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# Routine-to-Research-to-Innovation (R2R) Framework for Translational Microbiology: Linking Probiotics, Microbial Metabolites, Natural Products, and Thai Patent Mapping

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Article

# Routine-to-Research-to-Innovation (R2R) Framework for Translational Microbiology: Linking Probiotics, Microbial Metabolites, Natural Products, and Thai Patent Mapping

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## Abstract

Microbiology laboratories generate extensive experimental outputs that are often insufficiently translated into applied innovation and technology development. This study presents a Routine-to-Research-to-Innovation (R2R) framework integrating routine laboratory workflows with bioactivity validation, formulation development, and intellectual property (IP) mapping. Lactic acid bacteria isolated from Thai fermented foods demonstrated strong bacteriocin activity and storage stability, while secondary metabolites derived from *Streptomyces* and *Brevibacillus* exhibited antibacterial, antioxidant, and anti-inflammatory activities with prototype formulation potential. Red palm oil-based systems enriched with microbial bioactives also showed favorable physicochemical stability under accelerated conditions. Patent landscape analysis (Thailand, 2020–2025) demonstrated translational alignment between laboratory outputs and existing innovation domains, supporting the potential application of the R2R framework in translational microbiology, technology transfer, and early-stage innovation development.

**Keywords:** Routine-to-Research-to-Innovation (R2R); translational microbiology; technology transfer; probiotics; lactic acid bacteria; bacteriocins; microbial secondary metabolites; *Streptomyces*; *Brevibacillus*; natural product formulations; red palm oil; patent landscape analysis; intellectual property mapping; microbial biotechnology; prototype development; incubation-ready technology; early-stage innovation

## 1. Introduction

Routine microbiology laboratories routinely generate large volumes of experimental data; however, a substantial proportion of these outputs is not fully translated into downstream innovation or application-oriented development. To address this limitation, the Routine-to-Research (R2R) concept has been proposed as a practical translational framework that links everyday laboratory activities with structured research processes and innovation-oriented pathways [1,2]. This framework emphasizes the systematic conversion of routine experimental work into research outputs with potential relevance for applied development and technology generation.

In applied microbiology, lactic acid bacteria (LAB) and actinomycetes are widely recognized as important microbial resources due to their ability to produce antimicrobial peptides, enzymes, and diverse secondary metabolites with relevance to pharmaceutical, food, and industrial applications [3–6]. These organisms continue to serve as foundational platforms for bioactive compound

discovery and functional microbial applications. In parallel, natural product-based systems, including plant-derived oils and microbial extracts, have attracted increasing attention for their potential roles in cosmeceutical, anti-inflammatory, and functional formulation development [7–10].

At the same time, the translation of laboratory findings into practical applications is increasingly reflected through intellectual property (IP) generation. Patents are widely used as indicators of innovation activity and technology development progress, providing a bridge between experimental research outputs and potential commercialization or technology transfer pathways [11,12]. However, despite the increasing availability of both microbial bioactivity data and patent information, these two domains are often analyzed separately, limiting their combined interpretive value for translational assessment.

Despite the growing recognition of R2R concepts and the expanding body of research in microbial biotechnology and natural products, a key gap remains in the systematic integration of routine microbiological outputs with downstream innovation mapping and intellectual property analysis. Most existing studies tend to focus either on biological activity characterization or on standalone patent landscape analysis, but rarely connect experimental microbiology, formulation development, and IP positioning within a unified translational workflow. This fragmentation limits the ability to evaluate how routine laboratory findings may be positioned within early-stage innovation or technology transfer pathways.

Based on this gap, we hypothesize that a structured R2R framework integrating microbial screening, bioactivity validation, formulation prototyping, and patent landscape analysis can provide a coherent translational pipeline that better aligns laboratory-derived microbial resources with identifiable innovation domains. Furthermore, such integration may enhance the interpretability of experimental outputs in terms of their potential positioning within technology development and incubation pathways, particularly in probiotics, microbial secondary metabolites, and natural product-based formulation systems.

In this context, the present study integrates laboratory experimental workflows with Thai patent evidence (2020–2025) to explore a structured continuum from routine microbiological practice to experimental validation, intellectual property mapping, and early-stage innovation development. This approach aims to better align microbiological research outputs with application-oriented and translational development pathways in probiotics, microbial metabolites, and natural product-based formulations (**Figure 1**).



**Figure 1.** Conceptual schematic of the Routine-to-Research-to-Innovation (R2R) framework, illustrating the end to end translational pipeline from routine laboratory experimentation through research validation and intellectual property (IP) development to product innovation and societal impact.

## 2. Materials and Methods

### 2.1. Patent Collection and Content Analysis

Patent data were retrieved from the Department of Intellectual Property of Thailand covering the period 2020–2025. Each record included title, abstract, claims, and application details. The patents were systematically classified into three categories: (i) probiotics and lactic acid bacteria (LAB), (ii) microbial secondary metabolites derived from *Streptomyces* and *Brevibacillus*, and (iii) natural product-based formulations, with emphasis on red palm oil-based systems.

A qualitative content analysis was conducted following Krippendorff's methodological framework [1]. A predefined coding scheme was developed to ensure systematic and reproducible classification of patent records based on three analytical dimensions: novelty, technical scope, and translational relevance are provided in the Supplementary Materials (Table S1). Each patent record was independently evaluated according to these criteria to minimize subjectivity and ensure analytical consistency.

Patent–experimental alignment was assessed using a structured similarity-based mapping approach. Experimental outputs were compared with patent records using three matching dimensions: (i) lexical similarity of key descriptors, (ii) functional equivalence of bioactive mechanisms, and (iii) correspondence of application domains. Alignment outcomes were classified as strong, partial, or no match based on predefined coding rules. Representative examples of the mapping process are provided in the Supplementary Materials (Table S2).

## 2.2. Isolation and Screening of Lactic Acid Bacteria (LAB)

Lactic acid bacteria were isolated from traditional Thai fermented foods, including pla-som and boo-doo. Samples were cultured on de Man, Rogosa, and Sharpe (MRS) medium [13] and incubated at  $30 \pm 2$  °C under microaerophilic conditions. Preparation of culture media and microbial cultivation followed standard microbiological procedures [13], while antimicrobial screening and functional evaluation were performed according to established bioactivity methodologies [3,4,10].

Isolates were identified using MALDI-TOF MS and partial sequencing of the 16S rRNA gene. Preliminary functional screening focused on antimicrobial activity against *Escherichia coli* TISTR 25922, *Staphylococcus aureus* ATCC 25923, and methicillin-resistant *S. aureus* (MRSA). Bacteriocin activity was quantified as arbitrary units per milliliter (AU/mL). Selected strains were further evaluated for viability and storage stability under 4 °C and 25 °C over a period of four weeks, with all experiments performed in triplicate.

## 2.3. Production and Evaluation of Microbial Secondary Metabolites

*Streptomyces* and *Brevibacillus* isolates were cultured in yeast extract malt extract (YM) and Luria–Bertani (LB) media, respectively, at 30–35 °C with agitation at 150 rpm for 4–14 days [4–6]. Secondary metabolites were subsequently extracted from culture supernatants using ethyl acetate followed by solvent evaporation.

The crude extracts were evaluated for bioactivity using antibacterial, antioxidant, and anti-inflammatory assays following previously established protocols [4–6,10]. Antibacterial activity was determined against *Staphylococcus aureus* TISTR 517 and *E. coli* TISTR 884 using agar diffusion methods, while antioxidant capacity was assessed using the DPPH radical scavenging assay. Anti-inflammatory potential was evaluated using the bovine serum albumin (BSA) protein denaturation assay. Metabolite yield was expressed as mg/L, and all experiments were performed in triplicate.

## 2.4. Natural Product Formulation Development

Red palm oil was formulated with Thai herbal extracts and microbial-derived bioactive fractions to develop cream and gel-based systems [7–10]. Emulsification was carried out using standard homogenization techniques, and formulation properties were assessed in accordance with established cosmetic science principles [8].

Formulation stability was evaluated under accelerated storage conditions at 4 °C, 25 °C, and 45 °C over a period of three months. Stability assessment included monitoring of pH within the target range of 5.5–6.0, phase separation behavior, and viscosity changes. The bioactivity of the final formulations was further evaluated through anti-inflammatory activity using the BSA denaturation assay [10]. Anti-allergic activity was evaluated using a mast cell histamine release inhibition assay conducted in collaboration with an external laboratory, following a standard protocol with minor adaptations appropriate to the formulation system.

## 2.5. Integration of Teaching and Laboratory-Based Learning

Routine laboratory workflows, including microbial isolation, bioactivity screening, metabolite extraction, and formulation development, were integrated into an R2R-based experiential learning model [2]. Within this framework, students were actively involved in experimental procedures, data interpretation, and preliminary patent mapping as part of translational research training. The overall

learning and experimental design was guided by established microbial biotechnology and innovation mapping frameworks [4–6,11,12].

### 2.6. Statistical Analysis

All experiments were conducted in triplicate. Data were expressed as mean  $\pm$  standard deviation. Statistical analysis was performed using one-way analysis of variance followed by Tukey's post hoc test using GraphPad Prism version 9. A p-value of less than 0.05 was considered statistically significant.

### 2.7. Routine-to-Research-to-Innovation (R2R) Translational Framework

This study implemented a structured R2R framework designed to systematically translate routine microbiological laboratory activities into research outputs, intellectual property generation, and prototype development.

The framework consists of five sequential stages beginning with routine laboratory operations, which involve microbial isolation and primary cultivation from environmental and fermented food sources. This is followed by a research activation phase, during which functional screening for antimicrobial, antioxidant, and anti-inflammatory activities is conducted using standardized bioassays [3–6,10]. The third stage involves validation, in which bioactivity is quantified, stability is assessed, and reproducibility is confirmed under controlled laboratory conditions. The fourth stage focuses on prototype development, where bioactive compounds are extracted and formulated into topical or functional products under accelerated stability conditions [7–9]. The final stage involves innovation and intellectual property mapping, where experimental outputs are systematically aligned with Thai patent records from 2020 to 2025 to evaluate translational potential and innovation readiness [11,12].

Quality control and reproducibility were ensured throughout all stages of the workflow. All experiments were performed in triplicate, and variability was reported as standard deviation. Positive and negative controls were included in all assays, and standardized media, incubation conditions, and analytical protocols were applied consistently across the study.

Progression between stages was determined using predefined decision criteria. These included a bioactivity threshold defined as inhibition zones of at least 10 mm or functional activity of at least 50%, a stability threshold defined as at least 90% viability or formulation stability retention, a reproducibility criterion defined as a coefficient of variation below 15%, and an innovation readiness assessment based on qualitative alignment with patent claims and Technology Readiness Level classification ranging from TRL 3 to TRL 6. The framework was designed as a reproducible translational workflow adaptable to microbiology laboratories with limited infrastructure and funding environments.

The R2R framework integrates routine microbiological practice with structured research validation and innovation mapping. Detailed operational procedures, including SOP-level workflows and decision matrices, are provided in the Supplementary Materials (Supplementary Figure S1 and Table S3).

## 3. Results & Discussion

### 3.1. Translational Outcomes

The integration of laboratory experimentation, microbial screening, and Thai patent mapping demonstrated a coherent implementation of the Routine-to-Research-to-Innovation (R2R) framework, effectively linking experimental outputs with translational development and intellectual property (IP) generation.

Lactic acid bacteria (LAB) isolated from traditional Thai fermented foods (pla-som and boo-doo) exhibited strong functional potential, producing bacteriocin at  $1,200 \pm 50$  IU/mL and achieving >95%

inhibition against *Staphylococcus aureus* and *Escherichia coli*. The isolates maintained >90% viability after 4 weeks under both 4 °C and 25 °C storage conditions, indicating high formulation stability and suitability for starter culture applications. These findings are consistent with bacteriocin-mediated antimicrobial mechanisms previously reported in fermented food systems [3] and align with Thai patents (Nos. 16079, 24726, 26064) [14,21,27], supporting direct laboratory to IP translation.

The overall experimental outcomes and their translational applications across microbial platforms are summarized in **Table 1**.

**Table 1.** Experimental Outputs and Translational Potential Across Microbial and Natural Product Systems within the R2R Framework.

Research Domain	Key Experimental Outputs	Analytical Endpoint	Translational Interpretation	Potential Application Domain
<b>Probiotics / Lactic Acid Bacteria (LAB)</b>	Bacteriocin production: 1,200 ± 50 IU/mL; pathogen inhibition >95% ( <i>S. aureus</i> , <i>E. coli</i> ); viability >90% after 4 weeks storage (4 °C & 25 °C)	Antimicrobial activity; viability stability; functional preservation under storage conditions	Indicates functional stability and bioactivity consistency of LAB isolates derived from fermented food sources, supporting their potential use in controlled fermentation systems Demonstrates multi-functional bioactivity profile of actinomycete-derived metabolites, supporting their role as candidate bioactive resources for downstream formulation development	Functional fermented foods; probiotic starter cultures; food safety-oriented fermentation systems
<b>Secondary Metabolites (<i>Streptomyces</i>, <i>Brevibacillus</i>)</b>	Antibacterial activity: 12–18 mm inhibition zones; antioxidant activity: 65–70% (DPPH assay); yield: 0.85 ± 0.07 mg/L	Bioactivity screening across antimicrobial, antioxidant, and metabolite yield parameters	Suggests formulation-level compatibility of natural lipid matrices with microbial-derived bioactives, supporting prototype development for topical systems Provides integrated experimental evidence base supporting system-level interpretation of microbial and natural product interactions within translational workflow	Cosmeceutical actives; antimicrobial formulations; bioactive ingredient development
<b>Natural Product Formulations (Red Palm Oil-based systems)</b>	Anti-inflammatory / anti-allergic activity: 60–65%; formulation stability >90% over 3 months (pH 5.5–6.0)	Functional bioactivity retention and physicochemical stability under accelerated conditions		Topical formulations; cosmetic emulsions; anti-inflammatory product systems
<b>Cross-System Integration (R2R Experimental Layer)</b>	Combined dataset: antimicrobial, antioxidant, anti-inflammatory activities with stability profiles across systems	Multi-assay functional validation under standardized laboratory conditions		Foundation for R2R pipeline development and laboratory-to-innovation transition models

Note: Different bioactivity endpoints were used according to assay type (antimicrobial, antioxidant, and anti-inflammatory systems), reflecting methodological differences across experimental platforms.

Secondary metabolites derived from *Streptomyces* and *Brevibacillus* demonstrated notable bioactivity, including antibacterial inhibition zones of 12–18 mm and antioxidant activity of 65–70% (DPPH assay) [10], with a production yield of 0.85 ± 0.07 mg/L. These bioactive compounds were further translated at a prototype level into formulations such as gels, films, and powders, supporting

early-stage application development in cosmetic and biomedical product development. These findings are consistent with previous studies on actinomycete-derived natural products [4,6] and are supported by related Thai patents (Nos. 17949, 17442, 20299, 20364, 25829, 24852) [15–18,22,25], collectively suggesting innovation and technology transfer potential rather than confirmed commercialization readiness.

Red palm oil (RPO)-based formulations enriched with microbial bioactives and herbal extracts exhibited 60–65% reduction in inflammatory and allergic response-related assays, with formulation stability exceeding 90% over 3 months under accelerated conditions (pH 5.5–6.0). These findings are consistent with previous reports on cosmetic science, natural product formulations, and red palm oil bioactivity [7–9], as well as Thai Patent No. 25915 [26], indicating potential suitability for further formulation development and early-stage product development.

Additional translational outputs included anti-acne bioactive gels, nutrient optimization systems, plasmid engineering platforms, and microbial encapsulation technologies corresponding to Thai Patent Nos. 102008, 24727, 25302, and 25509 [19,20,23,24], reflecting a broader portfolio of early-stage technologies with incubation and spin-off potential within the R2R framework.

The integration of experimental workflows, innovation stages, and intellectual property outputs within the R2R framework is systematically presented in Table 2, which summarizes the progression from laboratory research to prototype development, incubation-stage validation, and potential spin-off pathways

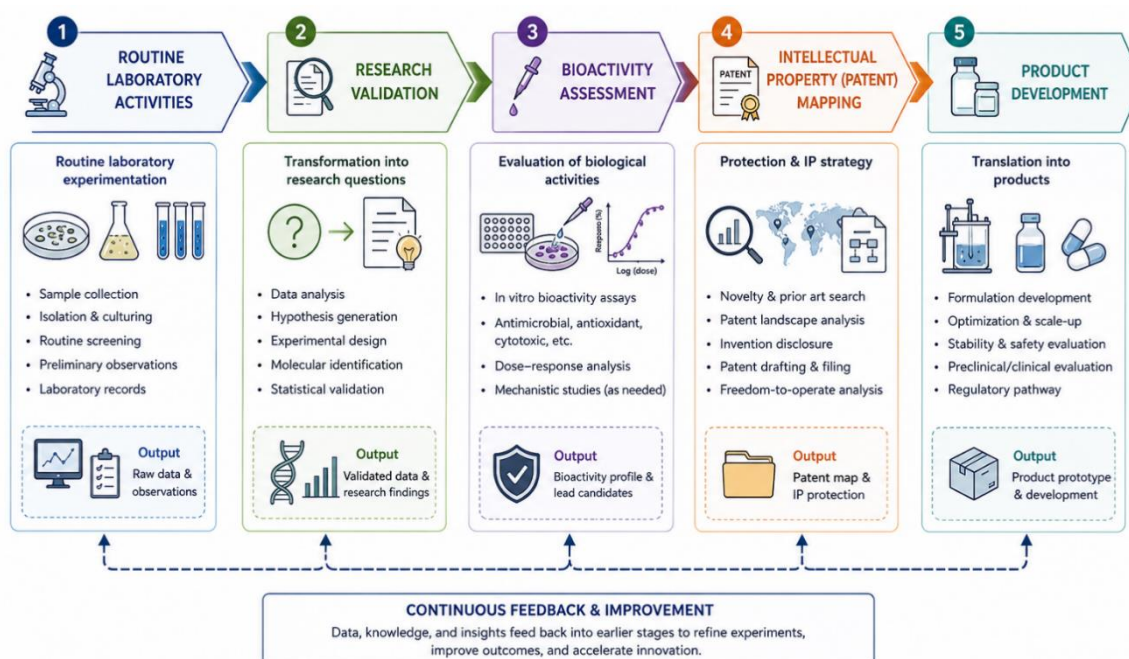
**Table 2.** Translational Development and Technology Transfer Pipeline within the R2R Framework.

Research Domain	Laboratory Stage (Lab Discovery)	Prototype Stage (Proof-of-Concept)	Incubation Stage (Technology Maturation)	Spin-off / Commercial Pathway
<b>Probiotics / Lactic Acid Bacteria (LAB)</b>	Isolation from fermented foods; bacteriocin production (1,200 ± 50 IU/mL); >95% pathogen inhibition; storage stability >90%	Starter culture prototype; freeze-dried or powder formulation concept; preliminary functional food model	Stability optimization under storage conditions; scalability assessment for fermentation systems; batch reproducibility validation	Functional probiotic starter culture platform for fermented food industry; potential incubation-oriented development pathway and probiotic ingredient supply
<b>Secondary Metabolites (<i>Streptomyces</i>, <i>Brevibacillus</i>)</b>	Extraction of crude metabolites; antibacterial activity (12–18 mm inhibition zones); antioxidant (65–70% DPPH); anti-inflammatory activity	Prototype bioactive extracts in gel, film, and powder formulations; preliminary cosmeceutical and antimicrobial product concepts	Formulation optimization (stability, yield, delivery efficiency); standardization of bioactive content; pilot-scale fermentation feasibility	Bioactive ingredient development platform for cosmeceuticals and antimicrobial applications; potential spin-off in microbial-derived functional ingredients
<b>Natural Product Systems (Red Palm Oil-based formulations)</b>	Bioactivity screening of microbial–plant oil combinations; anti-inflammatory and anti-allergic responses (60–65% reduction)	Prototype topical formulations (cream/gel); physicochemical stability (>90% over 3 months)	Emulsion optimization, shelf-life extension, safety profiling, and formulation robustness testing	Cosmeceutical formulation platform for topical anti-inflammatory products; potential startup in natural skincare biotechnology
<b>Cross-System Integration (R2R Platform)</b>	Integrated dataset generation (antimicrobial, antioxidant, anti-	Multiplatform prototype validation system linking microbes +	Standardization of R2R workflow; TRL assessment (3–6); reproducibility and	Integrated R2R technology platform for microbial

	inflammatory assays)	metabolites + formulations	scale-up framework development	biotechnology innovation; potential spin-off as translational microbiology and bioprocess innovation company
<b>IP &amp; Technology Mapping Layer</b>	Patent landscape analysis (Thailand 2020–2025); alignment with microbial and natural product domains	Identification of IP clusters and white-space opportunities	Technology positioning for licensing or incubation pathways; IP bundling strategy	Support for technology transfer office (TTO) licensing, startup formation, and university spin-off pipeline development

Note: This mapping represents conceptual alignment between experimental outputs and existing patent records and does not imply direct causality or confirmed commercialization outcomes. TRL classification of outputs is estimated within TRL 3–6 range based on laboratory validation status.

To further visualize the conceptual progression, the R2R framework illustrating the transformation from routine laboratory activities to research validation, bioactivity assessment, patent mapping, and product development is shown in **Figure 2**.



**Figure 2.** Schematic representation of the Routine-to-Research-to-Innovation (R2R) workflow, illustrating the progressive transformation of routine laboratory activities into research validation, bioactivity assessment, intellectual property (patent) mapping, and product development.

Collectively, these findings demonstrate that routine microbiological workflows can be systematically converted into validated research outputs and early-stage technology assets with potential for translation into applied and incubatable innovations through a structured R2R pipeline.

### 3.2. Limitations

Despite the promising translational outcomes obtained in this study, several limitations should be acknowledged. First, all bioactivity evaluations were performed under *in vitro* conditions, which may not fully represent *in vivo* physiological responses or clinical effectiveness [5,6]. Second, the molecular mechanisms underlying the observed antimicrobial, antioxidant, and anti-inflammatory activities were not investigated. In particular, gene regulation pathways, metabolite–target interactions, and omics-level responses were beyond the scope of this study, limiting mechanistic interpretation of the results [4,10].

Third, although patent mapping can serve as an indicator of innovation readiness and translational alignment, intellectual property status alone does not guarantee commercialization success, industrial scalability, or market adoption [11,12]. In addition, variations in microbial strains, fermentation conditions, and extraction parameters may influence metabolite yield and reproducibility across different laboratory or industrial environments [4,6].

Finally, large-scale production processes, long-term formulation stability, regulatory evaluation, and economic feasibility were not assessed in the present work. These factors remain essential considerations for future industrial translation and commercialization of microbiology-based innovations.

### 3.3. Future Directions

Future studies should further validate the translational potential of the proposed R2R framework through both laboratory and applied research approaches. In particular, *in vivo* studies and safety evaluations are needed to confirm the biological effectiveness and practical applicability of the microbial metabolites, probiotics, and natural product formulations identified in this work [5,6].

Further investigation into the molecular mechanisms underlying antimicrobial, antioxidant, and anti-inflammatory activities would also strengthen the scientific basis of these findings. Omics-based approaches, including genomics, transcriptomics, and metabolomics, may help explain the regulatory pathways and bioactive interactions involved in microbial metabolite production and functional activity [4,10].

To support industrial translation, future work should include scale-up production using controlled bioreactor systems to evaluate process stability, metabolite yield, and manufacturing feasibility under industrial conditions [4]. Additional assessment of formulation stability, storage conditions, and regulatory compliance will also be important for future commercialization.

Moreover, future R2R implementations may benefit from integrating quantitative innovation assessment tools such as Technology Readiness Level (TRL), cost–benefit analysis, and life-cycle assessment (LCA) to better define translational maturity and sustainability [11,12].

Finally, stronger collaboration among universities, industry partners, local communities, and innovation agencies could help accelerate the conversion of routine laboratory findings into practical products, intellectual property, and community-based innovations with broader societal and economic impact.

## 4. Conclusions & Translational Perspectives

This study presents a Routine-to-Research-to-Innovation (R2R) framework designed as a structured pathway for technology transfer from microbiological laboratory outputs to early-stage innovation development. The findings suggest that routine microbial work can be systematically transformed into validated research outputs and prototype-level technologies with potential for downstream development.

The combination of probiotic systems, microbial secondary metabolites, and natural product-based formulations demonstrates a coherent set of transferable bioactive platforms that may be suitable for further development within incubation or spin-off environments. Although the current findings remain at laboratory and prototype scale, they provide a foundation for technology maturation and applied product development.

Future development should focus on scale-up processes, formulation optimization, regulatory pathways, and pilot-level validation to support transition from laboratory research to pre-commercial and spin-off-ready technologies. Strengthening collaboration between academic laboratories, technology transfer offices, and industry partners will be essential to accelerate this transition.

Overall, the R2R framework provides a structured model for bridging academic microbiology with technology transfer pathways and early-stage innovation ecosystems.

**Supplementary Materials:** The following supporting information can be downloaded at website of this paper posted on Preprints.org, Table S1: Full coding rubric for qualitative content analysis and patent–experimental mapping within the R2R framework; Table S2: Representative patent–experimental mapping examples within the R2R framework using structured qualitative content analysis; Figure S1: Standardized Routine-to-Research-to-Innovation (R2R) Workflow for Translational Microbiology; Table S3: Standardized Routine-to-Research-to-Innovation (R2R) Workflow for Translational Microbiology (PROTOCOL BOX – R2R Workflow). CRediT Author Statement: Monthon Lertcanawanichakul (ML): Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Patent analysis and applications; Writing—original draft; Writing—review and editing; Supervision. Tuanhawanti Sahabuddeen (TS): Investigation; Visualization; Validation support; Writing—review and editing.

**Author Contributions:** Monthon Lertcanawanichakul (ML): Conceptualization; Methodology; Patent applications; Data management; Drafting and revising manuscript. Tuanhawanti Sahabuddeen (TS): Illustration; Research execution.

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**Institutional Review Board Statement:** Ethics Approval and Consent to Participate: This study did not involve human participants or live vertebrate animals. All microbial isolates were obtained from commercially available or traditionally fermented Thai foods, and no endangered species were used. Therefore, formal ethics approval was not required.

**Informed Consent Statement:** Not applicable.

**AI Usage Statement:** During the preparation of this manuscript, AI-assisted image generation tools were used to create preliminary graphical elements and conceptual figure layouts. The resulting figures were subsequently reviewed, edited, organized, and approved by the authors to ensure scientific accuracy and consistency with the manuscript content. No AI tools were used for data fabrication, scientific analysis, interpretation of experimental results, or reference generation.

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**Clinical Trial:** Not applicable.

**Conflicts of Interest:** The authors declare that they have no competing interests.

## Abbreviations

The following abbreviations are used in this manuscript:

R2R	Routine-to-Research-to-Innovation
IP	Intellectual Property
LAB	Lactic Acid Bacteria
TRL	Technology Readiness Level
SD	Standard Deviation
ANOVA	Analysis of Variance
DPPH	2,2-diphenyl-1-picrylhydrazyl (radical scavenging assay)
BSA	Bovine Serum Albumin (protein denaturation assay)
AU/mL	Arbitrary Units per Milliliter (bacteriocin activity unit)

<i>S. aureus</i>	<i>Staphylococcus aureus</i>
<i>E. coli</i>	<i>Escherichia coli</i>
MRSA	Methicillin-resistant <i>Staphylococcus aureus</i>
MRS	de Man, Rogosa and Sharpe medium

## References

- Krippendorff K. Content analysis: An introduction to its methodology. 4th ed. SAGE Publications; 2018.
- Nair M, George A, Chacko TV. Routine to research: Promoting research in health professions education through an innovative faculty development workshop. *Journal of Advances in Medical Education & Professionalism*. 2020;8(3):127–133. <https://doi.org/10.30476/jamp.2020.85269>
- Cotter PD, Hill C, Ross RP. Bacteriocins: Developing innate immunity for food. *Nature Reviews Microbiology*. 2005;3(10):777–788. <https://doi.org/10.1038/nrmicro1273>
- Baltz RH. Production of bioactive secondary metabolites by industrial microorganisms. *Journal of Industrial Microbiology & Biotechnology*. 2008;35(7):785–799. <https://doi.org/10.1007/s10295-008-0353-1>
- Atanasov AG, Zotchev SB, Dirsch VM, Orhan IE, Banach M, Rollinger JM, et al. Natural products in drug discovery: Advances and opportunities. *Nature Reviews Drug Discovery*. 2021;20(3):200–216. <https://doi.org/10.1038/s41573-020-00114-z>
- Newman DJ, Cragg GM. Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. *Journal of Natural Products*. 2020;83(3):770–803. <https://doi.org/10.1021/acs.jnatprod.9b01285>
- Brandt K, Christensen LP, Hansen M. Bioactive natural products in cosmetic formulations. *International Journal of Cosmetic Science*. 2020;42(1):5–18. <https://doi.org/10.1111/ics.12540>
- Barel AO, Paye M, Maibach HI. Handbook of cosmetic science and technology. 4th ed. CRC Press; 2014.
- Ong ASH, Choo YM, Ma AN. Red palm oil: A potential natural antioxidant source for food and nutrition. *Journal of Food Lipids*. 2006;13(1):1–14. <https://doi.org/10.1111/j.1745-4522.2006.00032.x>
- Santos R, Rodrigues A, Teixeira JA. Antioxidant activity of microbial metabolites. *Applied Biochemistry and Biotechnology*. 2018;184(1):1–16. <https://doi.org/10.1007/s12010-017-2534-y>
- Santos VS, Oliveira ACS, Lima DM. Patents as an innovation indicator in biotechnology. *Journal of Technology Management & Innovation*. 2018;13(3):1–10. <https://doi.org/10.4067/S0718-27242018000300001>
- Ong ES, Len SM, Hong YJ. Intellectual property management for natural products research. *Journal of Ethnopharmacology*. 2010;132(3):513–522. <https://doi.org/10.1016/j.jep.2010.07.001>
- de Man JC, Rogosa M, Sharpe ME. A medium for the cultivation of lactobacilli. *Journal of Applied Bacteriology*. 1960;23(1):130–135. <https://doi.org/10.1111/j.1365-2672.1960.tb00188.x>
- Lertcanawanichakul M, Chawawisit K. Method for producing bacteriocin film for acne treatment. Thai Patent No. 16079. 2020.
- Lertcanawanichakul M, Chawawisit K. Method for culturing *Streptomyces* KB3 in vitro to increase secondary metabolite production. Thai Patent No. 17949. 2021 Jun 14.
- Lertcanawanichakul M, Wongsuwan K, Sukkasem J. Bacteriocin wound-healing gel and its production method. Thai Patent No. 17442. 2021.
- Lertcanawanichakul M. Method for irradiating *Streptomyces* strains with microwave. Thai Patent No. 20299. 2022.
- Lertcanawanichakul M, Chawawisit K. Method for preparing sterilized liquid product from *Streptomyces* KB1 culture. Thai Patent No. 20364. 2022.
- Lertcanawanichakul M, Junglok W. Anti-acne gel containing semi-purified bioactive protein. Thai Patent No. 102008. 2024.
- Lertcanawanichakul M. Nutrient formula for culturing *Streptomyces* KB1 TISTR 2304 in vitro to stimulate bioactive compound production. Thai Patent No. 24727. 2024.
- Lertcanawanichakul M, Sahabuddeen T. Method for preparing heat-resistant *Enterococcus faecalis* TISTR 2932 starter culture powder. Thai Patent No. 24726. 2024.
- Lertcanawanichakul M. Method for producing dye powder from *Streptomyces* KB3. Thai Patent No. 24852. 2024.

23. Lertcanawanichakul M. Plasmid enhancing bacteriocin gene expression in lactic acid bacteria and method of plasmid construction. Thai Patent No. 25302. 2025.
24. Lertcanawanichakul M. Method for preparing gel beads entrapping *Pseudomonas otitidis* TISTR 2468. Thai Patent No. 25509. 2025.
25. Lertcanawanichakul M, Dahmi P, Thairach P, Buapetch P. Method for producing cosmetic gel containing secondary metabolites. Thai Patent No. 25829. 2025.
26. Lertcanawanichakul M, Fahmi P, Niden A. Red palm oil cream formulation for reducing inflammation and rash and its production method. Thai Patent No. 25915. 2025.
27. Lertcanawanichakul M, Sahabuddeen T. Method for preparing starter culture powder for fermented fish production. Thai Patent No. 26064. 2025.

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