Assessing the survival and ability of Lactobacillus strains in coconut neera to bolster its suitability as a functional beverage after storage

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Abstract
Coconut neera is a translucent liquid sap that comprises sugar, fat, minerals, vitamins, and proteins, which render it a suitable substrate for microbial growth. The objective of this study is to observe the survival of Lactobacillus casei AP and Lactobacillus plantarum strains in coconut neera along with their ability to produce short-chain fatty acids (SCFAs). The survival test was conducted by measuring the total plate count, and SCFAs were analyzed using high-performance liquid chromatography. Lactobacillus casei AP and L. plantarum could grow in the neera from about 6 log CFU/mL to up to 7.86 and 6.40 log CFU/mL after 9 hrs of inoculation, respectively. Additionally, they can survive at 4°C in storage for 14 days. These Lactobacillus strains could produce SCFAs in the form of butyrate. Therefore, the inoculation process of Lactobacillus strains can present an alternative to developing new functional beverages from coconut neera.

1. Introduction

Probiotics are one of the functional foods that can affect health by supplementing living microorganisms in the food. Probiotic drinks with milk-based ingredients are most often found for consumption in the market. The development of new probiotics with substrates other than milk is crucial to meet the needs of probiotics in people with lactose allergies and high (bad) cholesterol content. Hence, the substrates in the form of fruits, vegetables, cereals, soybeans, and non-dairy ingredients, such as neera, can be selected for meeting the needs of probiotics.

Neera is a translucent liquid sap that is extracted by tapping the immature inflorescence of coconut (Mashud and Matana, 2014). Importantly, neera is obtained by cutting the spadix of the immature inflorescence of coconut palms. On average, one spadix can produce about 2 liters of sap per day (Mashud and Matana, 2014). Neera contains sugar, fat, minerals, vitamins, and proteins, hence making it a suitable medium for microbial growth. Additionally, neera can easily undergo a fermentation process. Therefore, coconut neera could assist in developing healthy probiotic drinks, with the use of lactic acid bacteria (LAB) as the living organisms.

The Lactobacillus genus is one of the genera that includes a large number of species that fall into the “generally recognized as safe” category. Lactobacillus casei and L. plantarum are some examples of Lactobacillus strains that are often found in commercial probiotic drinks. Lactobacillus plantarum (de Vries et al., 2006) and L. casei AP (Widodo, 2017) have demonstrated survival abilities in the gastric transit, and can live while developing in the intestinal tract of humans and other mammals. Besides, L. plantarum and L. casei AP can also produce short-chain fatty acid (SCFA) compounds. SCFAs have several functions in human health, such as maintaining the diversity of intestinal microbiota and a considerable involvement in signaling in the immune system (Ríos-Covián et al., 2016).

Several studies have been conducted to determine the ability of L. casei AP and L. plantarum to produce SCFA in the de-Man Rogosa Sharpe medium (MRS). According to Kusmiyati et al. (2018), L. casei AP can produce SCFA in the form of acetate, propionate, and butyrate. Moreover, L. plantarum is also known to have...
the ability to produce SCFA (Pessione et al., 2015). Therefore, the objective of this study is to determine the ability of Lactobacillus (L. casei AP and L. plantarum) strains to grow and survive along with their ability to synthesize SCFA in coconut neera. This study also investigates each sensory characteristic to examine the possibility of producing new functional beverages from coconut neera.

2. Materials and methods

Lactobacillus casei AP was provided by Dr. Widodo from the Faculty of Animal Science Universitas Gadjah Mada Indonesia, and L. plantarum was obtained from the Indonesian Culture Collection Lembaga Ilmu Pengetahuan Indonesia/inaCC LIPI. Coconut neera was obtained from the Ngupoyo Bogo farmer group, Hargotiro village, Kokap sub district, and Kulon Progo district. Neera had been extracted in the afternoon and collected in the morning. Thereafter, neera was taken to the laboratory using a cool box to maintain a temperature of 4°C–10°C and was stored at −20°C before use.

2.1 Sample preparation

Sterile neera was prepared by centrifugation, then filtered using a Whatman filter paper No. 1, and further pasteurized for 10 mins at 84°C. Each culture of L. casei AP and L. plantarum was inoculated into the MRS broth medium and incubated at 37°C for 12 hrs. Next, 10% (v/v) of inoculum was subcultured for 4 hrs to maintain the logarithmic phase. Bacteria were activated by growing them twice to achieve the cell viability of about 10⁸–10⁹ CFU/mL. The cultures were harvested by centrifugation for 5 mins at 13,000 rpm, and the biomass was washed twice with the saline solution. The cultures were then introduced into the sterile neera (50 mL) with cell viability of about 10⁶ CFU/mL. Four treatments of inoculation were performed based on the culture composition (single or mixed), namely, a single culture of L. casei AP, a single culture of L. plantarum, and a combination of L. plantarum and L. casei AP at the ratios of 1:1 and 1:3. The duration incubation of treatments was determined by the bacterial growth curves of L. plantarum and L. casei AP. After incubation, at 37°C, all the treatments were analyzed for cell viability, pH, °Bx, total protein, glucose, and organic acids.

2.2 pH, sugar content, and total protein

pH was measured using a pH meter. The sugar content (°Bx) was measured using a refractometer (AS ONE IPR 101–α, Japan). The total protein was examined using the Biuret method. Importantly, the total protein was examined at 0, 7, and 14 days of storage, whereas pH and Bx were measured during the inoculation treatment (0 or first day of storage).

2.3 Glucose and organic acids

The concentration of glucose was determined by high-performance liquid chromatography (HPLC) (Shimadzu Prominence HPLC, Kyoto) equipped with a refractive index detector (RID-10A). An isocratic separation was performed using the NH2 ion exchanger column with ultrapure water and acetonitrile (15:85), and at a mobile phase with a flow rate of 1.0 mL/min. Organic acids such as lactic acid and SCFAs (butyric acid and acetic acid) were determined by HPLC equipped with the SPD-M20A DAD detector. An isocratic separation was performed using a Shim-Pack GIST C18 5 μm, 4.6 × 150 mm chromatography column with a mobile phase comprising a sodium phosphate buffer solution of 25.0 mmol/L, at a pH of 2.4 and a flow rate of 1.0 mL/min.

2.4 Survival of Lactobacillus strain during storage

The survival of Lactobacillus strains during storage was examined by the total plate count method using the MRS agar medium on 0, 7, and 14 days of storage.

2.5 Sensory evaluation

Ten persons from the Graduate School of Biotechnology of Universitas Gadjah Mada who were familiar with sensory evaluation were selected as panelists for the sensory panel. All the panelists measured the color, odor, acidity, texture, and taste of bacterial inoculation treatment according to the five-point hedonic scale - a scale from 0 (dislike) to 5 (extremely like).

2.6 Statistical analysis

All the data of this study were subjected to one-way analysis of variance statistical method using the SPSS software version 22.0 (IBM SPSS Pvt. Ltd.). The mean analysis using the Tukey test at a significance level of p ≤ 0.05 was performed if needed.

3. Results

3.1 The growth ability and survival of Lactobacillus strains in coconut neera

The bacterial growth curve of L. plantarum and L. casei AP helped in determining the length of incubation time of each predetermined inoculation treatment to produce new functional beverages from coconut neera. Figure 1 and Figure 2 show that the initial stationary phases of L. plantarum and L. casei AP were at the incubation times of 7 and 9 hrs, respectively.
The bacterial inoculation treatment of *L. casei* AP showed that the combined cultures of *L. casei* AP and *L. plantarum* (1:1 and 1:3) exhibited higher viability up to 7.86 log CFU/mL than a single culture of *L. plantarum* with cell viability of about 6.40 log CFU/ml (Table 1).

Table 1 shows that both single cultures of *L. plantarum* and *L. casei* AP cultures along with their combination (1:1 and 1:3) could maintain cell viability in the shelf life of 14 days at 14°C. Importantly, the dose of probiotics in fermented drinks was decreased but still met the criteria of probiotic dose.

### 3.2 The ability of *Lactobacillus* strains to produce SCFA in coconut neera

The environments in which LAB thrive are rich in sugars and proteins. Additionally, the environment rich in fats, vitamins, and nucleotides are also optimum for LAB’s survival (Teusink and Molenaar, 2017). The combination of *L. plantarum* and *L. casei* AP (1:1) had the lowest glucose consumption with a concentration of 19.00 mg/mL as compared to the control concentration of 19.03 mg/mL (Table 2). *Lactobacillus plantarum* had the lowest reduction of sugar content (°Bx) (15.17) as compared to the control (15.17) (Table 2).

The production of lactic acid and butyric acid by bacterial culture could lead to a decrease in pH (Table 2, Table 3). There was a correlation between lactic acid production and a change of pH in the bacterial inoculation treatment (Table 3 and Figure 3). If lactic acid production was higher, then the pH was lower, except for *L. casei* AP treatment. During the inoculation treatment, *L. casei* AP lowered the pH (as much as 5.21) more than it was lowered by the combination of *L. plantarum* and *L. casei* AP (1:1).

*Lactobacillus casei* AP exhibited lactic acid production of 0.773 mg/mL. At seven days of storage, with the pH value and lactic acid production of 5.04 and 1.117 mg/mL, respectively, the lactic acid production of *L. casei* AP almost reached the same level as that obtained by the combination of *L. plantarum* and *L. casei* AP (1:3). Other than the...
production of lactic acid, the highest butyric acid produced by *L. casei* AP could contribute to decreasing the pH in coconut neera during the inoculation process and storage as 4.912, 5.036, and 5.349 mg/mL.

### 3.3 Sensory evaluation

According to the sensory data during the inoculation treatment or 0 days of storage, the odor and acidity from each bacterial inoculation treatment showed the same values of 2.5 and 2.7 that were slightly approved by panelists (Figure 4). The acidity sensory data were supported by the pH value of about 5.2 at 0 days of storage (Table 3). For the taste indicator, the panelists preferred the single culture of *L. plantarum* and *L. casei* AP with the value of 4. For the texture, the panelist slightly preferred the combination of *L. plantarum* and *L. casei* AP (1:1 and 1:3). The color sensory data showed that the panelists preferred the color of the single culture of *L. plantarum* and the combination of *L. plantarum* and *L. casei* AP (1:1 and 1:3). Overall, coconut neera inoculated by *L. plantarum* and *L. casei* AP was approved by the panelists and there was no significant difference in the sensory evaluation of each parameter between the samples (Table 4).

### 4. Discussion

*Lactobacillus plantarum* had a shorter lag phase than *L. casei* AP, but *L. casei* AP had higher cell viability than *L. plantarum* (Figure 1 and Figure 2). This phenomenon could be attributed to various factors, such as growth inhibition and the availability of nutrients in the media (Siragusa *et al*., 2014). A combination of *L. casei* AP (1:1 and 1:3).
plantarum and L. casei AP could offer an alternative solution to obtain a probiotic dose of 7 log CFU/mL with an acceptable flavor. The ratio combination of L. plantarum and L. casei AP depends on the value of the cell viability of L. casei AP because L. casei AP had exhibited the highest cell viability. An effective dose of probiotics positively affects the health of an individual if the consumption quantity is around $10^7$–$10^9$ CFU/g (CFU/mL) (Bertazzoni et al., 2013). The cell viability results after incubation at 37°C in coconut neera media showed that the single culture of L. plantarum did not meet the probiotic dose criteria because the cell viability was less than $10^7$ CFU/mL (or 7 log CFU/mL) and was 6.40 log CFU/mL.

Changes in the sugar content and total protein could indicate bacterial activities (Table 2). Glucose is used to produce lactic acid, and fructose is used for cell growth (Plumed-Ferrer et al., 2008). °Bx is the weight of dissolved solids in the form of sucrose in a sugar solution (Toledo, 2014). The reduction of sugar content (°Bx) could indicate that sucrose is consumed by the culture to be further metabolized into glucose and fructose. The glucose content in coconut neera and sucrose metabolism by bacterial culture will contribute to the production of lactic acid, which is an organic compound and non-SCFA (Figure 3). The cell viability was affected by the fructose content in the coconut neera and sucrose metabolism (Table 2).

Most LABs are auxotrophic for a large number of amino acids and vitamins, and the loss of function in the presence of some specific nutrients sometimes provides a selective advantage (Teusink and Molenaar, 2017). The total proteins or amino acids affect the production of SCFA because of bacteria (Rios-Covián et al., 2016). Some probable explanation can be provided for the correlation between the consumption of protein, survival bacteria and the production of butyric acid. According to Muralidharan and Nair (2013), neera contains 16 amino acids with glutamic acid, threonine, and aspartic acid as the main constituents. Glutamic acid is known to play a role in the metabolism and stress resistance in LAB (Ricciardi et al., 2015). Furthermore, it can induce the butyrogenic genes of L. plantarum, which cause an increase in the production of butyric acid (Botta et al., 2017). In the digestive system, SCFA, especially butyrate, is used as a carbon source by the host cells and other intestinal microbiota (Den Besten et al., 2013). Furthermore, butyrate is involved in signaling in the immune system by balancing the acetylation and deacetylation activities of histones, further preventing colon cancer (Rios-Covián et al., 2016). Although L. casei AP exhibited higher butyric acid production than lactic acid production, butyric acid had a small effect on pH. This phenomenon can be attributed to the fact that lactic acid has a lower pKa value (pKa = 3.83) than butyric acid (pKa = 4.82); hence, the production of lactic acid tends to more affect pH (Dibner and Buttin, 2002).

5. Conclusion

Based on the research results, L. casei AP and L. plantarum could grow in the neera with L. casei AP had higher cell viability than L. plantarum. Both L. casei AP and L. plantarum could survive 14 days of storage at 4°C. Lactobacillus casei AP can produce butyric acid in greater quantities, as compared to L. plantarum, in coconut neera.

Conflict of interest

The authors declare no conflict of interest.

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