and safety of Cambodian rice.

Taking measurements by a grain scanner is one way to process many samples rapidly, however, it will be necessary to conduct further examinations.

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