

The Commercial and Community Significance of Yeasts in Food and Beverage Production

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1.1 Introduction

The history of yeast association with human society is synonymous with the evolution of bread, beer and wine as global food and beverage commodities, originating some 5,000 years ago. The microbial science of these products commenced in the mid-1600s with the first observations of yeast cells being reported by Antonie van Leeuwenhoek (The Netherlands). The significance of these findings laid dormant until the classic studies of Pasteur (France) and Hansen (Denmark) during 1850–1900, which heralded the beginnings of the disciplines of microbiology and biochemistry. Subsequent studies by Guilliermond (France) and Kluyver (The Netherlands) in the early 1900s established yeasts as a unique group of microorganisms that had a major role in food and beverage production (Rose and Harrison 1969; Rose 1977). Since the 1950s, several classic texts have specifically highlighted the commercial and social significance of yeasts in foods and beverages (Cook 1958; Rose and Harrison 1970, 1993; Phaff et al. 1978; Skinner et al. 1980; Spencer and Spencer 1990; Reed and Nagodawithana 1991; Deak and Beuchat 1996; Boekhout and Robert 2003).

Today, the impact of yeasts on food and beverage production extends beyond the original and popular notions of bread, beer and wine fermentations by *Saccharomyces cerevisiae* (Table 1.1). In a positive context, they contribute to the fermentation of a broad range of other commodities, where various yeast species may work in concert with bacteria and filamentous fungi. Many valuable food ingredients and processing aids are now derived from yeasts. Some yeasts exhibit strong antifungal activity, enabling them to be exploited as novel agents in the biocontrol of food spoilage. The probiotic activity of some yeasts is another novel property that is attracting increasing interest. Unfortunately, there is also a darker side to yeast activity. Their ability to cause spoilage of many commodities, with major economic loss, is well known in many sectors of the food and beverage industries, while the public health significance of yeasts in foods and beverages is a topic of emerging concern. This chapter defines the scope and diversity of the many beneficial and

Table 1.1 The commercial and community significance of yeasts in food and beverage production

- Production of fermented foods and beverages.
- Production of ingredients and additives for food processing.
- Spoilage of foods and beverages.
- Biocontrol of spoilage microorganisms.
- Probiotic and biotherapeutic agents.
- Source of food allergens.
- Source of opportunistic, pathogenic yeasts.

detrimental aspects of yeasts in foods and beverages. Subsequent chapters in this book will provide more detailed and specific coverage of these concepts.

1.2 The Informative Process

To effectively exploit and manage the growth and activities of yeasts in foods and beverages, a structured process of knowledge development and understanding is needed, the concepts of which are outlined in Table 1.2 (Fleet 1999). Obtaining this information is a challenging task, and requires the collaborative interaction of microbiologists, chemists, biochemists, molecular biologists, and food scientists. Application of molecular technologies to the detection and identification of yeasts in food and beverage ecosystems (Fernandez-Espinar et al., Chap. 3) and to determining the genetic bases of their biochemical and physiological responses to these habitats (Walker and van Dijck, Chap. 5; Barrio et al., Chap. 6; Bond and Blomberg, Chap. 7; Dickinson and Kruckeberg, Chap. 8) have greatly facilitated acquisition of this fundamental knowledge and understanding. Moreover, there is now a broad recognition and acceptance that many yeasts species other than *Saccharomyces cerevisiae* are intimately and significantly involved in food and beverage production Romano et al. (Chap. 2) and that their individual contributions can be moderated and impacted by interactions with bacteria and filamentous fungi (Viljoen, Chap. 4). For most commodities, the chain of knowledge linking yeast ecology, yeast activity, product chemistry and product quality is very incomplete. Wine could be singled out where most progress has been made in this context.

1.3 Production of Fermented Foods and Beverages

Most individuals, whether they have a scientific or nonscientific background, have a positive image of yeasts because of their well-known association with the production of bread, beer, wine and other alcoholic beverages. Some will know that there are differences between baker's yeast, brewer's yeast, wine yeast and distiller's yeast, and the more learned will know these as either *S. cerevisiae*, *S. bayanus*, or *S. pastorianus*, according to current taxonomic classifications (Vaughan-Martini and Martini 1998; Kurtzman 2003). However, there is increasing awareness that many species other than those of *Saccharomyces* make positive contributions to the fermentations of foods and beverages, and the diversity of these associations are described in Chap. 2.

Table 1.2 Information needed to exploit and manage yeasts in food and beverage production

- Taxonomic identity of species and strains that contaminate and colonize the food throughout the total chain of production and sale.
- Growth profiles of individual species and strains throughout the chain of production and sale.
- Physical location and spatial distribution of species within the product.
- Biochemical, physiological and molecular explanation of how yeasts colonize the product and change its chemical and physical properties.
- Impact of intrinsic, extrinsic and processing factors on yeast growth and metabolic activity in the product.
- Correlation between growth and activity of individual species/strains, and product quality and safety.

In addition to *S. cerevisiae* and *S. bayanus*, it is now well established that various species of *Hanseniaspora*, (*Kloeckera*), *Candida*, *Pichia*, *Metschnikowia*, *Kluyveromyces*, *Schizosaccharomyces* and *Issatchenkia* can make positive contributions to the fermentation of wine from grapes and cider from apples (Fleet 1998, 2003a; Pretorius 2000). *Dekkera* (*Brettanomyces*) species, in addition to *S. pastorianus* and *S. cerevisiae* are significant in the production of some styles of beer (Dufour et al. 2003), while *Schizosaccharomyces pombe* can be important in rum fermentations (Fahrasmane and Ganou-Parfait 1998).

Although the microbiology of dairy products is generally dominated by discussions of lactic acid bacteria, there is now substantial literature describing the important role of yeasts in flavour and texture development during the maturation stage of cheese production, and in the production of fermented milks such as kefir and koumiss (Fleet 1990; Frohlich-Wyder 2003). The most predominant and important species in these associations are *Debaryomyces hansenii*, *Yarrowia lipolytica*, *Kluyveromyces marxianus* and *S. cerevisiae*, but *Galactomyces geotrichum*, *Candida zeylanoides* and various *Pichia* species are also significant. In addition to lactic acid bacteria, micrococci and staphylococci, yeasts also play an important role in the fermentation of meat sausages and the maturation of hams. *D. hansenii*, other *Debaryomyces* species, *Y. lipolytica* and various *Candida* species are involved, and contribute to flavour and colour development in these products (Lucke 1998; Samelis and Sofos 2003).

Yeasts other than *S. cerevisiae* are found in the fermentation of various cereal products, including sourdough breads, where their activities impact on product flavour and rheology. Prominent contributors are *S. exiguus*, *C. humicola*/*C. milleri*, *Torulaspora delbrueckii*, various *Pichia* species and other species of *Candida* (e.g. *C. krusei*/*Issatchenkia orientalis*) (Jenson 1998; Meroth et al. 2003; Hammes et al. 2005). Coffee beans and cocoa beans (chocolate) undergo natural, indigenous fermentations in the primary stages of their processing, where the growth and activities of a diversity of *Hanseniaspora*, *Candida*, *Pichia*, *Issatchenkia*, *Kluyveromyces* and *Saccharomyces* species have been reported. Essentially, these yeasts assist in degradation of bean pulp and contribute to the production of chocolate flavour precursors (Schwan and Wheals 2003, 2004). *Zygosaccharomyces rouxii*, *C. versatilis*, and *C. etchellsii* are important osmotolerant species that play a key role in soy sauce fermentation (Hanya and

Nakadai 2003). Finally, a vast range of traditional, fermented products are produced in Africa, Asia and Latin America, where, along with bacteria, a diversity of yeast species make important contributions (Steinkraus 1996; Nout 2003).

With very few exceptions (e.g. beer), most fermented foods and beverages involve a mixed ecology of yeasts, bacteria, filamentous fungi in some cases, and their viruses. Consequently, complex microbial interactions are likely to be involved (Chap. 4). The ultimate goal is to understand which species are important to product quality and process efficiency, and to develop operational parameters that maximize their positive contributions. Novel bioreactor technologies could be developed to improve process efficiency (Strehaiano et al., Chap. 9) and targets for genetic improvement of strains could be identified (Verstrepen et al., Chap. 13).

1.4 Yeasts as Sources of Ingredients and Additives for Food Processing

Because yeasts have a positive image with consumers, they are considered as a safe source of ingredients and additives for food processing (Demain et al. 1998). Preparations of baker's and brewer's yeasts have been available for many years as dietary, nutrient supplements because of their high contents of B vitamins, proteins, peptides, amino acids and trace minerals. Also, yeasts are often considered as an alternative source of protein for human consumption (Peppler 1970; Harrison 1993). Many products are now derived from yeasts and, according to Stam et al. (1998), about 15–20% of the global industrial production of yeasts is used for this purpose. Abbas (Chap. 10) describes the production of antioxidants, aromas, flavours, colours and vitamins by yeasts. Other detailed accounts of these topics may be found in Halasz and Laszity (1991) and Reed and Nagodawithana (1991).

Flavour ingredients based on yeast extracts, yeast autolysates and dried yeast preparations represent the most commercially significant products extracted from yeasts, and are used extensively in the food industry as a source of savoury, roasted, nutty, cheesy, meaty and chicken flavours. In addition, some extracts are specifically enriched in their contents of glutamic acid and nucleotides that function as strong flavour enhancers (Dziezak 1987; Nagodawithana 1992; Kollar et al. 1992; Stam et al. 1998). While baker's and brewer's yeasts have been the traditional sources of these products, their diversity and functionality are being expanded by the use of other yeasts such as *C. utilis* (*Pichia jadinii*) and *K. marxianus* (Lukondeh et al. 2003). Yeasts are frequently mentioned as potential sources of high value aroma and flavour substances such as vanillin (*S. cerevisiae*, *Rhodotorula glutinis*), citronellol, linalool and geraniol (*K. marxianus*), and γ and δ -decalactones (*Sporidiobolus sulmonicolor*, *Y. lipolytica*) (Hagedorn and Kaphammer 1994; Vandamme and Soetaert 2002).

The yeast cell wall, composed principally of β -(1 \rightarrow 3) and β -(1 \rightarrow 6)-glucans and mannoprotein, represents about 20–30% of the cell dry weight (Fleet 1991; Nguyen et al. 1998). The β -glucans have gelling, thickening and fat-sparing functional properties that offer a range of applications in food processing (Seeley 1977) and, moreover, they have been reported to have anticancer, (Bohn and Be Miller 1995) immunomodulating (Sandula et al. 1999) and cholesterol-lowering activities

(Bell et al. 1999). They also absorb mycotoxins and could offer a method for removing these substances from beverages such as wine (Yiannikouris et al. 2004; Bejaoui et al. 2004).

Food colorants such as astaxanthin and other carotenoid pigments (Lyons et al. 1993; Johnson and Schroeder 1995) and a diversity of vitamins (Reilly 1991; Sauer et al. 2004) can also be derived from yeasts.

1.5 Spoilage of Foods and Beverages by Yeasts

There is an extensive literature on yeasts as food and beverage spoilage agents and, no doubt, this reflects the enormous commercial and economic significance of this problem. Stratford (Chap. 11) gives an updated account of this topic. Earlier, comprehensive discussions include those of Ingram (1958), Walker (1970), Deak (1991), Fleet (1992), Tudor and Board (1993), Thomas (1993), Deak and Beuchat (1996) and Loureiro and Querol (1999). Yeast spoilage is a constant threat and widespread problem in the food and beverage industries that can only be managed by employing educated staff and implementing effective quality assurance programs.

Yeast spoilage is very predictable, principally occurring in those products where bacterial growth is either retarded or prevented by the intrinsic, extrinsic and processing that prevail. Without this competition, yeasts will grow and spoil the product. Typically, high-acid, low-pH foods, products with high sugar (e.g. more than 10% w/v) or high salt (more than 5% NaCl) content, and products preserved with weak organic acids (e.g. sorbic, benzoic, acetic) are prone to yeast spoilage. Fruits, fruit juices, and fruit drinks, fruit pulp, fruit juice concentrates, sugar and flavour syrups, confectionery products, alcoholic beverages, carbonated beverages, vegetable salads with acid dressings, salt- and acid-based sauces, fermented dairy products and fermented or cured (salted) meat products represent prime candidates for yeast spoilage (Walker 1970; Tudor and Board 1993; Deak and Beuchat 1996). Some yeasts (e.g. *Cryptococcus* and *Rhodotorula* spp.) grow better than bacteria at subfreezing temperatures, and will spoil frozen meat, poultry, seafood and other products stored for lengthy periods. Some high-fat, low-water-activity commodities such as margarine and butter can support the surface growth of yeasts (e.g. *Y. lipolytica*). While there is significant diversity in the yeast species associated with food and beverage spoilage, some specific associations are frequent and often predictable. For example, these include *Z. rouxii* in very high sugar products, *D. hansenii* in salted meat products, *Z. bailii* in products preserved with weak organic acids and *Y. lipolytica* in high-fat products. However, an open and enquiring outlook should be maintained, because new spoilage and food processing species may be present and await discovery – for example, *Z. lentus* (Steels et al. 1999) and *Tetrapisispora fleetii* (Kurtzman et al. 2004).

Controlling the growth and activity of spoilage yeasts requires good understanding of their physiology (Chap. 5), biochemistry (Chaps. 8, 9) and genetic responses (Chaps. 6, 7). Unfortunately, there remain large gaps in this knowledge, especially for yeasts other than *S. cerevisiae*. Factors affecting growth and survival, and being able to predict yeast response to these factors, are particularly important at the practical levels of quality control and assurance. For most yeasts, the growth and survival limits, and inactivation kinetics for basic technological parameters such as temperature,

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