Review

Safety and quality of bacterially fermented functional foods and beverages: a mini review

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Abstract

Bacteria have been employed widely in the food and beverage industry, with evolving dimensions in recent years. Proteases derived from lactic acid bacteria (LAB) are useful in the production of fermented functional beverages and are of particular use in conditioning their shelf life, nutritional content, flavour, and texture quality, thus making fermented foods and beverages functional and therapeutic. This review focuses on bacteria, especially protease-producing LAB used in food processing, and their usefulness in the production of functional foods and beverages. A case study of oat beverages was briefly explored due to its popularity. The safety and quality importance of the food products were also considered with a few recommendations.

Key words: protease; functional foods; fermented beverages; lactic acid bacteria; safety.

Introduction

The link between the consumption of beverages and healthy living is one that has enjoyed scientific scrutiny over the past few years. Foods are increasingly outgrowing their conventional nutritional function and energy supply to the body and are fast taking up medicinal capabilities. Since the times of Hippocrates, the Greek Philosopher once quoted ‘let food be thy medicine and medicine be thy food’ (Otles and Cagindi, 2012), evolving civilizations afford nutritionists curated ways of enriching and fortifying foods to supply nutrients in excess of the natural nutritional components in the raw food, with preventive and therapeutic medicinal aims. Beverages based on composition may be regarded as the most active functional foods around today, having certain inherent capacities for modification and can be tailored to meet specific consumer needs (Ashaolu, 2019a).

The production of fermented foods and beverages was originally performed to enhance the shelf life of perishable raw materials of agricultural and animal husbandry origin. Today, this bioprocess technology aims at the use of microorganisms and their enzymes, through acidification, alcoholization, proteolysis, and/or amino acid conversions, to make products with desirable quality characteristics regarding shelf life, texture, taste, mouthfeel, flavour, and colour (De Roos and De Vuyst, 2018; Ashaolu, 2019a). Among the microorganisms and microbial enzymes used are proteolytic bacteria such as lactic acid bacteria (LAB) and their proteases. In the food industry, proteases are useful for fermentation and digestion. These enzymes are renowned for their activities such as enhancement of oil recovery from seafood, meat tenderization, and reduction of allergenicity in food substances (Ashaolu and Yupanqui, 2017; Ashaolu et al., 2017). Much has been documented on the usefulness of proteolytic bacteria in detergents, pharmaceutical, leather processing, waste treatment, silk degumming, and food industries (Borla et al., 2010; Heredia-Sandoval et al., 2016; Hammami et al., 2018). This review however focuses on bacteria, especially protease-producing LAB used in food processing, and their usefulness in the production of functional foods and beverages. The safety and quality importance of the food products were also considered with a few recommendations.

Functional Foods—Oat Beverage as a Case Study

Apart from its nutritional profile, functional food has the ability to confer immune health to an individual. This only occurs when the...
food is administered in an efficacious quantity, which can be active, biologically (Chua et al., 2013; Staka et al., 2015). It is noteworthy that functional and conventional foods may appear similar, except that functional foods have the tendencies and abilities to reduce the possibilities of chronic diseases than what ordinary nutritional functions can offer, and they help to maintain gut health (FAO, 2007). The preparation of foods by ‘scientific intelligence’ either with pre-emptive knowledge of why the food is being taken or not results in function foods. Recently, there is a considerable evolution of the request for functional foods and beverages due to the concerns and attention of people about the quality of life they live as well as their health (Sunmero et al., 2015; Shah et al., 2016).

An example of functional foods is the fermented oat beverage and this classification may be due to the effects of dependent probiotic starter cultures and prebiotic fibre β-glucan (Iserliyska et al., 2015; Russo et al., 2017) on the beverage. Oats have high functional potentials. Considered rich in dietary fibre, they possess protein in appropriate ratios (Londono et al., 2013; Staka et al., 2015; Shah et al., 2016). When compared to other grain crops, oats make provision for more fibre, iron, calcium, zinc, and other important amino acids needed by the body (Sangwan et al., 2014; Tosh and Chu, 2015; Shah et al., 2016). The group of cereals under which oats is classified is known for its therapeutic powers in ameliorating a wide range of diseases and ailments including diabetes, dyslipidemia, vascular injury, and hypertension (Londono, 2013; Vasudha and Mishra, 2013; Sangwan et al., 2014; Shah et al., 2016).

The health benefits attributed to oats have been fundamentally attached to the proportion of β-glucan, which makes oats highly sticky. The β-glucan is quite effective in lowering the cholesterol levels present in the blood as well as the absorption rate of glucose by the intestine (Iserliyska et al., 2015; Tosh and Chu, 2015). The drinks made from oats come from the processing of oat in addition to milk or other aqueous formulations. This mixture is labelled in the market as a supplementary food that is good for human health, convenient, and fast (Angelov et al., 2018).

**Fermented Functional Foods and Beverages**

One of the primitive processes involved in preserving food is fermentation. In the developing world, the importance of beverages and fermented foods cannot be overestimated (Blandino et al., 2003; Nyanzi and Jooste, 2012). Conventionally, fermentation is used in different places around the world to get various products from different cereals. Several benefits are attributed to fermentation of food including energy saving during matrix processing, desired biochemical alterations for nutritional improvement, safety of food, product shelf life, and improved sensory properties (Blandino et al., 2003; Guyot, 2012; Nionelli et al., 2014). Different types of beverages derived from traditional cereals can be seen in different parts of the globe (Nyanzi and Jooste, 2012; Mäkinen et al., 2016). These products are largely consumed in Africa and their preparations are mostly from millets, sorghum, and maize through the use of self-generated formation process obtained from diluted microbial cultures, especially yeasts and LAB. In Africa, Kanunzaki is produced from Nigeria, Ben-saalga from Burkina Faso, Koko from Ghana, Munkoyo from Zambia and Congo, Thobwa from Malawi and Tanzania, Uji from Uganda, Kenya and Tanzania, Mageu from Southern Africa and Arabian Gulf countries, Bushera from Uganda, and so on. Both infant and general populations in these countries consume these products (Nyanzi and Jooste, 2012; Vasudha and Mishra, 2013; Nionelli et al., 2014; Mäkinen et al., 2016; Ashaolu, 2019a).

In the Balkan region of Turkey, Bulgaria, Albania, and Romania, Boza is a renowned traditional beverage. Its preparation is achieved through mixing either rye, wheat, millet, or other cereals with sugar and water (Nyanzi and Jooste, 2012; Vasudha and Mishra, 2013; Mäkinen et al., 2016). In Eastern Europe, the common local drink is Kvass, and it is prepared from barley malt flour or rye and rye bread that is stale (Nyanzi and Jooste, 2012). Pozol is the beverage drink in Mexico prepared by soaking maize in limewater over an extended period. Before dissolving in water, Nixtamal, known as dough balls, is enclosed in the leaves of banana and allowed to ferment for 0.5–4 days (Nyanzi and Jooste, 2012; Vasudha and Mishra, 2013; Ashaolu, 2019a).

**Lactobacillus** genera is often used in the fermentation of cereals, and they include _L. plantarum_, _L. casei_, _L. rhamnosus_, _L. reuteri_, _L. fermentum_, _L. brevis_, _L. acidophilus_, and others; _Pediococcus_ ( _P. acidilactici_, _P. pentosaceus_, etc.), _Bifidobacterium_, _Candida_, _Debaryomyces_, _Endomycopsis_, _Hansenula_, _Pichia_, _Saccharomyces_, and _Trichosporon_ (Guyot, 2012; Nyanzi and Jooste, 2012; Vasudha and Mishra, 2013; Nionelli et al., 2014; Russo et al., 2017; Angelov et al., 2018) are also used. There are different other fermented foods with the use of different bacteria that have been developed all around the world depending on regions and culture. Table 1 represents examples of such foods and beverages.

**Protease-Producing LAB Versus Functional Foods and Beverage Industry**

Every living organism including plants and animals relies on proteolytic activity to some extent. Bacterial proteases are useful for a diverse range of industrial processes, which include pharmaceutical, medical, animal (leather-based products), and food industries. Proteolysis by LAB plays paramount roles in the formation of the unique flavour of fermented meat because the peptides and amino acids generated are the major precursors of specific flavour compounds (Hughes et al., 2002; Mcfeeters, 2004). However, the proteolytic pathway of LAB may cause certain proteins to degrade, such as sarcoplasmic and myofibrillar proteins (Fadda et al., 2002). Proteolysis is one of the major physiological traits of LAB and its importance is derived from its contribution to the development of organoleptic properties of fermented food and production of bioactive health beneficial peptides (Savijoki et al., 2006). In addition, the proteolytic system of LAB also affected the texture development of fermented fish (Riebro and Benjakul, 2005). Bacteria aid in the production of proteases that then assist in fermented foods flavour and texture formation. Therefore, a number of proteases from multifarious strains of bacteria have been purified and characterized for industrial applications (Silva et al., 2011; Hsiao et al., 2014; Li et al., 2014).

Bacterial proteases are very important in the production of beverage products. For example, milk beverages when produced from the factory are shipped to a variety of retailers from where they are dispatched to the final consumer. Thus, enzymes present in milk beverages often aid the products to survive a variety of harsh conditions during transportation. LAB isolated from milk products are multiple amino acid auxotroph (Chopin, 1993). Apart from the common functional properties of proteases such as coagulation and gel strength and foaming, the catalytic function of proteases is relevant in the preparation of protein hydrolysates, which is found in most infant food products, fruit juice, and soft drinks (Neklyuyov et al., 2000; Gupta et al., 2002; Ashaolu and Yumanqui, 2018). In the dairy industry, proteases are primarily used in cheese manufacturing.
to hydrolyse specific peptide bonds to produce casein and macro peptides (Rao, 1998; Ashaolu, 2019b). In addition, the ability of proteases to hydrolyse connective tissues and muscle fibre proteins is applied in meat tenderization (Kumar and Takagi, 1999).

**Safety and Quality Needs of Functional Foods and Beverages**

It is paramount that there should be continuous improvement and development of newer starter cultures for the production of functional foods and beverages, in order to ensure safety and quality maintenance, as well as better defined and characterized bacterial strains meant for local foods fermentation. This can ensure more qualitative sensory properties of the food and beverage products. Additionally, pathogens found in fermented food products and beverages are largely due to unhygienic processing conditions, which should not be a problem due to much lower pH obtained during the fermentation process and the reduction of toxic metabolites (Ashaolu, 2019a). However, diverse contaminating avenues ranging from vessels used, starting raw materials to acidicophilic pathogens, cause huge health risks. Therefore, the benefits and risks found with fermentative and pathogenic bacteria should be critically investigated. Bacterial toxins are of health concerns in this regard and more pronounced in tropical developing regions of the world including

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**Table 1. Selected common fermented foods and beverages worldwide and their fermentative bacterial species**

| Fermented product | Raw material/substrates | Country/region | Bacterial species used |
|--------------------|-------------------------|----------------|------------------------|
| Amasi              | Milk (cow, various)     | Zimbabwe/Africa, East Africa | Lactococcus (L. lactis), Lactobacillus, Leuconostoc, Enterococcus. |
| Aryan              | Milk (cow, various)     | Turkey         | Lactobacillus bulgaricus, Streptococcus thermophilus |
| Garris             | Milk (camel)            | Sudan/East Africa | Lactobacillus (Lb. paracasei), Lb. fermentum, and Lb. plantarum, Lactococcus, Enterococcus, Leuconostoc. |
| Kefir              | Milk (cow, various)     | Eastern Europe | Lactococcus, Lactobacillus, Leuconostoc, Acetobacter. |
| Kivuguto           | Milk (cow)              | Rwanda         | Leuconostoc (Leu. mesenteroides, Leu. pseudomesenteroides) and L. lactis. |
| Koumiss            | Milk (horse)            | Eurasia        | Lactobacillus. |
| Kusmis             | Milk (cow)              | South America, Columbia | Lb. cremonis, L. lactis, Enterococcus (E. faecalis, E. faecium) |
| Nyarme             | Milk (camel)            | Ghana/West Africa | Lb. mesenteroides, Lb. bulgaricus, Lb. helveticus, Lb. lactis, L. Lactis. |
| Rob                | Milk (unspecified)      | Sudan          | Lb. fermentum, Lb. acidophilus, L. lactis, Streptococcus salivarius |
| Susac              | Milk (unspecified)      | Kenya          | Lb. mesenteroides, Lactobacillus (Lb. plantarum, Lb. crusat, Lb. salivarius, Lb. raffinolactis) |
| Shubat             | Milk (camel)            | China          | Lactobacillus (Lb. sakei, Lb. Helveticus, Lb. brevis), Enterococcus (E. faecium, E. faecalis), Lb. lactis and Weissella hellenica. |
| Boza               | Various (barley, oats, rye, millet, maize, wheat, or rice) | Balkans (Turkey, Bulgaria) | Leuconostoc (Leu. paranear المستويات، Leu. sanfranciscensis, Leu. mesenteroides), Lactobacillus (Lb. plantarum, Lb. acidophilus, Lb. fermentum). |
| Bushera            | Sorghum, millet flour   | Uganda         | Lactobacillus, Streptococcus, Enterococcus |
| Koko Sour Water    | Cereal (pearl millet)   | Ghana          | Weissella confusa, Lb. fermentum, Lb. salivarius, Pediococcus spp. |
| Kvass              | Rye bread, rye, and barley malt/flour | Russia | Lb. casei, Leu. mesenteroides |
| Pozol              | Maize                   | Mexico         | L. lactis, Streptococcus suis, Lactobacillus (Lb. plantarum, Lb. casei, Lb. alimentarium, Lb. delbrueckii), Bifidobacterium, Enterococcus |
| Togwa              | Maize flour, finger millet malt | Tanzania | Lactobacillus spp. |
| Hardaliye          | Maize flour, mustard seeds/cherry leaf | Tanzania | Lactobacillus spp. |
| Kombucha           | Tea                     | China, Worldwide | Gluconacetobacter (G. xylinus), Acetobacter, Lactobacillus Lb. Plantarum |
| Kivunde            | Cassava                 | Tanzania       | Pediacoccus acidilactici, Lb. pentosus, Lb. plantarum, P. pentosacnes |
| Sausages           | Meat, pork              | Italy, Thailand | Lb. kefiri, Lb. casei, Lb. brevis, Lb. plantarum, Lactobacillus lact subsp. lactis, L. lactis subsp. cremonis, L. lactis subsp. lactis biovar diacetylactis, Streptococcus lactis |
| Kefir              | Kefir grains, Cow’s milk | Iran, Spain    | Weissella cibara, W. confusa, W. koreensis. |
| Kimchi             | Cabbage                 | Korea          | Lb. mesenteroides, Lb. plantarum, Lb. casei, L. lactis |
| Sauerkraut         | Cabbage                 | China, USA     | L. acidophilus, L. rhamnosus, Streptococcus thermophilus, L. bulgaricus, L. casei, Lb. plantarum, P. jensenii, Propionibacterium freudenreichii |
| Fermented milk     | Milk                    | Europe         | Lb. plantarum, Lb. reuteri |
| Pla-som            | Fish                    | Thailand       | L. brevis, L. paralactinura, P. pentosacer, W. cibara, Leu. citreum, W. Koreensis |
| Sourdough          | Wheat                   | Greece, South Korea | Enterococcus casseliflavus Lactobacillus pentosus, Lb. plantarum Streptococcus thermophilus, Lactobacillus acidophilus, Lb. casei, Lb. paracasei, Bifidobacterium spp. |
| Fermented olives   | Green olives            | Spain          | Streptococcus thermophilus, Lb. delbrueckii subsp. bulgaricus |
| Cheddar cheese     | Milk                    | Ireland, Australia | Tetragnococcus, Halophilus |
| Yogurt             | Sheep milk              | Bulgaria       | Tetragnococcus, Halophilus |
| Sauce              | Soybean, fish           | Thailand       | Tetragnococcus, Halophilus |

Sources: Marsh et al. (2014), Macori and Cotter (2018), and Ashaolu (2019a).
Africa and South Asia. Furthermore, phytate, lectins, tannins, saponins, oligosaccharides, protein inhibitors, and cyanogenic glycosides serve as natural anti-nutritional elements in most of the raw materials employed in bacterial fermentation of foods and beverages (Ashaolu, 2019a). Therefore, fermented foods should be monitored properly for their nutrient content and safety. Most of the traditionally fermented beverages have not been thoroughly investigated for their alcohol content levels, which the modern-day consumer is interested in. This information can help to monitor the health of an individual. Finally, biochemical residues should be assessed in fermented foods.

Conclusions

The use of diverse bacterial strains especially LAB groups in the production of functional fermented foods and beverages has huge commercial applications with even more futuristic advantages. Since many functional foods and beverages are produced locally, it is recommended that several improvements be made on the safety and quality of the food products.

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Conflict of interest statement

The author declares no conflicts of interest.

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