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Research Article

Comparison of Fermentation Kinetics of Milk Kefir and White Rice Kefir at Low Temperatures: Exploring the Effects on Product Quality

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Abstract

Kefir fermentation has been extensively studied because of its potential to develop novel functional drinks and its various biological activity. This study investigates the comparative fermentation kinetics of milk kefir and white rice kefir at low temperatures, addressing a gap in current research. Utilizing a comprehensive research methodology, including sample preparation, fermentation processes, and various analyses, the study explores the distinct patterns observed in the fermentation kinetics, physicochemical properties, and microbiological characteristics of both kefir types. The results highlight significant differences influenced by low temperatures, emphasizing the need to consider specific attributes for each kefir type in low-temperature fermentation. The findings contribute novel insights into optimizing fermentation conditions and enhancing product quality. The results offer additional perspectives on the influence of fermentation temperature on microbial dynamics, physicochemical properties, and health-related aspects in various fermented products. This study advances our understanding of kefir fermentation, providing valuable implications for the production of high-quality and functional beverages.

Keywords: kefir, low-temperature fermentation, fermentation kinetics, microbial composition, product quality assessment

1. INTRODUCTION

Modern society's awareness of healthy lifestyles has created a new need for food that not only fulfils nutritional intake but can also improve health. Probiotics are the answer to this. Kefir itself is a probiotic food that has many benefits. The fermentation of kefir has been the subject of extensive research due to its potential to produce new functional beverages and its diverse biological activities [1][2]. Kefir grains have been studied for their ability to ferment different substrates, leading to the production of various functional beverages, and thus providing product diversification [1]. Additionally, the buffer capacity and calcium concentration of water have been found to influence microbial species diversity, grain growth, and metabolite production during water kefir fermentation [3].

Furthermore, the influence of different substrates on the fermentation characteristics and microbial composition of water kefir has been examined, indicating the impact of fruit substrates and nitrogen limitation [4]. Moreover, the potential of kefir to produce high-quality products has been demonstrated in various studies. For instance, the use of thermally-dried immobilized kefir cells in low-alcohol winemaking resulted in high-quality products approved by sensory panels [5]. Additionally, the addition of oleaster flour combined with high-pressure homogenization has been shown to affect the acidification kinetics, physicochemical, functional, and rheological properties of kefir, leading to the enhancement of total phenolic contents and antioxidant activity [6].

The potential health benefits of kefir consumption have been a focus of research, with studies emphasizing the isolation of microorganisms from kefir grains exhibiting probiotic properties and the exploration of kefir's anticancer properties [7][8]. Additionally, the

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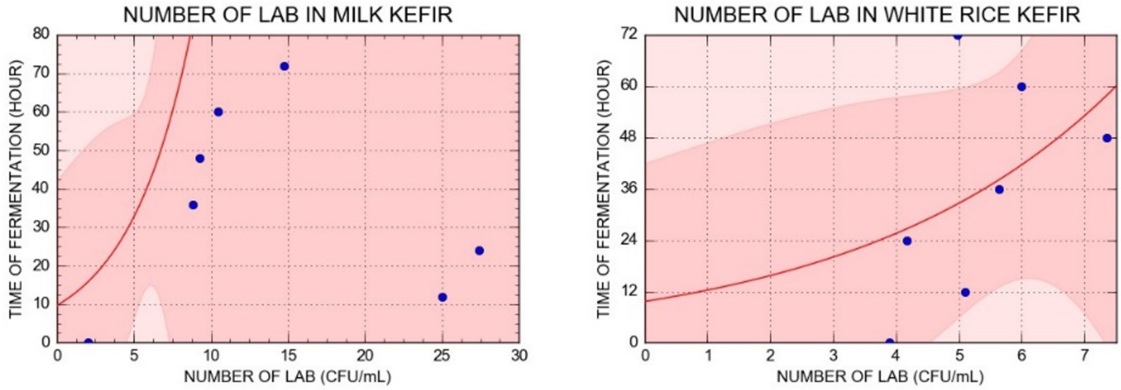

Figure 1. LAB kinetics of milk kefir and white rice kefir during fermentation.

production of kefir with ACE (Angiotensin-Converting Enzyme) inhibitory activity has been investigated, demonstrating significant increases in ACE inhibition rate and sensory evaluation under optimal conditions [9]. The fermentation kinetics of kefir have also been explored, with studies investigating the physical and microstructural characteristics of kefir made of milk and colostrum, as well as the effect of microbial transglutaminase on the viscosity and protein network of kefir made from different types of milk [10][11]. Moreover, the application of whey permeate fermented with kefir grains for the shelf-life improvement of food and feed has been studied, highlighting the potential of kefir in food preservation [12].

John and Deesenthum [13] conducted research on milk kefir, including an examination of the microstructural features of kefir formed from milk and colostrum. Meanwhile, Suphandi et al. conducted a study on white rice kefir [14]. However, no research has been conducted to determine the influence of low temperatures on the product's extended shelf life [15][16]. The preceding literature analysis on kefir fermentation kinetics and its impact on product quality reveals a gap in the comparative understanding of the fermentation kinetics of milk kefir and white rice kefir at low temperatures. While existing research has extensively explored the fermentation characteristics, microbial composition, and health benefits of kefir, there is a lack of comprehensive studies comparing the fermentation kinetics of different types of kefirs at low temperatures. Therefore, there is a clear need for research that addresses this gap, providing novel insights into the effects of low temperatures on the fermentation kinetics of milk kefir and white rice kefir, and their implications for product quality.

2. MATERIALS AND METHODS

2.1. Materials

Organic white rice (*Oryza sativa* Linn.) was obtained from a marketplace in Indonesia in November 2023. Kefir grain culture was obtained from the Teaching Factory Laboratory collection at UIN Sunan Gunung Djati, Bandung, Indonesia. The de Man Rogosa Sharpe Agar (MRSA) was purchased from Oxoid, Hampshire, England.

2.2. Methods

2.2.1. Sample Preparation and Inoculation

Fresh milk kefir grains and white rice kefir grains were obtained from reliable sources. Milk and white rice substrates were prepared under sterile conditions. The substrates were then inoculated with the respective kefir grains and starter cultures.

2.2.2. Fermentation Process

The fermentation process was conducted at low temperatures (5 and 10 °C) to simulate refrigeration conditions. The fermentation kinetics were monitored by sampling at regular intervals (e.g., every 4 or 6 h until 72 h fermentation) to assess changes in pH, titratable acidity, and microbial population dynamics.

2.2.3. Physicochemical Analysis

The physicochemical properties of the fermented milk kefir and white rice kefir were analyzed, including rheological, textural, and color properties [16]. The concentrations of lactic acid, acetic acid, citric acid, and other relevant metabolites were measured to understand the fermentation kinetics [17].

2.2.4. Microbiological Analysis

The microbial composition of the fermented products was characterized using culture-dependent and molecular techniques to identify the dominant microorganisms and their dynamics during fermentation [18]. The diversity of lactic acid bacteria (LAB) was explored during communities during fermentation to understand the impact of low temperatures on microbial populations by using the total plate count method [19].

2.2.5. Product Quality Assessment

The sensory attributes and organoleptic properties of the fermented milk kefir and white rice kefir were evaluated to assess product quality [20].

2.2.6. Statistical Analysis

Statistical analysis was performed by using appropriate methods such as analysis of variance (ANOVA) to compare the fermentation kinetics, physicochemical properties, and microbiological characteristics of milk kefir and white rice kefir at different temperatures.

2.2.7. Data Interpretation and Comparison

The fermentation kinetics and microbial diversity were compared by using Curve Expert Interpret to understand the implications of low-temperature fermentation on the quality and functional properties of the fermented products.

3. RESULTS AND DISCUSSIONS

The comparison of fermentation kinetics of milk kefir and white rice kefir at low temperatures has yielded significant results, shedding light on the effects of low temperatures on the product quality of these fermented beverages. The study involved a comprehensive analysis of the fermentation process, physicochemical properties, microbiological characteristics, and product quality assessment, providing valuable insights into the differences between milk kefir and white rice kefir under low-temperature conditions.

3.1. Fermentation Kinetics

The fermentation kinetics of milk kefir and white rice kefir at low temperatures were found to exhibit distinct patterns. The analysis revealed that the fermentation rates, as indicated by changes in pH, titratable acidity, and microbial population dynamics, differed significantly between the two types of kefirs. The kinetics of acid production and consumption during fermentation were influenced by the specific characteristics of the substrates and the microbial composition, leading to variations in the fermentation profiles of milk kefir and white rice kefir [18]. Figure 1 shows the difference in

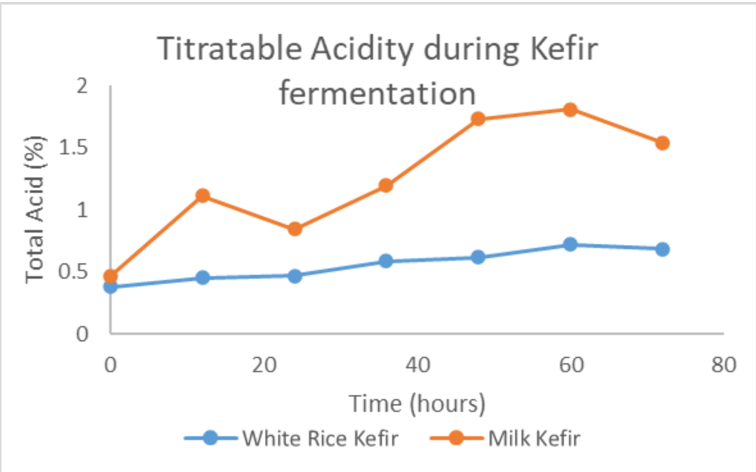

Figure 2. Titratable acidity of milk kefir and white rice kefir during fermentation.

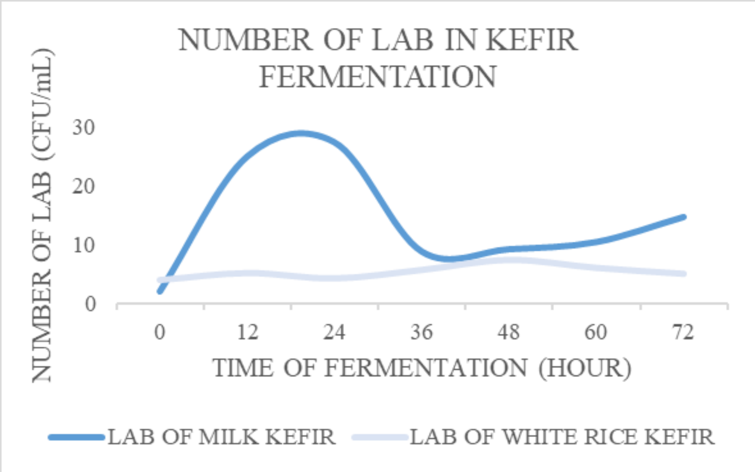

Figure 3. Number of LAB of milk kefir and white rice kefir during fermentation.

kinetics due to the fermentation from the milk and the white rice kefir. Each sample has a different equation of the graph. The reason is that different sources formed different products and also different equations [21].

3.2. Physicochemical Properties

The physicochemical analysis demonstrated notable differences in the physicochemical properties of the fermented milk kefir and white rice kefir. Titratable acidity in Figure 2 illustrates the psychochemical analysis in this instance, with a higher value for milk kefir than for white rice kefir. Rheological, textural, and color properties were found to be influenced by the fermentation process and the composition of the substrates, highlighting the impact of low temperatures on the structural and sensory attributes of the kefir products [22].

Huang et al. [23] investigated the effect of flaxseed supplementation in the diet of dairy cows on the volatile organic compounds of raw milk by HS-GC–IMS (Headspace-gas chromatography-ion mobility spectrometry). The study highlighted the potential impact of dietary factors on the composition of milk, which could influence the physicochemical properties of fermented dairy products such as kefir [23]. Moreover, the study by Deeseenthum et al. [13] examined the physical and microstructural characteristics of kefir made of milk and colostrum, providing insights into the influence of raw materials on the properties of kefir [10].

3.3. Microbiological Characteristics

Characterization of the microbial composition revealed distinct microbial communities in milk kefir and white rice kefir during low-temperature fermentation in Figure 3. The microbial diversity and dynamics were found to be influenced by the substrate composition and the environmental conditions, contributing to the unique microbiological characteristics of each type of kefir under low-temperature fermentation [18]. Milk and white rice have different characteristics of kefir as shown by the number of LAB, which milk kefir has a higher LAB than white rice kefir. This is caused by the kefir milk made from the milk that carries the LAB from its milk, thus the numbers are higher than white rice kefir [14].

Zhou et al. [15] investigated the effect of temperature (5–25 °C) on epiphytic LAB populations and fermentation of whole-plant corn silage. The study highlighted the inefficient silage fermentation at low temperatures, attributing it to the inhibition of bacterial metabolism and plant enzymatic activities due to low temperatures [15]. Furthermore, the study by Zhou et al. [16] explored the effects of fermentation temperature (10 and 20 °C), long-term storage at 5 °C, and subsequent warming of corn silage on microbial diversity. The results indicated a shift in dominant bacterial flora with increasing temperature, emphasizing the influence of temperature on microbial dynamics during fermentation [16].

3.4. Product Quality Assessment

The evaluation of product quality encompassed sensory attributes, organoleptic properties, antioxidant activity, and functional properties of the fermented milk kefir and white rice kefir. The sensory analysis indicated differences in aroma, taste, and overall acceptability, reflecting the influence of low-temperature fermentation on the sensory quality of the kefir products. The aroma of the white rice kefir is more likely than milk kefir. Additionally, the assessment of antioxidant activity and functional properties provided insights into the potential health benefits associated with consuming milk kefir and white rice kefir fermented at low temperatures [24].

Yoon et al. [25] investigated the antioxidant activity of yoghurt fermented at low temperatures and its anti-inflammatory effect on colitis in mice. The study demonstrated the impact of low-temperature fermentation on the antioxidant activity of yoghurt, providing insights into the potential health benefits associated with consuming yoghurt fermented at different temperatures [25]. Additionally, the study by García-Ríos et al. [26] utilized iTRAQ (isobaric tags for relative and absolute quantification)-based proteome profiling to analyze *Saccharomyces cerevisiae* and cryotolerant species during low-temperature wine fermentation. The findings shed light on the physiological adaptations of yeast species to low-temperature fermentation, which could have implications for product quality and flavor development in fermented beverages [26].

Liu et al. [27] investigated the fermentation temperature and the phenolic and aroma profile of persimmon wine. The study demonstrated the influence of fermentation temperature on the phenolic composition and aroma profile of fermented beverages, highlighting the importance of temperature control in the production of aromatic fermented products [27]. Additionally, Berthold-Pluta et al. [28] discussed the health-promoting properties and application of exopolysaccharide-producing lactic acid bacteria in the dairy industry, emphasizing the potential impact of fermentation temperature on the functional characteristics of fermented dairy products [28].

4. CONCLUSIONS

From this research, looking at the kinetics fermentation due to the number of LAB, and the value of pH, we can conclude that the kefir fermentation by low temperatures both of milk and white rice happened successfully. Milk kefir and white rice kefir at low temperatures were found to exhibit distinct patterns characterized by different equations of the graph. Titratable acidity which represents the psychochemical properties for milk kefir has higher value than white rice kefir. When milk is used as the substrate, the number of LAB is more likely than white rice kefir. However, based on the organoleptic test, the aromatic from the white rice is stronger than the milk kefir.

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Author Contributions

This research formed of the collaboration between Conceptualization, N. W. and R. B. S.; Methodology, A. Z. E. and M. M.; Food Engineering Methodology E. A. and W. S. S. W. K.; Software, I. S. A.; Preparation sample, F. A. and L. L.; Gaining Fermentation Data, A. M. N.; Data Analysis, R. N. H.; Validation test, P. W. M. and I. J. A.

Conflicts of Interest

The authors declare no conflict of interest.

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