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Dadih, traditional fermented buffalo milk: a comprehensive review of the aspects of gastronomy, health benefits, and product development

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Abstract

Indonesia is a country with a rich array of traditional meals renowned for their health benefits and potential to serve as functional foods, including dadih. Several studies have shown that dadih is a traditional fermented product from Indonesia, with various culinary applications. In addition, it is typically produced from fermented buffalo milk, which forms an unchanged or broken lump when fermented at room temperature. This product is also widely consumed by the Minangkabau ethnic group in Central Sumatra (nowadays known as the provinces of West Sumatra, Riau, Kepulauan Riau, and Jambi), holding a significant position in their culinary practices. Dadih is often traditionally processed through spontaneous fermentation in bamboo containers without the need for additional inoculation with buffalo milk. The indigenous dadih lactic acid bacteria has been evaluated to have several advantages, including immunomodulatory, antioxidant, antimutagenic, hypocholesterolemic, and antimicrobial properties, by various mechanisms. In addition, this product offers significant nutritional content, promoting digestive health and enhancing the body's resilience.

Keywords Dadih, Gastronomic, Health benefit, Indonesia, Minangkabau

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Introduction

Functional foods are defined as meals containing bioactive components that have benefits to human physiology, potentially aiding in the chronic diseases prevention [1]. Despite their significance, several studies have shown the presence of varying definitions around the world [2]. In addition, functional foods, comprising both fresh and processed meals, have positive effects on human health and nutritional requirements [3]. These findings must be supported by scientific data, emphasizing the importance of regular consumption [4]. The inclusion of processed and fresh meals as forms of functional foods can facilitate their growth in the academic and business fields [5]. According to previous studies, there are three primary types of functional foods based on the constituent microbes, including prebiotics, probiotics, and synbiotics (mixtures of prebiotics and probiotics) [6, 7].

Indonesia has traditional meals that has potential as functional foods, but the majority of studies focus on modern varieties, which are often produced with the assistance of technology or scientific exploration [8]. The factors influence the consumption of traditional functional foods, with descriptive norms being one of the most influential [9–11]. In addition, Verbeke and López [12] reported that traditional meals can be referred to as “ethnic foods” due to their ability to symbolize specific cultural markers. Previous studies have also acknowledged that some traditional meals possess functional food qualities [13]. Therefore, “traditional functional foods” refers to Indonesian meals that have been consumed for generations, in the context of Indonesia [8].

Dadih (curd) can be classified as traditional foods [8] due to their potential health benefits as Indonesian traditional meals. According to Purwaningsih et al. [5], there is an increasing trend in studies and development within the field of functional foods in Indonesia. This suggests increased public interest, particularly in local and traditional meals. Dadih is a fermented milk variety prominent in the cuisine of West Sumatera. In addition, it is often produced from buffalo milk by lactic acid bacteria (LAB) within bamboo containers for 2 to 3 days at ambient temperature. Dadih has been reported to have a unique sour flavor as well as contain several essential nutrients and probiotics [14, 15]. LAB, such as *Lactococcus lactis*, *Enterococcus lipophilus*, *Leuconostoc mesenteroides*, *Bifidobacterium bifidum*, *Lactobacillus casei*, *Lactobacillus bulgaricus*, and *Streptococcus thermophilus,* are microorganism that are mostly involved in fermentation of dadih. In the fermentation process, these bacteria can originate from banana leaves, bamboo tubes, or buffalo milk. Additionally, in the inner bamboo tube section contain *C. metapsilosis* [16–18]. In line with previous studies, it typically presents as intact or broken buffalo milk lumps with a white appearance similar to that of tofu. During the production process, no starter is often added to initiate fermentation [19]. Curd is one of Indonesia’s traditional foods that has been widely explored and has the potential as a probiotic food derived from buffalo milk [20]. Although there is also another buffalo milk derivative product, namely dangke from South Sulawesi, these two products have differences in the ingredients and microorganisms in them [21, 22]. Several reports have shown that it is favored by elderly Malay individuals, particularly in central Sumatra, as a regular health food [15, 23]. Apart from West Sumatra, it is also found in the province of Riau due to their close cultural links [21]. Dadih has uniqueness compared to other traditional fermented foods in Indonesia; Minangkabau, West Sumatra, uses bamboo pieces as containers, has many health benefits, and is one of the most popular processed foods in Indonesia. To clarify this, it will be explained in this manuscript section.

Despite its potential, several obstacles have been identified in dadih manufacturing, prompting a collaboration between local government and scientists to find solutions. Therefore, this study aims to generate and disseminate information regarding the evolution of dadih [15]. To strengthen its identity as a traditional meal, particularly in the Minangkabau ethnic culture, it is essential to conduct an in-depth identification to ensure that local and foreign audiences comprehend its origins [24]. This study discusses the history and cultural aspects of dadih, the manufacturing process, its potential as functional foods, and the development of dadih products in Indonesia.

Method

The research on dadih, an Indonesian traditional cuisine with promise for functional food, that has been published in foreign publications is still few. The current study’s examine earlier research on the creation and caliber of dadih by using papers from various databases, including conference proceedings, books, Google Scholar, Science Direct, and reliable sources. The lack of journals or scientific articles on this subject led to the combination of these popular and scientific references. Furthermore, as the articles’ areas of specialization fall beyond the purview of this study, those that emphasize dadih’s history, production method, and health advantages were chosen over those that promote various recipes.

History of dadih and Minangkabau cultural attachments

As an archipelagic country, Indonesia comprises various tribes and cultures, with a diverse array of traditional meals [25]. Indonesian traditional meals represent authentic culinary practices using local ingredients and a range of local cooking methods, reflecting unique regional characteristics. In addition, it is passed down from generation to generation and harmoniously aligns with religious and cultural values while leveraging locally available produce and spices [24, 26]. In line with previous studies, buffalo (*Bubalus bubalis*) has long played integral roles in Minangkabau culture in West Sumatra, Indonesia, serving purposes such as transportation, rice field plowing, sugar cane processing for sugar production, and tourism, particularly through combat [27]. The architectural style of Minangkabau buildings, resembling the shape of buffalo horns and known as "gadang" homes, also shows the deep cultural affinity of the Minangkabau people with this animal. Several studies have shown that buffalo is often raised for its meat, milk (used for curd production), and hides. The production of dadih, also known as curd, from buffalo milk holds significant cultural significance for the Minangkabau people, symbolizing the host family's hospitality toward guests. Moreover, its production contributes to the local economy and enhances food security among the Minangkabau people [17]. Minangkabau ethnic groups living in central Sumatra, therefore, have a long-standing familiarity with Dadih, predating the introduction of fermented milk products from external sources, such as yoghurt or commercially produced fermented milk.

Dadih is a traditional food typical of the ethnic Minangkabau people in West Sumatra. Physically, it has the appearance of Greek yogurt and has a creamy texture, cream white tastes sour, and color [15]. It holds a significant position among the culinary traditions of the Minangkabau ethnic group, particularly prevalent in West Sumatra Province, Indonesia. Minangkabau people consume dadih for various purposes such as side dishes, dishes during traditional events such as circumcision parties, wedding parties (*Baralek*), and there are also those who consume it for traditional medicinal purposes. Although Minangkabau specialty food, dadih, can also be found in neighboring provinces, such as the Kerinci area in Jambi Province and the Kampar area in Riau Province, the proximity of these regions to West Sumatra indicates a significant influence on the spread and development of the product. [28]. In rural areas, dadih is commonly served either alone or alongside rice, often garnished with sliced shallots and red chilies, or incorporated into refreshing beverages blended with brown sugar, coconut milk, and *ampiang katan pulut* (Sticky Rice Chips) [29]. According to Sugitha [30], it serves various purposes, including being consumed as a side dish, an intermission food, part of rituals, and a traditional remedy. Dadih is notably produced in the district of Kerinci, comprising of Kayu Aro, Air Hangat, and Gunung Kerinci in Jambi Province. Kerinci district dadih bears a resemblance to that of West Sumatra and other areas, maintaining the authentic essence of this cherished Minangkabau food.

Although there is no written history or when dadih first appeared [31], in ancient times, Minangkabau people had the habit of eating curd with sliced onions and rice. However, there are also those who state that based on the history that is believed to have been passed down from generation to generation by the heirs of *Dadiah Aia Dingin*, initially buffalo farmers used buffalo milk for the daily needs of the community in ancient times, both for personal consumption and for sale to meet economic needs. However, one day the buffalo milk was placed in a cup and not drunk for a long time, so that the buffalo milk eventually began to curdle, taste sour, and harden somewhat, which indicated that the milk was stale. In order to prevent this from happening, the community tried to overcome the problem by transferring the unconsumed buffalo milk into a sealable bamboo container in the hope that it could be used for consumption in the next few days, only to find that once opened, the buffalo milk became hard and had a different taste, but was still suitable for consumption. In rural areas, dadih is commonly served either alone or alongside rice, often garnished with sliced shallots and red chilies, or incorporated into refreshing beverages blended with brown sugar, coconut milk, and *ketan emping.* (*Ketan emping* is a condiment in food made from glutinous rice that has been roasted and then flattened so that it is chip-shaped.) So the hardened or fermented buffalo milk is called dadiah which comes from mandidiah (boiling) [32].

The dadih making process

The method for producing dadih from buffalo milk had been passed down without modification [33]. Historically, dadih was typically produced through spontaneous fermentation in a bamboo container, eliminating the need for the inoculation of buffalo milk and heating [21]. In addition, the enzymes and natural LAB contained in the milk were preserved in unheated, unpasteurized fresh buffalo milk. Milk was then placed in a bamboo container and covered with a banana leaf. The sample was aged overnight, allowing mesophilic microorganisms to cause fermentation [34], leading to coagulation [15]. Fermentation of the curd typically occurs between 6 and 18 h to facilitate the thickening of buffalo milk [21, 33]. In addition, the dadih fermentation process occurs spontaneously involving microorganisms found on the buffalo milk used, the leaves used to cover the bamboo, and the inner surface of the bamboo tube [17].

Based on several studies, the bamboo tube used in dadih production has an important role in preserving the product quality [35]. Talang bamboo (*Schizostachyum brachycladum*), betung bamboo (*Dendrocalamus asper*), ampel bamboo (*Bambusa vulgaris*), gombong bamboo (*Gigantochloa verticillata*), were often used during the production process [36] [37]. In addition, the indigenous Minangkabau people preferred Gombong bamboo over other varieties [31]. Minangkabau people prefer to use gombong bamboo for several reasons, such as its abundance, and it also has a slightly bitter taste that does not attract ants so that the curd is not swarmed by ants. Another reason is because the Minangkabau people follow the tradition that has been done by the community for generations in making curd using this type of bamboo [37]. Bamboo segments contain several microorganisms, including fungi, yeasts, lactic acid microorganisms, proteolytic microorganisms, and also spores. The bamboo was then covered with a banana leaf, taro leaf, or plastic lid, and the fermentation process was continued [37, 38]. Dadih fermentation using bamboo and fermented dadih is shown in Fig. 1. Due to its relatively low water content, it could be used to manufacture high-quality dadih. The bamboo was cut to a diameter of 5 to 8 cm and a height of 20 to 30 cm, and the perforated hole at the top was roughly the size of a human finger. The tube was further cleaned and reversed to eliminate any remaining debris [36]. The hygroscopic of bamboo to prevent the product from separating into whey and ants, and it contained several types of microorganisms that fermented milk organically into dadih [31, 39]. Banana leaves were used to generate the optimal facultative anaerobic environment for the fermentation process and to prevent undesirable contamination. Rubber bands and banana bark were then employed to bind the cover [28].

Traditional dadih processing, which relies on a spontaneous fermentation process, makes the dadih produced have characteristics and shelf life inconsistency, in general at room temperature has three days only [40]. Dadih stored at low temperature and can prolong the dadih shelf life up to 30 days [41].

Nutritional content of dadih

The nutritional value of buffalo dadih varied by type of buffalo milk and the manufacturing region [42]. The nutritional profiles of buffalo milk and dadih are presented in Tables 1 and 2. Apart from water and fat, practically all components of buffalo milk dadih were higher compared to cow's milk dadih (Table 2). The water content of the two dadihs was nearly identical, ranging between 75.26% and 76.74%. However, the fat level of the cow's milk variant was greater compared to the buffalo milk variant. This was because the fat content of cow milk was altered before its processing into the product. The fat content in dadih was increased by the evaporation of up to 50% of the initial volume and the addition of cream or skim milk to boost the fat-free dry matter of cow milk. Several studies have shown that buffalo milk dadih contained more protein compared to cow milk variants [43–45]. This was because buffalo milk contained more naturally occurring protein compared to cow milk [44].

Table 3 and Fig. 2 show that dadih from various regions contained various types of LAB. Bacteria transformed milk into dadih and consumed milk proteins during curd fermentation. Therefore, protein hydrolysis could promote the yield product, LAB growth, and simpler to digest compared to raw milk. Based on previous studies, some of the bacteria contained in the curd included *Lactococcus*, *Klebsiella*, *Proteus*, *Acetobacter*, *Bifidobacteriaceae*, *Leuconostoc*, *Enterobacteriaceae*, *Streptococcus*, *Enterobacteriaceae*, *Lactobacillaceae*, *Acinetobacter*, *Oxalobacteraceae*, *Vagococcus*, and *Lactobacillus* [17]. The varying content of LAB in curd provides potential as a probiotic, and the effects on body health are discussed in the health benefits section (Fig. 3). Meanwhile, yeast has found in dadih including *Saccharomyces cerevisiae*, *Kluyveromyces marxianus*, and *Candida metapsilosis*. In addition, *C. metapsilosis* was the most frequently found [22].

Health benefits of dadih

Increase body immunity

Zeng et al. and Chattaraj et al. show dadih for maintaining intestinal homeostasis was a function of the commensal bacteria present in the normal microflora. In addition, reductions in the diversity and quantity of commensal bacteria often led to gastrointestinal dysbiosis, which increased the pathogens number, induced inflammation, and contributed to colorectal cancer development [46, 47]. By stimulating the formation of pathogen-specific memory, probiotics could be used to modulate, regulate, and prevent immune responses [48–50]. The investigation was using 8-week-old male BALB/c mice. Dadih was administered to mice at dosages of 112 mg/20 g BW for a total of 8 weeks. Gram-positive bacteria in dadih were mostly *L. lactis* subsp. *lactis*, by 3×10^7 CFU. Furthermore, an increase in both the pro-inflammatory cytokines (IL-1β and TNF-α) and anti-inflammatory cytokines (IL-10) was observed. This phenomenon shows that curd has the potential for immune system maintenance of mice as experimental animals [51]. The immunomodulatory effect of LAB in dadih was demonstrated in the supplementation of underweight Indonesian preschool children with *E. faecium* IS-27626 (2.31×10^8 CFU/day in 125 mL low-fat milk). The results showed that after 90 days of supplementation, salivary secretory immunoglobulin A (sIgA) increased ($p < 0.05$) Weight growth was found in children with normal BW, suggesting that *E. faecium* IS-27626 could aid in preserving

Fig. 1 The process of making dadih. **A** Fermented dadih using bamboo with a plastic cover, **B** dadih that has been fermented and is ready to be consumed. Dadih that has undergone fermentation is characterized by a thicker or solid texture with a white color

intestinal integrity, thereby promoting optimal nutrition absorption. Through competition for binding sites and nutrition or immunological regulation, the adherence to and colonization of mucosal surfaces were possible protective strategies against infections [52]. After 90 days of supplementation with *L. plantarum* IS-10506 (probiotic)

Table 1 Comparison of nutritional content between buffalo milk and cow's milk

Parameter	Swamp buffalo (*kerbau rawa*) [34]	Mud buffalo (*kerbau lumpur*) [34]
Milk production (L/day)	1–5	6–8
Protein content (%)	5.14	4.68
Fat content (%)	7.23	4.13
Solid material without fat (%)	10.61	11.50
Water content (%)	81.87	80.33
Specific gravity (kg/m3)	1.030	1.036
Total plate count (cfu/mL)	3.79×10^6	5.08×10^5

and zinc, the children's humoral immune response increased significantly, along with their zinc status [53, 54].

Dadih can be used as a probiotic that has influence the immune system on multiple levels, including raising cytokine and immunoglobulin levels, mononucleose cell proliferation, macrophage activation, natural killer cell activity, modifying self-immunity, and promoting immunity against harmful bacteria and protozoa [55]. T cell cytokine generation and lymphocyte proliferation were inhibited in the presence of probiotics. Moreover, these microbes exerted these beneficial effects on the immune system without triggering a detrimental inflammatory response. When multiple probiotics were ingested simultaneously and operated synergistically, the immune response could be improved [56]. This effect was typically noticed when *Lactobacilli* and *Bifidobacterium* spp. were mixed. Probiotics also modulate phagocytosis in distinct ways in healthy and allergic individuals [57]. Supplementation with *L. plantarum* IS-10506 from dadih has been shown to increase sIgA production in children under 2 years old by stimulating TGF-β1. The results showed that there was a substantial association between fecal sIgA and TGF-β1/TNF-α levels [58]. IgA was the first line of defense for the intestinal epithelium against pathogenic bacteria and enteric toxins. sIgA facilitated the clearance of antigens and pathogenic microorganisms from the intestinal lumen by immunological exclusion by promoting their evacuation by mucociliary, entrapping them in mucus, preventing their access to epithelial receptors, and peristaltic processes [59]. Probiotics had the potential to operate as immunomodulators due to their capacity to interact with lymphocytes, macrophages, dendritic cells, and epithelium. Dendritic cells in the digestive system detected the *L. lactis* bacteria wall components, which affected their function. LAB in probiotics could potentially cause an inflammatory response. The TNF-α enhancement in dadih-induced

Table 2 The nutritional content of dadih from different areas in West Sumatera

Nutrition content	Buffalo milk				Cow milk
	Agam [35]	Solok [35]	Sijunjung [36]	Tanah datar [37]	[38]
Water (%)	82.40	81.78	75.45	66.09 ± 6.00	74.47
Fat (%)	8.17	7.98	6.50	5.70 ± 1.73	6.39
Protein (%)	7.06	6.91	5.01	12,41 ± 1.30	5.62
Ash (%)	0.91	0.92	0.68	0.72 ± 0.13	–
pH	4.80	4.76	4.47	4.55 ± 0.21	4.80

Table 3 LAB of dadih from different areas in west Sumatera

Dadih sources (area)	LAB variety	References
Bukit Tinggi dan Padang Panjang	*Lactobacillus sp, Lactococcus sp, dan Leuconostoc sp*	[39]
Bukit Tinggi	*Lactococcus lactis subsp. lactis, Lactobacillus brevis, Lactobacillus plantarum, Lactobacillus paracasei dan Leuconostoc mesenteroides*	[40]
Limapuluh Kota, Agam, Tanah Datar, Solok	*L. brevis, Lactobacillus viridescens, Lactobacillus buchneri, L. plantarum, L. mesenteroides, L. paramesenteroides, S. lactis subsp. diacetylactis, Streptococcus faecium, Streptococcus rafinolactis, Lactococcus piscium*	[41]
Payakumbuh	*L. plantarum*	[42]
Sijunjung	*L. plantarum*	[43]
Padang dan Solok	*L. fermentum, Pediococcus pentosaceus dan Pediococcus acidilactici*	[44]
Solok	*L. plantarum*	[45]

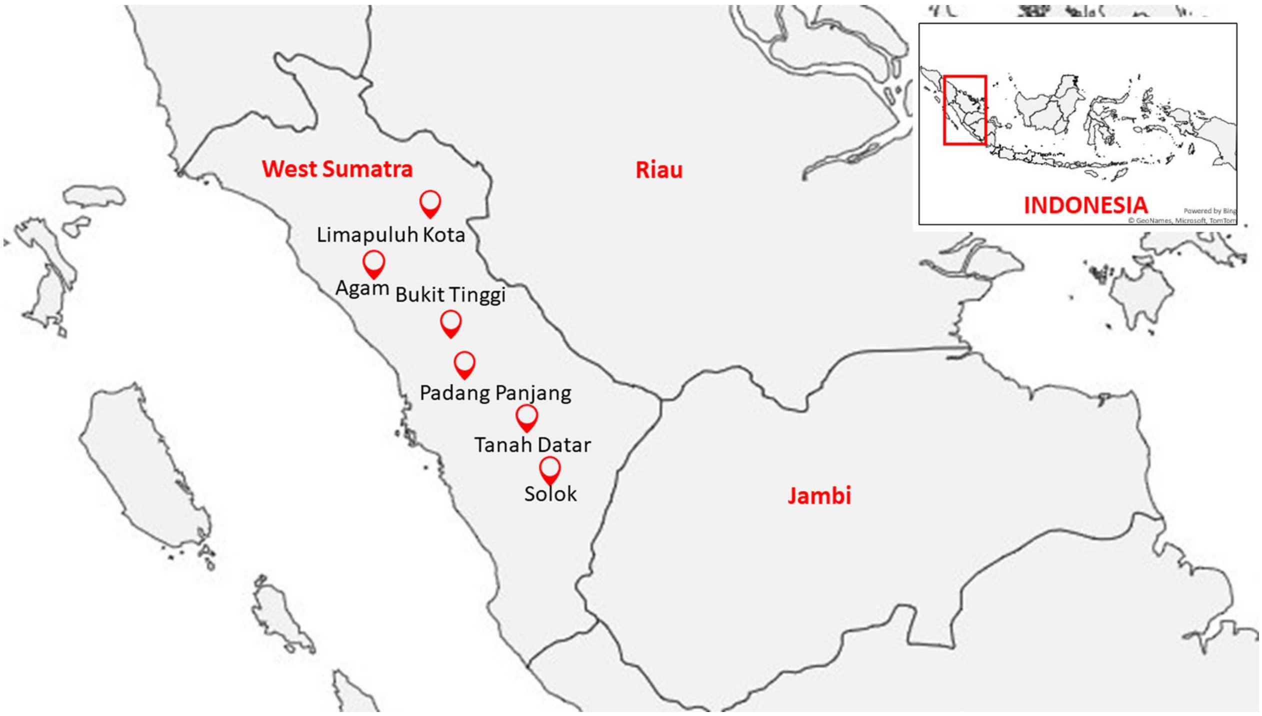

Fig. 2 Distribution and production areas of dadih in West Sumatra Province, Indonesia. This image shows the almost even distribution of dadih throughout the West Sumatra Province, which gives rise to differences in the characteristics of dadih, especially the microorganisms involved during dadih fermentation

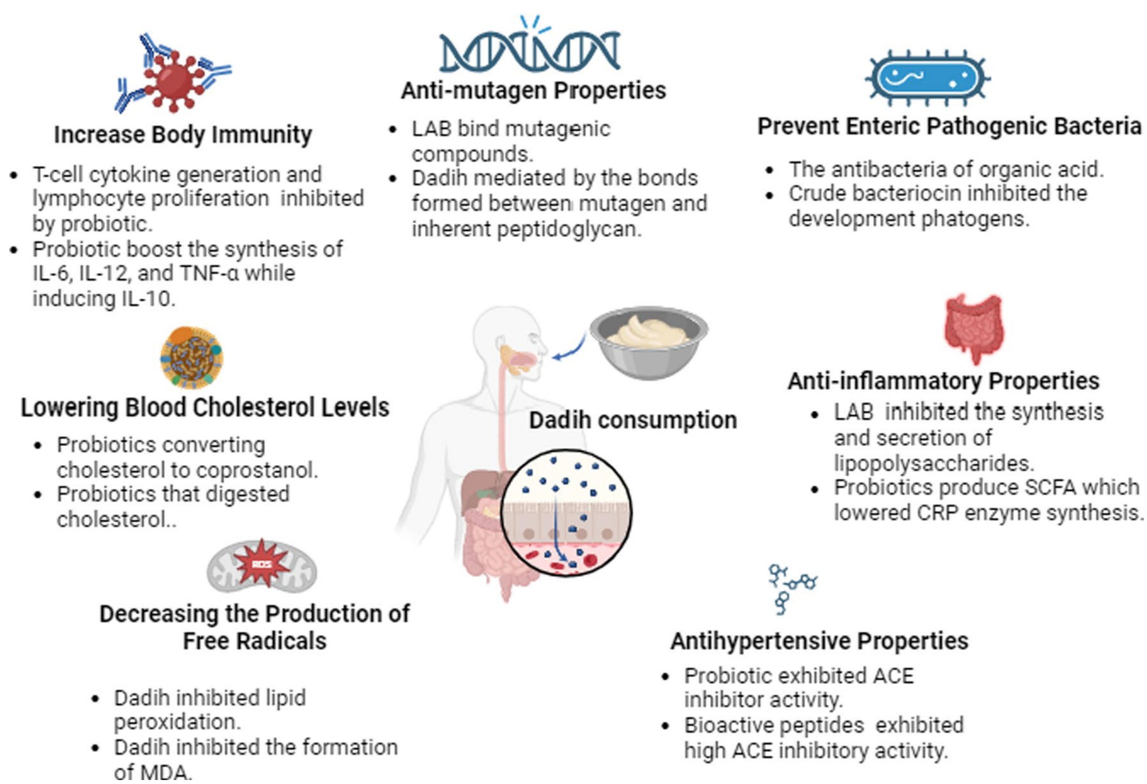

Fig. 3 Health benefits of dadih consumption

animals compared to the control group was due to the intestinal microbiota causing dendritic cells and macrophages to generate TNF-α, IL-1β, and IL-6, promoting Th17 development. According to previous studies, Th17 secretes pro-inflammatory cytokines (IL-17). The synthesis of TNF-α, IL-12, IL-6 boosts by probiotic bacteria while also inducing IL-10. These cytokines were produced by several cells, including keratinocytes, dendritic cells, macrophages, Th-2, and Tregs. IL-10 had an anti-inflammatory impact by suppressing the Th-1.6 response, and IL-10 cytokines were shown to be greater in dadih-induced animals compared to control mice. Probiotics also interacted with Treg, Th2, Th1, dendritic cells, and enterocytes in the digestive tract, modulating adaptive immune cells to create anti- and pro-inflammatory cytokines. IL-10, a cytokine generated by numerous cells, including Treg cells, keratinocytes, Th-2, dendritic cells, and macrophages, may be induced by probiotics. IL-10 inhibits the Th-1 response through an anti-inflammatory mechanism. In this investigation, dadih-induced mice had greater amounts of IL-10 cytokines than mice that did not receive dadih. According to certain research, probiotic administration could activate Foxp3 + Treg cells, which in turn produced IL-10 and TGF-β [51].

The number of LAB colonies in dadih is 21×10^{9} CFU/g, according to FAO standards as a probiotic. Probiotic bacteria contained in dadih are *Lactobacillus* and *Bifidobacterium*. *Lactobacillus* is a gram-positive bacteria that is anaerobic, rod-shaped, and immobile and is most widely used as a probiotic agent. Probiotic bacteria will cause immunocompetent cells (dendritic cells and macrophage), to become activated. This will allow the lymphoid tissue in the lamina propria to encourage plasma cells to make IgA, which is involved in the function of the mucosal immune system. Thus, *Lactobacillus plantarum* has role as an immunostimulant by producing IgA in the mucosa. The entry of antigen orally will stimulate the formation of IgA, which can enter and exit the intestinal lumen or blood circulation. Supplementation of *Lactobacillus plantarum* with a higher dose may increase immunoglobulin A levels [60, 61]. Changes in the normal functioning of the neurological system are linked to variations in the makeup of the microbiota. According to the theory behind the anxiety disorders, mood, and microbiota–brain axis can be prevented as well as treated by altering the gut microbiota through probiotic supplementation. Dadih pudding, as a source of probiotics, can help alleviate anxiety through the microbiota–gut–brain axis mechanism. It is thought that probiotics can be administered as an attempt to treat anxiety issues and other psychiatric diseases, even if there are still a lot of variances in clinical trials [62].

Prevent enteric pathogenic bacteria

Based on a previous study, 29 bacteria colonies originating from dadih were isolated, described, and identified. The colonies consisted of 1 isolate for *Bacillus anthracis*, *Bacillus thuringiensis*, *Enterococcus durans*, and *Lactobacillus delbrueckii*, 7 isolates of *Klebsiella pneumonia*, 13 isolates of *Enterococcus faecalis*, and 5 isolates of *Lactobacillus plantarum*. This analysis was carried out using genotypic characterization by molecular PCR analysis. Strong inhibition activities were shown by *Lactobacillus plantarum*, specifically inhibited *S. enteritidis* 4301/15 and *S. enteritidis* Strain ATCC BAA-727 [29]. The human intestine contained naturally occurring microorganisms that has important function in the digestion process [63]. Several bacteria in the digestive tract were frequently identified as pathogenic bacteria that caused chronic disease [64].

L. casei Subsp. casei R-68 (LCR68) and *L. casei* strain Shirota (LCS) suppressed the development of *E. coli* FNCC-19, *L. monocytogenes* FNCC-0156, *S. aureus* FNCC-15, and but not *S. typhi*. LCS and LCR68 antibacterial activity has heat resistant (60-95°C), and enzyme resistant including proteolytic enzymes and amylase but highly sensitive to pH (pH 4–9). The antibacterial ingredient of LCS and LCR68 was acetic and lactic acids. The inhibitory mechanism against pathogenic bacteria by antibacterial compounds found in cell-free supernatants was most likely induced by organic acid, specifically lactic acid, which created an acidic environment in the growth medium. LCS was reported to have a lower pH value compared to LCR68, leading to a larger inhibition zone since harmful bacteria could not thrive in acidic conditions. The capacity of LCR68 and LCS to prevent the growth of harmful bacteria was most likely due to organic acids. *Lactobacillus casei* was a facultative homofermentative LAB that produced two lactic acid molecules for every glucose molecule. In addition, it created minor amounts of acetate, ethanol, and diacetyl [65].

Dadih's LAB, such as *L. paramesenteroides* R-45, *S. lactis* subsp. *diacetylactis* R-22, and *S. faecalis* subsp. *liquefaciens* R-19, possessed antibacterial action inhibited all spoilage and pathogenic bacteria [66]. In addition, their activity against *Escherichia coli* was lost when the supernatants' pH was increased from 7 to 11 [65]. These LABs acquired their antibacterial action from organic acids, particularly lactic acid, which was created during their growth by the breakdown of simple sugars [67]. Bacteriocin gave the other LAB strains their inherent antibacterial characteristics. This was shown by the fact that inhibitory zones did not disappear when pH was adjusted to 11. The antibacterial activity of dadih LAB supernatants was robust at various pH levels and temperatures. Dadih LAB's crude bacteriocin inhibited *S. lactis* subsp.

diacetylactis R-43 had the greatest antibacterial activity, while *E. coli*, *S. faecalis* subsp. *liquefaciens* R-55 showed the least [66].

According to a previous study, dadih's 12 LAB strains inhibited *E. coli* growth in a variety of zones. However, 3 strains showed antibacterial activity from lactic acid, while 6 strains (R-41, R-45, R-55, R-19, R-32, and R-43) have bacteriocin that has antimicrobial action. *E. coli* growth was suppressed by crude bacteriocin with *Streptococcus lactis* subsp. *diacetylactis* R-43 having the strongest antimicrobial action. *S. lactis* subsp. *diacetylactis* R-43 produced bacteriocin that has potential natural preservative to inhibit *E. coli* [66]. Dadih also comprised secondary metabolites, including acetic acid and lactic acid, as well as antibiotic substances, including bulgarican, nicin, acidolin, and acidophylline, could suppress the growth of harmful and destructive bacteria [51, 68].

Surono et al. [69] described the in vitro probiotic activities of origin dadih LAB. Bacteriocin spectrum, antimutagenicity, and bile salt hydrolase (BSH) activity of bacteria cells. *L. lactis* subsp. *lactis* IS-16183 and IS-10285 has bacteriocin activity and can inhibit *Listeria monocytogenes* ATCC 19112 and *E. coli* 3301. Meanwhile, *L. brevis* IS-26958 had high BHS activity and can inhibit *S. aureus* IFO 3060, *L. monocytogenes* ATCC 19112, and *E. coli* 3301. All 10 dadih lactic strains showed bile tolerance and in vitro acid, showing probiotic activity. *Lactobacillus plantarum*, origin LAB from Kerinci dadih, can inhibit *S. aureus* strain ATCC 25923, *E. coli* strain ATCC 35401, *S. enteritidis* strain ATCC BAA-711, and *S. enteritidis* strain 4301/15 [29].

Syakur et al. [70] showed three isolates from dadih can inhibit and *S. typhi*, *E. coli* and *S. aureus*. Gram-negative bacteria were more resistant to antimicrobials than gram-positive bacteria (*S. aureus*) due to several mechanisms of resistance. These included the outer membrane's permeability barrier qualities, which slowed down the entry of antimicrobial chemicals, and certain resistance mechanisms, which rendered the substance inactive. This prevented the compound from binding to the intracellular side or penetrating the cytoplasmic membrane. The discovery prompted more investigation into the powerful indigenous LAB engaged in dadih fermentation, with the goal of avoiding contaminants and pathogens from both milk and the environment. New natural probiotics selection that blocked or displaced a specific pathogen could be exploited for further evaluation, human clinical interventions, and product development, aimed at preventing or treating pathogen-related infections. This improved favorable economic impact and human health, particularly in underdeveloped nations, such as Indonesia. Consequently, the microbes showed potential as future probiotic candidates. LAB inhibited pathogens and against infection by acting as a natural competitive barrier in the gastrointestinal system [31, 71]. Probiotics and their metabolite activity have positive health effects, including intestinal microbiota stabilization, pathogen antagonism, and increased immunological response, which contributed to improved overall health [53].

Maintaining a healthy microbiota is crucial for shielding the host from gastrointestinal disorders. The usual gut microflora undergoes radical changes during episodes of acute diarrhea, including a decrease in *Lactobacillus*, *Bacteroides*, and *Bifidobacterium* species. Probiotic medication may alter the host's microbial balance and lessen acute episodes of diarrhea, according to a number of studies. A clinical investigation on the subject examined the impact of *Pediococcus pentosaceus* (*P. pentosaceus*) on the frequency of diarrheal mouse stools, the balance of gut microbiota, and TNF-α levels [72].

Lowering blood cholesterol levels

Dadih contained probiotics that could decrease blood cholesterol levels by reducing cholesterol absorption in the intestines. Cholesterol trapped bacteria cell wall membranes after being assimilated by the probiotics in dadih, which were responsible for lowering cholesterol. Decreased absorption of this compound in the small intestine was followed by its entry into the cecum and subsequent elimination in the stool. Probiotics also lowered their levels in vitro by converting cholesterol to coprostanol using cholesterol reductase [73]. Dadih was a probiotic that could be used to treat diabetes, atherosclerosis, and lower blood cholesterol.

Recent research has shown that the provision of dadih in pudding consumed by type 2 diabetes mellitus (T2DM) patient can significantly reduce the patient's blood sugar levels. but there is a condition that regularly follows a diet with dadih as a pudding [74]. Probiotics in dadih can help regulate the hormonal balancing of insulin and glucagon [75], and regulate of blood glucose levels by increasing the activity of insulin and decreasing the activity of glucagon, probiotics can help lower blood sugar levels [76]. Meilia et al. investigated the dadih-fortified vitamin D3 on hs-CRP levels and caecum cholesterol concentration in T2DM mice [73]. Vitamin D3 in dadih intervention was reported to be more effective compared to a single intervention in terms of anti-inflammation, which could be related to increased caecum cholesterol content. Dadih's mechanism could decrease cholesterol through probiotics that digested cholesterol, leading to its entry into bacteria cell walls membrane. The cholesterol absorption decreased in the intestine, and it entered the caecum and was eventually eliminated by feces [16, 77].

Probiotics absorb cholesterol and transport it into the probiotic cells membrane. Consequently, its absorption in the intestine decreased and the cholesterol entered the cecum to be disposed of with stools [16, 78]. Probiotics could lower cholesterol levels in vitro by converting them to coprostanol via cholesterol reductase. This disorder caused an increase in cholesterol excretion in the feces while decreasing plasma levels [79]. Caecum cholesterol expelled through feces and an increased cholesterol concentration ejected from the body reduced the number of bile acids returning to the hepatic cycle, and those in blood circulation were used to synthesize new bile acids [77, 80]. The very significant inverse relationship between hs-CRP levels and caecum cholesterol could be explained by a decrease in circulating cholesterol levels, which corresponded to a decrease in inflammation [73].

Pato et al. [23] showed that fermented milk containing *L. lactis* subsp. *lactis* IS-10285 significantly lowered total bile acids, LDL cholesterol, and blood total cholesterol. Phospholipid and triglyceride levels were considerably lower in rats fed fermented milk of *L. lactis* subsp. *lactis* IS-102ose85 compared to the fed milk and fermented milk of *L. lactis* subsp. *lactis* IS-29862. *L. lactis* subsp. *lactis* IS-10285's hypocholesterolemic impact was linked to its ability to limit bile acid reabsorption into the enterohepatic circulation while also increasing bile acid excretion in hypercholesterolemic rats' stools.

Serum ferritin levels before and after therapy did not differ ($p = 0.191$) in adolescent girls aged 12–15 who were given dadih to avoid iron deficiency anemia. Although administering 100 g of curd on its own has not been shown to raise serum ferritin and hemoglobin levels, it is still necessary to take this precaution to avoid iron deficiency anemia [81].

Anti-inflammatory properties

Kodariah et al. [51] showed bacteria found in curd was *L. lactis* subsp. *lactis*. This microbe could enhance levels of pro-and anti-inflammatory cytokines, but the pattern of cytokines did not change with dadih. The proportion of cytokines in the dadih group was higher compared to the without dadih treatment, including 34% for TNFα and 33% for IL1β and IL10. In addition, the levels of TNFα, IL1β, and IL10 cytokines were higher in rats given dadih compared to the control group. Inflammatory responses could be caused by the presence of LAB (probiotics). This effect was evident in the increase in TNFα among card-induced mice compared to controls because the gut microbiota stimulated dendritic cells and macrophages to produce IL6, IL1β, and TNFα, as well as induced differentiation of Th17. The microbe had also been reported to have a role in the inflammatory cytokines secretion, such as IL17. Several probiotics could enhance TNFα, IL12, and IL6 production.

Buffalo milk fermentation created a peptide ranging from 4 to 20 kDa that resisted free radicals caused by pancreatic beta-cell apoptosis and chronic inflammation [82]. LAB could balance the gut flora, inhibiting the synthesis and lipopolysaccharides secretion. The LPS reduction content in the intestinal epithelium led to a decline in pro-inflammatory cytokines [83]. Dadih included LAB, which had the potential to lower blood-CRP levels and increase several anti-inflammatory cytokines production. These microbes also had the potential to decrease COX-2 expression, an enzyme that catalyzed the production of prostaglandins from arachidonic acid, thereby stimulating inflammatory processes and cell proliferation [84]. LAB balanced the intestinal flora, hence inhibiting LPS synthesis and secretion. A decrease in LPS levels in the intestinal epithelium led to a decrease in pro-inflammatory cytokines. Probiotics could also create SCFA in the colon, which lowered CRP enzyme synthesis in the liver [73, 85].

Lactose hydrolysis in the untreated "dadih" was also observed, most likely as a result of the microorganisms fermenting within the "dadih". On day 7, however, the untreated sample's hydrolysis of lactose was just marginally greater than 20%, resulting in a reduction of lactose from 3.63 to 2.9%. In order to reduce the lactose content of dadih' > 70%, a limit deemed acceptable for lactose-intolerant consumers, modified "dadih" was prepared using Lactozym 3000L with a final activity of 1 ml/l. The enzyme-treated modified "dadih" has a lot of promise for commercialization because lactose-intolerant consumers in the Asian region have created a large market gap [86]. Another study showed the effect of curd probiotics on MDA levels in diabetic rats with alloxan induction. MDA levels were measured on the 18th day. Curd probiotics at doses of 1.87 g/200 gBW and 3.74 g/200 gBW can reduce MDA levels in experimental rats [87].

Anti-mutagen properties

Dadih had numerous antimutagenic strains, including *L. plantarum* IS20506 and *E. faecium* IS27526. The return of TrpP1 in fecal samples from *Enterococcus faecium* IS27526 fermented milk was significantly lower compared to other groups. In addition, it was used to verify the antimutagenicity of cultured milk in vivo. The method could comprise bacteria cell binding, leading to a substantial decrease in TrpP1 recovery in stool samples [88]. The chemical binding of mutagens in LAB was observed, which was the binding of heterocyclic amines to the cell wall. Several reports showed that this was allegedly attributable to a cation exchange mechanism [89] or protein [90]. Binding was a physical mechanism, and inactive mutagens were bound [91]. Adhesions were an essential component of the probiotic LAB that could colonize the gastrointestinal tract [88]. Some strains of dadih LAB have high binding properties toward the mutagenic pyrolysate Trp-P1. Lactic bacteria cell walls were composed of peptidoglycan and several types of polysaccharides. These microbes were associated with bile tolerance as well as binding properties towards mutagens [33, 69]. *Lactobacillus casei* subsp. casei R-68 (LSR68) had the potential to be anti-cancer because LAB had antimutagenic properties by binding mutagenic compounds, such as N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosopyrrolidine (NPYR), N-nitrosopiperidine (NPIP) [92], and Trp-P1 [88]. LAB antimutagenic properties were mediated by the bonds formed between carcinogens or mutagens and the inherent peptidoglycan. Mutagens and carcinogens that were bound were eliminated by feces and urine [93].

Decreasing the production of free radicals

Based on a previous study, consumption of dadih, such as 4.5 g once a day and 4.5 g twice a day for 42 days, was not significant for MDA reduction but was higher in the control group. MDA production could be inhibited by 4.5 g of dadih intake per day [14]. Several studies showed that probiotics had scavenging action as an antioxidant by decreasing the production of free radicals during oxidative processes. In addition, dadih inhibited lipid peroxidation through the aforementioned method due to its peptides and LAB, which could prevent the production of ROS [94]. Dadih's probiotics were commensal microorganisms, which could affect antioxidants by decreasing the activity of enzymes producing ROS, altering the antioxidant activity of hosts, producing antioxidants, and connecting metal ions [95, 96]. This showed that dadih inhibited the formation of MDA due to oxidative damage produced by an increase in free radicals caused by aging [14]. According to a previous study, it could diminish renal interstitial fibrosis through various mechanisms. TGF-β1 played an essential role in renal fibrosis, where it controlled ECM production and increased fibrogenic bFGF2 levels. In the early phase of fibrosis, TGF-β1 expression served as a chemoattractant for fibroblasts and also caused smooth muscle cells through the production of ECM proteins and the transition of tubular epithelial cells into myofibroblasts [14]. MDA could cause cell damage in various ways, and its level in rats' bodies reflected the amount of free radicals created by lipid peroxidation. The results showed that intracellular cell-free extracts, intact cells, and culture supernatant increased antioxidative enzyme activity in serums while significantly lowering MDA levels in both serums and the liver [95].

Antihypertensive properties

L. plantarum ssp. *plantarum* DG17 and *L. lactis* ssp. *lactis* DK12 were highly effective ACE inhibitors when isolated from dadih. In the peptide profiles of these isolates, 2 lower molecular weight bands ranging from 12 to 14 kDa were identified and presumed to be antihypertensive peptides. Due to the presence of V residue at the N terminal and F residue at the C terminal, 1 of the peptide sequences produced from *Lactobacillus plantarum* ssp. plantarumDG17 exhibited significant ACE inhibitor activity. In addition, there was no significant difference ($P > 0.05$) in inhibition properties. Both isolates showed strong activity, namely 60.796.2% and 61.987.8%, respectively, but lower than the control (captopril). There were no significant variations between the IC50 values of the 2 isolates, namely 439.9 µg/mL and 442.2 µg/mL, respectively. The inhibitory activity was primarily due to the formation of bioactive peptides during fermentation. Recent studies showed that diverse LAB-fermented milk types contained peptides with varying ACE inhibitory actions [97, 98]. During fermentation phase, the LAB proteolytic system degraded the existing protein, depleting the bioactive peptide structural mechanism, and releasing amino acids and peptides to enable their growth. Due to the formation of bioactive peptides during fermentation process, dadih-derived isolates exhibited high ACE inhibitory activity (50%). Although their inhibition activity was less than that of a synthetic ACE inhibitor (captopril), the result showed that these isolates had the potential to produce antihypertensive peptides for further investigation. *L. plantarum* ssp. *plantarum* DG17 and *L. lactis* ssp. *Lactis* DK12 isolates from dadih had the potential as starter culture in functional fermented milk [99].

Immunomodulating peptides, phosphopeptides, and antihypertensive peptides were the most popular bioactive peptides for use in meals designed to deliver specific health advantages. Angiotensin-I-converting enzyme (ACE; kininase II; EC 3.4.15.1) was a multifunctional ectoenzyme found in several tissues that regulated the levels of multiple endogenous bioactive peptides [98]. ACE was classically connected with the renin-angiotensin system, which regulated peripheral blood pressure by catalyzing the generation of the inactivation of the vasodilator bradykinin and vasoconstrictor angiotensin-II. Previous studies showed that ACE inhibition primarily had an antihypertensive properties, but it could also affect several regulatory systems related to nervous system activity, immunological defense, and blood pressure [100].

The development and potential of milk curd as functional foods

Dadih is quite famous in West Sumatra, Jambi, and Riau. However, in its development, Dadih has begun to be abandoned by the local community. In fact, the younger generation is almost unfamiliar with dadih, even though dadih has great potential as one of the functional foods that are sources of probiotics. Malaysia and Japan have utilized bacteria isolated from dadih to produce fermented milk commercially. Given that the number of buffaloes is declining and the continued fall in buffalo milk production in the dairy producing area, the usage of buffalo milk as a raw material must be taken into consideration. In 2004–2009, the buffalo population in West Sumatra decreased quite significantly from 322,692 to 52,927. This condition automatically reduces buffalo milk production. Buffalo milk as the raw material for dadih in West Sumatra is obtained from swamp buffalo. This type of buffalo is raised primarily as working livestock and for meat production, but in some areas it is also milked (Bahri and Talib 2008; Wirdahayati 2008). Swamp buffalo milk production ranges from 1–2 l/day (Mason 1974). In order to maintain the production of curd, it is necessary to find substitutes for buffalo milk, such as using cow's milk. This will help solve the drop in buffalo milk production. Nevertheless, curd manufacturing requires technology since buffalo milk differs from other livestock milk in certain ways [38, 101].

The process of coagulation of buffalo milk is caused by acids produced from the breakdown of carbohydrates in milk by microbes. The making of curd can be modified by using cow's milk that has been treated first, for example, homogenized and concentrated by evaporating the milk until the volume decreases. The process of evaporating cow's milk in making curd can be done using a vacuum evaporator or by heating it manually [38]. The best evaporation rate in making curd is 50% of the initial volume, which produces cow's milk curd that has an appearance and characteristics resembling buffalo milk curd [102]. The curd production process by using cow's milk that was evaporated up to 50% of the initial volume to obtain total solids that resemble buffalo milk and adding probiotic bacterial starters *L. plantarum*, *L. acidophilus*, and *B. bifidum*. The best starter concentration for making curd is 3% (v/v), which produces better texture and clots than concentrations of 4% and 5%. The differences in physical and chemical characteristics between cow's milk and buffalo milk cause the curd produced to be different. The texture of cow's milk curd tends to be softer than buffalo milk curd, which has a compact and dense texture. To obtain cow's milk curd that resembles buffalo milk curd, cow's milk is given food additives that act as thickeners or coagulants [103]. To obtain solid and compact cow's milk curd, proteolytic compounds that coagulate milk casein, such as enzymes extracted from plants or produced by microbes and probiotics, can also be used to further increase the functional value of cow's milk curd, in addition to forming better product flavor components [38].

Controlled fermentation process using single or combination starter cultures in appropriate amounts, quality, and well-maintained is an important factor to produce good quality, consistent, and safe to consume curd. Starters for food fermentation in Indonesia are generally available in liquid form in glass bottles with cotton caps [104]. Cultures in liquid form are easily contaminated, their potential decreases rapidly during storage, and they are difficult to handle. The use of liquid starter cultures requires special handling to avoid contamination. The development of dry starter cultures in granular form can make it easier for consumers to handle, store, and apply them. Drying the culture by microencapsulation (encapsulation) can make it easier to handle the starter, control the fermentation process, and ensure product quality consistency. Starters in dry form also facilitate distribution/transportation because the microbes do not lose their activity and extend their shelf life [105].

Based on BPOM (Indonesian Food and Drug Authority), functional foods are meals that contained one or more substances that, based on scientific studies, were thought to have certain physiological functions with potential benefits for health [106]. These compounds could be found in foods naturally or through a process. At present, buffalo milk curd was believed to have a beneficial effect on health. Claims for LAB isolated from curd as a disease prevention agent (prophylactic) and therapy (therapeutic) had also been made [69]. Health benefits of dadih had been explained in the previous section, considering that it had the potential as functional foods that could be developed into a commercial product and could be widely marketed to consumers. At present, dadih was produced on a small scale and in a conventional way.

Dadih is still produced using a traditional method that relies on spontaneous fermentation. As a result, there is no control over the substrates, processes, storage, packaging, or sanitation, which encourages the growth of pathogenic or rotting microbes. The microbial populations linked to fermentation may be impacted by the cleanliness of the utensils, water, ingredients, substrates, and surrounding environment (such as temperature and humidity). Additionally, excellent hygiene practices can also have an impact. A properly managed fermentation process often ensures the creation of a product that is safe for the end user. Natural LAB found in Delhi can protect against foodborne illnesses brought on by unsanitary settings. Dadih is made safer for consumers by the LAB, which starts the acidification process in the buffalo milk as raw materials by generating bacteriocins, aromatic compounds, and organic acids to prevent pathogenic and spoiling germs [18, 31, 107, 108].

Construction of business and product design of dadih

In general, dadih had special characteristics, including a thick consistency, a smooth texture, and a pleasant flavor, offering milk nutrition [109]. The restricted shelf life and marketing challenges associated with dadih items packaged in bamboo tubes impeded market penetration. Therefore, a change in its packaging was expected to enhance sales and retain a shelf life comparable to that of other fermented milk product [110]. In reality, its development must strengthen the product's appeal and encourage distribution to boost the selling power [111]. Gathering all reviews enabled producers to identify the product's shortcomings and strengths, thereby enhancing the quality. Opinion mining could show issues in evaluating the quantity of customer studies on product features. The objective of opinion mining was to discover whether the consumer reviews were positive, negative, or neutral [112]. The technology of opinion mining had several practical applications. Individuals who intended to purchase a product could benefit from opinion mining by viewing a summary of available user opinions that aided in decision-making. This information was useful not just for marketing and product comparison but also for product development and design [113]. A previous study regarding dadih development used business intelligence architecture and Naive Bayes classifier to map consumers' emotional demands. The results of the investigation showed the direction of consumers' opinions and the principles for the emotive design of dadih items. The consumers' affective needs for the dadih development items were classified by ergonomics, shape, texture, label, color, and typeface. Based on these affective demands, there were the top ten rules of analysis using Association Rule Mining (ARM), and the affective design of dadih items was based on an ergonomic design, a complete label, a positive opinion, and a large text size [110].

Development of packaging of dadih

Packaging and storage are a single process that is closely related to maintaining the quality of food products and increasing their appeal, in addition to increasing their shelf life. Marketing of dadih from Riau to Malaysia is still constrained because the packaging is still conventional so that the shelf life is relatively short, which is only 3 days [114]. Dadih from cow's milk in plastic tube packaging with *Streptococcus lactis* starter has a shelf life of 15 days at room temperature [115]. Dadih packaged in plastic tubes is easier to carry and more attractive, in addition to being able to provide information on the nutritional content and product ingredients.

Buffalo milk curd in polyvinyl propylene (PP) plastic tubes is still suitable for consumption up to the 9th day, while it is 6 days for bamboo tubes [114]. In addition, curd packed in polystyrene plastic had a lower total number of bacteria and *L. plantarum* compared to curd in bamboo tubes, but consumers preferred curd in bamboo tubes [116]. Clay packaging (earthenware) is commonly used in Malaysia in the traditional manufacture of curd using inoculum [86]. Research is related to the use of various packaging to determine the quality of cow's milk curd during storage at room temperature (27–30 °C) and cold temperature (4 °C). The best packaging for cow's milk curd is a pouch and cup packaging made of polypropylene plastic. In this packaging, curd can be stored for up to 24 days at cold temperatures and 8 days at room temperature. In this packaging, L. casei bacteria are able to maintain their viability in the product at more than 108 cfu/ml [102].

To extend the shelf life, dairy products, including curd, are usually stored at low temperatures (4 °C). Storage at room temperature or in inappropriate conditions causes dairy products to be easily damaged because milk contains high nutrients so that it is easily overgrown by destructive microbes. The shelf life of buffalo milk curd made by applying pasteurization technology, hygienic preparation of bamboo tubes for packaging, and the use of L. casei starter culture show that curd with L. casei starter is a probiotic product because it has a population of 1013 cfu/ml, and curd can be stored for 7 days at room temperature and 20 days at cold temperatures without damage [117]

In several ways, the appearance of a product influenced consumers selection. To pique the interest of consumers in consuming dadih, it was essential that the packaging must be aesthetically pleasing. Therefore, enhanced dadih packaging was expected to grow its market, lengthen its shelf life, and facilitate consumption. The definition of Kansei Engineering (KE) was a system that turned consumer sentiment into design standards. Using KE, this study analyzed packaging elements and designed dadih's product based on consumers preferences.

Principal component analysis (PCA) was used as the method to identify the product and package appearance elements to ascertain the typical essential characteristics. The outcome showed design support for determining the appropriate combination of product form elements in terms of specified product strategy sets. The use of these methodologies was expected to yield ideal formulations for the design of dadih product based on each personality type to produce appealing, inventive, and consumer-preferred dadih product while minimizing the chance of market failure for new designs. This study explored and designed the product packaging system using KE. In addition, there were 4 stakeholders in the system, including producers, customers, and the product creator. Volume, transparency, label, material, shape, typography, color, and height-to-weight ratio were the results of categorizing the design of package appearance elements into 8 categories based on the identification of dadih product. In addition, the shape and color of the packaging were classified according to the container's top and body. This study also identified 3 design techniques for dadih product, including modern, economical, and distinctive. The appearance techniques from the packaging could be used by designers to create packaging designs with the characteristics that distinguish the product while limiting the risk of market failure [111]. Various conclusions were reached due to in this study due to the pre-established objectives. First, the descriptive norm had a strong and positive effect on traditional consumption of functional foods. Second, perceived behavioral control had a positive and significant effect on the consumption of traditional functional foods. Third, the perceived threat of NCD did not alter the use of traditional functional foods. Fourth, the frequency of healthy food community group meetings had a large and positive effect on the consumption of traditional functional foods. However, neither the frequency of healthy food extension instruction nor the frequency of healthy food-related newspaper and magazine use affected traditional functional foods consumption. Lastly, the frequency of use of healthy food-related websites and healthy food-related social media did not influence traditional functional foods consumption. According to this study's conclusions, the government and/or companies must consider 2 practical implications to increase consumption. First, it was essential to facilitate the consumption of traditional functional foods. Second, it was critical to develop an extension education strategy that included a prominent person or leader in the community as well as healthy food community group meetings [10].

Conclusion

In conclusion, buffalo had been an essential animal for the Minangkabau people for centuries due to the resourcefulness of its part, including as a food source. In addition, dadih had been extensively explored for its possible health advantages, both in vitro and in vivo. The indigenous LAB in dadih exhibited immunomodulatory, antioxidant, antimutagenic, hypocholesterolemic, and antibacterial activities. Indigenous microorganisms, such as LAB and yeasts, present in bamboo tubes and buffalo milk contributed to the flavor and texture of dadih. Diverse qualities of the product were also detected due to spontaneous fermentation and the different microbe compositions in buffalo milk and bamboo tubes employed in fermentation. Dadih was expected to gain importance in the food business in line with various developments. The several health benefits of curd and its good nutrition for humans were an added value for curd to be preserved because it had the characteristic of being a functional Indonesian food. Although dadih is currently sold commercially, it is generally sold in traditional packaging using bamboo so that the shelf life is limited, which results in limited sales distribution. This results in dadih only being sold in certain areas in West Sumatra Province. Dadih has the potential as a functional food, so further identification is needed regarding specific probiotic bacteria. Although these bacteria originate from West Sumatra, they can be preserved to become a starter for Dadih fermentation in other areas in Indonesia, so that the commercialization of dadih can reach wider areas. In the end, the promotion of dadih becomes more massive and more widespread, so that dadih as an Indonesian cultural heritage can be preserved.

Abbreviations

ARM	Association rule mining
BPOM	Indonesian food and drug authority
BSH	Bile salt hydrolase
KE	Kansei engineering
LAB	Lactic acid bacteria
LCR68	Lactobacillus casei Subsp. casei R-68
NDEA	*N*-nitrosodiethylamine
NDMA	*N*-nitrosodimethylamine
NPIP	*N*-nitrosopiperidine
NPYR	*N*-nitrosopyrrolidine
PCA	Principal component analysis
sIgA	Secretory immunoglobulin A
UHT	Ultra-high temperature

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Declarations

Consent for publication

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References

1. Banerjee P. Functional food: a brief overview. Int J Bioresour Sci. 2019;6(2):57.
2. Alongi M, Anese M. Re-thinking functional food development through a holistic approach. J Funct Foods. 2021;81:104466. https://doi.org/10.1016/j.jff.2021.104466.
3. Chen G, Li Y, Li X, Zhou D, Wang Y, Wen X, et al. Functional foods and intestinal homeostasis: the perspective of in vivo evidence. Trends Food Sci Technol. 2021;111:475–82.
4. Amaliah I, David W, Ardiansyah A. Perception of millennial generation toward functional food in Indonesia. J Funct Food Nutraceutical. 2019;1(1):31–40.
5. Purwaningsih I, Hardiyati R, Zulhamdani M, Laksani CS, Rianto Y. Current status of functional foods research and development in Indonesia: opportunities and challenges. J Teknol dan Ind Pangan. 2021;32(1):83–91.
6. John R, Singla A. Functional foods: components, health benefits, challenges, and major projects. DRC Sustain Futur J Environ Agric Energy. 2021;2:61–72.
7. Ganguly A, Chattaraj S, Ganguly M, Chattaraj M, Banerjee A, Mandal A, et al. Effect of three probiotic Bacillus strains supplemented feeds on growth, carcass composition and blood parameters of *Clarias magur* (Hamilton). J Appl Aquac. 2024;1–16.
8. Widyaningsih T, Wijayanti N, Nugrahini NIP. Aspek Kesehatan, Evaluasi, dan Regulasi. Malang: UB Press; 2017.
9. Barauskaite D, Gineikiene J, Fennis BM, Auruskeviciene V, Yamaguchi M, Kondo N. Eating healthy to impress: how conspicuous consumption, perceived self-control motivation, and descriptive normative influence determine functional food choices. Appetite. 2017;2018(131):59–67. https://doi.org/10.1016/j.appet.2018.08.015.
10. Sumaedi S, Sumardjo. A model of traditional functional food consumption behaviour. Br Food J. 2021;123(1):13–30.
11. Setyowati N, Masyhuri MJH, Irham YB. The hidden treasure of wedang uwuh, an ethnic traditional drink from Java, Indonesia: its benefits and innovations. Int J Gastron Food Sci. 2023;31:100688. https://doi.org/10.1016/j.ijgfs.2023.100688.
12. Verbeke W, López GP. Ethnic food attitudes and behaviour among Belgians and Hispanics living in Belgium. Br Food J. 2005;107(11):823–40.
13. Rojas-Rivas E, Espinoza-Ortega A, Thomé-Ortiz H, Moctezuma-Pérez S. Consumers' perception of amaranth in Mexico: a traditional food with characteristics of functional foods. Br Food J. 2019;121(6):1190–202.
14. Harun H, Yanwirasti Y, Purwanto B, Rahayuningsih EP. The effect of giving dadih on malondialdehyde levels and renal interstitial fibrosis at aging kidney. Maced J Med Sci. 2020;8:293–6.
15. Arnold M, Rajagukguk YV, Gramza-Michałowska A. Characterization of dadih: Traditional fermented buffalo milk of minangkabau. Beverages. 2021;7(3):60.
16. Nuraida L. A review: health promoting lactic acid bacteria in traditional Indonesian fermented foods. Food Sci Hum Wellness. 2015;4(2):47–55. https://doi.org/10.1016/j.fshw.2015.06.001.
17. Venema K, Surono IS. Microbiota composition of dadih—a traditional fermented buffalo milk of West Sumatra. Lett Appl Microbiol. 2019;68(3):234–40.
18. Herlina VT, Setiarto RHB. From tradition to innovation: dadih, the Minangkabau tribe's traditional fermented buffalo milk from Indonesia. J Ethn Foods. 2024. https://doi.org/10.1186/s42779-024-00234-6.
19. Alzahra H, Melia S. Nutrient analysis of dadih from Lintau Regency, West Sumatra Indonesia. IOP Conf Ser Earth Environ Sci. 2021;888(1):012041.
20. Nur MMA. Potency of microalgae as source of functional food in Indonesia (overview). Eksergi. 2014;11(2):1–6.
21. Surono IS. Traditional Indonesian dairy foods. Asia Pac J Clin Nutr. 2015;24(December):S26-30.
22. Jatmiko YD, Howarth GS, Barton MD. Evaluation of yeast diversity in dadih and dangke using PCR-RFLP of internal transcribed spacer region. IOP Conf Ser Earth Environ Sci. 2019;391(1):012025.
23. Pato U, Surono IS, Koesnandar HA. Hypocholesterolemic effect of indigenous dadih lactic acid bacteria by deconjugation of bile salts. Asian-Austr J Anim Sci. 2004;17(12):1741–5.
24. Yudhistira B. The development and quality of jackfruit-based ethnic food, gudeg, from Indonesia. J Ethn Foods. 2022. https://doi.org/10.1186/s42779-022-00134-7.
25. Yudhistira B, Fatmawati A. Diversity of Indonesian soto. J Ethn Foods. 2020. https://doi.org/10.1186/s42779-020-00067-z.
26. Komariah K, Marwanti, Lastariwati B M DE. Makanan Tradisional Yogyakarta Dan Pemanfatannya [in Bahasa]. In: Prosiding Seminar Keunggulan Kuliner Indonesia. 2019. p. 56–61.
27. Purwati E, Aritonang SN, Melia S, Juliyarsi I, Purwanto H. Manfaat Probiotik bakteri asam laktat dadiah menunjang kesehatan masyarakat. Lembaga Pengembangan Teknologi Informasi dan Komunikasi (LPTIK) Universitas Andalas; 2016.
28. Putra A, Marlida Y, Azhike S, dan Wulandari R. Perkembangan dan usaha pengembangan dadih: sebuah review tentang susu fermentasi tradisional minangkabau R. J Peternak Indones. 2011;13(3):159–70.
29. Ary E, Dadrasnia A, Ameen F, Alwakeel S, Ismail S. Antimicrobial screening of lactic acid bacteria isolated from fermented milk buffalo (dadih). Int J Sci Res Publ. 2021;11(4):70–80.
30. Sugitha I. Dadih makanan tradisional Minang, manfaat dan khasiatnya. In: Widyakarya Nasional Khasiat Makanan Tradisional. Jakarta: Kantor Menteri Negara Urusan Pangan; 1995. p. 532–40.
31. Surono IS. Indonesian Dadih. In: Fermented milk and dairy products. 2020. p. 408–31.
32. Purwati E. Dadiah Nagari Aia Dingin. Kemendikbud. 2021.
33. Surono IS, Hosono A. Performance of dadih cultures in fluid milk application at low temperature storage. Asian-Austral J Anim Sci. 2000;13(SUPPL. A):495–8.
34. Akuzawa R, Miura T, Surono IS. Fermented milks | Asian Fermented Milks. In: Encyclopedia of dairy sciences. Elsevier; 2011. p. 507–11. https://doi.org/10.1016/B978-0-12-374407-4.00186-2.
35. Sisriyenni D, Zurriyati Y. Kajian kualitas dadih susu kerbau di dalam tabung bambu dan tabung plastik. J Pengkaj dan Pengemb Teknol Pertan. 2004;7(2):171–9.
36. Zulbardi M. Gagasan pengembangan potensi ternak kerbau melalui pembuatan dadih bagi peningkatan pendapatan masyarakat peternak di Sumatera Barat. J Anim Prod. 2003;5(2):92–8.
37. Ginting N. Dadih bamboo ampel (bambusa vulgaris) and bamboo gombong (gigantochloa verticilata) 2 and 3 days fermented: effect on salad dressing hedonic quality. IOP Conf Ser Earth Environ Sci. 2018;130(1):012029.
38. Usmiati S, Risfaheri. Pengembangan dadih sebagai pangan fungsional probiotik asli sumatera barat. J Litbang Pert. 2013;32(1):20–9.
39. Usmiati S, Broto W, Setiyanto H. Karakteristik Dadih Susu Sapi yang Menggunakan Starter Bakteri Probiotik. J IlmuTernak dan Vet. 2011;16(2):140–52.
40. Naibaho B, Simanjuntak R, Silalahi M. Pengaruh Suhu dan Lama Penyimpanan Terhadap Sifat Kimia, Total Koloni Bakteri dan Organoleptik Dadih. J Bios Logos. 2023;13(3):192–212.
41. Habibi NA, Sartika W, Amalia S. The potential of dadih as a functional food in disaster preparedness. In: The 4th international conference with theme the utilization of disaster technology in management of disaster due to health crisis The. Padang; 2024. p. 103–7.
42. Afriani A. Kualitas Dan Potensi Dadih Sebagai Tambahan Pendapatan Peternak Kerbau Di Kabupaten Kerinci. J Ilm Ilmu-ilmu Peternak Univ Jambi. 2008;11(3):144–9.
43. Delhi N. Buffalo milk vs. cow milk: difference and health benefits of both. 2023;3(8).
44. Wirawati CU. Characteristic and development of cow's milk dadih as an alternate of buffalo's milk dadih. Indones Bull Anim Vet Sci. 2018;27(2):95.
45. Yang TX, Wang F, Li H, Liu QS, Li QY. The nutrition of buffalo milk: a comparison with cow milk. Adv Mater Res. 2013;781–784:1460–3.

46. Zeng MY, Inohara N, Nuñez G. Mechanisms of inflammation-driven bacterial dysbiosis in the gut. Mucosal Immunol. 2017;10(1):18–26.
47. Chattaraj S, Mitra D, Chattaraj A, Chattaraj M, Kundu M, Ganguly A, et al. Antioncogenic potential of probiotics: Challenges and future prospective. Indian J Microbiol Res. 2023;10(1):1–10.
48. Azad MAK, Sarker M, Wan D. Immunomodulatory effects of probiotics on cytokine profiles. Biomed Res Int. 2018;2018:1–10.
49. Mazziotta C, Tognon M, Martini F, Torreggiani E, Rotondo JC. Probiotics mechanism of action on immune cells and beneficial effects on human health. Cells. 2023;12(1):184.
50. Ganguly A, Banerjee A, Mandal A, Das Mohapatra PK. Probiotic-based cultivation of *Clarias batrachus*: importance and future perspective. Acta Biol Szeged. 2018;62(2):158–68.
51. Kodariah R, Armal HL, Wibowo H, Yasmon A. The effect of dadih in BALB/c mice on pro-inflammatory and anti-inflammatory cytokine productions. J Thee Med Sci. 2019. https://doi.org/10.19106/JMedSci005104201902.
52. Kwoji ID, Aiyegoro OA, Okpeku M, Adeleke MA. Multi-strain probiotics: synergy among isolates enhances biological activities. Biology (Basel). 2021;10(4):1–20.
53. Surono IS, Koestomo FP, Novitasari N, Zakaria FR, Yulianasari K. Novel probiotic enterococcus faecium IS-27526 supplementation increased total salivary sIgA level and bodyweight of pre-school children: a pilot study. Anaerobe. 2011;17(6):496–500. https://doi.org/10.1016/j.anaerobe.2011.06.003.
54. Surono IS, Martono PD, Kameo S, Suradji EW, Koyama H. Effect of probiotic *L. plantarum* IS-10506 and zinc supplementation on humoral immune response and zinc status of Indonesian pre-school children. J Trace Elem Med Biol. 2014;28(4):465–9. https://doi.org/10.1016/j.jtemb.2014.07.009.
55. Pagnini C, Saeed R, Bamias G, Arseneau KO, Pizarro TT, Cominelli F. Probiotics promote gut health through stimulation of epithelial innate immunity. Proc Natl Acad Sci U S A. 2010;107(1):454–9.
56. Maldonado Galdeano C, Perdigón G. The probiotic bacterium Lactobacillus casei induces activation of the gut mucosal immune system through innate immunity. Clin Vaccine Immunol. 2006;13(2):219–26.
57. Ashraf R, Shah NP. Immune system stimulation by probiotic microorganisms. Crit Rev Food Sci Nutr. 2014;54(7):938–56.
58. Kusumo PD, Bela B, Wibowo H, Munasir Z, Surono IS. Lactobacillus plantarum IS-10506 supplementation increases faecal sIgA and immune response in children younger than two years. Benef Microbes. 2019;10(3):245–52.
59. Mantis NJ, Rol N, Corthésy B. Secretory IgA's complex roles in immunity and mucosal homeostasis in the gut. Mucosal Immunol. 2011;4(6):603–11.
60. Sonik MD, Neldi V, Ramadhani P. Review Artikel: Efektivitas Dadih (Yogurt Khas Sumatra Barat) Sebagai Probiotik. J Farm Higea. 2023;15(1):77.
61. Dewi SS, Anggraini H. Aktivitas lactobacillus plantarum isolat ASI terhadap imunoglobulin (Iga, Igg) pada tikus wistar model sepsis. Res Coloquium. 2015;2015:503–6.
62. Susmiati S, Helmizar H, Asrawati A, Yani FF, Khairina I, Anggreiny N, et al. Supplementation dadih pudding as a probiotic on the psychosocial problems of children with CoviD-19 undergoing isolation. Biomed Pharmacol J. 2024;17(2):1223–30.
63. Wong CB, Odamaki T, Xiao JZ. Insights into the reason of Human-Residential Bifidobacteria (HRB) being the natural inhabitants of the human gut and their potential health-promoting benefits. FEMS Microbiol Rev. 2020;44(3):369–85.
64. Yu Y, Zhu S, Li P, Min L, Zhang S. Helicobacter pylori infection and inflammatory bowel disease: a crosstalk between upper and lower digestive tract. Cell Death Dis. 2018. https://doi.org/10.1038/s41419-018-0982-2.
65. Pato U, Setiaris V, Johan D, Khairunnisa F, Doli R, Hasibuan H. Antibiotic resistance and antibacterial activity of dadih originated *Lactobacillus casei subsp. Casei r-68* against food borne pathogens. Biotech Environ Sci. 2017;19(3):577–87.
66. Pato U, Yusmarini Y, Fitriani S, Jonnaidi NN, Wahyuni MS, Feruni JA, et al. Antimicrobial Activity of lactic acid bacteria strains isolated from dadih against *Escherichia coli*. IOP Conf Ser Earth Environ Sci. 2021;709(1):012019.
67. Deraz SF, Karlsson EN, Hedström M, Andersson MM, Mattiasson B. Purification and characterisation of acidocin D20079, a bacteriocin produced by Lactobacillus acidophilus DSM 20079. J Biotechnol. 2005;117(4):343–54.
68. Chattaraj S, Ganguly A, Mandal A, Das Mohapatra PK. A review of the role of probiotics for the control of viral diseases in aquaculture. Aquac Int. 2022;30(5):2513–39. https://doi.org/10.1007/s10499-022-00915-6.
69. Surono IS. In vitro probiotic properties of indigenous dadih lactic acid bacteria. Asian-Austral J Anim Sci. 2003;16(5):726–31.
70. Syukur S, Rijal F, Jamsari PE. Isolation and molecular characterization of lactic acid bacteria by using 16s rRNA from fermented buffalo milk (Dadih) in Sijunjung, West Sumatera. Res J Pharm Biol Chem Sci. 2014;5(6):871–6.
71. Lani MN, Bahar N, Taghavi E, Ahmad FT, Sharifudin SA, Arif Aziz Japar WM. Effects of microbiological and physicochemical properties of cow's milk and goat's milk dadih inoculated with various lactobacillus species. Malays J Fundam Appl Sci. 2021;17(6):689–710.
72. Syam AF. Can the tradiotional food "dadih" be used for treating diarrhea?" [Internet]. 2012. p. 1998. Available from: https://media.neliti.com/media/publications/68175-EN-can-the-traditional-food-be-used-for-tre.pdf
73. Meilina A, Anjani G, Djamiatun K. The effect of fortified dadih (fermented buffalo milk) with vitamin D 3 on caecum cholesterol concentration and high sensitivity C-reactive protein (Hs-Crp) level in type 2 diabetes mellitus rat model. Potravin Slovak J Food Sci. 2020;14:960–6.
74. Wulandari LS, Kusumastuty I, Cempaka AR, Nugroho FA. Effect of buffalo curd milk-edamame pudding snack consumption on fasting blood glucose levels and lipid profile in diabetes mellitus patients. Amerta Nutr. 2023;7(4):583–8.
75. Pan YQ, Zheng QX, Jiang XM, Chen XQ, Zhang XY, Wu JL. Probiotic supplements improve blood glucose and insulin resistance/sensitivity among healthy and GDM pregnant women: a systematic review and meta-analysis of randomized controlled trials. Evidence-based Complem Altern Med. 2021;2021:9830200.
76. Kim YA, Keogh JB, Clifton PM. Probiotics, prebiotics, synbiotics and insulin sensitivity. Nutr Res Rev. 2018;31(1):35–51.
77. Kumar M, Nagpal R, Kumar R, Hemalatha R, Verma V, Kumar A, et al. Cholesterol-lowering probiotics as potential biotherapeutics for metabolic diseases. Exp Diabetes Res. 2012;2012:1–14.
78. Ejtahed HS, Mohtadi-Nia J, Homayouni-Rad A, Niafar M, Asghari-Jafarabadi M, Mofid V, et al. Effect of probiotic yogurt containing Lactobacillus acidophilus and Bifidobacterium lactis on lipid profile in individuals with type 2 diabetes mellitus. J Dairy Sci. 2011;94(7):3288–94. https://doi.org/10.3168/jds.2010-4128.
79. Lye HS, Rusul G, Liong MT. Removal of cholesterol by lactobacilli via incorporation and conversion to coprostanol. J Dairy Sci. 2010;93(4):1383–92. https://doi.org/10.3168/jds.2009-2574.
80. Kusuma RJ, Azzyati F, Purbarani G, Sulistyorini R, Nofiartika F, Huriyati E. Effect of traditional fermented buffalo milk (dadih) on body weight, adipose tissue mass and adiposity inflammation in high fat-induced obese rats. ECNutrition. 2015;1(3):106–14.
81. Budiyatri R, Anjani G, Legowo AM, Syauqy A, Limijadi EKS. The effect of Dadih for the prevention of iron deficiency anemia in adolescent girls 12–15 years old. AcTion Aceh Nutr J. 2024;9(1):91.
82. Zaenal MA, Fatimah F, Mustopa A, Andrianto N, Faridah DN. Antioxidant production of lactic acid bacteria isolated from indonesian traditional fermented buffalo milk (dadih). Artic IOSR J Pharm Biol Sci. 2017;12(5):76–82.
83. Chuengsamarn S, Rattanamongkolgul S, Sittithumcharee G, Jirawatnotai S. Association of serum high-sensitivity C-reactive protein with metabolic control and diabetic chronic vascular complications in patients with type 2 diabetes. Diabetes Metab Syndr Clin Res Rev. 2017;11(2):103–8. https://doi.org/10.1016/j.dsx.2016.08.012.
84. SaeidiFard N, Djafarian K, Shab-Bidar S. Fermented foods and inflammation: a systematic review and meta-analysis of randomized controlled trials. Clin Nutr ESPEN. 2020;35:30–9. https://doi.org/10.1016/j.clnesp.2019.10.010.
85. Asemi Z, Zare Z, Shakeri H, Sabihi SS, Esmaillzadeh A. Effect of multispecies probiotic supplements on metabolic profiles, hs-CRP, and oxidative stress in patients with type 2 diabetes. Ann Nutr Metab. 2013;63(1–2):1–9.

86. Manan DMA, Abd Karim A, Kit WK. Lactose content of modified enzyme-treated "dadih." Food Chem. 1999;65(4):439–43.
87. Fitriani I, Efrida H, Almurdi YE. Pengaruh probiotik dadih terhadap kadar malondialdehide tikus diabetes melitus dengan induksi aloksan. Maj Kedokt Andalas. 2023;46(4):517–25.
88. Surono IS, Pato U, Koesnandar HA. In vivo antimutagenicity of dadih probiotic bacteria towards Trp-P1. Asian-Austral J Anim Sci. 2009;22(1):119–23.
89. Morotomi M, Mutal M. In vitro binding of potent mutagenic pyrolyzates to intestinal bacteria. JNCI J Natl Cancer Inst. 1986;77:195.
90. Tanabe T, Suyama K, Hosono A. Effect of sodium dodecylsulphate on the binding of *Lactococcus lactis*. subsp lactis T-80 cells with Trp-P1. J Dairy Res. 1994;61(2):311–5.
91. Sreekumar O, Hosono A. Antimutagenicity and the influence of physical factors in binding lactobacillus gasseri and bifidobacterium longum cells to amino acid pyrolysates. J Dairy Sci. 1998;81(6):1508–16.
92. Hosono A, Tanabe T, Otani H. Binding properties of lactic acid bacteria isolated from kefir milk with mutagenic amino acid pyrolysates. Milchwissenschaft. 1990;45:647–51.
93. Harun H, Wirasti Y, Purwanto B, Purwati E. Characterization of lactic acid bacteria and determination of antimicrobial activity in dadih from air dingin alahan panjang district, solok regency-west sumatera. Syst Rev Pharm. 2020;11(3):583–6.
94. Nardone A, Ronchi B, Lacetera N, Ranieri MS, Bernabucci U. Effects of climate changes on animal production and sustainability of livestock systems. Livest Sci. 2010;130(1–3):57–69. https://doi.org/10.1016/j.livsci.2010.02.011.
95. Shen Q, Shang N, Li P. In vitro and in vivo antioxidant activity of bifidobacterium animalis 01 isolated from centenarians. Curr Microbiol. 2011;62(4):1097–103.
96. Wang AN, Yi XW, Yu HF, Dong B, Qiao SY. Free radical scavenging activity of *Lactobacillus fermentum* in vitro and its antioxidative effect on growing-finishing pigs. J Appl Microbiol. 2009;107(4):1140–8.
97. Elkhtab E, El-Alfy M, Shenana M, Mohamed A, Yousef AE. New potentially antihypertensive peptides liberated in milk during fermentation with selected lactic acid bacteria and kombucha cultures. J Dairy Sci. 2017;100(12):9508–20. https://doi.org/10.3168/jds.2017-13150.
98. Gobbetti M, Ferranti P, Smacchi E, Goffredi F, Addeo F. Production of angiotensin-I-converting-enzyme-inhibitory peptides in fermented milks started by *Lactobacillus* delbrueckii subsp. bulgaricus SS1 and *Lactococcus lactis* subsp. cremoris FT4. Appl Environ Microbiol. 2000;66(9):3898–904.
99. Utami Wirawati C, Eva Nirmagustina D, Widodo YR. Antihypertensive peptides produced by indigenous lactic acid bacteria from dadih origin. Pakistan J Biotechnol. 2020;17(2):85–91.
100. Meisel H. Casokinins as inhibitors of angiotensin-converting-enzyme. In: New perspectives in infant nutrition. Stuttgart: Thieme; 1993. p. 153–9.
101. Wirdahayati R. Strategi pelestarian produksi susu kerbau lokal (swamp buffalo) bagi peningkatan gizi masyarakat. Bogor: Pusat Penelitian dan Pengembangan Peternakan; 2008. pp 556–562.
102. Miskiyah, Usmiati S. Sifat fisikokimia dadih susu sapi: pengaruh suhu penyimpanan dan bahan pengemas. In: Prosiding seminar nasional teknologi peternakan dan veteriner 2011. 2011. pp 432–41.
103. Taufik E. Dadih susu sapi hasil fermentasi berbagai starter bakteri probiotik yang disimpan pada suhu rendah: Karakteristik kimiawi. Media Peternak. 2004;27(3):88–100.
104. Dewi P. Ketahanan hidup sel Acetobacter xylinum pada pengawetan secara kering-beku menggunakan medium pembawa. Biosaintifika. 2009;1(1):41–8.
105. Zain WNH. Karakteristik Biologis Granul Kultur Starter dengan Sinbiotik Terenkapsulasi untuk Menghasilkan Yoghurt dan Dadih Sinbiotik. IPB University; 2010.
106. BPOM RI. Peraturan Kepala Badan Pengawas Obat dan Makanan Republik Indonesia Nomor HK.03.1.23.11.11.09909 Tahun 2011 Tentang Pengawasan Klaim dalam Label Iklan Pangan Olahan. Bpom Ri. Jakarta; 2011. pp. 1–46.
107. Hatta W, Sudarwanto M, Sudirman I, Malak R. Prevalence and sources of contamination of *Escherichia coli* and *Salmonella* spp. in cow milk dangke, Indonesian fresh soft cheese. Glob Vet. 2013;11(3):352–6.
108. Skowron K, Budzyńska A, Grudlewska-Buda K, Wiktorczyk-Kapischke N, Andrzejewska M, Wałecka-Zacharska E, et al. Two faces of fermented foods—the benefits and threats of its consumption. Front Microbiol. 2022;13(March):1–17.
109. Puniya AK. Fermented milk and dairy products. Boca Raton: CRC Press; 2015.
110. Delfitriani DT. Construction of business intelligence in dadih product affective design. IOP Conf Ser Earth Environ Sci. 2019;230(1):012053.
111. Delfitriani D, Djatna T, Syamsir E. Development of packaging appearance element design of dadih with Kansei Engineering approach. IPTEK J Proc Ser. 2018;0(3):16.
112. Ghorashi SH, Ibrahim R, Noekhah S, Dastjerdi NS. A frequent pattern mining algorithm for feature extraction of customer reviews. Int J Comput Sci Issues. 2012;9(4):29–35.
113. Liu B, Hu M, Cheng J. Opinion observer: analyzing and comparing opinions on the web. Proc 14th Int Conf World Wide Web [Internet]. 2005;342–51. Available from: http://dl.acm.org/citation.cfm?id=1060797
114. Sisriyenni D, Zurriyati Y. Kajian kualitas dadih susu kerbau d dalam tabung bambu dan tabung plastik. J Pengkaj dan Pengemb Teknol Pertan. 2004;7(2):171–9.
115. Sugitha IM, Mukthar H, Kasrad, Yuherman. Rekayasa dadih dengan Streptococcus lactis dan Lactobacillus acidophilus untuk mencegah kanker dan mengurangi kolesterol darah. Padang; 1999.
116. Sunarlim R, Usmiati S. Sifat Mikrobiologi dan Sensori Dadih Susu Sapi yang Difermentasi Menggunakan Lactobacillus plantarum dalam Kemasan yang Berbeda. Vol. 30, Buletin Peternakan. 2012. p. 208.
117. Usmiati S, Setiyanto H. Karakteristik dadih meng- gunakan starter Lactobacillus casei selama penyimpanan. In: Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner 2010. Bogor: Pusat Penelitian dan Pengem- bangan Peternakan; 2010. p. 406–14.

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