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The Potential of Dadih as a Nutritious Animal Protein Source and Functional Food from West Sumatra

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Abstract

Dadih is a traditional fermented buffalo milk product from West Sumatra, renowned for its high-quality animal protein and beneficial probiotic microorganisms. This study aims to analyze the nutritional value of dadih, the characteristics of its indigenous lactic acid bacteria (LAB), and evaluate its potential for development as a modern functional food. A descriptive literature review was conducted, synthesizing scientific publications from the last decade. Findings indicate that dadih contains protein levels ranging from 6.3–8.4% and fat content between 5.5–8.7%. The lactic acid bacteria present in dadih exhibit significant probiotic properties that support gastrointestinal health and enhance the immune system. The traditional fermentation process using bamboo tubes and banana leaf covers not only imparts a unique flavor and texture but also serves as a natural isolation medium for beneficial bacteria. This article concludes that product diversification, fermentation technology innovation, and modern packaging are essential strategies to increase the added value and competitiveness of dadih in the global market. As a functional food, dadih holds strategic prospects in supporting national food security and public health.

Keywords: Dadih, buffalo milk, probiotics, functional food, West Sumatra.

Dadih is a traditional fermented buffalo milk product native to the Minangkabau ethnic group in West Sumatra, Indonesia. This indigenous delicacy is produced through a unique spontaneous fermentation process using bamboo tubes (*Bambusa verticillata*) covered with banana or taro leaves, which create a facultative anaerobic environment ideal for microbial growth [5]. Unlike modern fermented dairy, dadih is manufactured without the addition of a starter culture or prior pasteurization, relying instead on the natural microflora present in the raw buffalo milk and the inner surface of the bamboo [4, 5]. This artisanal process results in a product with a thick, yogurt-like consistency, a distinctive sour aroma, and a smooth texture that holds a central place in traditional Minangkabau ceremonies and daily nutrition [3, 7].

From a nutritional perspective, dadih serves as a superior source of animal protein and essential bioactive compounds compared to common bovine milk products [2, 10]. It typically contains high protein levels ranging from 6.3% to 12.4% and fat content between 5.5% and 18.0%, which vary significantly based on the regional buffalo diet and fermentation conditions [4, 8]. Beyond basic macronutrients, buffalo milk's naturally higher total solids foster a nutrient-dense matrix rich in calcium (up to 185 mg/100 mL), magnesium, and essential amino acids [2, 6]. During fermentation, microbial activities further enhance this profile by releasing short-chain fatty acids (SCFAs) and bioactive peptides, which are linked to various health-promoting properties, including antioxidant and anti-hypertensive effects [2].

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The functional value of dadih is primarily attributed to its diverse community of indigenous lactic acid bacteria (LAB), with counts reaching as high as \(10^{7}\) to \(10^{9}\) CFU/g [4, 7]. Predominant strains such as *Lactobacillus plantarum*, *Lactococcus lactis*, and *Leuconostoc* species have been isolated and characterized for their significant probiotic potential [3, 5, 10]. These microorganisms exhibit critical functional traits, including bile salt tolerance and the ability to inhibit enteric pathogens through the production of organic acids and bacteriocins [9, 10]. Recent clinical and preclinical studies have demonstrated that dadih consumption supports gastrointestinal health, enhances immune response through immunomodulation, and may play a role in reducing serum cholesterol levels [3, 6, 8].

Despite its vast potential, the transition of dadih from an artisanal craft to a standardized functional food faces several systemic challenges [5]. The reliance on spontaneous fermentation often leads to inconsistent product quality, limited shelf life, and safety concerns regarding the absence of heat treatment [4, 11]. Furthermore, the traditional use of non-reusable bamboo tubes poses sustainability issues and complicates large-scale industrialization [11]. Addressing these hurdles through innovations in controlled fermentation technology, standardized starter cultures, and modern packaging is essential to elevate dadih's competitiveness in the global functional food market [9, 11]. This article evaluates the current scientific understanding of dadih's nutritional and probiotic characteristics to outline a roadmap for its development as a sustainable pillar of national food security.

1. Literature Review

Nutritional Composition of Buffalo Milk and Dadih

The nutritional superiority of dadih is fundamentally rooted in its raw material: buffalo milk. Compared to bovine milk, buffalo milk possesses significantly higher total solids, which contributes to the dense, curd-like texture of dadih after fermentation [12]. Research indicates that buffalo milk contains approximately 40% more protein and 100% more fat than cow’s milk, providing a richer substrate for microbial transformation [13]. During the fermentation process, indigenous microorganisms metabolize lactose into lactic acid, which subsequently lowers the pH to approximately 4.5. This acidification triggers the gelation of caseins, creating a bioavailable matrix where minerals like calcium and phosphorus are highly concentrated [14]. Furthermore, the proteolysis occurring during dadih maturation results in the release of bioactive peptides. These peptides have been documented to possess antioxidant capacities and ACE-inhibitory activities, potentially offering cardiovascular benefits to regular consumers [15].

Microbial Diversity and Probiotic Potential

The hallmark of dadih as a functional food is its diverse community of lactic acid bacteria (LAB). Unlike commercial yogurts that use standardized starters, dadih relies on "wild" fermentation, leading to a complex microbial ecosystem. Studies using 16S rRNA gene sequencing have revealed that *Lactobacillus plantarum*, *Lactococcus lactis* ssp. *lactis*, and *Pediococcus acidilactici* are the dominant species found in dadih from various regions of West Sumatra [16]. These strains are categorized as "indigenous probiotics" because they survive the transit through the human gastrointestinal tract, demonstrating high tolerance to gastric acid and bile salts [17]. Beyond survival, these LAB strains exhibit strong adherence to intestinal mucosa, which is a critical trait for competitive exclusion of pathogens such as *Salmonella typhimurium* and *Escherichia coli* [18]. Recent literature also highlights the role of dadih-derived probiotics in modulating systemic inflammation and improving lipid profiles in animal models [19].

Traditional Fermentation and the Role of Bamboo

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The use of bamboo tubes (*Bambusa* spp.) is not merely a traditional packaging choice but a critical technological component of dadih production. The porous nature of the bamboo inner wall acts as a natural "microbial reservoir," harboring LAB from previous fermentation cycles [20]. This phenomenon ensures a consistent inoculation process even without a laboratory-prepared starter. Additionally, the bamboo allows for slight moisture evaporation, which further increases the viscosity and nutrient density of the final product [21]. However, the spontaneous nature of this process presents challenges regarding safety and standardization. Research into "controlled fermentation" suggests that by isolating these indigenous strains and re-introducing them into pasteurized buffalo milk, producers can maintain the traditional sensory profile while ensuring microbiological safety and extended shelf life [22].

Development as a Modern Functional Food

Transitioning dadih from a traditional household product to a commercial functional food requires strategic innovation in processing and marketing. Current market trends show a rising demand for "clean label" and probiotic-rich foods, placing dadih in a favorable position globally [23]. Nevertheless, the distinctive sharp, sour taste and the traditional presentation in bamboo tubes may limit its appeal to a broader, non-local audience. Literature suggests that diversification into products such as dadih-based smoothies, dried probiotic powders, or encapsulated supplements could bridge the gap between tradition and modern consumer preferences [24]. Furthermore, improving the cold chain logistics and developing biodegradable modern packaging that mimics the gas-exchange properties of bamboo are identified as vital steps for the international scaling of dadih [25].

3. Methodology

Study Design

This study employed a descriptive and qualitative systematic literature review (SLR) approach. The primary objective was to synthesize existing empirical data regarding the nutritional profile, microbiological characteristics, and industrial potential of dadih. The methodology followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, replicability, and objective selection of sources [26,27].

Data Sources and Search Strategy

The literature search was conducted across high-impact electronic databases, including ScienceDirect, PubMed, SpringerLink, Google Scholar, and the Indonesian Publication Index (IPI). The search strategy utilized a combination of Boolean operators (AND, OR) and specific keywords: *"Dadih"*, *"Buffalo milk fermentation"*, *"Lactic Acid Bacteria Indonesia"*, *"Functional Food West Sumatra"*, and *"Probiotic characteristics of Dadih"*. To maintain contemporary relevance, the search was limited to peer-reviewed journals, conference proceedings, and scientific reports published between 2014 and 2024.

Inclusion and Exclusion Criteria

Inclusion Criteria; (a) Studies focused on dadih made specifically from West Sumatran buffalo milk; (b) Research providing quantitative data on macronutrients (protein, fat, pH); (c) Microbiological studies identifying specific strains of Lactic Acid Bacteria (LAB); (d) Articles discussing the technological development of dadih as a functional food.

Exclusion Criteria; (a) Articles published in predatory journals; (b) Studies using non-buffalo milk as the primary substrate; (c) Non-scientific articles or opinion pieces without empirical testing.

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Data Extraction and Analysis
Data were extracted from the selected literature and categorized into four thematic clusters; (a) Nutritional Cluster: Compiling percentage ranges of protein, fat, and lactic acid content [28]. (b) Microbiological Cluster: Cataloging identified LAB strains and their probiotic markers (acid tolerance, bile salt resistance) [29]. (c) Technological Cluster: Analyzing traditional fermentation variables (bamboo type, duration, temperature) [30]. (d) Strategic Cluster: Identifying gaps in current processing methods and opportunities for industrial diversification.

The collected data were then subjected to a Narrative Synthesis. Quantitative values (such as protein percentages and microbial counts) were tabulated and compared across different regional samples to determine a standard nutritional baseline for dadih. Qualitative insights regarding the sensory properties and cultural significance were integrated to provide a holistic view of the product's potential as a global functional food.

4. Results and Discussion

4.1 Nutritional Matrix and Biochemical Transformation

The systematic review reveals that Dadih is not merely a dairy product but a complex biochemical matrix. The protein content, synthesized from various studies, ranges between 6.3% and 12.4%, which is significantly higher than commercial bovine yogurt. This elevation is attributed to the higher total solids in buffalo milk (approx. 17–20%) compared to cow's milk (approx. 12%). During the spontaneous fermentation period of 24–48 hours, a significant biochemical transformation occurs. Proteolytic activities by indigenous LAB break down casein into bioactive peptides. These peptides, particularly those with low molecular weight, have been identified as having ACE-inhibitor properties, which contribute to antihypertensive effects in consumers [31].

Furthermore, the fat content (5.5%–18.0%) is characterized by a high concentration of short-chain fatty acids (SCFAs). The fermentation process in bamboo tubes allows for a natural concentration of these fats, as the porous nature of the bamboo promotes slight syneresis (water loss). This concentration not only enhances the caloric density—making it an ideal supplementary food for stunting prevention—but also contributes to the unique "creamy-acidic" flavor profile that is highly valued in Minangkabau gastronomy [32].

4.2 Microbial Community and Probiotic Mechanisms

The microbiological landscape of Dadih is dominated by a diverse consortium of Lactic Acid Bacteria (LAB), with population densities consistently exceeding the therapeutic threshold of 10^7 CFU/g. The most prevalent species identified across the literature are *Lactobacillus plantarum*, *Lactococcus lactis*, and *Pediococcus pentosaceus* [33]. These "wild" strains exhibit superior resilience compared to commercial starters. Specifically, *L. plantarum* isolated from Dadih has shown a survival rate of 88% after exposure to simulated gastric juice at pH 2.0 for 3 hours, a critical requirement for any probiotic to exert health benefits in the lower intestine [34].
The mechanism of pathogen inhibition in Dadih is dual-fold: through the production of organic acids (lactic and acetic acid) which drops the pH to 4.5, and the secretion of bacteriocins. Research indicates that Dadih extracts effectively inhibit the growth of *Staphylococcus aureus*, *Salmonella typhi*, and *Escherichia coli*. This antimicrobial property suggests that Dadih acts as a natural biopreservative, ensuring the product remains safe for consumption despite the lack of modern pasteurization in traditional settings [33, 36].

4.3 The Synergy of Bamboo-Mediated Fermentation

A unique finding in this review is the technological role of the bamboo tube (*Schizostachyum brachycladum*). The bamboo wall does not just serve as a container; it acts as a bioactive interface. The inner lining of the bamboo

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contains natural waxes and antimicrobial compounds that protect the milk during the initial lag phase of fermentation. More importantly, the bamboo tubes are often reused or cleaned in a way that preserves a "biofilm" of LAB from previous batches, effectively acting as a natural back-slopping technique [37].
However, the lack of temperature control in traditional methods leads to seasonal variations in quality. Studies comparing traditional dadih with "controlled dadih" (using isolated starters and stainless steel vats) show that while controlled versions have better safety profiles, they often lack the complex volatile aromatic compounds—such as diacetyl and acetoin—produced during the bamboo-mediated process. This suggests that future industrialization must find a middle ground, perhaps through "active packaging" that mimics the gas-exchange properties of bamboo [29, 38].

5. Conclusion

This systematic review underscores that dadih is a potent functional food from West Sumatra, characterized by its superior nutritional density and significant probiotic value. The high concentration of high-quality animal protein (6.3%–12.4%) and essential minerals like calcium and iron positions dadih as a strategic dietary intervention for combating malnutrition and stunting. Its functional properties are fundamentally driven by indigenous lactic acid bacteria, particularly *Lactobacillus plantarum*, which exhibit remarkable resilience to gastrointestinal conditions and provide critical immunomodulatory and antimicrobial benefits.
The study also highlights that the traditional use of bamboo tubes is not merely a cultural artifact but a technological necessity that facilitates a unique biochemical environment, contributing to dadih's distinct sensory profile and microbial biofilm development. However, to transition dadih from a local heritage product to a competitive global commodity, industrialization must address the current challenges of quality inconsistency and limited shelf life. The implementation of standardized starter cultures, modernized fermentation technologies, and advanced active packaging—which mimics the natural gas-exchange properties of bamboo—is essential. Ultimately, dadih holds immense potential as a sustainable pillar for national food security and a promising candidate in the international functional food market.

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