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Physicochemical, lactic acid bacteria survivability and sensory properties of salad dressing with yogurt containing bacterial cellulose from sweet fermented broken black glutinous rice (Khao-Mak)

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Abstract

Salad dressing containing bacterial cellulose was developed to provide an overview for the preparation of simple functional foods. Sweet fermented broken black glutinous rice (Khao-Mak) was used as a substrate to produce bacterial cellulose (BC) by *Acetobacter xylinum*. Proximate composition analysis indicated that bacterial cellulose from the Khao-Mak solution (BCK) contained 8.05 (g/100 g) moisture, 7.46 (g/100 g) proteins, 0.63 (g/100 g) total fats, 0.94 (g/100g) ash, 82.92 (g/100g) total carbohydrates, and 367 (kcal/100 g) energetical values. Yogurt (Y) made with YC-380 culture contains two types of bacterial cellulose like bacterial cellulose from coconut water (BCC) and BCK were used to produce salad dressings. The results showed that salad dressing made from yogurt with BCK (S-YBCK) yielded the highest texture profile analysis (TPA) parameters. These parameters were higher than salad dressings made from yogurt with BCC (S-YBCC) and salad dressings without yogurt (S-control). Sensory evaluation of salad dressing revealed that S-YBCK (7.68±0.92) and S-control (7.45±0.99) contributed to the highest overall acceptability score ($p \leq 0.05$) over the S-YBCC (6.93±0.73). Viability of lactic acid bacteria in S-YBCK was detected at the value of 8.94 ± 0.01 log Colony Forming Unit (CFU)/g. Moreover, after storage at 4°C for 7 days, a 0.22-log decrease of lactic acid bacteria cells was observed in S-YBCK, still higher than S-YBCC and S-control which were higher than the minimum therapeutic dose (6.00 log CFU/g). The resulting products have promising properties with respect to lactic acid bacteria survive potential in an unconventional way.

Keywords: Bacterial cellulose, Broken black glutinous rice, Khao-Mak, Salad dressing, Sweet fermented rice, Yogurt

1. Introduction

Black glutinous rice is a source of anthocyanin which produces a purple pigment that is a naturally occurring plant pigment and belongs to the flavonoid family. The pigment is widely used for its antioxidant and pharmacological properties. The anthocyanins in rice are active antioxidants, which can inhibit inflammation throughout the body, act as anticarcinogens, promote blood circulation, slow tissue damage, and reduce cholesterol and blood sugar levels. Broken black glutinous rice is a by-product of rice production, but it was not used as a staple food. Currently, it is commonly used in food to add flavor and enhance appearance. Processing broken rice creates added value as a whole. Fermentation of food from the starchy matrix of broken rice increases applications for use in products such as alcoholic beverages and Khao-Mak which is a Thai fermented sweet rice desert. Broken rice was combined with other foods such as cereal and instant rice berry porridge [1-3].

Traditionally, Khao-Mak usually is a product of glutinous rice or can be mixed with cooked black glutinous rice. Black glutinous rice is a rich source of phytochemicals such as anthocyanin [4]. The mixture of cooked rice and starter (Look-Pang; Thai traditional fermentation starter for alcoholic food and drinks production) leads to the fermentation step at room temperature for two or three days to obtain the desired Khao-Mak characteristics as lumps of cooked glutinous rice with a soft texture, pale white colour, succulent grains, and acidic sweet taste with little alcohol flavour [5].

Bacterial cellulose (BC) is a functional microbial polymer and is a type of dietary fiber as it consists of that can be produced by bacteria such as *Gluconacetobacter*, *Sarcina* and *Agrobacterium* [6]. However, its production process is quite a complicated phenomenon. The USA Food and Drug Administration has classified bacterial cellulose as Generally Recognized as Safe (GRAS) based on its nontoxic, biocompatible, biodegradable, and bioabsorbable nature [7].

Fermented products are one of the healthiest products especially yogurt which is a dairy product produced by microbial fermentation processes. The predominant organisms in these dairy products are lactic acid bacteria (LAB) such as *Lactobacillus bulgaricus* and *Streptococcus thermophilus* which are recognized as safe microflora i.e., GRAS [8]. Probiotics are defined as living microorganisms, and when ingested in sufficient amounts, beneficially influence the health of the host by improving the composition of intestinal microflora [9]. The probiotics market is steadily expanding due to consumers growing health concerns coupled with the efficacy of probiotics [10]. To produce therapeutic benefits, a suggested minimum level for probiotic bacteria in fermented milk is from 10^6 to 10^7 Colony Forming Unit (CFU)/mL [11]. There is a great interest related to the use of yogurt sauce as a flavoured dressing for various salads and foods. Apart from common bacteria that can be found in yogurt products, the addition of other suitable bacteria, as well as prebiotic compounds, to yogurt products can confer more health benefits to consumers [12].

Salad dressing is one of the most popular basic sauces in the world. This product has received growing attention in the food industry due to increased consumer demand for salads as a healthy food option [13]. Salad dressings are semi-liquid, acidic, oil-in-water emulsions exhibiting a characteristic of creamy texture. Polysaccharides (xanthan, pectins, etc.), are usually incorporated in commercial salad dressing products, especially those of low oil content, to stabilize the oil droplets against creaming and to compensate for the loss of thickening properties originating from their reduced oil content [14]. Creamy salad dressing is a yellow, pourable, viscous sauce usually made of vegetable oil, distilled vinegar, sugar, egg yolks, mustard, modified starch, water, and salt. Stabilizers, such as xanthan gum and guar gum, can also be added to provide viscosity and prevent syneresis [15].

For this reason, the aim of this study was to use bacterial cellulose produce from sweet fermented broken black glutinous rice (Khao-Mak) is added to yogurt and use it in the manufacturing of salad dressing with functionality enhancement such as a lactic acid bacteria cell. In addition, physical properties, chemical properties, sensory acceptability and cell viability of lactic acid bacteria in the salad dressing were determined.

2. Materials and methods

2.1 Material, ingredients, and sample preparation

Old coconut water, broken black glutinous rice Leum Pua and Look pang Khao-Mak purchased from local markets in the Buriram Province in Thailand were used. The preparation of Khao-Mak from broken black glutinous rice Leum Pua consisted of washing it five times; then soaking it in hot water for a minimum of 12 hours. This was followed by washing it for three more cycles to be steamed until cooked, washing the steamed rice until the mucilage (starch pasting) is gone, and then leave the rice to drain. The rice was mixed together with Look-Pang, packed in glass jars for four days and then kept at -20°C until needed for further experimentation.

2.2 Preparation of bacterial cellulose from coconut water and Khao-Mak from broken black glutinous rice "Leum Pua"

Old coconut water was filtered using a sieve to remove unwanted particulates. After the old coconut water was filtered, it was boiled at 100°C for five min. Then, 5% w/v white sugar was added into the coconut water followed by the 1% v/v acetic acid. The mixture was sterilized using a steam autoclave at 12°C for 15 min, cooling until below 40°C and added starter culture of 10% v/v *Acetobacter xylinum*. The samples were fermented at 37°C for 10 days.

Khao-Mak from broken glutinous rice Leum Pua was blended with water in a 1:2 ratio and then acetic acid was added to control pH 4 and the sweetness was adjusted by adding sugar to make a total soluble solid at 10 °brix. The sample was boiled at 100°C for 5 min, 0.3% w/v $(NH_4)_2SO_4$ was added and allowed to cool; then 10% v/v *Acetobacter xylinum* was added. The samples were fermented at 37°C for 10 days [16]. Nata de coco layer was cut into 2 x 2 cm squares and boiled for about 30 minutes; then, the bacterial cellulose was dried at 80°C for five hours. The dried bacterial celluloses were ground up. Then, the ground bacterial cellulose was packed in aluminum plastic bags kept at -20°C for further analysis.

2.3 Preparation of yogurt

Raw milk was pasteurized at 65°C for 30 min and cooled to 45°C in chilled water. The commercial freeze-dried yogurt starter 0.2% w/v of YC-380 (Chr. Hansen, Denmark) were dissolved in distilled water, bacterial cellulose powder from old coconut water (BCC) and Khao-Mak from broken black glutinous rice "Leum Pua" (BCK) were added to the milk at the ratios of 1%, 2% and 3% w/v. Then, the mixture was fermented at 42°C for six hours. The yogurt was stored at 4±2°C for further analysis [17].

2.4 Preparation of salad dressing

Salad dressing formulations consisted of different ingredients (g/100 g): soybean oil (15 g/100 g), egg yolk (8 g/100 g), vinegar (3 g/100 g), mustard (1 g/100 g), sugar (7 g/100 g) and salt (1 g/100 g). Salad dressings were prepared by mixing yogurt and other ingredients according to the following procedure. Egg yolks were first mixed with vinegar; then, added to a mixture of sugar, salt, yogurt and mustard. The mixture was homogenized for five minutes in a mixer (Bear, DDQ-A40A1, China). Finally, oil was added and homogenized for two minutes until homogenous process was completed [6]. The salad dressing was stored at 4±2 C for further analysis.

2.5 Measurement of pH, titratable acidity, and total soluble solid value

Titratable acidity was determined according to standards established by the Association of Official Agricultural Chemists (AOAC) (2000) [18]; the samples consisting of 10 g were homogenized. The samples were mixed with 100 mL of distilled water, two-to-three drops of 1% w/v phenolphthalein indicator were added; then, the sample was titrated with 0.1 N NaOH solution until the end point of the phenolphthalein. The results were expressed as the percentage of lactic acid and calculated as follows:

$$\text{Titratable acidity (\% lactic acid)} = \frac{V \times N \times 90.08}{W \times 10} \quad (1)$$

Where V = volume of NaOH, mL; N = normality of the NaOH and W = weight of sample, g.

The pH value of sweet fermented broken glutinous rice (Khao-Mak) during fermentation was determined by using a pH meter (Satorius, Docu-pH, Germany). The total soluble solids were measured by using a digital hand-held Pocket Refractometer PAL-1 (ATGO, Japan) and recorded as °brix value.

2.6 Color measurement

The colors of bacterial cellulose (fresh and powder) were measured by using a colorimeter (color Flex Hunter Lab EZ 45/0L, USA) with the CIE L^*, a^* b^*. In the color system, L^* is a lightness to darkness (from black equaling 0, and white equaling 100); a^* is a measure of redness (a^* and - a^* redness and greenness) and b^* and -b^* for yellowness and blueness respectively.

2.7 Proximate analysis

The AOAC standards of analytical methods were used to determine moisture, ash, protein, and fat contents. The moisture content was analyzed by dried at 105 °C using a hot air oven until constant weight following AOAC procedure 925.40 and ash content was determined by following AOAC procedure 942.05. The samples were incinerated at 550°C to obtain the ash. The Kjeldahl method was used to determine the nitrogen content of bacterial cellulose samples following AOAC procedure 984.13 and the protein content was calculated as nitrogen x 6.25. The fat content was evaluated on a soxhlet extraction with hexane, following AOAC 963.15 procedures. Carbohydrate content was determined by the difference.

2.8 Texture profile analysis

Texture measurements were analyzed using a texture analysis method to obtain a texture profile analysis (TPA) [19]. The samples were packed in cylindrical plastic containers 43 mm in diameter and 30 mm high. A cylindrical probe (TA4/1000) was used to penetrate the sample to 40% of high sample. Two penetration cycles were determined at test speed 2 mm/s, trigger load 20 g, distance target 8 mm. The force-deformation parameters were processed with Texture Pro CT V1.5 software to determine the textural parameters: hardness, springiness, and gumminess. Three replicates for each sample were made.

2.9 Sensory evaluation

The sensory evaluation of salad dressing without yogurt (S-control), salad dressing made from yogurt with bacterial cellulose from coconut water (S-YBCC), and salad dressing made from yogurt with bacterial cellulose from Khao-Mak solution (S-YBCK) was made by a panel of 40 untrained testers. The sensory evaluation was carried out in a sensory laboratory. Sensory analysis was based on a 9-point hedonic scale of 1 to 9 (where 9 = extremely liked, 8 = liked very much, 7 = liked moderately, 6 = liked slightly, 5 = neither, 4 = disliked, 3 = disliked moderately, 2 = disliked very much and 1 = extremely disliked) was carried out. The analyses were under controlled temperatures and lighting conditions in individual booths. Sensory evaluation was conducted on the samples after one day of cold storage at 4±2°C. The salad dressing containers held 20 g of dressing; all salad dressing samples were codified with three-digit numbers and presented to the panelists in randomized order. Panelists evaluated characteristics related to color, odor, taste, viscosity, appearance, and overall acceptance of the samples [20].

2.10 Determination of total lactic acid bacteria (LAB)

Total lactic acid bacteria were determined using pour plate technique and lactobacillus deMan Rogosa and Sharpe (MRS) (Himedia, India) method. All salad dressing samples contained 25 g and were added to 225 mL of sterile 0.1% w/v peptone water and mixed in a stomacher (Seward, 400 Circulator Lab Blender, UK) for one minute. The samples were serially diluted, and 1 mL of an appropriate dilution was used to inoculate a plate in duplicate. The plates were incubated at 37°C for 48-72 h. A sample is used to calculate for lactic acid bacteria in agreement with the procedure described by Srisuk [21]. All results were expressed in Colony Forming Unit (log CFU/g) (AOAC, 2000) and calculated according to the follow:

$$\text{Lactic acid bacteria (log CFU/g)} = \frac{log\ 10[(n \times d)]}{V} \tag{2}$$

Where n = number of colonies on the plate within the countable range of 30 to 300 colonies per plate; d = dilution factor and V = sample volume of cultured plate.

2.11 Statistical analysis

All data were reported as means ± standard deviation. Statistical analysis was performed using SPSS statistical software program version 19. The physical properties, chemical properties, and lactic acid bacteria counts of samples were analyzed using analysis of variance (ANOVA) using Completely Randomized Design. The results from sensory evaluation were analyzed by analysis of variance using Randomized Complete Block Design. The experimental data were subjected to ANOVA, and Duncan's multiple range test (DMRT) ($p \leq 0.05$) was used to identify significant differences between group means.

3. Results and discussion

3.1 Chemical properties of sweet fermented broken black glutinous rice **(***Khao-Mak***)**

The results of titratable acidity, pH, and total soluble solidity of sweet fermented broken black glutinous rice **(**Khao-Mak**)** during fermentation are presented in Table 1. The fermentation time had a significant impact on the chemical properties of Khao-Mak. Titratable acidity and total soluble solidity increased during fermentation time. The pH values of Khao-Mak tended to be reduced when fermentation time increased**.** This result confirmed that sweet fermented broken black glutinous rice could be a good substrate for microbial growth during fermentation processes**.** The total soluble solidity is an indicator of the amount of dissolved solids in water, which refers to various kinds of sugars and includes organic acids [22]. It has been shown that fermentation process also produces organic acids and is beneficial to microorganisms. These substances could help to promote microbial growth during fermentation of bacterial cellulose process.

Table 1 Titratable acidity, pH, and total soluble solid of sweet fermented broken black glutinous rice **(**Khao-Mak**)** during fermentation.

Days	Titratable Acidity (%)	pH	Total Soluble Solid (TSS)
0	0.06±0.02^{e}	6.48±0.01^{e}	2.35±0.62^{c}
1	0.24±0.01^{d}	4.46±0.05^{d}	8.45±0.56^{b}
2	0.42±0.06^{c}	3.92±0.09^{c}	8.88±0.67^{ab}
3	0.52±0.04^{b}	3.78±0.07^{b}	9.33±0.75^{ab}
4	0.69±0.10^{a}	3.62±0.06^{a}	9.83±0.61^{a}

Note: Values are mean ± SD (n = 3). Different superscripts in the same column indicate significant differences at $p \leq 0.05$.

3.2 Physiochemical properties of bacterial cellulose from sweet fermented broken black glutinous rice (Khao-Mak)

The production of bacterial cellulose in the culture *Acetobacter xylinum* using a Khao-Mak solution (BCK) as a medium was studied. Some properties of BCK are shown in Table 2. Weight and thickness values of bacterial cellulose that were produced from Khao-Mak solutions were 149.33±34.18 g [%Yield = 29.87% (weight basis)] and 21.74±2.54 mm, respectively. This experimental result suggested the possibility of applying Khao-Mak solution as a raw material in bacterial cellulose production.

Table 2 Characteristics of bacterial cellulose from sweet fermented broken black glutinous rice (Khao-Mak).

Parameters	Values
Bacterial cellulose (Fresh)	
Weight (g)	149.33±34.18
Thickness (mm)	21.74±2.54
L	56.98±0.83
a^*	-1.05±0.09
b^*	1.86±0.25
Bacterial cellulose (Powder)	
L	68.31±0.13
a^*	4.34±0.05
b^*	19.37±0.02
Water activity (Aw)	0.42±0.01
Ash (g/100)	0.94
Energy (Kcal/100g)	367.19
Moisture (g/100)	8.05
Protein (g/100)	7.46
Total fat (g/100)	0.63
Total carbohydrate (g/100)	82.92

3.3 Chemical properties of yogurt containing bacterial cellulose

The titratable acidity, pH and total soluble solidity of yogurt production with bacterial cellulose were evaluated during the fermentation process**.** The results showed that the end of fermentation, resulting in lower pH values and higher titratable acidity values (Table 3). The titratable acidity of yogurt (calculated as lactic acid) was between 0.77 and 0.95. The results showed that the highest titratable acidity was found in the Y + 3% BCK sample. The pH value of yogurt was between 4.17 and 4.41. The results also showed that the highest and the lowest values of pH were revealed in Y + 2% BCC and Y + 2% BCK, respectively**.** The results indicated that yogurt fortified BC were slightly higher in total soluble solidity than Y-control. From the preliminary experiments, yogurt was used to produce salad dressing; the results demonstrated that the salad dressing mixed with yogurt with 3% of bacterial cellulose had a very high viscosity. Due to the fact that yogurt with 3% bacterial cellulose is too viscous and has a lumpy texture, it is not suitable for salad dressing. For this reason, Yogurt with 2% bacterial cellulose was considered for further experimentation.

The mean level of acidity of the yogurt samples supplemented with BCK was higher than the control. This could be related to the stimulation of bacteria in starter cultures by cellulose [11]. Lactic acid was produced causing the milk pH level to be decreased and the acidity to be increased [23]. The titratable acidity of normal fermented milk products was within the range of 0.7-1.2% [24] and the minimum of titratable acidity expressed as percentage of lactic acid (%, w/w) of yogurt was 0.6% [25]; therefore, the fermentation was considered to have proceeded in a normal way. This experimental result suggested the possibility of applying bacterial cellulose as a raw material in fermentation to promote the survival of microorganisms. Lactic acid bacteria cells could attach and live within or onto the fibrous structure of bacterial cellulose without chemical bonding or physical adsorption with carrier support. The cellulose ribbons were overlapped, inter twisted and parallel formed but disorganized and had the potential to hold the bacterial cells in the spaces and on the surface to enhance their survivability [26].

Table 3 Chemical properties of yogurt containing bacterial cellulose from coconut water and Khao-Mak solution.

Samples	Titratable Acidity (%Lactic acid)	pH	Total Soluble Solid (°brix)
Y-Control	0.81±0.01^{d}	4.21±0.02^{d}	13.43±0.06^{e}
Y + 1% BCC	0.77±0.01^{e}	4.32±0.02^{c}	14.40±0.10^{c}
Y + 2% BCC	0.77±0.01^{e}	4.41±0.01^{a}	14.47±0.15^{c}
Y + 3% BCC	0.81±0.01^{d}	4.34±0.01^{b}	15.47±0.15^{b}
Y + 1% BCK	0.91±0.01^{c}	4.19±0.01^{de}	14.17±0.15^{d}
Y + 2% BCK	0.92±0.01^{b}	4.17±0.01^{e}	14.37±0.06^{cd}
Y + 3% BCK	0.95±0.01^{a}	4.31±0.01^{c}	16.00±0.10^{a}

Note: Values are mean ± SD (n = 3). Different superscripts in the same column indicate significant differences at $p \leq 0.05$. Y = yogurt, BCC = bacterial cellulose from coconut water, BCK = bacterial cellulose from Khao-Mak solution

3.4 Texture profile analysis of salad dressing

The addition of yogurt into salad dressings, as well as the type of bacterial cellulose affected the textural properties of the samples ($p \leq 0.05$) (Figure 1). Hardness, springiness, and gumminess values of salad dressings were examined (Figure 2). Salad dressing made from yogurt with bacterial cellulose from Khao-Mak solutions (S-YBCK) had higher hardness, springiness, and gumminess values than those of salad dressings without yogurt (S-control) and salad dressings made from yogurt with bacterial cellulose from coconut water (S-YBCC). This can be explained by increasing the dry matter of salad dressing enriched with yogurt containing bacterial cellulose. Increasing the dry matter caused a firmer and stronger gel. Moreover, higher water binding capacity of bacterial cellulose may produce a firmer gel network [11]. Consequently, adding bacterial cellulose in food products resulted in increased gel strength and water-holding capacity due to its enhanced network structure. [11].

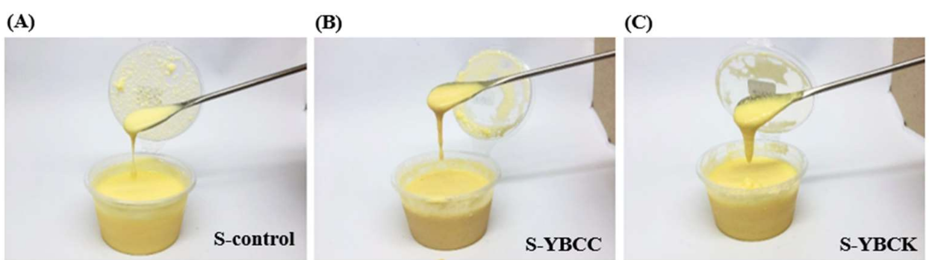

Figure 1 Characteristics of (A) salad dressing without yogurt (S-control), (B) salad dressing made from yogurt with bacterial cellulose from coconut water (S-YBCC) and (C) salad dressing made from yogurt with bacterial cellulose from Khao-Mak solution (S-YBCK).

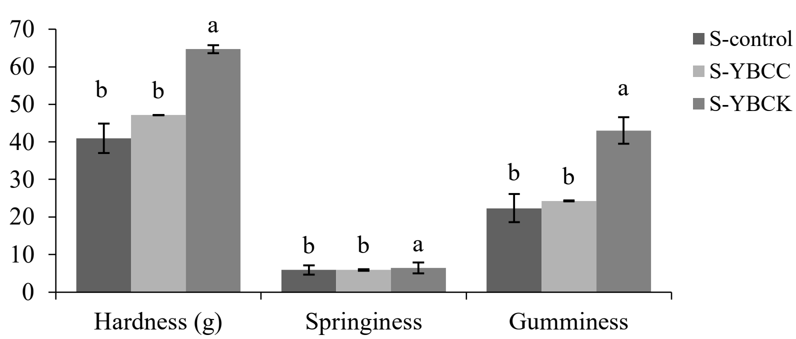

Figure 2 Texture profile analysis of salad dressing without yogurt (S-control), salad dressing made from yogurt with bacterial cellulose from coconut water (S-YBCC) and salad dressing made from yogurt with bacterial cellulose from Khao-Mak solution (S-YBCK).

3.5 Sensory evaluations

The sensory qualities of the salad dressing samples were evaluated in terms of color, odor, taste, viscosity, appearance, and overall acceptability, as shown Table 4. The results of organoleptic evaluation indicated that the salad dressing enriched with YBCK received the highest scores. This could be related to better viscosity and appearance of these samples. Salad dressings containing YBCK showed the highest scores of color, odor, taste, viscosity, and appearance compared to other treatments. Regarding the overall acceptability, S-YBCK had the highest acceptance with the score of 7.68 ± 0.92.

Table 4 Sensory evaluation of salad dressing without yogurt (S-control), salad dressing made from yogurt with bacterial cellulose from coconut water (S-YBCC) and salad dressing made from yogurt with bacterial cellulose from Khao-Mak solution (S-YBCK).

Parameters	S-control	S-YBCC	S-YBCK
Color	7.75 ± 1.13^{a}	6.90 ± 0.87^{b}	7.48 ± 0.78^{a}
Odor	7.15 ± 1.10^{ab}	6.85 ± 1.27^{b}	7.55 ± 0.99^{a}
Taste	7.45 ± 1.30^{ab}	7.00 ± 0.82^{b}	7.58 ± 1.22^{a}
Viscosity	6.50 ± 0.99^{b}	6.65 ± 0.77^{b}	7.63 ± 1.19^{a}
Appearance	7.55 ± 1.13^{a}	7.00 ± 1.18^{b}	7.85 ± 0.70^{a}
Overall acceptability	7.45 ± 0.99^{a}	6.93 ± 0.73^{b}	7.68 ± 0.92^{a}

Note: Values are mean ± SD (n = 3). Different superscripts in the same row indicate significant differences at $p \leq 0.05$.

3.6 Microbiological properties of salad dressing during storage

For viable lactic acid bacteria cells in salad dressing shown in Figure 3, it was found that all salad dressing treatments maintained between 8.49-8.94 log CFU/g. Some of the salad dressing samples, the S-YBCK sample still contained high amounts of lactic acid bacteria which equaled 8.72 log CFU/g as compared with the S-control (8.49 log CFU/g) and S-YBCC (8.50 log CFU/g) after storage for seven days. In general, the lactic acid bacteria were derived from yogurt samples, whereas other ingredients used in salad dressing processes did not contain these bacteria. At the end of storage, although the viable counts of lactic acid bacteria dropped in all salad dressings, the counts of lactic acid bacteria were found to be above the threshold for therapeutic minimum (10^6 - 10^7 CFU/g) standards in all samples. On the other hand, after the seventh day of storage, the highest lactic acid bacteria were found in S-YBCK which was under the threshold for therapeutic minimums which is higher than the specified value. In addition, the total minimums of lactic acid bacteria in probiotic food were 6 log CFU/g of viable cells to be accepted as the therapeutic minimum [27]. Similarly, Phrompeth et al. [28] reported that *L. plantarum* cells immobilized on bacterial cellulose reserved their viability, at a higher level, during storage in the acidic environment of mamao juice, while Fijałkowski et al. [29] determined that immobilization of LABs on bacterial cellulose provides high levels of protection for microorganisms against the effect of gastric juices and bile salts. Various dietary fibers had been suggested that they can protect the lactic acid bacteria cells by a mechanism involving the physical cells immobilization onto the fiber during processing and storage of food [30].

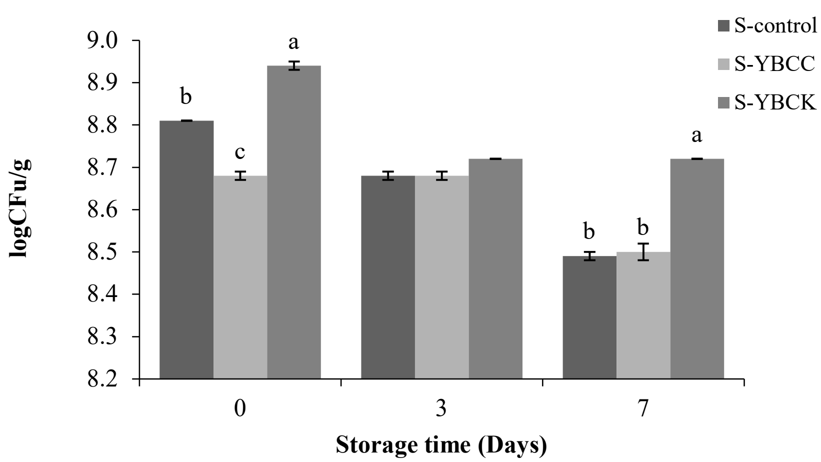

Figure 3 Cell viability of lactic acid bacteria in salad dressing samples. Note: Values are mean ± SD (n = 3). Different superscripts (a-c) in salad dressing sample indicate significant differences at $p \leq 0.05$.

4. Conclusion

The results of this experiment suggested the possibility of applying broken black glutinous rice as a raw material in Khao-Mak production to provide appropriate ingredients for BCK production. Usage of BCK positively affected yogurt fermentation, which was considered a normal process for fermentation. The addition of BCK had significant effects on the textural, sensory characteristics and lactic acid bacteria counts of salad dressings. Sensory characterization of salad dressings with blended yogurt containing bacterial cellulose from Khao-Mak solution prevailed against salad dressings produced with bacterial cellulose from coconut water and without bacterial cellulose. This also reinforced the concept of formulating novel functional products, considering the nutritional value of BCK, which is high in dietary fiber. The present work demonstrated that salad dressings combined with yogurt containing bacterial cellulose from Khao-Mak solution presented a high survival rate during storage. This study demonstrated that bacterial cellulose from Khao-Mak solution could be used as an alternative source of bio-functional components to fortify salad dressings.

5. Acknowledgements

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