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Editorial overview: Food biotechnology: Microbial ecosystem management: strategies to adapt ecosystems to improve performance and health impact

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Michiel Kleerebezem is professor of Host Microbe Interactions, at the Department of Animal Sciences of Wageningen University as well as Principal Scientist at the Health Department of NIZO food research. His research expertise centers around the molecular biology and physiology of bacteria, with a special focus on lactic acid bacteria, probiotics, and the intestinal microbiota. In recent years he has expanded his field to the (post-genomic) molecular analysis of the mechanisms of communication between intestinal bacteria and the host mucosa. His work aims to understand and improve the functional performance of starter cultures for industrial fermentation and probiotic application, while his work on the intestinal microbiota and probiotics strives to decipher the molecular cross-talk between these intestinal microbes and the host's mucosa in order to enhance their application potential for the benefit of human and animal health.

Microbes and their ecosystems are intimately connected to our life, environment, food and health. Microbes of our body, particularly the gut microbiota, provide many essential functions related to development, immunity, digestion, nutrition and pathogen protection. Probably the biggest challenge facing humanity is our capacity to feed the world, with an expanding and ageing population. Moreover, the United Nations World Food Program, estimated that more than 870 million people are malnourished. Many of these people are children, leading to approximately one out of six children being underweight, and knowing that malnutrition contributes to the death of 2.6 million children each year. At the same time, approximately one-third of all available food products is wasted. Feeding a global population that is projected to reach 9 billion by 2050 will require an increase of agricultural yields by 70–100%, but also demands major food innovations aimed to nourish Man's health, by preventing and treating the expanding chronic diseases. In view of these requirements it is crucial to improve our understanding of the roles fulfilled by microbes and ecosystems in the environment and food production processes, but also those associated with our own body. Such understanding is crucial to harness the tremendous potential of microbes in food processing, nutrition and health.

Over the past years, considerable advances have been made in characterizing composition and roles of microbes in food and in the human gut. Tremendous advances in life sciences supported by next generation sequencing (NGS) that fuels (meta-)genomics, as well as high-resolution metabolomics are revolutionizing our understanding of microbes and ecosystems associated with nutrition and health. These advances have led to groundbreaking discoveries in novel functions of microbes in food and humans. This includes functions related to production of safe, sustainable and healthy fermented foods as well as health-promoting microbes and other food ingredients. The intestinal microbiota research is starting to decipher how food and food ingredients may support pathogen protection, restoration of gut microbiota balance and diversity, and nutrient digestion and conversion, which in the long run could contribute to the prevention or correction of a broad range of chronic diseases, including those related to inflammation and immunity (IBD, IBS, [food-] allergy, autoimmunity, etc.), metabolism (obesity, diabetes, etc.), and/or even neurology (Parkinson, autism, etc.). However, causality, underlying mechanism, and nutritional strategies for microbiota modulation are still to be demonstrated. The high biodiversity of the intestine provides a unique source of microbial capacities, encompassing known and many still to be discovered functions. Molecular methods have tremendously contributed to our understanding of the genetic and metabolic

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potential of the intestinal ecosystem. However, harnessing the potential of microbiota for the improvement of health, still requires their cultivation and functional characterization. This is a challenging task for strict anaerobes, and using cultivation techniques that were mainly developed in the sixties, which may recover less than 30% of the overall intestinal microbes. This challenge certainly extends to efficient large scale production and processing of gut microbes for health-promoting supplement applications, but also impacts our capacity to rationally design dietary ingredients aiming to stimulate health-supporting microbiota, or even correcting the unbalanced microbiota correlated with disease.

Imposing selective environmental pressures on microorganisms may be exploited to deliberately adapt microbes to environmental niches or industrial processes in which they are applied, selecting for improved industrial performance in food fermentation processes or enhanced functionality within microbial ecosystems. Inversely, environmental challenges can also cause unbalanced, dysbiotic ecosystems with undesirable phenotypes, such as accumulation of resistance genes upon antibiotic treatment, or an inflammation stimulating microbiota in the obese host. The microbial communities adapted to the intestinal ecosystem can be modulated by altering the physicochemical conditions of such habitat by nutritional interventions. Nutritional factors such as fibers, exogenous microbes, and other dietary compounds have not yet been fully investigated for their potential to enhance microbiota fitness, and to prevent or correct non-homeostatic (dysbiotic) host-microbe interactions in human disease. Intestinal microbiota modulations by food hold the potential to influence human health in a variety of domains, including nutritional, metabolic, and immune status with impact on both intestinal — as well as systemic health.

In this issue on food biotechnology, the ten excellent contributions address the current status of knowledge of microbial fitness in food production and intestinal microbiota–host interactions, and how this can impact on industrial food-production and ingredient-production, and/or the intestinal microbiota and host health.

From fermented foods, to intestinal microbiota–host interactions, and novel prebiotics and probiotics

Our understanding of the molecular changes underlying microbial evolution has been accelerated tremendously by NGS genomics, providing holistic information of the genetic changes that drive the adapted behavior of evolving microbes. Bachmann *et al.* highlight the revival of experimental evolution strategies for the production of industrial strains with improved fermentation performance and/or enhanced environmental fitness. Recent developments in single cell technologies such as those relying on microfluidics, combined with NGS are fueling the comprehensive character of such approaches and enable improved experimental designs to obtain desired phenotypes.

Sustainable performance of microbes in industrial fermentation depends on the effective prevention of phage predation. Mahony and van Sinderen describe the recent advances in the molecular understanding of phage-host recognition and the characterization of the docking molecules involved can open novel avenues for prevention of problems associated with phages in industrial fermentation. Moreover, improved understanding of phage diversity and its mechanisms of interaction with its microbial host may also revive the concept of phage therapy, for example to eradicate food-borne pathogens from products.