Effect of ripening and coating on characteristics of Dangke cheese inoculated with a starter culture of *Lactococcus lactis* subsp. *lactis* FNCC-0086

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Abstract. Dangke is a traditional dairy product from Enrekang Regency, South Sulawesi, Indonesia, categorized as cheese based on its shape and manufacturing process. This traditional cheese has a very short shelf life, lasting only about 2 days at room temperature and approximately 5 days when refrigerated. Innovative product development to create cultured cheese varieties as a diversification of dangke cheese with a longer shelf life is carried out by inoculating a starter culture of lactic acid bacteria, *Lactococcus lactis* subsp. *lactis* FNCC-0086. In this study, Dangke cheese is made from fresh cow's milk curdled with papaya latex. In other conditions, Dangke Cheese can also be made from buffalo milk, goat milk, or even horse milk. The papaya latex is diluted with distilled water in a 1:10 ratio. The milk is pasteurized at 85°C for 1 minute, after which 0.03% of papaya latex is added and stirred slowly until curd forms. The starter culture is inoculated once the milk reaches a temperature of 30°C. The curd is then molded using a semicircular mold with a diameter of 10 cm, resembling the original dangke mold. It is compacted by pressing the curd with a spoon to make the cheese more compact, until no more whey liquid comes out of the curd. The molded cheese is then placed on a cheese rack and ripened at temperatures of 5°, 15°, and 25°C for 3, 6, 9, and 12 days before being coated with beeswax. Dangke cheese was evaluated for its physical-chemical properties. The optimal result was Dangke cheese stored at 5°C for 12 days, exhibiting a pH of 4.36, 0.53% lactic acid, 21.53% protein, 48.98% water, 13.05% fat, 13.52% lactose, and 2.92% minerals after being coated with beeswax.

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1 Introduction

Dangke is a dairy product, and when viewed from the manufacturing process, the type of product is classified as cheese. Dangke (*Dangk well,* from Dutch, meaning "thank you") is a traditional Enrekang product that utilizes fresh milk from buffalo, cow, goat, or sheep, coagulating it with papaya sap or other coagulating agents [1]. In Enrekang Regency, Dangke is a superior and trendy traditional food product. It currently has widespread marketing and enthusiasts, not only within the Enrekang community itself but also among other communities in South Sulawesi. Traditional Dangke has a short shelf life [2] of approximately 1-2 days in room temperature storage and 3-5 days in refrigerated storage (5 °C).

Therefore, it is necessary to develop this traditional cheese product with innovation to extend its shelf life while creating new cheese variants by inoculating starter milk cultures, such as lactic acid bacteria (LAB), including *Lactobacillus lactis and Lactobacillus acidophilus*, and other LAB [3]. In addition to achieving a more compact texture and enhancing the flavor of Dangke, the ripening process is carried out after inoculating the starter, depending on the type of starter used, to optimize the texture, taste, physicochemical properties, and microstructure. To enhance the product's hygiene during transportation and marketing, the coating process in this study utilizes beeswax as an edible coating that is safe for consumers [1,2,4,5].

Coatings for cheese typically utilize materials that do not allow water to penetrate the product, while also preventing the product from becoming contaminated with the ingredients of the coating product itself [1,4]. Cerqueira et al. (2009) [6] used different polysaccharides for cheese coating, namely chitosan, galactomannan, and agar, with varying formulations and adding plasticizers and corn oil. Shit et al. (2014) [7] also used edible polymers for coating food products to prevent microbial contamination. This research aims to investigate the effect of ripening incubation, different coatings, and their interactions on the physical properties of Dangke cheese inoculated with *L. lactis, as well as* its nutritional composition.

2 Materials and methods

2.1 Preparation of Fresh Milk and Papaya Sap

Fresh bovine milk was obtained from a smallholder farm, Enrekang Regency, South Sulawesi. Milk was transported to the Biotechnology of Milk Processing laboratory, Hasanuddin University in Makassar, using cold milk containers. Papaya sap is a coagulant tapped from fresh papaya fruit in a tree. The process of making dried papaya sap involves tapping it from fresh fruit, collecting it, and then freezing it using a freeze-dryer for 5 hours. This papain powder is then dissolved in sterile distilled water at a ratio of 1:100 (w/v) to serve as a coagulating agent. The starter culture bacteria used are *Lactococcus lactis* subsp. *lactis* FNCC-0086 was obtained from the Center for Food and Nutrition Studies, Gadjah Mada University, Yogyakarta. A starter culture for application in Dangke curd was prepared using reconstituted Skim milk (RSM, 10% w/v). The RSM media was then sterilized at 105°C for 5 minutes, cooled to 40°C, inoculated with 1% *L. lactis*, and then incubated at 30°C for 12 hours.

2.2 Dangke-Cheese Making

Fresh milk was pasteurized at 85°C for 15 seconds, and a solution of papaya sap was added at a concentration of up to 0.2%. Each sample was made from 500 ml of fresh milk. The heating temperature was increased to 95°C and maintained at this temperature for 5 minutes. After the protein milk was coagulated, the milk temperature increased to reach 70°C. Whey is separated by filtration using a coconut shell with a hole at the bottom, through which the whey drains. Curd that is formed, given pressure, and left in the mold for 20 minutes to maximize whey

separation. However, during this process, Lactic Acid Bacteria inoculation was carried out using three types of fermented milk culture starters, each inoculated with *Lactococcus lactis at* a concentration of 1%, with fermentation times of 10, 15, and 20 hours at 30°C. Dangke, with the best quality, carried out the ripening process at temperatures of 5 °C, 10 °C, and 15°C for 24 hours, 48 hours, and 72 hours. The best dangke in the ripening process will be coating using beeswax with various levels of dangke dipping (once, twice, and three times dipping).

2.3 Parameters to be measured

The parameters measured in this research are the product's physicochemical properties. Physical properties include lactic acid %, pH, moisture, protein, fat, carbohydrates, and minerals.

3 Results and discussion

3.1 Dangke-cheese Physical Properties

The average pH of Dangke control (not coating) in Figure 1 was 5.5 to 6.5, and lactic acid was 0.37-0.44 in 5, 15, and 25 °C, where lactic acid was highest in 25 °C. The pH of regular milk is 6.7 [8]. Dangke's pH will continue to decrease with longer storage time and higher ripening temperatures, directly proportional to lactic acid production during ripening [9]. The average lactic acid production in Dangke Cheese is 0.35 to 0.45%, and it increases with ripening time and temperature [10]. Total lactic acid increases if the ambient temperature supports milk's acidic properties and carbon dioxide activity [11]

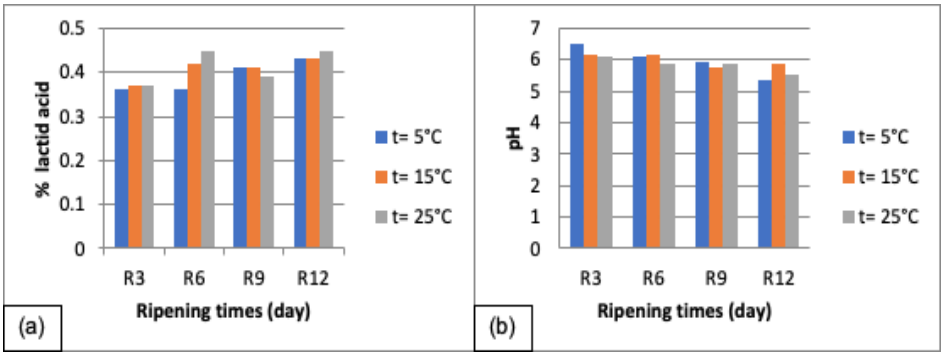

Fig. 1. Effect of ripening time and temperature of Dangke control on (a) lactic acid production and (b) pH (t = temperature; R = ripening day).

The temperature and ripening time affected the pH of Dangke inoculated with *L. lactis* and coated with beeswax (Figure 2). The low temperature increased pH (15 and 25 °C <5 °C). Duration of curing decreased the pH level of Dangke and will continue to decline with the length of ripening time (R12 < R3, R6, R9). The interaction between temperature and the ripening time of Dangke affects the decrease in pH.

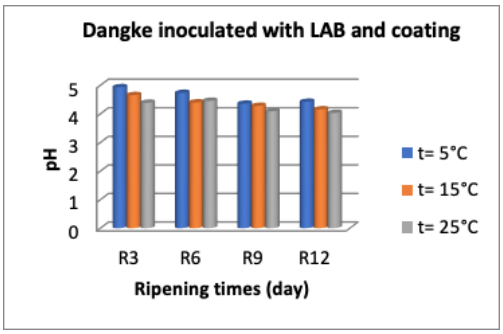

Fig. 2. Effect of ripening time and temperature on pH of dangke inoculated with LAB and beeswax coating (t = temperature; R = ripening day).

The pH value of Dangke ripening decreased with low temperature and increased with the length of ripening. The decrease in pH is caused by H^+ ions derived from the metabolic products of lactic acid bacteria (LAB), as LAB can convert lactose into lactic acid [12]. Environmental temperature conditions primarily determine the metabolic ability of LAB [13–15]. The pH value of ripening Dangke is a measurement of the acidity of the metabolic products of starter bacteria that convert lactose into lactic acid. The ripening temperature determines the ability of *L. lactis* to be active, and the duration determines the amount of *L. lactis* activity [16–18]. The decrease in the pH of ripening Dangke indicates that the ripening process is successful.

Lactococcus lactis is a microorganism that metabolizes glucose into lactic acid [19]. The final pH achieved in glucose broth can range from 4.0 to 4.5. Fresh milk has a pH ranging from 6.6 to 6.7 [20], and if bacteria acidify it enough, these numbers will decrease significantly. The combination of temperature and ripening time increased the production of lactic acid. The temperature of 5ºC suppressed the growth of LAB, resulting in lower lactic acid production compared to 15°C and 25ºC. Environmental temperature conditions strongly influence LAB activity in producing lactic acid. *L. lactis* can survive at temperatures ranging from 5 to 50 °C, with an optimum growth temperature of 30 °C.

The yield of control Dangke (a) was categorized as higher than that of other Dangke (Figure 3). The difference in yield values between dangke may be influenced by the milk protein (casein) and fat content. The longer the curing time, the greater the weight loss of the dangke due to water evaporation during storage. In the Dangke treatment inoculated with L. lactis (b), there will be a higher weight loss because these lactic acid bacteria utilize water during lactic acid metabolism, resulting in a weight loss of 40.6-78.7 g. However, this difference is not statistically significant. This is significantly different from the coating treatment (c) and the dangke treatment, which involves coating and inoculating with *L. lactis.* The coating prevents water evaporation, resulting in a higher yield weight of 74.3-81.7 g. Casein is the primary element that affects the yield (percentage of product) of cheese, resulting in higher total solids [21]. The acidity of the milk also influences protease activity during coagulation, affecting the strength of the curd and thereby controlling the yield of the cheese produced [22].

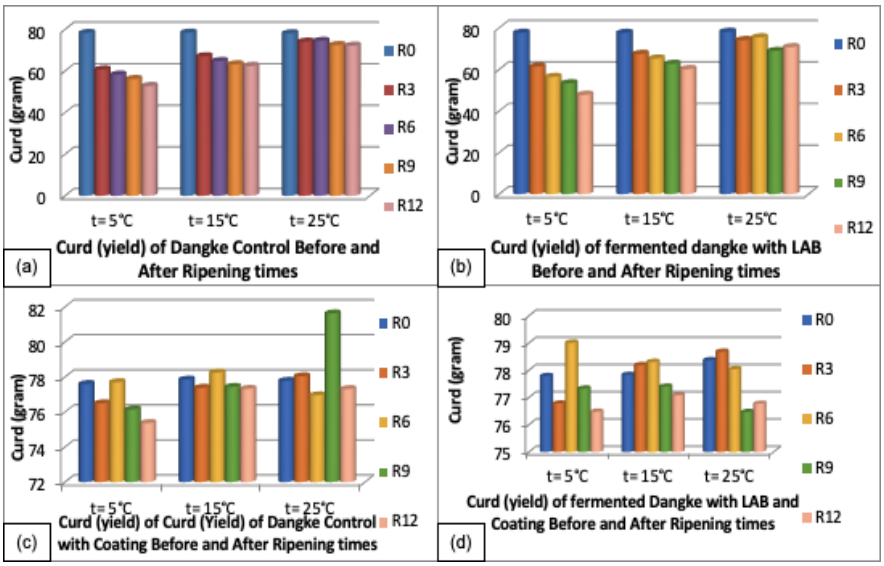

Fig. 3. Effect of before and after ripening time and temperature on curd (yield) of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

3.2 Dangke-cheese Nutritional Composition

3.2.1 Moisture

The moisture content of the control Dangke was 38-55% (Figure 4). The moisture content of the control fluctuated in response to ripening and temperature. The physical and chemical properties of water in food vary because water is bound in food with different degrees or strengths of bonds [23]. Water in food can exist between cells, be trapped within cells, or be bound to a chemical compound. There was a decrease in the water content of Dangke with the addition of *L. lactis* at low curing temperatures (5 °C < 15 °C < 25 °C), along with a longer ripening time (Figure 4). The ripening temperature determines the growth ability of *L. lactis* to carry out metabolic processes. The optimal temperature for *L. lactis* growth affects the number of water molecules in Dangke, which is a result of metabolism. The moisture of Dangke cheese inoculated with *L. lactis* at a ripening temperature of 25 °C was higher (63%) compared to the control (56%) at ripening times of 3, 9, and 12 days. The moisture of Dangke was only coated without *L. lactis* fermentation was highest after nine days of ripening at a temperature of 5°C (66%). Meanwhile, the humidity of dangke cheese, coated and inoculated with *L. lactis* for almost all ripening times, seemed more stable, in the 58-67% range.

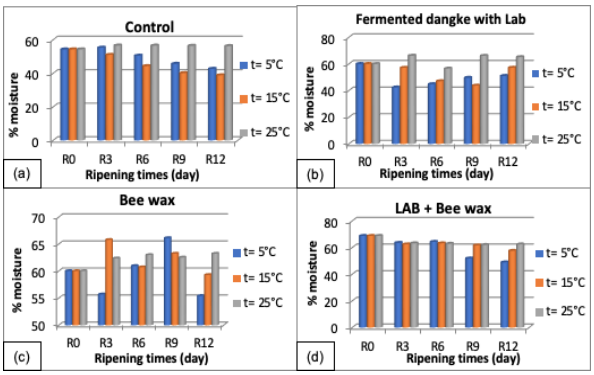

Fig. 4. Effect of ripening time and temperature on the moisture of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

The water content of ripening Dangke with LAB and coating was significantly different only at 12 days, with various steeping temperatures (Figure 4). The provision of coatings limits the activity of *L. lactis* in the overhaul of Dangke. The duration of ripening is the time during which *L. lactis* continues to metabolize, thereby increasing the water content. The range of ripening time significantly affects the ability of *L. lactis* to continue breaking down lactose and producing lactic acid, which in turn breaks down the protein and fat of Dangke. The metabolism of *L. lactis* can increase along with ripening, which is influenced by the ability to grow and the availability of nutrients from Dangke cheese. The chemical reaction of the formation of macromolecular components of Dangke liberates water molecules.

Beeswax-coated Dangke produced different moisture content during ripening with varying temperatures. The temperature and length of ripening determine the moisture content of Dangke, as it is related to the ability of *L. lactis* to produce lactic acid, which plays a role in the hydrolysis of macromolecular chemical components, thereby releasing water molecules. Water molecules can be chemically bound to other molecules through hydrogen bonds [24] and can form layers on the surface of hydrophilic food, including monolayers and multilayers.

3.2.2 Protein

The protein content of the control Dangke differed significantly ($P < 0.05$) in response to variations in ripening time and temperature (Figure 5). Protein levels in the control Dangke varied due to the effect of proteolysis on protein metabolism, which breaks down proteins into amino acids. Protein metabolism produces casein deposits. Casein is a complex protein in milk that exhibits distinctive properties, enabling it to clot and form a compact mass [25].

Generally, the low temperature gave the highest protein content during ripening (Figure 5). The highest protein composition was found at low and longer milking temperatures. This occurs because the growth phase of *L. lactis* is inhibited under these conditions, allowing it to exhibit more proteolytic activity. Consequently, the growth of lactic culture bacteria is significantly inhibited at a temperature of 10°C. The protein level in all processing conditions for dangke that underwent a ripening process, whether fermented with *L. lactis* or not, as well as those that experienced a coating process or were not coated with beeswax, ranged from 14.3 to 20.5%. However, Dangke, with fermentation and coating treatment, has a higher protein percentage stability than other treatments. The protein content of Dangke with a beeswax coating significantly differs ($P < 0.05$) between each temperature and ripening length. Giving beeswax coating inhibits the environmental influence on accelerating the metabolic process of enzymes in milk. Lactic acid is positively charged, and milk protein.

It is a negatively charged ion. When lactic acid intersects with milk protein, a neutralization process will occur so that clots are formed. The presence of clots is one of the factors that determines the level of Dangke protein. During ripening, *L. lactis* growth and proteolysis occur, which strongly influence the pH of Dangke. Milk protein precipitation can occur due to acidification, which causes the solution to reach its isoelectric point [26].

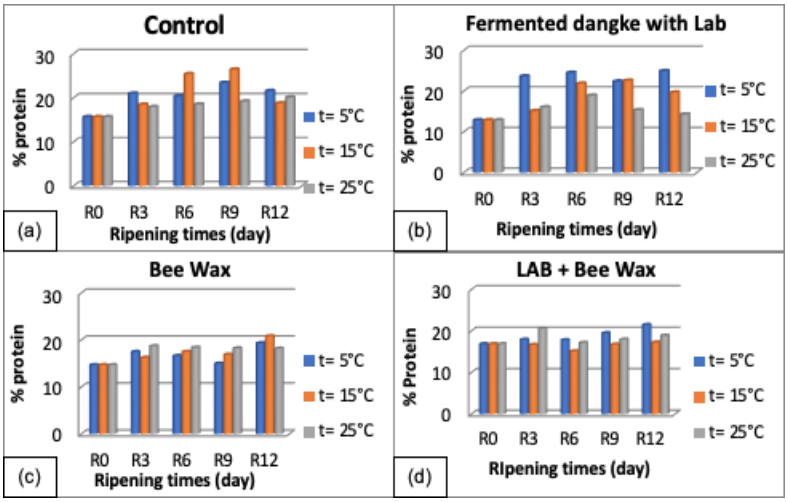

Fig. 5. Effect of ripening time and temperature on the protein of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

The duration of ripening increased the protein content of dangke. The range of ripening time affects the growth phase of *L. lactis* and the proteolytic yield. Bacterial protein components and proteolytic activity determine dangke protein content. The longer the ripening period, the more the Dangke protein content may decrease due to the death phase of *L. lactis*, resulting in reduced proteolysis. The bacteria will cause a death phase after the stationary growth phase [27]. The interaction of temperature and ripening time for each treatment is significantly different ($P<0.05$) due to the growth ability and activity of *L. lactis* affecting the protein content of Dangke. The highest protein levels were at lower ripening temperatures and longer ripening times. This occurs because the growth phase of *L. lactis* is inhibited, allowing for more time for proteolytic activity.

The protein content of dangke ripening at a temperature of 5ºC for 12 days is the highest. The protein content (24.97%) in ripening Dangke can be said to meet the standards for the class of ripening cheese. The cheddar cheese contains 24.9% protein, and the protein content of cheddar cheese is 26% [23].

3.2.3 Fat

The fat content of the control Dangke decreased with the length of ripening time and the difference between each temperature (Figure 6). The fat breakdown is influenced by lipase enzymes naturally found in milk (Dangke raw material). According to Bachrudin et al (2000) [28] statement that the role of *L. lactis* in cheese-making is to produce acid and flavor, help curd formation, and produce lipolytic and proteolytic enzymes that are important in cheese maturation.

The fat composition of the Dangke fermented with LAB and the length of ripening time significantly differed ($P<0.05$) between each temperature (Figure 6). The length of ripening

is the time for *L. lactis* to break down the Dangke fat and only occurs as long as the lipase enzyme in Dangke is available. At a specific time, the lipase enzyme can decrease due to the activity of *L. lactis,* which has died. Lactic acid production will stop if the lactose content in the cheese is entirely fermented [26]. If the lactose has run out, the growth opportunity of *L. lactis* will decrease. The interaction of temperature and ripening time affects the growth of *L. lactis* and *the* fat breakdown that can be produced during ripening. The temperature that allows *L. lactis* to grow will increase the lipase enzyme for the lipolysis process and will continue to decrease as the length of curing increases due to reduced nutrient availability, too high acidity or the life span of *L. lactis* has expired.

The decrease in the fat content of ripening Dangke is significantly different ($P<0.05$) from ripening time and temperature. The interaction of temperature and different ripening times greatly influenced the fat content of Dangke Ripening. The growth activity factor of *L. lactis* determines the ability to produce enzymes [29] and hydrolyze fat. Besides being influenced by the hydrolysis process, fat content can also be influenced by the fat content of Dangke raw materials. The low fat of ripening Dangke can be influenced during the whey extraction process. The fat content of cheddar cheese is 34%; the low-fat content is a characteristic of Dangke ripening, a protein0rich dairy product [30].

The fat content of dangke decreased very significantly after the ripening process. The fat in the dangke cheese control (not ripened with *L. lactis* nor coated with beeswax) ranged between 5.1% and 9.8% at all incubation temperatures. There was no significant difference between storage at 5, 10 and 15°C.

3.2.4 Carbohydrate

The carbohydrates of Dangke were different during the ripening period and between the ripening temperatures (Figure 7). The Dangke carbohydrate is mostly milk lactose. In cheese making, lactose is used as an ingredient for LAB fermentation to produce lactic acid. The ripening temperature greatly influences the ability of *L. lactis to* metabolize the carbohydrates of Dangke. Widodo (2003) [31] stated that cheese ripening controls the decomposition of cheese due to the activity of enzymes and bacteria.

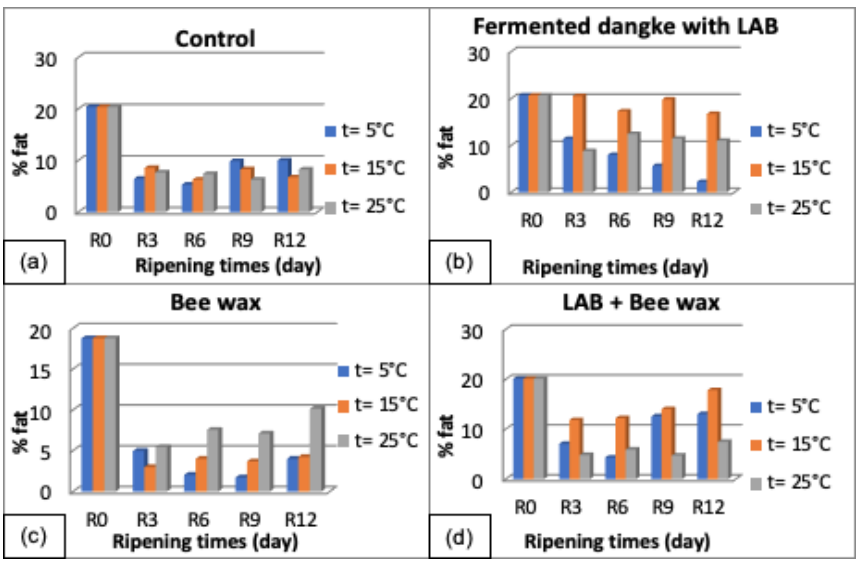

Fig. 6. Effect of ripening time and temperature on the fat of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

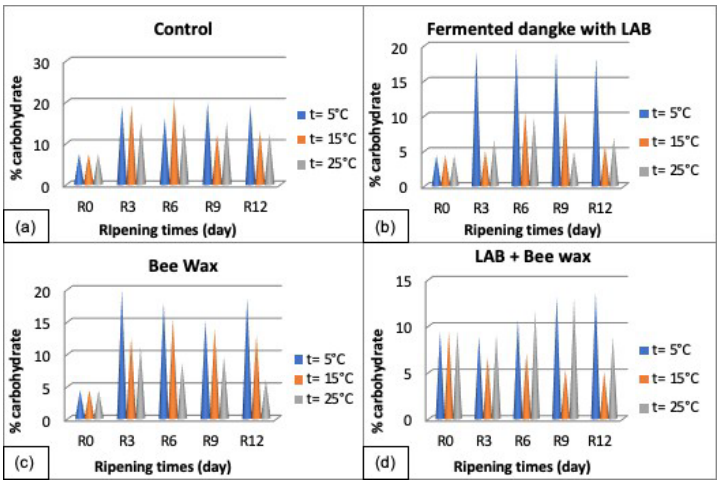

Fig. 7. Effect of ripening time and temperature on the carbohydrate of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

Lactococcus lactis in metabolizing Dangke carbohydrates is also controlled by the ripening time. The longer the ripening, the lower the carbohydrate content of Dangke. The decrease in carbohydrate content is due to the extended storage; *L. lactis* metabolizes the more Dangke carbohydrate*s* into lactic acid. Lactic cultures can continue to form acids until the amount at which cell activity begins to decline [15], and some cells may even die if the acidity is too high.

There was a decrease in the carbohydrate content of beeswax-coated Dangke with longer ripening times and higher ripening temperatures (Figure 7). This is due to changes in its chemical properties during the ripening process. The research results indicate that the higher the temperature and the longer the cooking time, the lower the carbohydrate content in Dangke, which is attributed to the ripening temperature affecting the ability to metabolize carbohydrates into lactic acid. Ripening time will also affect *L. lactis* activity. Lactococcus lactis in milk fermentation acts as an acidifier, which is produced optimally at optimal environmental temperatures [32].

The low ripening temperature of 5 °C inhibits the growth of L. lactis, thereby reducing its ability to degrade carbohydrates compared to temperatures of 15 °C and 25 °C. However, when stored at 5 °C, these lactic acid bacteria will continue to survive, continuously degrading carbohydrates over time [33]. A refrigerator temperature of 5°C does not completely stop microbial activity. Pathogenic bacteria generally cannot move, but lactic acid bacteria can continue to grow.

3.2.5 Ash

The ash of the control dangke ranged from 2-3.5% at various lengths and temperatures (Figure 8). Raw milk materials and processing strongly influence the ash content of the control dangke. The ash content of fermented dangke is influenced by the condition of the raw materials, the processing process, and the activity of *L. lactis* during fermentation. Acidification provides an opportunity for *L. lactis* to metabolize the nutrients of dangke cheese. The composition of Ash beeswax-coated dangke was not significantly different ($P>0.05$) in temperature and length of ripening. There is a tendency for changes in ash content to occur due to the activities that take place in Dangke during ripening *Lactococcus lactis* activity.

during ripening affects the macro-chemical composition changes and the ash content produced after ripening [34].

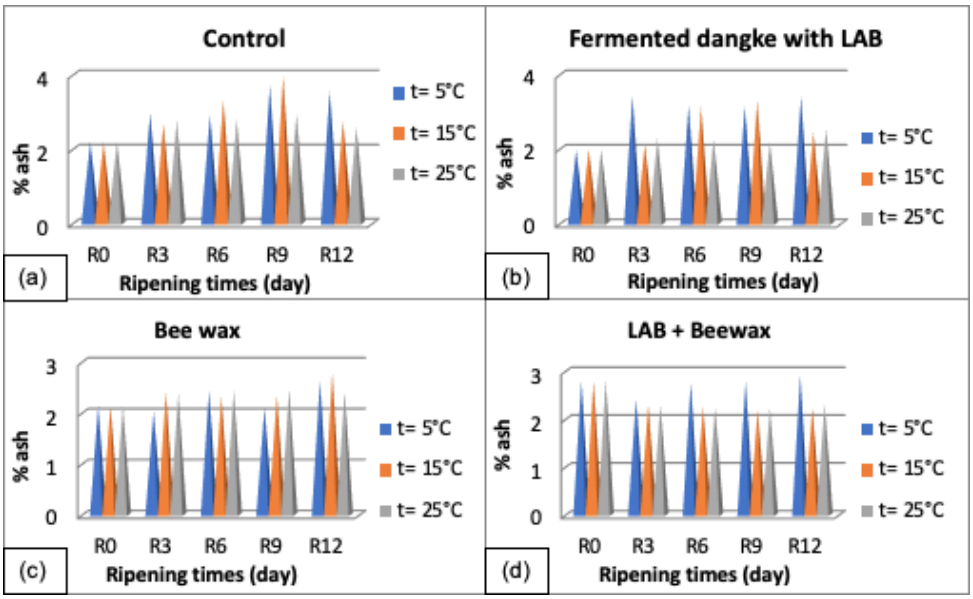

Fig. 8. Effect of ripening time and temperature on the ash of Dangke (a) control; (b) fermented with LAB; (c) control with beeswax coating; (d) fermented with LAB and beeswax coating (t = temperature; r = ripening day).

4 Conclusion

The best result is the use of *Lactococcus lactis* subsp. *lactis* starter culture for the fermentation process with bee wax coating with 12 days of ripening, giving the best Dangke cheese characteristics, namely % curd 78.4%; pH 4.36; 0.53% lactic acid; 21.53% protein; 48.98% water; 13.05% fat; 13.52% lactose and 2.92% minerals.

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Data availability statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution statement
Ratmawati Malaka: Conceptualization, Methodology, Investigation, Writing- Original draft preparation. A. Amidah Amrawaty: Data curation, Writing- Reviewing and Editing. Wendry Satriadi Putranto: Investigation, Writing- Reviewing and Editing. Rizky Widiyanty Kadir: Investigation, Writing- Reviewing and Editing. Fitri Armianty Arief: Investigation, Writing- Reviewing and Editing.

References

[1] K. Liburdi, C. Boselli, G. Giangolini, et al. An Evaluation of the Clotting Properties of Three Plant Rennets in the Milks of Different Animal Species, Foods 8 (2019) 600. https://doi.org/10.3390/foods8120600.

[2] R.H.B. Setiarto, N. Nur, A. Romulo. Dangke: unveiling Indonesian traditional fermented cheese from Enrekang, South Sulawesi, Journal of Ethnic Foods 12 (2025) 16. https://doi.org/10.1186/s42779-025-00279-1.

[3] M.A. Zakariah, R. Malaka, A. Laga, et al. Isolation and Identification of Lactic Acid Bacteria from Dangke a White Soft Traditional Cheese from Enrekang Regency, International Journal of Recent Technology and Engineering 8 (2019) 4148–4151. https://doi.org/10.35940/ijrte.B3160.078219.

[4] Perez-Vazquez, P. Barciela, M. Carpena, et al. Edible Coatings as a Natural Packaging System to Improve Fruit and Vegetable Shelf Life and Quality, Foods 12 (2023) 3570. https://doi.org/10.3390/foods12193570.

[5] Nunes, M. Silva, D. Farinha, et al. Edible Coatings and Future Trends in Active Food Packaging–Fruits' and Traditional Sausages' Shelf Life Increasing, Foods 12 (2023) 3308. https://doi.org/10.3390/foods12173308.

[6] M.A. Cerqueira, A.M. Lima, B.W.S. Souza, et al. Functional Polysaccharides as Edible Coatings for Cheese, Journal of Agricultural and Food Chemistry 57 (2009) 1456–1462. https://doi.org/10.1021/jf802726d.

[7] S.C. Shit, P.M. Shah. Edible Polymers: Challenges and Opportunities, Journal of Polymers 2014 (2014) 1–13. https://doi.org/10.1155/2014/427259.

[8] E. Yang, Q. Yang, B. Troemper, et al. Investigation on Bacterial Growth and pH in Milk after the Expiration Date, Scientific World Journal 2023 (2023) 9982886. https://doi.org/10.1155/2023/9982886.

[9] W. Erliana, T. Widjaja, A. Altway, et al. The effects of various pH and temperature to enhance lactic acid production using Lactobacillus casei and Lactobacillus rhamnosus, in Proceedings of the 2nd International Conference on Chemical Process and Product Engineering, ICCPPE 2019, AIP Conference Proceedings 2197 (2020) 060005. https://doi.org/10.1063/1.5140932.

[10] A.N. Mukhlisah, I.I. Arief, E. Taufik. Physical, Microbial, and Chemical Qualities of Dangke Produced by Different Temperatures and Papain Concentrations, Media Peternakan Fakultas Peternakan Institut Pertanian Bogor 40 (2017) 63–70. https://doi.org/10.5398/medpet.2017.40.1.63.

[11] E. Abedi, S.M.B. Hashemi. Lactic acid production – producing microorganisms and substrates sources-state of art, Heliyon 6 (2020) e04974. https://doi.org/10.1016/j.heliyon.2020.e04974.

[12] F. Winarno. Kimia Pangan dan Gizi (Gramedia, Jakarta, 2004).

[13] N. Ahansaz, A. Tarrah, S. Pakroo, et al. Lactic Acid Bacteria in Dairy Foods: Prime Sources of Antimicrobial Compounds, Fermentation 9 (2023) 964. https://doi.org/10.3390/fermentation9110964.

[14] T. Goa, G. Beyene, M. Mekonnen, et al. Isolation and Characterization of Lactic Acid Bacteria from Fermented Milk Produced in Jimma Town, Southwest Ethiopia, and Evaluation of their Antimicrobial Activity against Selected Pathogenic Bacteria, International Journal of Food Science 2022 (2022) 1–15. https://doi.org/10.1155/2022/2076021.

[15] Y. Wang, J. Wu, M. Lv, et al. Metabolism Characteristics of Lactic Acid Bacteria and the Expanding Applications in Food Industry, Frontiers in Bioengineering and Biotechnology 9 (2021). https://doi.org/10.3389/fbioe.2021.612285.

[16] R. Dorau, J. Chen, P.R. Jensen, et al. Complete Genome Sequence of Lactococcus lactis subsp. lactis bv. diacetylactis SD96, Microbiology Resource Announcements 9 (2020). https://doi.org/10.1128/MRA.01140-19.

[17] M. Ruggirello, P. Dolci, L. Cocolin. Detection and Viability of Lactococcus lactis throughout Cheese Ripening, PLoS One 9 (2014) e114280. https://doi.org/10.1371/journal.pone.0114280.
[18] T. Cheng, L. Wang, Z. Guo, et al. Technological characterization and antibacterial activity of Lactococcus lactis subsp. cremoris strains for potential use as starter culture for cheddar cheese manufacture, Food Science and Technology 42 (2022). https://doi.org/10.1590/fst.13022.
[19] Johanson, A. Goel, L. Olsson, et al. Respiratory Physiology of Lactococcus lactis in Chemostat Cultures and Its Effect on Cellular Robustness in Frozen and Freeze-Dried Starter Cultures, Applied and Environmental Microbiology 86 (2020). https://doi.org/10.1128/AEM.02785-19.
[20] E. Yang, Q. Yang, B. Troemper, et al. Investigation on Bacterial Growth and pH in Milk after the Expiration Date, The Scientific World Journal 2023 (2023) 1–9. https://doi.org/10.1155/2023/9982886.
[21] Sameen, F. Muhammad A, N. Huma, et al. Quality Evaluation of Mozzarella Cheese from Different Milk Sources, Pakistan Journal of Nutrition 7 (2008) 753–756. https://doi.org/10.3923/pjn.2008.753.756.
[22] P. Fox, T. Guinee, T. Cogan, et al. Fundamentals of Cheese Science, 2nd Edition (Springer, USA, 2017).
[23] F. Kusnandar. Kimia Pangan: Komponen Makro (PT Dian Rakyat, Jakarta, 2010).
[24] M.R. Kasaai. Use of Water Properties in Food Technology: A Global View, International Journal of Food Properties 17 (2014) 1034–1054. https://doi.org/10.1080/10942912.2011.650339.
[25] Runthala, M. Mbye, M. Ayyash, et al. Caseins: Versatility of Their Micellar Organization in Relation to the Functional and Nutritional Properties of Milk, Molecules 28 (2023) 2023. https://doi.org/10.3390/molecules28052023.
[26] M. Asaduzzaman, M.S. Mahomud, M.E. Haque. Heat-Induced Interaction of Milk Proteins: Impact on Yoghurt Structure, International Journal of Food Science 2021 (2021) 5569917. https://doi.org/10.1155/2021/5569917.
[27] K. Papadimitriou, A. Alegría, P.A. Bron, et al. Stress Physiology of Lactic Acid Bacteria, Microbiology and Molecular Biology Reviews 80 (2016) 837–890. https://doi.org/10.1128/MMBR.00076-15.
[28] Z. Bachrudin, Astuti, Y. Dewi. Isolasi dan Seleksi Mikroba Penghasil Laktat dan Aplikasinya pada Fermentasi Limbah Industri Tahu, in Proceedings of the Seminar Nasional Industri Enzim Dan Bioteknologi (2000).
[29] Y. Yang, Y. Zhaou, H. Lei. Protective effects of Lactococcus lactis subsp. lactis HFY14 supplementation on the brain, intestines, and motor function of antibiotic-treated mice, Frontiers in Microbiology 15 (2024) 1–10.
[30] P. Gaman, K. Sherrington. The Science of Food, Fourth Edition (Elsevier, USA, 1996).
[31] Widodo. Bioteknologi Industri Susu (Lacticia Press, Yogyakarta, 2003).
[32] F. Afiati, Yopi, R. Maheswari. Pemanfaatan Bakteri Probiotik Indigenus dalam Pembuatan Keju Lunak, Jurnal Teknologi Dan Industri Pangan 25 (2014) 7–15. https://doi.org/10.6066/jtip.2014.25.1.7.
[33] Putriana. Nilai pH, Jumlah Mikroba, Jumlah Bakteri Asam Laktat Keju Probiotik yang Dibuat dengan Tiga Level Kultur Bakteri Asam Laktat, Jurnal Ilmiah Peternakan 1 (2013) 525–530.
[34] M. Sardiñas-Valdés, J.A. Hernández-Becerra, H.S. García-Galindo, et al. Physicochemical and sensory properties of Manchego-type cheese fortified with nanoemulsified curcumin, International Food Research Journal 28 (2021) 326–336. https://doi.org/10.47836/ifrj.28.2.13.