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Physiology of food spoilage organisms

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Abstract

A thorough understanding of the physiological responses of microorganisms to stresses imposed during food preservation is essential if novel combination systems based on mild food processing procedures are to be developed effectively. The influences of intrinsic characteristics as well as external factors such as water activity, temperature, preservatives, composition of the gaseous atmosphere, etc. on the stress response of microorganisms are discussed. The interaction of spoilage organisms with each other as well as with food pathogens and the ultimate consequences for food safety and quality are also explored in this review.

Keywords: Spoilage; Homeostasis; Physiology; Food preservation

1. Food spoilage

Microbial food spoilage costs the food industry (and indirectly, the consumer) many millions of Euros annually and ultimately represents an enormous waste of a valuable resource. Food losses begin on the farm and continue throughout post-harvest storage, distribution, processing, wholesaling, retailing and use in the home and in catering. Although it is technically possible to produce food entirely free of microbial contamination by well-known technologies such as gamma irradiation, such a severe approach is contrary to the current consumer demand for foods that are minimally processed and perceived as ‘‘fresh’’. Therefore, in addition to ensuring the safety of foods, the challenge remains to produce high-quality foods that are easy to prepare, do not require daily trips to the supermarket and rely less heavily on chemically synthesised food preservatives.

2. Modes of action of food preservatives and microbial physiology

Most traditional food preservation processes have been developed empirically without a full understanding of the mechanisms of action of the antimicrobial agents used. However, with the move away from using high concentrations of individual food preservatives towards increasing reliance on combinations of sub-lethal levels of antimicrobial compounds or processes, there is a need to re-examine the basics. It could be argued that truly novel combination systems can only be developed logically if they are based on a thorough understanding of the physiology of microorganisms in foods

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(Russell and Gould, 1992; Knochel and Gould, 1995). Thus, if the homeostatic mechanisms of microorganisms could be better understood, improved ways of perturbing them might be more easily devised in the future.

Unfortunately, in recent years the accumulation of knowledge on the physiology of spoilage microorganisms has lagged behind that on microbial genetics and molecular biology. For example, the entire genome of *Saccharomyces cerevisiae*, a beneficial and economically-important yeast as well as a spoilage agent of foods, has been sequenced and reported, but only about 50% of the 6000 genes identified are of known function (Bassett et al., 1996; Goffeau et al., 1996; Oliver, 1996). Important aspects of the regulation of growth and metabolism in many spoilage microorganisms are still poorly understood from a fundamental viewpoint.

3. Survival and resistance to food-associated stresses

Some of the major stresses encountered by microorganisms in foods include low or high temperatures, acidity, low water activity and modified atmospheres (Table 1). Whilst the types of stresses encountered by spoilage and pathogenic organisms may be the same, spoilage organisms tend to be more adaptable to harsh environmental conditions, often developing resistance to chemical food preservatives, cleaning and sanitising agents. Furthermore, food spoilage organisms outnumber food pathogens in terms of both numbers and types.

4. Maintaining homeostasis

In general, microbial exposure to low water activity by dehydration or addition of salts or sugars leads to the activation of constitutive transport systems culminating in the accumulation of compatible solutes inside the cell. These are often small, highly soluble molecules and include potassium, proline, glutamate, betaine and trehalose. Notably, accumulation of compatible solutes has been shown, in some microorganisms, to confer increased resistance to heat and improved ability to grow at reduced temperatures. In the last 10–15 years, cross-resistance to different types of stresses has become a recurring theme in studies of microbial physiology.

5. Spoilage consortia

The study of individual food spoilage organisms is an attempt to provide guidelines for systematic and predictive determination of shelf-life. Unfortunately, most foods contain a mixed microbial flora in which strains compete for survival and/or growth. Therefore, poorly understood microbial interactions in foods often conspire to invalidate conclusions drawn on the basis of work done with pure cultures.

6. Future prospects

The introduction of entirely new food preservatives will be slow in the future, despite the technological capabilities of genetic engineering and mainly due to regulatory constraints and the high

Table 1
Examples of major stresses encountered by spoilage microorganisms in foods

Food preservation technique	Stress imposed on microorganisms
Refrigeration and freezing	Low temperature and dehydration
Fermentation (production of organic acids and ethanol)	Low pH, ethanol damage
Drying, salting, preserving with sugar	Osmotic stress, dehydration
Addition of synthetic food preservatives	Direct attack on cell structures: membranes, cell walls, etc.
Storage in controlled or modified atmospheres	Shortage of oxygen, carbon dioxide toxicity

cost of safety testing now required for all new food additives. It is more likely that, by systematic study of the stress responses of microorganisms together with detailed assessment of technological performance of available preservatives and preservation technologies in real food formulations, much more sophisticated usage will emerge, resulting in new processes and products.

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