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# Characterization of Physicochemical Properties and Microbiological Quality of Khmer Rice Vermicelli (*Num Banhchok*) Collected in Phnom Penh Capital, Cambodia

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**Abstract:** *Khmer rice vermicelli "Num Banhchok" is lightly fermented Cambodian rice noodles. Num Banhchok is commonly served as a breakfast noodle dish with curry soup or Khmer fish soup in the country. Food safety concerning microbiological contamination over Khmer rice vermicelli has escalated since the manufacturers and retailers lack hygiene practices with the family-scale of production. Here, this study aimed to assess the physicochemical properties and microbiological quality of Khmer rice vermicelli sold in markets in Phnom Penh city. Thirty Khmer rice vermicelli samples were collected from 11 wet markets such as Tom Nop, 7-Makara, Orussey, Kandal, Depo, Samaki, Kilo 4, Central, Toul Songkae, Olympic, and Kilo-7 markets. The physicochemical analysis, including pH, titratable acidity, moisture content, water activity ($a_w$), and color of L* values were carried out, while total plate count (TPC), total yeast and mold count (TYMC), lactic acid bacteria (LAB), Enterobacteriaceae, total coliforms (TC), Escherichia coli (E. coli), Staphylococcus aureus (S. aureus), and Bacillus cereus (B. cereus) were considered in microbiological analysis. The results showed that the values of pH, acidity, moisture content, water activity ($a_w$), and color of L* values ranged from 3.78-4.35, 0.09-0.19%, 68.07-76.07%, 0.9818-0.9883, and 64.16-73.94, individually. In terms of microbiological contamination, the samples were ranged with TPC (3.6-6.0 logs CFU/g), TYMC (3.3-5.5 logs CFU/g), LAB (2.9-4.9 logs CFU/g), Enterobacteriaceae (0.3-3.6 logs CFU/g), TC (0.4-3.6 logs CFU/g), E. coli (0.3-1.8 logs CFU/g), S. aureus (1.8-4.8 logs CFU/g), and B. cereus (1.9-4.8 logs CFU/g). The numerous microbial contaminants in Khmer rice vermicelli could be an indicator of the lack of sanitation by food handlers or producers, as well as poor environmental conditions in the production line and marketplaces affecting Khmer rice vermicelli quality.*

**Keywords:** Khmer rice vermicelli; Microbiological quality; Pathogenic bacteria; Food safety; Food quality

## 1. INTRODUCTION

Rice (*Oryza sativa L.*) is a staple food in most Asian countries that are regularly consumed as cooked milled rice [1]. In Cambodia, rice is approximately cultivated on 85% of the total land [2]. Rice produced 10.8 million metric tons in 2018, accounting for over half of the country's agricultural GDP [3]. Rice is a primary food source for the Cambodian population, served for primary meals, rice-based snacks, and desserts. Domestic rice varieties in Cambodia are made of various rice-based products such as Khmer rice vermicelli (*Num Banhchok*), *Banh Hoy*, *Banh Kanh*, *Koyteavkat*, and *Koyteav* [4]. Almost all of these rice-based products were initially made from *indicia rice* varieties, which have a higher amylose content than *japonica rice* varieties [5]. Khmer rice vermicelli is traditionally made from long-grain rice with high amylose content (>22% amylose). The high amylose content of rice provides bright color to rice vermicelli [1,6].

*Num Banhchok* is typically made on a family scale, in Cambodia, with poor sanitation and a short shelf-life, which contaminate bacteria [7]. Cambodia does not have a standard Num Banhchok manufacturing yet; mostly, Num Banhchok is

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daily produced approximately a hundred kilograms per day on a family-scale. The consumption of non-hygiene Num Bachchok contaminated with pathogenic bacteria primarily causes food poisoning and is harmful to the human [4]. Nevertheless, microbial activities can alter physicochemical parameters such as pH, titratable acidity, moisture content, water activity ($a_w$), and color variables [8]. The low pH and rise in titratable acidity are probably due to the ammonia liberated by proteolytic bacteria priority to acidification by lactic acid bacteria and also other types of microorganisms during the fermentation process [8]. Fresh rice vermicelli is particularly vulnerable to spoiling due to the high moisture content and water activity [9]. Moreover, the presence of water in vermicelli affected the protein concentration and its structure. Afterward, a drop in reflectance with a reduction in the color value of L* may be caused by changes in the orientation of protein molecules and protein structure [10]. The color and appearance are important indicators of the product's quality [11,12].

Microbial contamination is a recognized factor affecting rice vermicelli quality. The presence of a higher amount of total plate counts, and total yeasts; and mold count indicate an inadequate processing procedure, such as inappropriate cleaning, sanitation, and storage conditions [13]. Lactic acid bacteria contamination shows that the product is spoiled during the fermentation process and storage period [14]. *Enterobacteriaceae,* and total coliforms bacteria contamination display poor environmental conditions, lack of hygiene practices, as well a cross-contamination processes, while the presence of *Escherichia coli* illustrates fecal contamination. In this stage, the presence of a larger number of *Staphylococcus aureus* and *Bacillus cereus* demonstrates the presence of toxins [15]. For instance, in 2014, the 143 people with vomiting and acute diarrheal rapidly increased to 215 people within a few hours after consuming Khmer rice vermicelli in Kandal province caused by *Staphylococcus aureus* [16]. In 2016, around 1,000 outbreaks of food poisoning were reported across Cambodia [4, 15].

The consequence of microorganisms, the influencing the physicochemical characteristic of rice vermicelli quality, as well as the lack of literature review on food safety and quality, the study on Khmer rice Vermicelli quality is conducted. The objectives of these studies are to investigate the physicochemical properties focused on pH, titratable acidity, moisture content, water activity ($a_w$), and color parameters; to assess microbiological quality including total plate count (TPC), total yeast and mold count (TYMC), lactic acid bacteria (LAB), *Enterobacteriaceae,* total coliforms (TC), *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), and *Bacillus cereus* (*B. cereus*) of Khmer rice vermicelli that are collected in Phnom Penh capital.

## 2. METHODOLOGY

### *2.1. Sample collection*

Thirty Khmer rice vermicelli samples were randomly collected from the wet markets in Phnom Penh capital. The samples were selected from eleven markets by using MAPS.ME app to show the locations that are presented in Table 1. All of the samples were placed in the sterilized air tight plastic bag and kept in a cool box with ice, then transported to the laboratory for analysis at the Institute of Technology of Cambodia.

**Table 1** Sampling location

| Markets | Geographic Coordinates |
|---|---|
| Tom Nop | 11°35′27.40″N,104°53′52.66″E |
| 7 Makara | 11°34′29.89″N,104°54′01.17″E |
| Orussey | 11°33′48.85″N,104°54′55.67″E |
| Kadal | 11°34′09.86″N,104°55′43.43″E |
| Depo | 11°33′50.06″N,104°54′23.92″E |
| Samaki | 11°34′06.52″N,104°54′03.83″E |
| Kilo 4 | 11°33′54.97″N,104°53′47.14″E |
| Central | 11°34′10.35″N,104°55′13.35″E |
| Toul Songkae | 11°35′30.69″N,104°54′25.68″E |
| Olympic | 11°33′09.57″N,104°54′37.92″E |
| Kilo 7 | 11°37′54.83″N,104°53′54.17″E |

### *2.2. Sample preparation*

The samples were weighed and homogenized by using Ultra Turrax homogenizer (T-25 digital ULTRA-TURRAX®-IKA, Germany) at 10000 rpm for 30 seconds priority to pH, titratable acidity, and microbiological analysis.

### *2.3. Physico-chemical analysis*

#### *2.3.1. pH and titratable acidity*

Five grams of the sample were weighed and mixed with 45 ml of distilled water in the 100 ml Erlenmeyer flask and were homogenized. Afterward, the pH of the solution was measured by a pH-meter (LAQUA F-72-HORIBA), as *expressed* in AOAC Official Method 981.12 [17]. Titratable acidity was analyzed by using the titration method, as described in AOAC Official Method 942.15 [17].

#### *2.3.2 Moisture content*

Two grams of each sample were weighed and put in a dried aluminum capsule, then placed in an oven for drying (model UM300) at 105 °C for 3 h until the constant mass was obtained, as reported in AOAC Official Method 925.10 [16]. The moisture content was determined as the following equation

$$\%MC = [W_2\text{-}(W_3 - W_1) / W_2] \times 100 \quad \textbf{(Eq. 1)}$$

where:
%MC = percentage of moisture content

$W_1$ = weight of the wet sample (g)
$W_2$ = weight of sample and aluminum before drying (g)
$W_3$ = weight of sample and aluminum after drying (g)

### 2.3.2. Water activity ($a_w$)

Two grams of the sample were chopped into small pieces and weighed. The water activity was measured by using a water activity meter (AQUALAB 4TEV) at the ambient temperature, as described in AOAC Official Method 978.18 [17].

### 2.3.3. Color measurement

The color of the sample was measured by using a portable colorimeter (Chroma CR400, Tokyo, Japan). The parameters were expressed in L* value (black to lightness), a* (- is greenness and + is redness), and b* (- is blueness and + is yellowness), which were recorded using a D65 illuminant on the color scale of fresh rice vermicelli [14].

### 2.4. Microbiological analysis

Twenty-five grams of the sample was weighed and mixed with 225 ml of 0.85% (NaCl) sterile saline solution homogenized. From the first dilution, 1 ml of the samples was aseptically diluted into another 9 ml of sterile saline water to make the serial dilutions from $10^{-1}$ to $10^{-3}$. Next, by using the spread plate method, 100 µl of each dilution were transferred onto sterile Petri dishes containing the agar gel of the Plate Count Agar (PCA, Merck, Germany), Potato Dextrose Agar (PDA, HiMedia, India), Baird Parker agar (BP, Merck, Germany), and Mannitol-egg-Yolk Polymyxin agar (MYP, Merck, Germany) for total plate count, total yeast and mold count, *Staphylococcus aureus*, and *Bacillus cereus* analysis, respectively. Afterward, by using the pour plate technique, 1 ml of diluted sample was pipetted onto empty Petri dishes and molten De Man, Rogosa and Sharpe broth (MRS, HiMedia, India), Violet Red Bile Glucose agar (VRBG, Hiedia, India), and Chromocult® Coliform Agar (CCA, Merck, Germany) were added to investigate lactic acid bacteria, *Enterobacteriaceae,* total coliforms and *Escherichia coli*, individually. Each microbiological analysis was made into a duplicate of the plate petri dish and incubated at 37°C for 24 - 48 h based on the bacteria growth. The colony counting number is displayed as colony-forming units per gram (CFU/g).

### 2.4 Statistical analysis

All data obtained in this research were expressed as mean values ± standard deviation (STD). One-way analysis of variance (ANOVA) was performed by using SPSS software and Duncan's multiple range test was used to determine significant differences between mean values among the treatments at a significance level of 95% ($p < 0.05$). Each sample was repeated in triplicate at different locals. Meanwhile, the colony number was converted to a logarithm colony forming unit per gram (log CFU/g).

## 3. RESULTS AND DISCUSSION

### 3.1. pH and titratable acidity

The pH of Khmer rice vermicelli collected from wet markets in Phnom Penh was ranged from 3.78±0.2 to 4.35±0.29 (Table 2). The pH was obtained with a statistically non-significant difference ($p>0.05$). The pH value found in TN-1 is 3.82±0.13 lower than K7-3 is 4.35±0.29 with a different significance ($p<0.05$). Based on the results obtained, the pH values were similar to the study of Keatkrai and Jirapakkul [8] found that the pH of 3.81 after being made into rice vermicelli. The low pH could be affected by the duration of fermentation and selling in the market, which is the increase of lactic acid bacteria (LAB) that produced lactic acid as the major metabolic end product of carbohydrates [18].

The results of the titratable acidity of the samples were found to be non-significantly different ($p>0.05$) (Table 2). In this study, the acidity ranged from 0.09±0.02% to 0.19±0.05%. The acidity had been found with a significant difference ($p<0.05$) in the TN-1 was 0.19±0.05% higher than 7M-3 and K7-3 were 0.09±0.02% and 0.10±0.04%, respectively. All of these results are higher than those studied by Lu et al. [5] was 0.05% when fermented for 12 h, as lactic acid. The rise in pH and titratable acidity are probably due to the ammonia released by proteolytic bacteria priority to acidification by lactic acid bacteria and also other types of microorganisms during the fermentation process.

### 3.2. Moisture content

The moisture content of Khmer rice vermicelli found with a non-significantly difference ($p > 0.05$) was demonstrated in Table 2. The results obtained in our study ranged from 68.07±4.33% to 76.07±1.25%. The moisture content of the samples differed significantly ($p < 0.05$), which was found in the DP-2 by 76.07±1.25% higher than K7-2 is 68.07±4.33%. Interestingly, all these results are higher than the study of Low et al. (2019) found that the fresh rice vermicelli has a high moisture content was 62.51% and 58.76% as mentioned by Duangkaew and Ratphitagsanti [12]. However, Yi et al. [19] studied that the high moisture content was ranged from 60-80% of fresh rice noodles or vermicelli given with highly textural quality and unique flavor. The high moisture content could be a factor increasing the microbial growth to affected rice vermicelli quality and shelf-life during storage, which is particularly vulnerable to deterioration or spoiling. In general, a large number of microorganisms increased with increasing moisture content [10].

### 3.3. Water activity ($a_w$)

**Table 2** Results of the physicochemical analysis (means±standard deviation) in the Khmer rice vermicelli samples

| Markets | Sample code | pH | Titratable acidity (%) | Moisture content (%) | Water activity ($a_w$) | Color of L* |
|---|---|---|---|---|---|---|
| Tom Nop | TN-1 | 3.82±0.13$^{a}$ | 0.19±0.05$^{c}$ | 70.49±1.91$^{abc}$ | 0.9852±0.003$^{ab}$ | 64.16±5.94$^{a}$ |
| | TN-2 | 4.06±0.32$^{ab}$ | 0.14±0.06$^{abc}$ | 71.34±4.86$^{abc}$ | 0.9878±0.001$^{b}$ | 66.40±8.48$^{a}$ |
| 7Makara | 7M-1 | 4.23±0.43$^{ab}$ | 0.12±0.08$^{abc}$ | 71.96±3.90$^{abc}$ | 0.9863±0.002$^{ab}$ | 66.87±7.41$^{a}$ |
| | 7M-2 | 4.01±0.10$^{ab}$ | 0.13±0.02$^{abc}$ | 72.58±1.85$^{abc}$ | 0.9870±0.000$^{b}$ | 67.41±8.58$^{a}$ |
| | 7M-3 | 4.34±0.18$^{b}$ | 0.09±0.02$^{a}$ | 73.39±0.40$^{abc}$ | 0.9859±0.001$^{ab}$ | 72.93±8.48$^{a}$ |
| Orussey | OR-1 | 4.12±0.13$^{ab}$ | 0.12±0.02$^{abc}$ | 72.27±2.48$^{abc}$ | 0.9862±0.002$^{ab}$ | 73.10±6.09$^{a}$ |
| | OR-2 | 4.14±0.21$^{ab}$ | 0.12±0.04$^{abc}$ | 71.80±2.61$^{abc}$ | 0.9848±0.002$^{ab}$ | 68.24±2.99$^{a}$ |
| | OR-3 | 4.01±0.30$^{ab}$ | 0.15±0.06$^{abc}$ | 70.23±3.90$^{abc}$ | 0.9818±0.003$^{a}$ | 68.63±0.23$^{a}$ |
| | KD-1 | 4.07±0.14$^{ab}$ | 0.13±0.02$^{abc}$ | 71.20±3.03$^{abc}$ | 0.9883±0.001$^{b}$ | 73.32±3.88$^{a}$ |
| Kandal | KD-2 | 4.22±0.57$^{ab}$ | 0.12±0.06$^{abc}$ | 71.38±5.30$^{abc}$ | 0.9866±0.001$^{ab}$ | 69.21±3.48$^{a}$ |
| | KD-3 | 4.06±0.16$^{ab}$ | 0.13±0.03$^{abc}$ | 71.62±2.74$^{abc}$ | 0.9867±0.001$^{ab}$ | 70.72±0.92$^{a}$ |
| | KD-4 | 4.05±0.07$^{ab}$ | 0.13±0.01$^{abc}$ | 69.54±4.41$^{ab}$ | 0.9860±0.002$^{ab}$ | 72.68±3.88$^{a}$ |
| Depo | DP-1 | 4.23±0.12$^{ab}$ | 0.11±0.01$^{ab}$ | 73.59±0.78$^{abc}$ | 0.9864±0.002$^{ab}$ | 72.42±1.67$^{a}$ |
| | DP-2 | 4.22±0.24$^{ab}$ | 0.11±0.04$^{abc}$ | 76.07±1.25$^{c}$ | 0.9874±0.001$^{b}$ | 72.05±6.18$^{a}$ |
| Samaki | SM-1 | 4.17±0.27$^{ab}$ | 0.12±0.05$^{abc}$ | 72.03±3.30$^{abc}$ | 0.9852±0.003$^{ab}$ | 72.01±6.14$^{a}$ |
| | SM-2 | 4.02±0.27$^{ab}$ | 0.14±0.05$^{abc}$ | 70.64±3.71$^{abc}$ | 0.9834±0.001$^{ab}$ | 72.15±4.46$^{a}$ |
| | SM-3 | 4.14±0.22$^{ab}$ | 0.12±0.03$^{abc}$ | 70.85±4.22$^{abc}$ | 0.9866±0.001$^{ab}$ | 73.50±3.15$^{a}$ |
| Kilo 4 | K4-1 | 4.03±0.17$^{ab}$ | 0.13±0.03$^{abc}$ | 71.18±3.99$^{abc}$ | 0.9833±0.004$^{ab}$ | 69.73±2.12$^{a}$ |
| | K4-2 | 4.11±0.11$^{ab}$ | 0.12±0.02$^{abc}$ | 71.06±2.28$^{abc}$ | 0.9850±0.005$^{ab}$ | 68.03±5.11$^{a}$ |
| | K4-3 | 4.00±0.18$^{ab}$ | 0.14±0.03$^{abc}$ | 69.42±1.65$^{ab}$ | 0.9835±0.007$^{ab}$ | 68.16±4.12$^{a}$ |
| Central | CM-1 | 4.03±0.23$^{ab}$ | 0.14±0.04$^{abc}$ | 71.52±0.97$^{abc}$ | 0.9877±0.001$^{b}$ | 70.85±3.62$^{a}$ |
| | CM-2 | 4.15±0.38$^{ab}$ | 0.12±0.05$^{abc}$ | 72.66±2.90$^{abc}$ | 0.9857±0.001$^{ab}$ | 71.90±4.38$^{a}$ |
| | CM-3 | 3.96±0.09$^{ab}$ | 0.15±0.02$^{abc}$ | 70.73±2.08$^{abc}$ | 0.9867±0.000$^{ab}$ | 69.96±3.67$^{a}$ |
| Toul Songkae | TS-1 | 4.05±0.35$^{ab}$ | 0.14±0.05$^{abc}$ | 71.06±2.43$^{abc}$ | 0.9852±0.002$^{ab}$ | 71.11±5.67$^{a}$ |
| | TS-2 | 4.05±0.22$^{ab}$ | 0.14±0.03$^{abc}$ | 71.55±1.23$^{abc}$ | 0.9862±0.001$^{ab}$ | 71.57±4.14$^{a}$ |
| Olympic | OP-1 | 3.78±0.02$^{a}$ | 0.18±0.00$^{bc}$ | 70.34±2.69$^{abc}$ | 0.9861±0.002$^{ab}$ | 68.01±6.70$^{a}$ |
| | OP-2 | 4.11±0.23$^{ab}$ | 0.13±0.04$^{abc}$ | 71.88±2.49$^{abc}$ | 0.9864±0.002$^{ab}$ | 73.94±6.02$^{a}$ |
| | K7-1 | 4.23±0.33$^{ab}$ | 0.11±0.05$^{abc}$ | 70.57±5.07$^{abc}$ | 0.9864±0.003$^{ab}$ | 67.86±5.79$^{a}$ |
| Kilo 7 | K7-2 | 4.15±0.14$^{ab}$ | 0.12±0.02$^{abc}$ | 68.07±4.33$^{a}$ | 0.9868±0.003$^{b}$ | 71.01±6.67$^{a}$ |
| | K7-3 | 4.35±0.29$^{b}$ | 0.10±0.04$^{a}$ | 75.43±1.15$^{bc}$ | 0.9850±0.003$^{ab}$ | 69.22±6.46$^{a}$ |

L* is Lightness; TN-1 = Tom Nop market-store 1; TN-2 = Tom Nop market-store 2; 7M-1 = 7 Makara market-store 1; 7M-2 = 7 Makara market-store 2; 7M-3 = 7 Makara market-store 3; OR-1 = Orussey market-store 1; OR-2 = Orussey market-store 2; OR-3 = Orussey market-store 3; KD-1 = Kandal market-store 1; KD-2 = Kandal market-store 2; KD-3 = Kandal market-store 3; KD-4 = Kandal market-store 4; DP-1 = Depo market-store 1; DP-2 = Depo market-store 2; SM-1 = Samaki market-store 1; SM-2 = Samaki market-store 2; SM-3 = Samaki market-store 3; K4-1 = Kilo 4 market-store 1; K4-2 = Kilo 4 market-store 2; K4-3 = Kilo 4 market-store 3; CM-1 = Central market-store 1; CM-2 = Central market-store 2; CM-3 = Central market-store 3; TS-1 = Toul Songkae market-store 1; TS-2 = Toul Songkae market-store 2; OP-1 = Olympic market-store 1; OP-2 = Olympic market-store 2; K7-1 = Kilo 7 market-store 1; K7-2 = Kilo 7 market-store 2; K7-3 = Kilo 7 market -store 3. $^{a-c}$Means value in the same column with different letters expressed with non-significantly differences ($p>0.05$) among the samples.

Water activity ($a_w$) is important in determining the rate of bacteria growth in foods. Table 2 illustrates the results of water activity ($a_w$) with a statistically non-significant difference ($p>0.05$), which was found to range from 0.9818±0.003 to 0.9883±0.001. However, there was differed significantly ($p<0.05$) found in the OR-3 by 0.9818±0.003 compared to 0.9868±0.03, 0.9870±0.00, 0.09874±0.001, 0.9877±0.01, 0.9878± 0.001, and 0.9883±0.001 have been found in the K7-2, 7M-2, DP-2, CM-1, TN-2, and KD-1, separately. As the results in our study are similar to Ahmad Zainuri et al. [1] found that the water activity ($a_w$) in flat rice noodles ranged between 0.983 to 0.992. The water activity of Khmer rice vermicelli collected in Phnom Penh was slightly higher than the rice noodle's water activity of 0.979 in the study of Li et al. [14]. The highest water activity ($a_w$) indicates the microbial is sufficient to grow in the foods. As mentioned by Qing et al. [9], high water activity ($a_w$) in noodles might hasten the spoiling process since more free water is available to increase microbial activity.

### *3.4. Color of L* values*

The L* color is an important quality characteristic that influences consumer acceptance and preferences for fresh rice vermicelli [10]. The color of L* (lightness) values have been found with a statistically non-significant difference ($p > 0.05$)

are depicted in Table 2. The lightness of L* values ranged between 64.16±5.94 and 73.50±3.15. As a result of our study, color values of L* are lower than those of Duangkaew and Ratphitagsanti [12] found with a color L* value was 74.74 for fresh rice noodles. The increase of L* value in fresh rice vermicelli might be influenced by enlarging the substitute level of rice along with the decrease of moisture content and water activity. Furthermore, the L* value of rice vermicelli reflects the protein content with the creation of a strong and dense protein-starch network resulting in thick, opaque vermicelli as the protein concentration increases. A drop in reflectance with a reduction in the color value of L* may be caused by changes in the orientation of protein molecules and protein structure.

### *3.5. Microbiological analysis*

#### *3.5.1. Total plate count*

The total plate count indicates the sanitation and safety of a product [13]. Fig. 1 indicates the statistical analytical results of the microbial analysis on Khmer rice vermicelli samples, which were not significantly different ($p>0.05$). The highest contamination of TPC recorded in the K7-3 reached 6.0 logs CFU/g with a significant ($p<0.05$) compared to DP-1 was 3.6 logs CFU/g. Ahmad Zainuri et al. [1] recorded that 6.0 logs CFU/g is considered to be an unacceptable TPC level in fresh rice vermicelli. As mentioned by Akhigbemidu et al. [20], they found that TPC contamination was 6.6 logs CFU/ml for fresh vermicelli higher than this study. The highest TPC in the samples could be contaminated from raw material, during transportation, and during selling in the market showed that rice vermicelli's quality is good for consumption [4].

#### *3.5.2. Total yeast and mold count*

The results of total yeast and mold count (TYMC) have been indicated in Fig.1. There was no significant difference ($p > 0.05$). The highest contamination of TYMC was detected at 5.5 logs CFU/g found in the K7-3 with a statistically significant difference ($p < 0.05$) compared to DP-1 (3.3 logs CFU/g). Additionally, the results seen with TYMC bacteria were recorded in the TN-1 (5.5 logs CFU/g) and TN-2 (5.4 logs CFU/g) compared to DP-1 (3.3 logs CFU/g) differed significantly. The unacceptable level of TYMC exceeding 2.0 logs CFU/g was considered on the rice vermicelli quality and declared spoiled when its bacterial count exceeding 5.0 logs CFU/g as reported by Food Standards Australia New Zealand [21]. Nevertheless, Lu et al. [5] reported that the contamination of yeast and mold bacteria in fresh rice vermicelli was 2.1 logs CFU/g lower than our study. The higher contamination of TYMC has revealed inadequate processing procedures, such as improper cleaning, sanitation, and storage conditions [13].

#### *3.5.3. Lactic acid bacteria*

Lactic acid bacteria (LAB) are high tolerance to low pH and are involved in the noodle fermentation process [24]. The results of lactic acid bacteria of the samples were non-significantly different ($p > 0.05$), as illustrated in Fig. 1. Although the highest LAB was recorded in the OR-2 sample (5.5 logs CFU/g) compared to the lowest LAB found in the DP-1 sample (2.9 logs CFU/g) are differed significantly. The unsatisfactory rice vermicelli quality exceeding 5.0 logs CFU/g considered of LAB level as recorded by Food Standards Australia New Zealand [21] and Mastew [22]. As mentioned by Lu et al. [5] found that the contamination of LAB in fresh rice vermicelli was 2.7 logs CFU/g lower than our study. Therefore, the highest LAB might be contaminated by raw material, soaking time, storage period, and during vending in the open market [23].

#### *3.5.4. Enterobacteriaceae*

*Enterobacteriaceae*, called a sizable bacterial family, is utilized to evaluate rice vermicelli and food products' general cleanliness level, which is a symptom of post-processing contamination and lack of food sanitation. Fig. 1 expresses the results of *Enterobacteriaceae* with a non-significantly difference ($p > 0.05$). Interestingly, there was significantly ($p < 0.05$) of *Enterobacteriaceae* that was discovered in the CM-2 (3.6 logs CFU/g) higher than K4-1 (0.3 logs CFU/g), TS-1 (0.4 logs CFU/g) and DP-2 (0.9 logs CFU/g). Referring to Mastew [22] reported that an unacceptable *Enterobacteriaceae* level exceeding 4.0 logs CFU/g. Nevertheless, all the samples analyzed with *Enterobacteriaceae* bacteria are lower than the standard, as mentioned by Food Standards Australia New Zealand [21] and Mastew [22] in ready-to-eat foods. Moreover, *Enterobacteriaceae* contamination would be considered from raw material, improper equipment, post-processing contamination, and food handling practices [4,15].

#### *3.5.5. Total coliforms*

The results of total coliform bacteria were stipulated in Fig.1 with a significant difference ($p < 0.05$). The presence of total coliform was non-detectable only two samples in the KD-1 and K4-3. The highest total coliform was detected in the TN-2 (3.6 log CFU/g) compared to the lowest recorded in the DP-1 that is a statistically significant difference. Similarly, the contamination of total coliforms was significantly detected in the CM-2 (3.4 logs CFU/g), higher than in K7-2 (0.9 logs CFU/g). However, as studied by Ikeda et al. [24] found that the total coliform in fresh rice vermicelli were 2.7 logs CFU/g. Total coliform bacteria exceeding 4.0 logs CFU/g, considered to be an unacceptable level for rice vermicelli quality [21]. As the results obtained, all the samples tested with total coliform bacteria are lower than the standard, as mentioned by Food Standards Australia New Zealand [21] and Mastew [22] Moreover, total coliform contamination could be considered from raw materials, poor equipment, and hygiene practices [4].

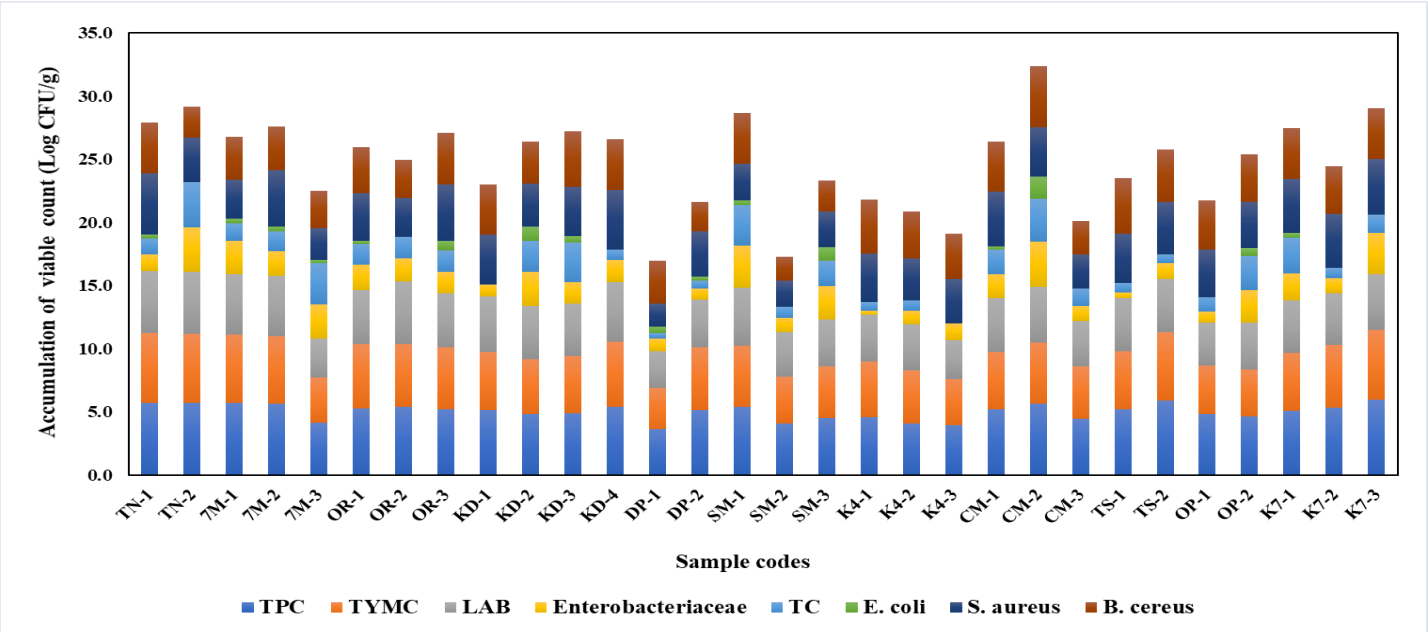


**Fig. 1.** Statistical analytical results of the bacterial analysis of the Khmer rice vermicelli samples with a non-significantly difference ($p>0.05$). Unacceptable level of: TPC > 6 log CFU/g, TYMC > 2 log CFU/g, LAB > 5 log CFU/g, *Enterobacteriaceae* > 4 log CFU/g, TC > 4 log CUF/g, *E. coli* > 2 log CFU/g, *S. aureus* > 4 log CFU/g, *B. cereus* > 5 log CFU/g (Mastew [22]; Food Standards Australia New Zealand [21]).

### *3.5.6. Escherichia coli*

As delineated in Fig. 1, there was a significant difference ($p < 0.05$) in *E. coli* bacteria. The presence of *E. coli* was detected, ranging from 0.3 logs CFU/g to 1.8 logs CFU/g with a significant difference ($p < 0.05$), it was found in the 7M-3 and CM-2 samples, discretely. Furthermore, there was no detected *E. coli* presenting in 46.7% of the samples. Similarly, *E. coli* contamination was detected in the KD-2 (1.1 logs CFU/g) and SM-3 (1.0 log CFU/g), lower than with a non-significantly of CM-2 (1.8 logs CFU/g). A study by Tang et al. [25] found that *E.coli* was 1.9 logs CFU/g in fresh rice vermicelli, which is higher than our study. However, Food Standards Australia New Zealand [21] and Mastew [22] reported that the acceptable level of *E. coli* was less than 2.0 log CFU/g in ready-to-eat foods. As attested by the results found are lower than the standard mentioned by Food Standards Australia New Zealand [21] and Mastew [22] meaning that the samples were good with a processing environment of those open markets was good as well. Moreover, the highest *E. coli* presence indicates fecal contamination might be contaminated by raw material, equipment, sanitation, and personal hygiene practices [4].

### *3.5.7. Staphylococcus aureus*

*Staphylococcus aureus* is recognized as one of the bacteria caused by food poisoning and food-borne diseases [26]. Fig. 1 depicts the results of *S. aureus* analysis with a statistically significant difference ($p > 0.05$). The highly contaminated *S. aureus* found in the KD-4 (4.7 logs CFU/g) sample differed significantly compared to the lowest that has been detected in the DP-1 (1.8 logs CFU/g) sample. Closely, higher *S. aureus* detection has been found in the OR-3, and K7-3 differed slightly non-significant were reached 4.5 logs CFU/g, and 4.4 logs CFU/g, separately. As studied by Kimsean et al. [16] found that *S. aureus* was 9.2 logs CFU/g recorded in Khmer rice vermicelli in Kandal province higher than our study. However, Food Standards Australia New Zealand [21] and Mastew [22] recorded that an unacceptable level of *S. aureus* in ready-to-eat foods exceeding 4.0 logs CFU/g. Öz et al. [27] studied that the presence of *S. aureus* in food, indicating poor raw material and inadequate hygiene practices, which is also linked to cross-contamination that occurs during processing, storage, and on the markets.

### *3.5.8. Bacillus cereus*

Bacillus *cereus* is known as one of the bacteria caused by foodborne pathogens. Fig.1 demonstrates the results of *B. cereus* of the samples were not significantly different ($p>0.05$). The highly detected *B. cereus* was found in the CM-2 (4.8 logs CFU/g). Similarly, higher *B. cereus* presence was recorded in the KD-3 (4.4 logs CFU/g), TS-1 (4.3 logs CFU/g), and K4-1 (4.2 log CFU/g). Moreover, the lowest *B. cereus* contamination of the

samples was found in the SM-2 (1.9 logs CFU/g) with a different significance ($p<0.05$) compared to the highest *B. cereus* detection. Nevertheless, Food Standards Australia New Zealand [21] reported that an unacceptable level of *B. cereus* in ready-to-eat foods exceeding 5.0 logs CFU/g. Based on the results obtained, *B. cereus* detected in the samples are lower than the standard and higher than those from study of Kimsean et al. [16] who found that *B. cereus* was less than 1.0 log CFU/g on Khmer rice vermicelli in Kandal province. However, as studied by Tang et al. [25] reported that the contamination of *B. cereus* on fresh rice noodles was less than 2 logs CFU/g in the retail market. The highly detected *B. cereus* might be considered to be contaminated by a variety of raw rice, rice grain, and uncooked rice [28].

## 4. CONCLUSIONS

In conclusion, this study demonstrated the Khmer rice vermicelli samples collected from various markets in Phnom Penh capital were contaminated with different microorganisms. There was no significant difference in the pH, titratable acidity, moisture content, water activity ($a_w$), and color of L* values. The decrease in pH and high titratable acidity values might be considered to be influenced the consumer acceptability and preferences. Furthermore, changes in color factor should be affected by increasing moisture content and water activity ($a_w$). There was no significant difference in the TPC, TYMC, LAB, *Enterobacteriaceae, S. aureus*, and *B. cereus* in the samples, but there were differed significantly in the total coliform and *E. coli* presences. The excessive microbiological contamination is a sign of inadequate food handler hygiene throughout the entire production chain. Poor food hygiene procedures employed by producers and during market displays lead to concerns about food contamination. Therefore, to increase the quality of rice vermicelli, food hygiene practices should be strengthened and developed.

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