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Policy Brief:

Suggestions for Improving Fermentation Processes in the Food Industry

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Abstract

Background and Objective: Fermentation is an important food biotechnology process that improves food preservation, nutritional quality, and sensory characteristics. Fermented dairy products, particularly yoghurt, have been associated with changes in gut microbiota composition and host metabolism. However, the molecular consequences of these changes remain insufficiently understood. This study aimed to evaluate the potential biological effects of fermented food consumption and propose policy recommendations to support future research and innovation in food biotechnology.

Material and Methods: Evidence was collected from published transcriptomic and systems biology studies investigating the effects of yoghurt consumption on host molecular pathways. Gene expression, protein interaction, and functional enrichment analyses were reviewed to identify biological processes potentially affected by fermented dairy products.

Results and Conclusion: Available evidence suggests that yoghurt consumption may influence gut microbiota composition, metabolic activity, and host gene expression. Functional analyses indicate potential effects on pathways related to cellular metabolism and iron homeostasis. Although fermented dairy products are generally considered safe and beneficial, the long-term biological significance of these molecular changes remains unclear. Therefore, further research is needed to clarify the relationship between fermented food consumption, gene regulation, and physiological health outcomes. Policy recommendations include supporting molecular nutrition research, optimizing fermentation technologies, and evaluating complementary food-processing approaches to strengthen evidence-based dietary guidance and innovation in food biotechnology.

Keywords: Acidified milk, Fermentation, Gene expression, Network analysis, Yoghurt

1. Introduction and statement of the problem

Fermentation is a biotechnological process in the food industry that contributes to food preservation and improves the sensory, nutritional, and functional characteristics of food products. The production of yoghurt through fermentation leads to alterations in the chemical and nutritional properties of the milk matrix [1]. Evidence indicates that consumption of fermented dairy products may influence human physiology through interactions with the gut microbiota. Also, studies have demonstrated that yoghurt consumption is associated with a transition in gut microbial composition and metabolic profiles that show a potential role of fermented products in regulating biological processes relevant to human health [2]. Furthermore, microbiota-associated metabolic alterations can change molecular pathways and gene regulation mechanisms involved in health and disease [3]. Ceruloplasmin is a kind of molecule involved in metabolic regulation that plays a critical role in maintaining systemic iron homeostasis through its ferroxidase activity and regulation of iron transport [4]. In addition, alterations in ceruloplasmin function have been associated with several neurodegen-erative disorders, including Parkinson's disease, Alzheimer's disease, and Wilson's disease [5]. Therefore, a comprehen-sive understanding of the biological consequ-ences of food biotechnology applications, particularly fermentation-based processes, is important for evaluating both their potential health benefits and possible adverse effects. Fermentation is employed in the food industry and is considered a safe and beneficial biotechnological approach for improving food preservation, nutritional quality, and sensory characteristics, and for sustaining processed products [6]. Fermented foods improve gastro-intestinal health, nutrient bioavailability, and microbial balance within the host [7]. Consequently, fermented food products, such as yoghurt, are regarded as health-promoting dietary components worldwide. Food-derived microbial products and alterations in gut microbiota composition may influence host molecular pathways, including metabolic and gene regulatory mechanisms [8]. However, the long-term biological consequences of these changes remain insufficiently understood. In addition, potential effects on key physiological systems such as iron homeostasis and neurological function require further investigation [4, 5]. This limited understanding of the molecular effects of fermented food consumption represents an important challenge in food biotechnology and public health research. Therefore, further studies are needed to clarify the interaction between fermentation-derived products and human molecular pathways to support evidence-based dietary recommendations and optimize both benefits and safety.

2. METHODS

Whole-blood gene expression data from individuals who consumed yoghurt and acidified milk were retrieved from the Gene Expression Omnibus (GEO) database. Differentially expressed genes (DEGs) were identified using GEO2R analysis. Significant DEGs were further analyzed through protein–protein interaction (PPI) network construction using the STRING database and Cytoscape software to identify critical genes and molecular interactions. Functional enrichment and gene ontology analyses were performed to determine the biological processes associated with the identified genes. The resulting molecular pathways were evaluated to investigate the potential biological effects of yoghurt consumption compared with acidified milk [9].

3. Results

Evidence suggests that yoghurt consumption may be associated with changes in gut microbiota composition and host metabolic activity, indicating potential interactions between fermented foods and systemic biological processes [2, 10]. Although these effects are generally considered beneficial, the downstream molecular consequences remain incompletely understood. Neurodegenerative and metabolic disorders are linked to alterations in ceruloplasmin function [4, 11]. Animal models further suggest that ceruloplasmin deficiency may be associated with disturbances in brain iron regulation and metabolic imbalance; however, direct evidence linking yoghurt consumption to ceruloplasmin modulation in humans is currently lacking [11]. Gene expression analyses comparing yoghurt and acidified milk consumption identified differentially expressed genes associated with metabolic regulation and cellular homeostasis. Protein–protein interaction and gene ontology analyses highlighted biological processes related to the formation of translation initiation complexes yielding circularized ceruloplasmin mRNA in a closed-loop conformation and identified several interconnected genes, including RPSA, RPS5, RPS14, and PABPC1 [9]. These findings suggest that yoghurt consumption may influence specific gene expression pathways; however, the biological significance of these transcriptional changes and their potential implications for human health remain unclear. Even though fermented dairy products are considered safe and beneficial, additional studies are needed to clarify their potential influence on molecular networks and gene expression profiles and to support evidence-based dietary recommendations.

4. Health Policy Framework

The following recommendations are proposed to clarify the benefits and potential biological implications of fermentation in the food industry:

1. It is recommended to design and perform systematic studies evaluating the molecular effects of fermented food consumption, including gene expression profiling under different dietary intake patterns.
2. Further research is suggested to optimize fermentation processes through the controlled addition or modification of bioactive components in fermented food products to enhance safety and nutritional quality.
3. Alternative food processing strategies, including physical and chemical approaches such as acidification, may be investigated as complementary or alternative methods for producing safe and high-quality food products.

5. CONVERT TO POLICY

Fermentation is recognized as a safe and advantageous biotechnological process in the food industry. The consumption of fermented products may be associated with changes in host gene expression, highlighting a potential need for further investigation into their systemic biological effects. Moreover, a more profound understanding of fermentation-related molecular interactions is essential for evaluating both the benefits and long-term implications of fermented food consumption.

6. Declarations

6.1. Acknowledgement

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6.2. Conflict of Interest

All authors declare no conflict of interest.

6.3. Using chatbots

ChatGPT (OpenAI) was used to assist with language editing, grammar correction, and improvement of manuscript structure. All scientific content, interpretation of findings, and final manuscript revisions were reviewed and approved by the authors.

6.4. Authors' Contributions

The author contributed to literature review, policy recommendation development, manuscript writing, revision, and final approval of the manuscript

7. References

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خلاصه سیاستی:

پیشنهادهایی برای بهبود فرآیندهای تخمیر در صنایع غذایی

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چکیده

سابقه و هدف: تخمیر یکی از فرآیندهای مهم زیست‌فناوری غذایی است که موجب بهبود ماندگاری، کیفیت تغذیه‌ای و ویژگی‌های حسی مواد غذایی می‌شود. فرآورده‌های لبنی تخمیری، به‌ویژه ماست، با تغییرات در ترکیب میکروبیوتای روده و متابولیسم میزبان همراه هستند. با این حال، پیامدهای مولکولی این تغییرات هنوز به‌طور کامل شناخته نشده است. هدف این مطالعه بررسی اثرات زیستی بالقوه مصرف فرآورده‌های تخمیری و ارائه پیشنهادهای سیاستی برای حمایت از پژوهش و نوآوری در حوزه زیست‌فناوری غذایی بود.

مواد و روش ها: شواهد موجود از مطالعات ترنسکریپتومیک و زیست‌شناسی سامانه‌ای مرتبط با مصرف ماست بررسی شد. داده‌های بیان ژن، شبکه‌های برهم‌کنش پروتئینی و تحلیل‌های غنی‌سازی عملکردی به‌منظور شناسایی فرآیندهای زیستی تحت تأثیر مصرف فرآورده‌های لبنی تخمیری مورد ارزیابی قرار گرفتند.

یافته‌ها و نتیجه‌گیری: یافته‌ها نشان داد که مصرف ماست می‌تواند با تغییر در ترکیب میکروبیوتای روده، فعالیت متابولیکی و الگوهای بیان ژن همراه باشد. تحلیل‌های عملکردی حاکی از تأثیر احتمالی بر مسیرهای مرتبط با متابولیسم سلولی، پاسخ‌های استرس اکسیداتیو و هموستازی آهن بودند. اگرچه فرآورده‌های لبنی تخمیری به‌طور کلی ایمن و سودمند محسوب می‌شوند، اهمیت زیستی و پیامدهای بلندمدت این تغییرات مولکولی همچنان نامشخص است. ازاین‌رو، انجام پژوهش‌های بیشتر برای روشن شدن ارتباط میان مصرف مواد غذایی تخمیری، تنظیم بیان ژن و پیامدهای سلامت ضروری است. همچنین حمایت از تحقیقات تغذیه مولکولی، بهینه‌سازی فناوری‌های تخمیر و بررسی روش‌های مکمل فرآوری مواد غذایی به‌عنوان راهبردهای سیاستی پیشنهاد می‌شود.

واژگان کلیدی: ماست ،شیر اسیدی‌شده، تخمیر، بیان ژن، تحلیل شبکه، زیست‌فناوری غذایی