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Review

Fermented beverages with health-promoting potential: Past and future perspectives

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Fermentation is an ancient form of food preservation, which also improves the nutritional content of foods. In many regions of the world, fermented beverages have become known for their health-promoting attributes. In addition to harnessing traditional beverages for commercial use, there have recently been innovative efforts to develop non-dairy probiotic fermented beverages from a variety of substrates, including soy milk, whey, cereals and vegetable and fruit juices. On the basis of recent developments, it is anticipated that fermented beverages will continue to be a significant component within the functional food market.

Introduction

Societies throughout the world independently discovered the value of fermenting food as a cheap means of preservation, improving nutritional quality and enhancing sensory characteristics. The fermentation of milk, cereals and other substrates to produce beverages with health-promoting properties is indigenous to many regions of Asia, Africa, Europe, the Middle East and South America. Evidence from pottery vessels show that fermented rice, honey and fruit beverages date as far back as 7000 B.C. in China (McGovern *et al.*, 2004), and there is evidence of kombucha manufacture dating back to approximately 220 B.C. (Dufresne & Farnworth, 2000), while recent proteomic analysis has shown kefir-like milk to have been fermented some 3500 years ago in Asia (Yang *et al.*, 2014). While many such beverages have for quite some time been noted for their putative health-promoting attributes, this interest is now being harnessed by modern biotechnological techniques to develop the next generation of fermented functional beverages.

The global functional beverage market is a growing sector of the food industry as modern health-conscious consumers show an increasing desire for foods that can improve well-being and reduce the risk of disease. Fermented milks, especially yoghurt-style products, are the most popular functional beverages with kefir in Western Europe and North America and ymer in Denmark being good examples. Notably, the global functional food and drink market increased 1.5 fold between 2003 and 2010, and is expected to grow a further 22.8% between 2010 and 2014 to be worth €21.7 billion (Leatherhead, 2011), with other estimates predicting the market will reach €65 billion by the year 2016 (Companiesandmarkets, 2013). Dairy-based produce account for approximately 43% of the functional beverage market, and is mainly comprised of fermented products (Özer & Kirmaci, 2010). It is also intriguing to note that a number of food companies that have been under pressure, due to the poor public perception regarding the 'healthiness' of the foods they produce, are now focussing on developing such functional products.

In this article we review the literature regarding traditional fermented beverages with reputed health benefits, and explore recent trends and developments in this field, as well as areas for future research.

Natural fermented beverages: sources and microbial composition

Naturally fermented milks

The yoghurt and fermented milks market is currently worth €46 billion, with North America, Europe and Asia accounting for 77% of the market. Many communities

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across the world produce naturally fermented milks with many of these products being of a yoghurt-style consistency. Fermented milk products can be made with milk (or skimmed milk) from various sources, including cow, camel, goat, sheep, yak and even coconut, milk, and can be either pasteurised or unpasteurised. They can be produced through the use of defined starter cultures, back-slopping or allowed to ferment naturally. Although fermented milk beverages are predominantly composed of lactic acid bacteria (LAB), the exact microbial content may vary depending on the source of milk, treatment of the milk (e.g. pasteurisation), use of starters, the nature of the local environmental microbes present, temperatures, hygiene, the type and treatment of containers used and the length of fermentation. Many artisanal fermented milk beverages are produced as a result of back-slopping, whereby a small portion of already-fermented milk is used to begin a new fermentation. In this way, cultures from the LAB naturally present in the raw milk are passed from household to household and between generations. While the consumption of spontaneously fermented milk is common to many different regions, the exact microbial differences between these products have not been ascertained. Table 1 lists a number of the most popular and best-studied fermented beverages from around the world, along with information with respect to their corresponding microbial compositions. From this, the domination of milk-based beverages fermented by LAB, mainly *Leuconostoc*, lactobacilli and lactococci, is clear. Fermentation in colder climates promotes the growth of mesophilic bacteria such as *Lactococcus* and *Leuconostoc*, whereas beverages produced at higher temperatures usually have greater counts of thermophillic bacteria such as *Lactobacillus* and *Streptococcus*. The contributions of slime-producing species or acetic acid producing species, generally present at low abundance relative to *Lactobacillus* or *Lactococcus* species, vary depending on abundance. There may also be significant numbers of coliforms present, depending on the level of hygiene employed during preparation, with high levels having been noted in some African beverages (Gran, Gadaga, & Narvhus, 2003). The quantity and types of yeasts involved can vary greatly, but *Candida* and *Saccharomyces* are the species most commonly detected.

Of the many fermented milk beverages, kefir, a drink that originated with shepherds in the Caucasian mountains has been a notable success, gaining worldwide popularity, with the market now worth €78.7 million in North America alone (Lifeway, 2014). The microorganisms responsible for the fermentation are actually a symbiotic combination of bacteria and yeast, bound within a polysaccharide matrix, known as kefir 'grains'. Koumiss, sometimes known as airag, is a popular beverage of nomadic cattle breeders in Asia and some regions of Russia. This beverage is similar to kefir, but there is no solid inoculation matrix, and this milk is fermented by back-slopping or by allowing the milk to ferment naturally, and has been reported to contain fewer lactococci. Shubat is a fermented camels milk popular in Asia, also believed to have healing properties (Rahman, Xiaohong, Meiqin, & Mingsheng, 2009). In Africa, fermented milk beverages are quite popular, where the art of making fermented products is passed down through generations. Examples of such beverages include amasi from Zimbabwe, kivuguto from Rwanda, suusac from Kenya, nyarmie from Ghana and rob and garris from Sudan. Considering that most of these are derived from the spontaneous fermentation of milk by its innate microbiota, it is likely that the fermented milks, although known by different names, are actually quite similar, and can be, in combination, referred to as naturally fermented milk (NFM) (Narvhus & Gadaga, 2003). Nonetheless, accurate categorization remains difficult in the absence of more detailed microbiological and biochemical analyses. Also, in many countries yoghurts are diluted with water to form drinkable fermented milk, such as doogh, ayran, chaas and lassi, with the resulting microbial composition generally being similar to that of yoghurt. The composition and purported health benefits associated with fermented dairy beverages can also be read about in a recent review by Shiby and Mishra (2013).

Non-dairy fermented beverages

Another important class of fermented beverages are those made from cereals, which are popular in tropical regions and on the continent of Africa in particular. As with many milk-based products, the natural microbial component is used to ferment grains including maize, millet, barley, oats, rye, wheat, rice or sorghum. The grains are often heated, mashed and sometimes filtered. Back-slopping is again quite common, but the microbial populations responsible for the fermentation of these beverages are not as well characterised.

Boza, consumed in Bulgaria and Turkey, is generated through the fermentation of a variety of cereals including barley, oats, rye, millet, maize, wheat or rice, with the specific composition affecting the viscosity, fermentability and content of the final beverage (Akpinar-Bayizit, Yilmaz-Ersan, & Ozcan, 2010). The cereal is boiled and filtered, a carbohydrate source is added, and the mixture can be left to ferment independently or with the use of back-slop. Boza has yet to be commercialised and studies have revealed that the microbial population varies. The function of the yeast present, which is only sometimes detected, remains unknown. Of several combinations, it has been suggested that fermentation by *Saccharomyces cerevisiae*, *Leuconostoc mesenteroides* and *Lactobacillus confusus* produce the most palatable beverage (Zorba, Hancioglu, Genc, Karapinar, & Ova, 2003).

Togwa, a sweet and sour, non-alcoholic beverage, is one of the better studied African cereal beverages. Produced from the flour of maize, sorghum and finger millet and, sometimes, cassava root, the chosen substrates are boiled,