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Dairy-based value addition in nipa palm (Nypa fruticans) distilled wine: A scoping review

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ABSTRACT

The Nipa palm (Nypa fruticans) is a mangrove palm that grows in coastal areas of Southeast Asia, South Asia, and the Pacific. Distillates of inflorescence sap contain 35% to 40% alcohol by volume (ABV) and exhibit antioxidant, antilipidemic, and enzyme-inhibitory activities. This review presents the processing, physicochemical properties, functional potential, and techniques for integrating nipa palm distilled wine into dairy products. The review also lays out the research agenda for developing beverages using nipa palm distillates with dairy constituents. The review followed the PRISMA guidelines for scoping reviews and the Joanna Briggs Institute (JBI) scoping review methodology. Seven databases were used to conduct a cross-domain evidence synthesis, which identified 22 empirical studies published between 2020 and 2026. The sources were synthesized by processing innovations, physicochemical, functional, and bioactive properties, nutritional composition, and dairy integration approaches. Spray-dried nipa palm vinegar powder contained 105 mg gallic acid equivalents (GAE) of phenolics per 100 g, with well-characterized fermentation parameters and an established acute safety profile. Documented integration pathways included whey distillation and cofermentation, cream liqueur formulation, and whey substitution in plant-derived alcoholic beverage substrates, confirmed by evidence from similar beverage systems. Across the 22 included sources, we found no direct empirical evidence on nipa palm and dairy integration. The convergence of nipa palm substrate evidence and analogous dairy integration findings creates an actionable research agenda. Whey substitution in nipa palm sap fermentation is the most testable integration strategy for smallholder nipa palm beverage producers in Southeast Asia, South Asia, and the Pacific.

Contribution/Originality: This study contributes to the existing literature by mapping evidence for dairy-based value addition in Nypa fruticans distilled wine. This study is one of the very few that have investigated this through cross-domain synthesis. The paper's primary contribution is finding that no direct empirical evidence exists, thereby defining an actionable research agenda.

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1. INTRODUCTION

Nipa palm (Nypa fruticans Wurmb.) is a mangrove-associated palm found in the tropical coastal zones of Southeast Asia, South Asia, and the Pacific. In coastal communities in the Philippines, Malaysia, Indonesia, and Thailand, nipa palm inflorescence sap is used to produce alcoholic beverages, vinegar, and sugar. The phenolic fraction of nipa palm sap is responsible for the antioxidant, antilipidemic, and enzyme inhibitory actions demonstrated by the alcoholic products obtained from the natural fermentation and distillation of the sap. Despite these functional properties and the ecological abundance of nipa palm across areas in Southeast Asia, commercial exploitation of nipa palm sap-derived products is still limited compared with analogous palm species, and nipa palm has been comparatively less systematically investigated in the food science and beverage technology literature.

Dairy-based value addition, defined as the incorporation of dairy constituents, cofermentation techniques, or advanced processing technologies into food and beverage systems, has been applied across non-traditional, plant-derived beverage systems. Studies on these product classes have demonstrated successful applications in cream liqueurs made from plant-derived distillates, spirits from cheese whey fermentation, and fermented beverages from the cofermentation of dairy whey with plant substrates. These findings establish that dairy integration is not limited to conventional dairy product categories and that plant-derived alcoholic substrates can serve as viable base substrates for dairy-based product development. However, no study has been conducted on dairy-based value addition in nipa palm distilled wine, an unexplored intersection between an underutilized tropical resource and an established food technology domain.

The lack of direct empirical evidence for nipa palm and dairy integration does not mean it is technically impossible but rather points to a lack of investigative effort, given that the substrate properties of nipa palm sap and transferable findings from similar dairy beverage systems lay a good scientific foundation for systematic investigation.

Tackling this gap has implications for functional beverage innovation, agricultural development in nipa-palm-producing regions, rural livelihood diversification among coastal farming communities, and dairy byproduct valorization through the productive use of whey and other dairy waste streams. A scoping review is the appropriate tool to map available evidence across these domains prior to direct empirical investigation.

This scoping review mapped available evidence on processing innovations, physicochemical properties, functional potential, and dairy integration strategies of nipa palm distilled wine. The review had three aims: (1) to synthesize available evidence on nipa palm sap processing and other similar dairy beverage systems, (2) to identify and characterize the research gap in dairy value addition for nipa palm distilled wine, and (3) to propose a research agenda for functional beverages containing nipa palm distillates and dairy constituents in Southeast Asian production contexts.

2. LITERATURE REVIEW

2.1. Nipa Palm Products

Although nipa palm has been increasingly studied as a substrate for beverages in Southeast Asia, the evidence base is geographically limited and small relative to the ecological and economic importance of nipa palm. The quality of sap at the collection stage has been identified through studies of fermentation dynamics as a primary determinant of downstream product quality. Multisite designs have revealed variation attributable to collection location, seasonal conditions, and ambient microbial load (Madigal, Cariaga, Suarez, & Agrupis, 2020). The use of closed-vessel collection systems has been shown to improve the chemical purity and microbiological quality of the collected material compared with open collection methods. The results suggest that consistency of the raw material is important for reproducible fermentation results and for studying the incorporation of dairy into nipa palm beverage systems (Perral & Adlaon, 2024). Studies on the thermal processing of nipa palm and similar palm substrates have established pasteurization conditions and verified that bioactive compounds in nipa palm products retain their functional integrity

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under optimized processing conditions (Athirah, Asaruddin, Bhawani, Simbas, & Jack, 2025; Bara, Wijaya, & Arnata, 2025).

The literature on processing and functional properties of nipa palm shares a common limitation. Most of the investigations have been conducted using nipa palm vinegar as the experimental material rather than nipa palm distilled wine, including studies documenting antioxidant activity, antilipidemic effects, enzyme inhibitory properties, and immunomodulatory activity (Chatatikun & Kwanhian, 2020; Laklaeng & Kwanhian, 2020; Palachum, Klangbud, & Chisti, 2022; Yasmin et al., 2023). The processing parameters and functional property results obtained for nipa palm vinegar cannot be assumed to be applicable to a distillate-based system without independent validation due to the compositional differences between nipa palm vinegar and nipa palm distilled wine, particularly in terms of alcohol content, acidity, and phenolic profile. Functional property evidence for nipa palm products is mostly supported by in vitro assays, and in vivo corroboration is only available at the level of acute toxicity, without human clinical studies (Yahaya et al., 2021). None of the studies examined whether the bioactive compounds responsible for the reported functional properties of nipa palm products survive fermentation and distillation. This is a knowledge gap, as phytochemical profiles in analogous plant substrates are significantly altered by thermal and biochemical processing (Khairi, Bahri, Ukhty, Rozi, & Nasution, 2020). The toxicological evidence for nipa palm sap does not extend to processed nipa palm products or to nipa palm combined with dairy constituents. It cannot substitute for the safety assessment that product development and regulatory submissions require (Yahaya et al., 2021). These limitations define the current knowledge of nipa palm as a beverage substrate and highlight the need for direct experimental investigation of nipa palm distilled wine as a separate product category.

2.2. Dairy Integration in Beverage Systems: Evidence from Analogous Studies

Evidence for dairy integration in non-traditional beverage systems is consistent across four product categories: whey distillation, plant substrate co-fermentation with dairy whey, cream liqueur formulation from non-traditional distillates, and whey substitution in traditional fermented beverages. Each product category has been documented in separate laboratory and pilot-scale experimental settings by independent research groups across diverse geographic locations and plant substrates (Hauser et al., 2025; Ljoljić et al., 2023; Mabusa, Mangonye, Mashakeni, Matsapola, & Ramongane, 2025; Mametjanov et al., 2025). The consistency of the findings across these studies adds to the inferential case for nipa palm and dairy integration more than any single analog study might do. However, each analogous system differs from nipa palm in substrate composition, pH profile, phenolic content, and microbial ecology, precluding direct transfer of parameters to the formulation and processing conditions of nipa palm distilled wine production.

The main limitation for transferability is pH compatibility. The pH range of nipa palm sap fermentation is close to the isoelectric point of casein, thus posing a risk of protein precipitation and phase instability that was not observed in any analogous dairy integration study reviewed (Hauser et al., 2025; Madigal et al., 2020; Mametjanov et al., 2025). The most significant unresolved technical limitation in the integration of nipa palm and dairy is the pH incompatibility between nipa palm-fermented products and casein stability that cannot be solved by analogy alone. Of the four integration pathways, the most immediately testable is the substitution of whey for process water during nipa palm sap fermentation. Similar studies of fermented beverages have shown that whey substitution enhances protein content and mineral profile while maintaining established fermentation protocols (Mametjanov et al., 2025). Okafor et al. (2023) demonstrated enzymatic compatibility between lactic acid bacteria strains of dairy origin and palm wine origin, supporting the co-fermentation hypothesis at the microbiological level. However, fermentation performance in a combined nipa palm sap and dairy-constituent fermentation substrate under nipa palm-specific conditions of pH, sugar composition, and alcohol tolerance remains uninvestigated.

Pathways for incorporating dairy constituents into non-traditional plant-based alcoholic beverage systems have been documented in separate experimental studies investigating analogous beverage systems (Hauser et al., 2025;

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Ljoljić et al., 2023; Mabusa et al., 2025; Mametjanov et al., 2025). The lack of direct empirical investigation into nipa palm and dairy integration reflects a lack of investigative effort rather than a technical barrier. The particular constraints identified in this section for nipa palm mean that findings from analogous dairy integration systems must be treated as hypothesis-generating rather than hypothesis-confirming, and direct experimental investigation is necessary before any characteristics of a nipa palm and dairy product can be established.

3. METHODS

3.1. Methodology and Review Framework

A scoping review methodology was employed to map the evidence on dairy-based value addition in Nypa fruticans distilled wine. Scoping reviews map the extent, distribution, and characteristics of an evidence base, identify research gaps, and define research agendas for emerging or underinvestigated fields, rather than estimating a pooled effect or evaluating intervention efficacy (Arksey & O'Malley, 2005; Peters et al., 2021). A scoping review was selected over a systematic review because the absence of direct empirical evidence on nipa palm and dairy integration precluded meta-analysis or quantitative synthesis. The cross-domain nature of the available evidence, spanning nipa palm processing, dairy technology, and analogous beverage systems, required a methodology capable of accommodating heterogeneous study designs and outcome measures. A narrative review was not selected on the grounds that it would not provide the systematic search transparency or reproducible selection process required to map the evidence base or justify the research gap.

The present review differs from prior nipa palm literature reviews in two respects. First, existing nipa palm reviews have addressed phytochemical composition, nutritional properties, and ecological characteristics. None applied a systematic database search methodology, a reproducible selection process, or a formal evidence synthesis framework. The present review applies the full PRISMA-ScR guidelines and JBI scoping review methodology to nipa palm for the first time, to the best of our knowledge, providing a reproducible evidence map rather than a narrative account. Second, no prior review, whether systematic, scoping, or narrative, has examined dairy-based value addition in relation to nipa palm products. The cross-domain synthesis strategy employed here incorporates evidence from nipa palm processing studies, dairy technology applications, and analogous beverage systems selected for transferable relevance to the nipa palm and dairy integration question, representing a methodological approach not previously applied to this topic.

The present review followed the PRISMA-ScR (Tricco et al., 2018) and JBI scoping review methodology (Peters et al., 2021) and applied the five-stage framework of Arksey and O'Malley (2005) as refined by Levac, Colquhoun, and O'Brien (2010): identification of the research question, identification of relevant studies, study selection, charting of the data, and collating, summarizing, and reporting of results. The review question was structured using the Population, Concept, and Context (PCC) framework recommended by Peters et al. (2021) (Table 1).

Table 1. PCC framework for the scoping review.

PCC Element	Component	Operationalization in This Review
Population	The participants, sources, or systems of interest	Nipa palm (Nypa fruticans Wurmb.) sap, fermented products, and distillates, together with analogous palm-based and dairy-integrated beverage systems as transferable evidence sources
Concept	The core focus or phenomenon under examination	Processing innovations, physicochemical properties, functional and bioactive potential, and dairy-based value-addition strategies applicable to nipa palm-distilled wine
Context	The setting, conditions, or geographical scope	Peer-reviewed food science and beverage technology literature published between 2020 and 2026, with emphasis on Southeast Asian production and emerging functional beverage development

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3.2. Search Strategy and Information Sources

A literature search was conducted in PubMed, Scopus, Web of Science, ScienceDirect, AGRICOLA, Food Science and Technology Abstracts (FSTA), and CAB Abstracts, covering publications from January 2020 to April 2026, with one earlier source included on the basis of direct relevance to the dairy integration question. The final search was conducted on 15 April 2026. The restriction to publications from 2020 to 2026 was applied because dairy-based value addition in nipa palm distilled wine had not emerged as a defined research area before this period and because dairy integration technologies applied to non-traditional beverage systems developed predominantly within this window. Foundational studies on nipa palm fermentation dynamics, phytochemical characterization, and sap composition published before 2020 may have been omitted as a consequence, and the evidence base for nipa palm as a beverage substrate may therefore be incompletely represented in the present review. Future reviews addressing the broader nipa palm processing literature should apply an unrestricted temporal scope.

Boolean operators and keyword combinations were applied for search sensitivity and specificity. Search strings included ("nipa palm" OR "*Nypa fruticans*") AND ("palm wine" OR "distilled wine" OR "fermented beverages") AND ("dairy integration" OR "milk-based beverages" OR "whey utilization") AND ("functional beverages" OR "value addition" OR "food innovation"), adapted to the syntax requirements of each database. Additional studies were identified through retrospective and forward citation tracking. Consistent with JBI guidance for iterative scoping searches, search terms were broadened to include whey-based distillates, yogurt-whey co-fermentation products, and cream liqueur formulations when initial results on nipa palm and dairy integration were limited.

Grey literature from government agricultural agency publications, industry technical reports, and unpublished institutional research from nipa palm-producing countries was not systematically searched. Grey literature was excluded because the absence of a reproducible search strategy consistent with PRISMA-ScR transparency requirements meant that unsystematic inclusion would have introduced selection bias. Applied product development knowledge held by traditional nipa palm beverage producers, government agricultural agencies in the Philippines, Malaysia, Indonesia, and Thailand, and industry stakeholders whose technical findings are not captured in indexed databases is not represented in the present review. Future reviews should incorporate systematic grey literature searching, including targeted searches of government agricultural databases, FAO technical documents, and industry association repositories in nipa palm-producing countries.

3.3. Eligibility Criteria

Source selection was guided by the inclusion and exclusion criteria presented in Table 2 (Liberati et al., 2009; McCrae, Blackstock, & Purssell, 2015).

Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Published between January 2020 and 2026	Published in languages other than English
Peer-reviewed journal articles, conference proceedings, or indexed institutional reports	Articles without accessible full text
Addressed nipa palm sap processing, dairy processing technologies applicable to beverages, or innovations in functional and fermented beverages with transferable relevance	Opinion-based contributions such as editorials and commentaries without empirical substantiation
Presented empirical findings on physicochemical, microbiological, or functional characteristics relevant to beverage development	Studies focused on unrelated botanical systems without explicit relevance to beverage processing or dairy integration

3.4. Source Selection Process

Records retrieved from the seven databases were imported into a reference management system for deduplication. The present review followed the four-stage PRISMA-ScR selection process of identification, screening, eligibility assessment, and inclusion. Two reviewers independently screened titles and abstracts, followed by full-text

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assessment of retained records. Disagreements were resolved through discussion, and a third reviewer was available to adjudicate unresolved cases. Inter-rater agreement was calculated using Cohen's kappa coefficient. The selection process is illustrated in Figure 1.

3.5. Data Charting

A charting instrument was developed a priori, pilot-tested across five sources, and independently applied by two reviewers. The instrument captured three variable categories. The first category comprised bibliographic and study design variables, including author names, year of publication, country of origin, study design, and materials and processing technologies investigated. The second category comprised empirical and analytical variables, including physicochemical outcomes such as alcohol content, pH, total soluble solids, viscosity, color parameters, and volatile compounds; functional characteristics such as antioxidant activity, phenolic content, and enzyme inhibition; nutritional composition; dairy integration approach where applicable; sensory outcomes; and statistical methods. The third category comprised interpretive and evaluative variables, including key findings, acknowledged limitations, and relevance to the nipa palm and dairy integration question. Table 4 in the Results section presents the completed charting instrument applied to all 22 included sources.

3.6. Source Appraisal and Relevance Assessment

Consistent with JBI scoping review methodology (Peters et al., 2021), formal quality appraisal was not applied as an inclusion or exclusion criterion. Study characteristics relevant to interpreting the evidence, including research design, analytical methods, presence of experimental controls, replication, and completeness of outcome reporting, were documented in the charting table.

3.7. Data Synthesis and Presentation

A narrative synthesis was employed given the heterogeneity of source designs, materials, and outcome measures (Peters et al., 2021). Findings were organized into five thematic categories: processing innovations, physicochemical characteristics, functional and bioactive properties, nutritional composition, and dairy integration approaches and analogous systems. Results are presented as a PRISMA-ScR flow diagram, a charting table summarizing the characteristics of all included sources, a thematic evidence map indicating the distribution of sources across the five categories, and a narrative synthesis organized by category. Limitations are reported in the Discussion section in accordance with PRISMA-ScR.

4. RESULTS AND DISCUSSION

4.1. Source Selection and Screening

Database searching yielded 221 records; 171 were duplicates, and 50 records were moved to title and abstract screening. Two reviewers screened all 50 records independently. Inter-rater agreement for categories at the title and abstract stage was slight (Cohen's $\kappa = 0.180$, $p = 0.049$). When decisions were uncertain, records were coded as included; binary kappa was fair (kappa = 0.275, $p = 0.031$; Table 3), because both categories resulted in full-text retrieval. Twenty records were excluded because they dealt with botanical systems other than nipa palm and beverage processing, had no empirical data, or were published in languages other than English.

Thirty records were obtained for full-text review. Inter-rater agreement at the full-text stage was fair for three categories (Cohen's $\kappa = 0.325$, $p = 0.057$). All 30 records were included based on Reviewer 2's recommendation. This resulted in a constant variable for which kappa could not be calculated. Three sources were excluded at the full-text assessment stage because they did not provide empirical evidence relevant to the review question, and four sources did not meet the empirical data criterion. The two reviewers discussed the discrepancies until they were resolved; no

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cases required adjudication by a third reviewer. Selection procedures are shown in Figure 1, and kappa statistics are summarized in Table 3.

Table 3. Cohen's Kappa coefficients for dual-reviewer screening agreement at two eligibility stages (n = 50 and n = 30).

Stage	Analysis	n	κ	Interpretation	p
T&A Screening	3-category	50	0.180	Slight	0.049
Full-Text	3-category	30	0.325	Fair	0.057
T&A Screening	Binary	50	0.275	Fair	0.031
Full-Text	Binary	30	N/A	R^2 constant	—

4.2. Characteristics of Included Sources

Twenty two empirical sources were included, published between 2014 and 2025, with 21 sources published between 2020 and 2025 and one source (Devi, 2014) retained for direct relevance to high pressure processing in dairy systems. Malaysia made the largest contribution (n = 4), followed by Europe and Australia combined (n = 4), Thailand (n = 3), the Philippines and Indonesia (n = 2 each), Nigeria, Sri Lanka, Brazil, South Africa, and Central Asia (n = 1 to 2 each). The most frequent designs were experimental laboratory designs (n = 15), while the remaining seven sources comprised one pilot-scale study, one characterization study, three reviews, and one case study. No source reported results from validation at an industrial scale or commercial validation.

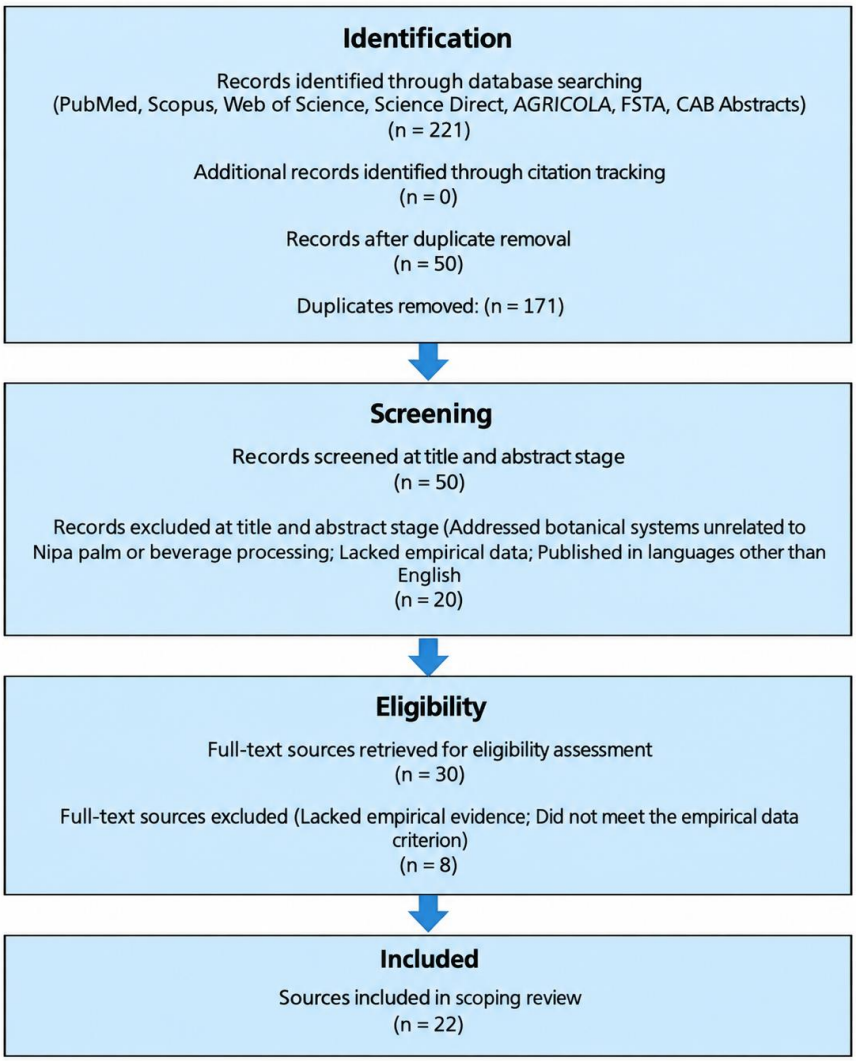


Figure 1. PRISMA-ScR flow diagram of source identification, screening, and inclusion for the Nipa palm scoping review (n = 22 empirical sources).

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Ten sources discussed physicochemical properties, nine discussed processing innovations, eight discussed functional and bioactive properties, five discussed dairy integration and analogous systems, and four discussed nutritional composition. Most of the sources provided evidence for more than one thematic category. The relevance ratings indicated that 14 sources were directly relevant with high transferability to the question of nipa palm and dairy integration, three sources were directly relevant with moderate transferability, one source was analogous with high relevance, two sources were analogous with moderate relevance, and two sources provided background context with limited alignment to the review question (Table 4).

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Table 4. Characteristics of included sources in the scoping review of dairy-based value addition in Nipa palm (*Nypa fruticans*) Distilled wine (n = 22).

ID	Author(s) & Year	Country	Design	Material / System	Primary Concept	Key Finding	Relevance
S01	Khairi et al. (2020)	Indonesia	Review	Nipa palm leaves/Fruit	Nutritional & bioactive characterization	Fruits: 56.41% carbs, 2.95% protein; leaves: 10.64- 14.23% protein; bioactive metabolites identified	Direct - high
S02	Palachum et al. (2022)	Thailand	Experimental	Nipa palm vinegar	Spray-drying optimization	Optimal: 170°C/15% maltodextrin; 105 mg GAE/100g phenolics; 883.9 mg K/100g; 180-day stability	Direct - high
S03	Moschopoulou (2021)	Greece	Review	Dairy (General)	HPP and novel dairy processing	HPP at 400-600 MPa achieves microbial reduction without significant nutrient loss	Direct - high
S04	Devi (2014)	Australia	Experimental	Dairy whey proteins	HPP effects on dairy physiochemistry	Casein disrupted at >400 MPa; 45 volatile compounds; enhanced gel/emulsion stability	Direct - high
S05	Ljoljić et al. (2023)	Croatia	Experimental	Cheese whey	Whey distillate production	~35% ABV distillate; complex volatile profile (acetaldehyde, ethyl lactate, higher alcohols)	Direct - high
S06	Hauser et al. (2025)	United States	Experimental	Dairy whey + grape pomace	Whey co-fermentation piquette	Altered volatile profile; novel dairy/salty/umami sensory notes; sustainability demonstrated	Direct - high
S07	Madigal et al. (2020)	Philippines	Experimental	Nipa palm sap	Fermentation dynamics	Progressive pH decline; alcohol increase over 3-7 days; TSS 14-15 °Brix initial; site variation	Direct - high
S08	Perral and Adlaon (2024)	Philippines	Experimental	Nipa palm sap/Liquor	Closed-vessel collection and distillation	7-11% improved chemical purity; lower microbial counts; 35-40% ABV distillate	Direct - high
S09	Okafor et al. (2023)	Nigeria	Experimental	LAB (Milk + palm wine)	Invertase activity of LAB	Invertase activity 0.191-0.75 mg/mL; palm wine isolates showed higher activity	Direct - high
S10	Mabusa et al. (2025)	South Africa	Experimental	Cream liqueur (Sorghum/Prickly pear)	Cream liqueur formulation	Stable physicochemical properties; innovative sensory profile; market differentiation potential	Direct - high
S11	Mametjanov et al. (2025)	Kyrgyzstan	Experimental	Fermented beverage + whey	Whey substitution for water	Improved protein and mineral content compared to water control	Direct - high

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ID	Author(s) & Year	Country	Design	Material / System	Primary Concept	Key Finding	Relevance
S12	Bara et al. (2025)	Indonesia	Experimental	Coconut sap	Pasteurization optimization	Optimal: 70°C/30 min; pH 4.5; TSS 15.8 °Brix; effective microbial reduction	Analogous - high
S13	Athirah et al. (2025)	Malaysia	Experimental	Nipa palm sap	Sap preservation methods	Preservation treatments improved physicochemical stability and shelf-life	Direct - high
S14	Bandara, Tholambugolla, and Jayasundera (2023)	Sri Lanka	Characterization	Coconut toddy/Spirit	Volatile compound profiling	Key flavor compounds identified in toddy and spirits via GC-MS	Analogous - moderate
S15	Hasan, Ahiduzzaman, Islam, Haque, and Hossain (2022)	Sri Lanka	Experimental	Palmyrah palm products	Value-added product development	Acceptable consumer sensory scores for palmyrah-based products	Analogous - moderate
S16	Dias, Vieira, Alves, Oliveira, and Lima (2025)	Brazil	Case study	Forage palm (Opuntia)	Creamy palm dessert development	96.5% considered product innovative; >50% willing to consume	Background - low
S17	Ramli et al. (2025)	Malaysia	Experimental	Nipa palm sugar in chocolate	Nipa as sugar alternative	Acceptable substitution; functional sugar alternative in complex food matrix	Direct - high
S18	Chatatikun and Kwanhian (2020)	Thailand	Experimental	Nipa palm vinegar	Phenolic profile and antilipidemic activity	High phenolic content; significant antilipidemic activity demonstrated in vitro	Direct - moderate
S19	Laklaeng and Kwanhian (2020)	Thailand	Experimental	Nipa palm vinegar	Immunomodulatory effects	Polyphenolics and flavonoids modulate immune cell function	Direct - moderate
S20	Yasmin et al. (2023)	Malaysia	Experimental	Nipa palm vinegar	Carbohydrate enzyme inhibition	Significant α-amylase and α-glucosidase inhibition observed in vitro	Direct - moderate
S21	Yahaya et al. (2021)	Malaysia	Experimental	Nipa palm sap	Acute toxicity evaluation	No significant toxicity at tested doses in Sprague Dawley rats	Direct - high
S22	Oluwole et al. (2023)	Nigeria	Review	Palm wine (Various species)	Fermented palm beverage review	Palm wines contain probiotic LAB and health-promoting compounds	Background – low

Note: ABV, Alcohol by Volume; HPP, High Pressure Processing; LAB, Lactic Acid Bacteria; TSS, Total Soluble Solids; GAE, Gallic Acid Equivalents; GC-MS, Gas Chromatography Mass Spectrometry.

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4.3. Thematic Evidence Mapping

The 22 included sources were distributed across five thematic categories, with most contributing to more than one category. The five thematic categories were coded as follows for ease of reference. CAT 1 (Processing Innovations). CAT 2 (Physicochemical Properties). CAT 3 (Functional and Bioactive Properties). CAT 4 (Nutritional Composition). CAT 5 (Dairy Integration Approaches and Analogous Systems). Physicochemical Properties (CAT 2) and Processing Innovations (CAT 1) had the broadest coverage and the greatest overlap. Nutritional Composition (CAT 4) had the most limited representation, with four sources contributing to this category.

The Population, Concept, and Context alignment assessment indicated that nine sources (40.9%) achieved full alignment across all three framework elements. Eight sources (36.4%) showed partial alignment, three sources (13.6%) provided analogous evidence, and two sources (9.1%) contributed background context with limited alignment. Fully and partially aligned sources accounted for 77.3% of the evidence base.

4.4. Processing Innovations

4.4.1. Distillation Technologies

The natural fermentation of nipa palm sap at collection sites in Cagayan province, Philippines, has been reported to increase alcohol content and decrease pH and total soluble solids (Madigal et al., 2020). Distillation concentrated the alcohol to 35-40% ABV, comparable to distillates of coconut arrack and palm toddy. Perral and Adlaon (2024) showed 7 to 11% greater chemical purity and microbiological quality in closed collection vessels than in open collection vessels, producing distillates within the same ABV range. Ljoljić et al. (2023) produced a distillate with an ABV of about 35% by fermenting albumin cheese whey with Kluyveromyces marxianus for five days, and its volatile profile included acetaldehyde, methanol, n-propanol, iso-butanol, n-butanol, 3-methyl-1-ol, 2-methylbutan-1-ol, and ethyl lactate.

4.4.2. Spray-Drying and Powder Production

Palachum et al. (2022) optimized the spray drying of nipa palm vinegar using an inlet temperature of 170 °C, a feed flow rate of 500 mL/h, an atomization air flow rate of 5 m^3/h, an outlet temperature of 90 °C, and 15% w/v maltodextrin with a dextrose equivalent value of 10 as the carrier. The resulting powder contained 105 mg of phenolics, expressed as gallic acid equivalents, per 100 g and remained stable for 180 days at 25 °C when vacuum-packed in aluminum-laminated polyethylene.

4.4.3. Membrane Processing and Advanced Separation

In dairy systems, membrane processing applications have been reported by Moschopoulou (2021) and include microfiltration for cold pasteurization, ultrafiltration for whey protein concentration and fractionation, nanofiltration for mineral and lactose concentration, and reverse osmosis for water removal. No source in the present review studied membrane processing of nipa palm products or combinations of nipa palm and dairy products. Membrane processing is an unvalidated new route for the manufacture of nipa palm and dairy beverages and should be considered in the near-term experimental agenda.

4.4.4. Thermal Processing and Pasteurization

Bara et al. (2025) identified 70°C for 30 minutes as the optimal pasteurization treatment for coconut sap, maintaining pH and total soluble solids while achieving microbial reduction. Athirah et al. (2025) demonstrated that thermal processing combined with preservatives improved physicochemical and microbiological stability in nipa palm sap. Devi (2014) demonstrated that high-pressure processing at 300 to 600 MPa altered viscosity, storage modulus, color, and volatile compound profiles in dairy systems, producing 45 volatile compounds through Maillard reactions, lipid oxidation, and thermal degradation pathways.

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4.5. Physicochemical Properties

4.5.1. Alcohol Content and Fermentation Parameters

Fresh nipa palm sap contains 10 to 20% sucrose as the primary fermentation substrate (Palachum et al., 2022). Madigal et al. (2020) documented increases in alcohol levels alongside decreases in pH and total soluble solids during natural fermentation across sites in Cagayan province. Perral and Adlaon (2024) confirmed that nipa distillates produced using closed-vessel collection yielded 35 to 40% ABV. Ljoljić et al. (2023) achieved approximately 35% ABV from albumin cheese whey fermented with Kluyveromyces marxianus, within the lower bound of the nipa distillate range. Hauser et al. (2025) reported lower ethanol content in yogurt whey piquette cofermented with grape pomace relative to conventional piquettes.

4.5.2. pH, Acidity, and Total Soluble Solids

Fresh nipa palm sap exhibits a pH of 3.57 to 3.97 and total soluble solids of 14 to 15 °Brix (Madigal et al., 2020), with fermentation driving the pH decline as organic acids accumulate. Palachum et al. (2022) reported a pH of 2.67 and acetic acid content of 4.42% w/v for nipa palm vinegar, with spray drying increasing pH to 3.20 while concentrating acetic acid to approximately 5% w/v. Bara et al. (2025) demonstrated that pasteurization at 70°C for 30 minutes stabilized pH at 4.5 and total soluble solids at 15.8 °Brix in coconut sap. Hauser et al. (2025) documented elevated titratable acidity in yogurt whey piquette, with elevated lactic and citric acid concentrations contributing to acidic and salty sensory characteristics relative to conventional piquettes.

4.5.3. Volatile Compounds and Flavor Profiles

Palachum et al. (2022) confirmed retention of the characteristic vinegar aroma in spray-dried nipa palm vinegar powder at an inlet temperature of 170°C. Ljoljić et al. (2023) identified acetaldehyde, methanol, n-propanol, iso-butanol, n-butanol, 3-methyl-1-ol, 2-methylbutan-1-ol, and ethyl lactate in whey distillate, contributing fruity, solvent-like, and dairy-derived aromas. Hauser et al. (2025) documented increased concentrations of hexanoic acid, 3-methylpentanol, 1-octanol, and 1-octen-3-ol alongside decreased linalool in yogurt whey piquette. Devi (2014) identified furfural, pyrazine, nonanal, 2-furanmethanol, and 2-pentanone as volatile compounds generated by high-pressure processing of dairy systems. Bandara et al. (2023) identified ethyl acetate, ethyl lactate, higher alcohols, acetaldehyde, organic acids, and short-chain fatty acids in coconut toddy and spirits by gas chromatography–mass spectrometry.

4.5.4. Sensory Characteristics

Palachum et al. (2022) reported favorable hedonic scores for color, odor, taste, and overall acceptability of spray-dried nipa palm vinegar powder under optimal processing conditions. Hauser et al. (2025) documented higher scores for dairy, salty, acidic, and umami attributes alongside reduced perceptions of fruitiness and sweetness in yogurt whey piquette relative to conventional piquettes. Bara et al. (2025) reported high sensory acceptance of pasteurized coconut sap at 70°C for 30 minutes. Ramli et al. (2025) demonstrated that nipa palm sugar maintained acceptable sensory quality, mouthfeel, and friction and lubrication properties during oral processing of dark chocolate. Dias et al. (2025) reported that 96.5% of respondents considered a creamy palm-based forage product acceptable and that more than half indicated willingness to consume the product.

4.6. Functional and Bioactive Properties

4.6.1. Antioxidant Activity

Chatatikun and Kwanhian (2020) confirmed the phenolic content of nipa palm vinegar, along with its antioxidant properties and capacity to reduce lipid levels in experimental models. Palachum et al. (2022) reported a retention of 105 mg gallic acid equivalents of phenolics per 100 g in spray-dried nipa palm vinegar powder at an inlet temperature

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of 170°C. Bara et al. (2025) noted higher antioxidant content in coconut sap than in sugarcane sap, alongside a lower glycemic index.

4.6.2. Phenolic Content and Bioactive Compounds

Chatatikun and Kwanhian (2020) characterized the phenolic profile of nipa palm vinegar and documented antilipidemic effects, including inhibition of HMG-CoA reductase, inhibition of pancreatic lipase, modulation of lipoprotein lipase, and activation of peroxisome proliferator-activated receptors (PPARs). Palachum et al. (2022) quantified 105 mg of gallic acid equivalents of phenolic compounds per 100 g in spray-dried nipa palm vinegar powder. Laklaeng and Kwanhian (2020) demonstrated that nipa palm vinegar polyphenolics and flavonoids modulate immune cell function by regulating cytokine signaling and activating immune cell pathways. Khairi et al. (2020) identified alkaloids, flavonoids, steroids, triterpenoids, phenols, tannins, and saponins in nipa palm leaves and fruit.

4.6.3. Enzyme Inhibition and Metabolic Health

Yasmin et al. (2023) reported that nipa palm vinegar inhibited α-amylase and α-glucosidase via a mechanism similar to that of acarbose. Chatatikun and Kwanhian (2020) identified nipa palm vinegar phenolics as the active constituents responsible for the inhibitory effects on enzymes involved in lipid metabolism. Okafor et al. (2023) reported invertase activities ranging from 0.191 to 0.75 mg/mL in lactic acid bacterial strains obtained from fermented milk and palm wine, such as Lactobacillus plantarum, L. fermentum, L. brevis, Pediococcus halophilus, L. bulgaricus, and L. casei.

4.6.4. Immunomodulatory and Therapeutic Effects

Laklaeng and Kwanhian (2020) reported that polyphenolics and flavonoids from nipa palm vinegar modulated immune function by regulating cytokines such as tumor necrosis factor alpha, interleukin-6, and interleukin-10 and by activating macrophages, natural killer cells, lymphocytes, and dendritic cells. Khairi et al. (2020) reported the anti-inflammatory effects of nipa palm plant materials and the anticancer activities of plant extracts. Oluwole et al. (2023) reported the presence of probiotic lactic acid bacteria in fermented palm wine, which play roles in gastrointestinal health, immune enhancement, and metabolic regulation.

4.7. Nutritional Composition

The proximate and mineral composition of nipa palm fruit and leaves was determined by Khairi et al. (2020), with carbohydrates being the predominant macronutrient fraction and protein and fat contents being low. Palachum et al. (2022) reported that thermal processing did not significantly alter the caloric, carbohydrate, potassium, vitamin C, and phenolic contents of spray-dried nipa palm vinegar powder. Bara et al. (2025) reported 0.04% residual protein in pasteurized coconut sap, indicating that protein fractions are susceptible to thermal degradation. Mametjanov et al. (2025) showed that substituting process water with dairy whey in the production of a traditional kurut fermented beverage resulted in a marked increase in protein content and an improvement in the mineral profile compared to water-based controls.

4.8. Dairy Integration and Analogous Systems

4.8.1. Analogous Dairy Integration Strategies

In another study, Ljoljić et al. (2023) fermented albumin cheese whey with Kluyveromyces marxianus for five days and distilled the fermented broth to obtain ~35% ABV with a complex volatile profile. Hauser et al. (2025) cofermented yogurt acid whey with grape pomace to produce piquette-style beverages with increased titratable acidity; increased concentrations of lactose, galactose, lactic acid, and citric acid; decreased ethanol content; and altered volatile profiles relative to traditional piquettes. Okafor et al. (2023) showed invertase activities ranging from

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0.191 to 0.75 mg/mL in lactic acid bacteria strains isolated from dairy and palm wine sources. Mabusa et al. (2025) documented a cream liqueur infused with sorghum and prickly pear, with stable physicochemical properties and an innovative sensory profile. Mametjanov et al. (2025) demonstrated that substituting process water with dairy whey in a traditional fermented beverage enhanced protein and mineral content relative to water-based controls.

4.8.2. Safety and Toxicological Evidence

Yahaya et al. (2021) conducted an acute toxicity evaluation of crude Nypa fruticans Wurmb sap in Sprague-Dawley rats using standard toxicological protocols. No toxicity was observed at the tested doses, and histopathological examination confirmed the absence of adverse treatment-related changes. None of the 22 included studies investigated dairy-based value addition to nipa palm distilled wine.

5. SUMMARIES

5.1. Summary of Evidence

This scoping review established that nipa palm sap satisfies the substrate requirements for dairy integration across all five thematic dimensions examined. The physicochemical characterization of nipa palm sap and its derivatives has documented fermentation parameters, pH profiles, and volatile compounds that define the opportunities and formulation constraints of a nipa palm–dairy product. In vitro and animal model data demonstrate antioxidant, antilipidemic, and enzyme inhibitory activity attributable to the phenolic fraction, and an established acute safety reference supports the rationale for investing in product development. Nutritionally, the protein and fat deficiencies in nipa palm products create a gap that dairy constituents are proposed to fill.

The analogous evidence for dairy integration is equally coherent. Across four product categories, whey distillation, plant substrate cofermentation, cream liqueur formulation, and whey substitution in fermented beverages, dairy constituents have been incorporated into non-traditional beverage systems, yielding products with functional, nutritional, and sensory profiles that demonstrate the technical accessibility of dairy integration as a development strategy. The convergence of evidence shows that nipa palm is a functionally rich substrate and that dairy integration is documented in analogous systems, establishing a strong scientific rationale for direct research on nipa palm and dairy that exceeds the inferential force of either body alone.

The primary finding of this review is one of absence rather than impossibility or implausibility. No study has investigated any aspect of dairy-based value addition in nipa palm distilled wine, and the convergence of the two bodies of evidence makes that absence a researchable and actionable gap rather than an open question without direction.

5.2. Research Gap

The absence of direct nipa palm and dairy integration evidence spans every product category and development stage. No formulation study has established optimal ratios of nipa palm distillate to dairy constituents, emulsification requirements, or shelf-life parameters. No co-fermentation study has characterized microbial dynamics, sugar conversion efficiency, or flavor development when nipa palm sap is combined with dairy whey, yogurt, or milk components. No sensory optimization or consumer acceptance data exist for a nipa palm and dairy formulation. No commercial-scale production, techno-economic analysis, or regulatory pathway assessment has been reported.

This gap persists despite four analogous demonstrations that establish the probability of integrating nipa palm with dairy. Ljoljić et al. (2023) demonstrated whey-to-spirit distillation as a pathway for dairy by-product valorization into alcoholic beverages. Hauser et al. (2025) demonstrated yogurt whey co-fermentation with a plant substrate as a pathway for producing dairy-plant hybrid fermented beverages. Mabusa et al. (2025) demonstrated that cream liqueur formulation from a non-traditional plant-based distillate is a viable product development framework. Mametjanov et al. (2025) demonstrated that whey substitution is the most applicable integration strategy for enhancing the

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nutritional value of a traditional fermented beverage during nipa palm sap fermentation. The absence of direct evidence reflects a lack of investigative effort rather than technical improbability.

Nipa palm is an ecologically and economically significant mangrove species and a livelihood crop across the Philippines, Malaysia, Indonesia, and Thailand. Addressing the research gap identified in this review carries implications for agricultural development in nipa-palm-producing regions, rural livelihood diversification among coastal farming communities, dairy byproduct valorization through productive use of whey and other dairy waste streams, and functional beverage innovation in the Southeast Asian food industry.

5.3. Strength and Limitations of Cross-Domain Evidence Synthesis

Cross-domain synthesis is recognized within the scoping review framework when direct evidence on the primary topic is absent, provided transferability limitations are transparently acknowledged (Peters et al., 2021). The strength of the evidence lies in its methodological diversity and directional consistency. Independent sources from different research groups, countries, and product systems point to the technical documentation of nipa palm and dairy integration pathways in analogous systems, thereby strengthening the inferential value beyond what any single analogous study could provide.

Transferability limitations are significant. The characteristic pH of 3.0 to 4.0 in nipa palm sap approaches the isoelectric point of casein at approximately pH 4.6, which could lead to protein precipitation, unlike in the pH-neutral systems examined by Hauser et al. (2025) and Mametjanov et al. (2025). Nipa-palm-specific phenolic compounds may suppress antioxidant activity and dairy protein functionality through hydrogen bonding and hydrophobic complexation, with no direct analogs in the included evidence. LAB fermentation behavior in nipa palm sap, given its sugar composition and organic acid profile, may differ from that in grape pomace or kurut systems. A graduated confidence framework therefore applies. Conclusions about nipa palm as a raw material rest on direct evidence from nine fully aligned sources and carry high confidence. Conclusions about the applicability of processing technology are supported by analogous evidence from dairy systems and carry moderate confidence. Conclusions about likely product characteristics, sensory properties, and consumer acceptability are inferential and carry low confidence.

This graduated confidence framework informs prioritization of the research agenda, with higher confidence domains addressed through near-term empirical studies and lower confidence domains treated as long-term investigative priorities.

5.4. Limitations

This scoping review carries several limitations consistent with PRISMA-ScR reporting standards. The restriction to publications from 2020 to 2026 was applied to focus the present review on current and emerging evidence relevant to the dairy integration question. However, this temporal boundary carries an evidentiary cost. Foundational studies on nipa palm fermentation dynamics, phytochemical characterization, sap composition, and traditional processing practices published before 2020 were excluded by design. These earlier studies may contain evidence that contextualizes, qualifies, or strengthens the findings of the 22 included sources, and their absence means the evidence base for nipa palm as a beverage substrate is not comprehensively represented in the present review. Readers and future investigators should treat the nipa palm processing and characterization evidence synthesized here as a current snapshot rather than a complete historical account, and future reviews addressing nipa palm processing should apply an unrestricted temporal scope.

The exclusion of grey literature represents a second limitation. Researchers did not systematically search government agricultural agencies' publications, industry technical reports, FAO documents, and unpublished institutional research from the Philippines, Malaysia, Indonesia, and Thailand, where nipa palm beverage production is most active. This exclusion omits applied product development knowledge unlikely to appear in indexed peer-reviewed journals, including traditional processing practices, smallholder production data, and regulatory

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assessments relevant to commercial development. The absence of a reproducible grey literature search strategy consistent with PRISMA-ScR transparency requirements does not diminish these evidentiary consequences, and future reviews should address this gap through targeted searches of agricultural databases and government repositories in nipa palm-producing countries.

The restriction to English-language sources may have underrepresented applied research published in Malay, Thai, Bahasa Indonesia, or Filipino, the languages of the regions where nipa palm is most ecologically and economically significant. No quality appraisal was applied as an inclusion or exclusion criterion, consistent with JBI scoping review methodology, meaning that findings from studies with limited replication carry the same inclusion status as findings from rigorously designed experimental work, though methodological distinctions among included sources are noted in the charting table and in the literature review. All conclusions regarding nipa palm and dairy product characteristics are inferential and must be treated as hypotheses pending direct experimental validation. The absence of a pre-registered protocol is acknowledged in accordance with PRISMA-ScR Item 24.

5.5. Implications for Practice and Industry

The evidence supports practical conclusions for food technologists, beverage producers, and agricultural development stakeholders in Southeast Asian nipa palm production. Nipa palm sap meets the substrate requirements for controlled fermentation and distillation. Perral and Adlaon (2024) demonstrated that closed-vessel collection should be implemented as a baseline quality standard to ensure raw material consistency. Spray drying parameters established by Palachum et al. (2022) and pasteurization parameters documented by Athirah et al. (2025) and Bara et al. (2025) provide starting points for nipa palm processing development, though direct validation is required before applying these parameters to nipa palm and dairy systems. The analogous demonstrations from Hauser et al. (2025); Ljoljić et al. (2023); Mabusa et al. (2025) and Mametjanov et al. (2025) provide methodologies for designing initial nipa palm and dairy integration experiments. Commercial investment decisions should not precede laboratory-scale and pilot-scale validation, as the absence of direct evidence means that no characteristic of a nipa palm and dairy product can be inferred from analogous literature.

6. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This scoping review has mapped the available evidence on dairy-based value addition in *Nypa fruticans* distilled wine, identifying a research gap in an area where no direct empirical investigation exists. The present review confirms that nipa palm sap possesses documented substrate characteristics, a phenolic-rich bioactive profile, and an established acute safety reference that support the rationale for initiating systematic product development research. The present review further confirms that dairy integration has been pursued across analogous beverage systems, including whey distillation, plant substrate cofermentation, cream liqueur formulation, and whey substitution in fermented beverages, with positive outcomes reported in those systems. The convergence of the nipa palm substrate evidence and the analogous dairy integration evidence defines an actionable research agenda and identifies the technical questions that direct experimentation must address. The evidence synthesized in the present review is entirely analogous and inferential with respect to nipa palm and dairy integration. No study has investigated any aspect of dairy-based value addition in nipa palm distilled wine, and the positive outcomes documented in analogous systems cannot be assumed to transfer to the nipa palm context without direct experimental confirmation. The present review demonstrates research opportunities rather than establishing technical feasibility. Conclusions about the characteristics, sensory properties, functional outcomes, or commercial viability of a nipa palm and dairy product must be treated as hypotheses requiring empirical validation rather than as inferences supported by existing evidence. Several nipa palm-specific constraints introduced in the Literature Review and Discussion sections reinforce the need for caution in interpreting the analogous evidence. The pH range of nipa palm fermented products approaches the isoelectric point of casein in a manner not encountered in the analogous dairy integration systems reviewed, creating a protein stability

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risk not addressed in any existing study. The phenolic composition of nipa palm sap and the interaction of nipa palm phenolic compounds with dairy proteins under processing conditions remain uncharacterized. The safety profile of nipa palm combined with dairy constituents has not been evaluated, and the acute toxicity reference available for crude nipa palm sap does not extend to processed distillate-based or dairy-integrated formulations. These constraints do not preclude nipa palm and dairy integration as a research direction, but the constraints mean that the path from current analogous evidence to a validated product is longer and more uncertain than the existing literature base alone would suggest. The finding that no study has investigated dairy-based value addition in nipa palm distilled wine, encompassing formulation, processing optimization, sensory evaluation, shelf-life stability, consumer acceptance, or commercial-scale production, positions the present review as a reference point for future investigators. The evidence synthesized in the present review provides a starting point for designing initial experiments and reduces the work required to justify the research rationale independently. The present review does not substitute for direct empirical investigation, and the research agenda proposed in Section 5.2 should be understood as a sequence of hypothesis-testing studies rather than a confirmation of expected outcomes.

The research gap identified in this review is precise. The following nine priority studies are proposed in developmental sequence.

1. Examine the physicochemical compatibility of nipa palm distillates with whey protein concentrate, whey protein isolate, cream, and skim milk across mixing ratios and pH conditions, with attention to casein stability within the pH range characteristic of nipa palm fermented products and emulsion formation in nipa palm distillate and cream formulations. This study addresses the most consequential unresolved technical constraint identified in the analogous evidence base.
2. Evaluating whey substitution for process water during nipa palm sap fermentation is the most immediately testable dairy integration strategy, examining effects on fermentation dynamics, alcohol yield, protein content, mineral profile, and sensory characteristics relative to water-based controls.
3. Establish pasteurization temperatures, high-pressure processing conditions, and spray-drying carrier parameters appropriate for nipa palm and dairy matrices, and examine their effects on phenolic bioavailability, dairy protein functionality, and volatile compound integrity under conditions specific to this combined substrate.
4. Characterize phase separation, microbial stability, phenolic degradation, and sensory deterioration of nipa palm–dairy formulations under ambient tropical and refrigerated storage conditions across relevant packaging types.
5. Employ fluorescence spectroscopy, isothermal titration calorimetry, and in vitro digestion modeling to quantify binding affinity, bioavailability effects, and sensory consequences of nipa palm phenolic complexation with whey proteins and casein fractions.
6. Employ trained descriptive panels and consumer acceptability panels in nipa palm-producing communities across the Philippines, Malaysia, and Indonesia to define cultural acceptance thresholds and guide formulation decisions before scale-up investment is pursued.
7. Conduct in vitro antioxidant and enzyme inhibition assays on nipa palm distillate and nipa palm and dairy formulations, followed by animal model studies and, where justified by those findings, human intervention trials with validated biomarker endpoints. No functional or health claims should be substantiated before human intervention trial evidence is available.
8. Evaluate probiotic lactic acid bacteria performance in nipa palm sap under relevant pH, sugar concentration, and alcohol content conditions, followed by co-fermentation trials examining microbial dynamics, sugar conversion efficiency, flavor development, and probiotic survival through processing and storage.
9. Conduct techno-economic analysis of nipa palm sap collection and processing cost structures in the Philippine, Malaysian, and Indonesian contexts, with regulatory pathway assessment under applicable food safety and labeling frameworks and social science investigation of producer and consumer perceptions of dairy addition to a plant-derived fermented beverage in coastal nipa palm communities.

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