Food Fermentation

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Introduction

Fermentation is a technology that utilizes the growth and metabolic activities of microorganisms for the preservation and transformation of food materials. During food fermentation, the growth of spoilage and pathogenic organisms is inhibited by the metabolites generated by the fermenting organisms, thereby extending the shelf life of perishable produce. For instance, during lactic acid fermentation, lactic acid bacteria synthesize metabolites such as lactic acid, acetic acid, carbon dioxide, ethanol, hydrogen peroxide, bacteriocins, and antimicrobial peptides (Di Cagno et al., 2013), which synergistically suppress the survival and growth of pathogenic and spoilage microorganisms.

Besides preservation, fermentation imparts characteristic aroma, flavor, texture, and nutritional profile into food. Thus, although ancient civilizations developed fermentation primarily as a way of preserving perishable agricultural produce, the technology has evolved beyond preservation into a tool for creating desirable organoleptic profiles in foods and improving their palatability. Bread is a classic example for this case, where the primary function of dough fermentation is to create the characteristic structure, texture, and organoleptic profile of bread after the baking process. Fermentation also helps to remove antinutritional factors and toxins in food materials and improve their nutritional profile. For instance, fermentation of soybean into products such as tempeh (fermented dehulled soybean with meatlike flavor and texture), natto (a fermented soybean dish from Japan with strong smell and flavor and a slimy texture), and soy sauce (a dark brown condiment made from fermentation of soybean, wheat, and salt) leads to reduction of antinutritional factors such as phytic acid and trypsin inhibitors and results in the hydrolysis of complex soy proteins into more digestible and bioavailable peptides and amino acids (Chen et al., 2013; Soni and Dey, 2014).

Food Fermentation Processes

Traditional food fermentation processes can be broadly classified into lactic acid fermentation, fungal fermentation, and alkaline fermentation. Examples of lactic acid fermented products, i.e., products primarily fermented by lactic acid bacteria, include yoghurt, sausages, cheese, sauerkraut (fermented cabbage from eastern and central Europe), and kimchi (fermented and spiced Napa cabbage from Korea). Yeast spp. are also involved in the fermentation of many of the lactic acid–fermented products, including kefir (a slightly alcoholic dairy beverage from the Caucasus), and kombucha (a fermented sweetened tea from China). Most of the well-known soy-based fermented foods from Asia such as tempeh and soy sauce are produced by fungal fermentation, except natto, which is produced by alkaline fermentation (Dirar, 1992).

Industrial fermentation processes use either submerged or solid-state bioreactors that are operated in batch, semibatch, or continuous mode. Most food fermentation processes from sauerkraut and kimchi to miso and tempeh use solid-state fermentation processes operated in batch mode, where microorganisms are cultivated on the surface of a water-insoluble substrate (Leona et al., 2013). Submerged fermentation processes are used in the production of yoghurt and other dairy-based beverages, alcoholic beverages, and food condiments such as vinegar.

Recent Trends

Fermented food products make up a significant part of the diet in developing nations and the Far East. In the West, with the exceptions of bread, cheese, and sausages, fermented foods have largely faded to the sidelines with the advent of modern technologies such as refrigeration. Nevertheless, there is a renewed interest in traditional fermented foods in recent times, mainly driven by the purported health benefits of fermented foods both as vehicles of probiotic organisms and health-promoting metabolites (**Figure 1**).

Fermented foods are currently being promoted to prevent or cure a range of diseases from obesity to cancer. For instance, kimchi is claimed to have anticancer, antiobesity, antiaging, and anticonstipation effects (Kim et al., 2011), whereas kefir is claimed to reduce lactose intolerance symptoms, stimulate the immune system, and lower cholesterol and to have antimutagenic and anticarcinogenic properties (Guzel-Seydim et al., 2011). Although most of the health claims around fermented

Figure 1 Examples of traditional and novel fermented foods and beverages.

foods are based on folk beliefs with no scientific substantiation (Leroy and De Vuyst, 2014; Marsh et al., 2014), findings from recent *in vitro* and animal models, as well as human intervention studies, support some of these claims. For example, a recent study by a Korean group (Kim et al., 2011) reported that consumption of kimchi for 2 weeks by obese and overweight individuals led to a decrease in body mass index, body fat, waist–hip ratio, blood pressure, fasting blood sugar, and total cholesterol (Kim et al., 2011).

Fermented foods are one of the top 10 food trends in 2016 (Riley, 2015), continuing the trend over the last few years. Food companies are responding to this growing trend either by commercializing traditional fermented foods (e.g., kefir and kombucha, whose market value in North America alone were $130 million and $480 million, respectively, in 2014) or developing novel fermented foods based on the traditional ones (e.g., Bionade, flavored malt-based beverages fermented using the starter culture of kombucha, and Rythem, coconut milk–based and fruit juice–based beverages fermented using kefir grains). Several soy- and cereal-based probiotic products are also in the market in response to the growing prevalence of allergies to dairy proteins, lactose and gluten intolerances, and life style choices such as veganism (Gupta and Abu-Ghannam, 2012).

Future Outlook

The future of fermented foods appears to be bright, fueled by the growing interest by consumers in everything perceived as natural and to promote health and longevity. Food manufacturers are also rediscovering the possibility for creating unique and characteristic flavor, texture, nutritional profile, and health benefits, while maintaining a 100% natural label via fermentation (Hugenholtz, 2013), and are seizing this opportunity as exemplified by the diverse products already in the market, a trend that is set to continue.

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