Short Note

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Microbial Dynamics in Fermented Foods: Health Implications, Cheese Production, and Advances in Analytical Techniques

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Microbial Dynamics in Fermented Foods: Health Implications, Cheese Production, and Advances in Analytical Techniques

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Abstract: Foods that are fermented have a crucial role in global diets, these foods benefit from the process of fermentation, which enhances nutrition, flavor, and safety through the use of probiotics, anti-aging compounds, and antibiotics. Traditional fermentation is based on the spontaneous activity of microorganisms, while modern methods utilize defined cultures for consistency. The microorganisms in cheese are important for the flavor and texture of the product. These microorganisms are either non-starter or starter bacteria, yeast, and mold. The advances in sequencing technology have facilitated an increase in our understanding of these communities and their contribution to the quality and safety of cheese. Despite the health benefits of fermented dairy products, such as yogurt, they can pose a risk of contamination with pathogens. New methods of management and sequencing are crucial to ensuring the safety and quality of fermented foods, combining traditional methods with modern advances.

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Introduction

Fermented food has been a part of the human diet worldwide for thousands of years and constitutes about one-third of global food consumption (Campbell-Platt, 1994). The production of these foods is based on microbial activity that brings about specific biochemical changes which serve to improve the nutritional profile and palatability of the substrate (Campbell-Platt, 1994; Nagarajan et al., 2022). The microbial processes result in metabolites that are rich in compounds with probiotic, antioxidant, and antimicrobial effects (Nagarajan et al., 2022).

Traditional Fermentation Practices Vs. Modern Fermentation Practices

Conventional fermentation processes, especially in Asia and Africa, rely on the microbial activity of spontaneity. In contrast, modern industrialized nations use defined starter cultures to guarantee uniformity and safety (Leeuwendaal et al., 2022). Recent research indicates that the consumption of fermented foods can have both short-term and long-term effects on the composition of the gut microbiota, either through microbial interactions or through compounds produced during fermentation (Leeuwendaal et al., 2022). The global consumption of fermented foods is increasing because of their potential health benefits. They can be used to improve public health as well as address health disparities found in resource-poor regions (Tamang et al., 2020).

Cheese Production: Microbial Communities

In cheese production, microbial communities play a key role. Every cheese variety is made by using special strains from the *Lactococcus, Leuconostoc* and *Lactobacillus* species. These are bacteria that produce lactic acid. Other microorganisms that make cheese their home during ripening include yeasts and molds.

The cheese microbiota is a labyrinth of interactions that are both simple and complicated and static and dynamic, including those between starter cultures, NSLAB (non-starter lactic acid bacteria), and secondary microorganisms (Andrade et al., 2009; Blaya et al., 2018). In the beginning, there is domination by starter cultures such as Lactococcus and Streptococcus during the early stages of cheese ripening. The population of these bacteria decreases as ripening advances due to environmental stresses acting against them, thus creating a void that allows NSLAB to fill it. These include various species of *Lactobacillus* (Blaya et al., 2018). Swiss-type cheeses use *Propionibacterium* as secondary microorganisms while blue cheeses use *Penicillium*; they are essential in obtaining the unique flavors and textures found in these types of cheese (McSweeney, 2007).

Andrade et al. (2009) reported that temperature, pH, and microbial interactions are environmental conditions that influence the development of cheese microbial consortia. The quality and safety of cheese products depend most on the microflora involved in cheese ripening. The recent application of next-generation sequencing and multi-omics tools has markedly enhanced our knowledge related to cheese microbial communities that serve as good-quality indicators, as well as sources for identifying bioactive compounds (Afshari et al., 2020).

Microbial communities in fermented dairy products are shaped by both the raw materials and the production environments, as well as specific manufacturing practices (Aspri & Tsaltas, 2020; Montel et al., 2014). A richer microbiota is often obtained from traditional methods of cheese production compared to industrial ones. For example, over 400 species of bacteria, yeasts, and molds can be harbored by raw milk (Montel et al., 2014). Indeed, this microbial diversity is not only involved in conferring sensory properties of traditional cheeses but also provides anti-pathogenic resistance based on potential health perspectives. (Montel et al., 2014; Macori & Cotter, 2018).

Processing environments also have a considerable effect on the composition of microbial communities. Product-specific 'house' microbiota comprising *Debaryomyces* and *Lactococcus* species can also influence final product features (Bokulich & Mills, 2013). The propagation of these microorganisms between successive fermentations underlines the contribution of the processing environment towards defining product quality (Bokulich & Mills, 2013). The application of advanced 'omics'-based approaches has allowed better insights into dairy product microbiota composition and functionality, thus described fermentations more clearly (Macori & Cotter, 2018).

Metabolic Activities and Health Advantages

The rich and varied flavors of fermented foods, as well as their potential health benefits, are determined during fermentation by the metabolic activities of microorganisms (Zhao et al., 2016; Nagarajan et al., 2022). For example, the ripening process in cheese involves, firstly, primary biochemical events such as proteolysis, lipolysis, and metabolism of carbohydrates, followed by secondarily flavor compound-forming reactions (McSweeney, 2004). Taste-active amino acids, peptides fatty acids freeduring sensory quality enhancing and health beneficial compound formation are generated by these processes (Zhao et al., 2016; Molimard & Spinnler, 1996; Nagarajan et al., 2022).

Health Implications of Fermented Dairy Products

Fermented dairy products, such as yogurt, contain beneficial live microorganisms: typically lactic acid bacteria (LAB) including Lactobacillus and Streptococcus species, which make them health-promoting (Fernandez et al., 2015; Mazahreh & Ershidat, 2009). The consumption of these products has been associated with decreased risk of different disease conditions— type 2 diabetes, metabolic syndrome, and heart diseases (Kok & Hutkins, 2018). In addition to being rich in LABs, other factors that can help improve gastrointestinal health are increased gut microflora, as well as intestinal transit and immune responses in individuals who may be suffering from conditions such as lactose intolerance or constipation or diarrhea — even inflammatory bowel disease. (Adolfsson et al., 2004; Kok & Hutkins, 2018).

While the microbial interactions in cheese production are important for quality, they may also present safety risks. The pathogenic bacteria Listeria monocytogenes and Escherichia coli may contaminate cheese. This happens more especially in products made from raw milk or due to unhygienic practices (Choi et al., 2016; D'Amico, 2014). The risks can be increased by such conditions as high moisture content and improper processing environments (Choi et al., 2016). Contamination can take place at different stages, right from the raw materials up to the processing environments (D'Amico, 2014; Nout, 1994). However, beneficial microorganisms in cheese are capable of producing antimicrobial compounds. This action helps in making sure that the safety of the product is maintained (Focardi, 2022). The assurance of cheese safety demands proper sanitation and milk handling besides taking care of animal health management. It also involves food safety management systems together with regulatory policies within which it is embedded (D'Amico, 2014).

Microbial Analysis Improvements

High-Throughput Sequencing-HTS technologies have opened up new horizons in studying microbial communities of fermented food products, allowing a detailed analysis of their structure and dynamics (Ercolini, 2013; Srinivas et al., 2022). The application of culture-independent methods, metagenomic and metatranscriptomic tools provide information about the diversity and functioning interactivity of microbes during fermentation (De Filippis et al., 2017). Implementation of HTS methodology will help to solve monitoring problems related to the dynamics of microflora under production conditions, as well as those of product quality and safety, in addition to optimizing the technological parameters of fermentation (van Hijum et al., 2013). That is important for preserving the traditionality introduced with homemade starter cultures, which are versatile and highly efficient in producing safe high-quality fermented foods but also carrying out additional commercial functions (van Hijum et al., 2013; Srinivas et al., 2022). As current sequencing methods are further improved, they could be increasingly used for industrial purposes to characterize the composition of species, the potential of beneficial microbiota at each stage of the technological process (De Filippis et al., 2017; Srinivas et al., 2022).

Conclusions

Microbial communities in fermented foods are very important in defining the sensorial properties and health benefits of the final product. Although safety is a major concern, especially for cheese production, it can be said that the use of traditional methods results in a more diversified microbial population which enhances the flavor and potential health effects of the food. Thereafter, sequencing and omics technologies have come up as an innovation to improve safety and quality on one hand while maintaining our traditional practices. This growing body of knowledge has promising prospects for future production while ensuring that consumers continue to receive high-quality fermented foods that promote good health.

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