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Influence of food matrix on the viability of probiotic bacteria: A review based on dairy and non-dairy beverages

Amal Bakr Shori

King Abdulaziz University, Faculty of Science, Department of Biological Sciences, Jeddah 21589, Saudi Arabia

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ABSTRACT

The food biotechnology industry has developed numbers of fermented products containing probiotic strains. Sufficient numbers of selected live probiotics in the products have several advantages for human health. Nowadays, there is increased demand for probiotic based beverages. The application of probiotic cultures in different food matrices (dairy and non-dairy based beverages), could represent a great challenge for viability of probiotics. The success of new probiotic beverages depend on capability of probiotics to provide enough numbers of viable cells that beneficially modify the gut microbiota of the host. Therefore, this article provides an overview of the application of probiotics in dairy and non-dairy based beverages and their viability during refrigerated storage.

Contents

1. Introduction

Consumer behavior towards food choice is changing due to the profound understanding in the relationship between diet and health (Mark-Herbert, 2004). Nowadays, consumers are increasingly demanding products fortified with probiotic bacteria (Stanton, Ross, Fitzgerald & Van Sinderen, 2005). Probiotics are defined as "live microorganisms which when administered in adequate amounts confer a health benefit on the host" (FAO/WHO, 2002). Scientific evidence supports the concept that these bacteria transit the gastrointestinal tract and help to maintain or create a favorable microbial condition to provide healthy digestive function and provide therapeutic benefits for the consumer (Madden & Hunter, 2002; Nomoto, 2005; Shanahan, 2002, 2004; Parvez, Malik, Kang & Kim, 2006). The most commercial probiotics available in the foods market are species of Lactobacillus and Bifidobacterium. Fermented beverages with probiotic bacteria are very important to the human diet around the world because fermentation is an economical technology that helps preserve the food, improve its nutritional value and enhance its sensory properties (Gadaga, Mutukumira, Narvhus & Feresu, 1999). Traditionally, the use of

E-mail address: shori_7506@hotmail.com

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probiotics in dairy beverages has been widely extended. However, since people who are allergic to milk proteins or have severe lactose intolerance cannot consume dairy beverages, non-dairy beverages such as fruits, vegetables and cereals juices may also represent an ideal vehicle to deliver probiotics to consumers (Kun, Rezessy-Szabo, Nguyen & Hoschke, 2008). The application of probiotic cultures in different food matrices based beverages could represent a great challenge. Different probiotic species show different sensitivities towards the acidity of the substrate, dissolved oxygen, post-acidification in fermented beverages, metabolism products, temperatures, dry and gastrointestinal tract conditions (Guérin, Vuillemard & Subirade, 2003; Vinderola & Reinheimer, 2003). Viability and metabolic activity of the bacteria are important features of probiotic inclusion in beverages. This is because the bacteria need to survive in the beverages during shelf life and gastrointestinal digestion (Tannock et al., 2000). To ensure health benefits can be delivered by beverages containing probiotics, the standard of a minimum level of viable cells of probiotic ranging from 10^6 to 10^7 cfu ml^{-1} at the expiry date has been recommended (Madureira, Amorim, Gomes, Pintado & Malcata, 2011). Therefore, the purpose of the present study is to review the application of probiotics in dairy and non-dairy based beverages and their viability during refrigerated storage.

2. Dairy based beverages

The success of probiotic dairy beverages is often limited by the subtle nature of the ingredients and anxiety over contamination or low viability of strains during storage. It is important that for probiotic strains selected maintain their viability and functional activity during the entire shelf-life of the product. Many factors may affect the viability of Lactobacillus spp. and Bifidobacterium spp. in dairy beverages including the probiotic strains used, pH, the presence of hydrogen peroxide and dissolved oxygen, the concentration of metabolites such as lactic and acetic acids, the medium buffering capacity, storage temperature and the nature of the added ingredients (Costa, Fonteles, de Jesus & Rodrigues, 2013; Donkor, Henriksson, Vasiljevic & Shah, 2006; Fonteles, Costa, de Jesus & Rodrigues, 2011; Pereira, Maciel & Rodrigues, 2011). Despite the fact that milk contains all the growth factors required by the probiotics, it is not always necessarily available in acceptable forms or in optimal concentrations (Gomes & Malcata, 1998). Several studies reported that vegetable and fruit juices or pulps addition (prebiotic) might be deleterious to the viability of some species and strains of probiotics in dairy beverages. This could be due to acidity and the presence of antimicrobial compounds such as organic acids (benzoic acid) and flavor compounds (Cleveland, Montville, Nes & Chikindas, 2001; Buriti, Komatsu & Saad, 2007; do Espírito Santo et al., 2012; Vinderola, Costa, Regenhardt & Reinheimer, 2002). Previous studies identified appropriate probiotic strains for incorporation into dairy beverages (Table 1).

The cheese whey and probiotic cultures use in the preparation of dairy beverages has been extremely attractive by food biotechnology industry. The supplementation of dairy beverages with whey protein concentrate (WPC) has a positive effect on the viability of *L. acidophilus* and Bifidobacterium during refrigerated storage. This occurs because of higher buffering capacity of whey proteins compared to caseins subsequently delaying the post-acidification during storage (Akalin, Gönç, Ünal & Fenderya, 2007). In addition, sulfur amino acid release during heat treatment of whey may lower the redox potential causing a positive effect on probiotic survival. Pescuma, Hébert, Mozzi, and de Valdez (2010) reported high viability of *L. acidophilus* CRL 636 (6 log cfu ml^{-1}) in WPC35 (WPC containing 35% of proteins)-based beverage formulated by mixing fermented WPC35 with peach juice or 2% (v/v) calcium lactate in peach juice (PL) at ratio of 1:3 (v/v). Another study emphasized the potential of the whey beverage as suitable food matrix for probiotic bacteria supplementation (Buriti, Freitas, Egito & dos Santos, 2014). Fermented whey-based goat milk beverage was prepared using *S. thermophilus* TA-40, *B. animalis* BB-12 and *L. rhamnosus* Lr-32. The study found that, the final product with pH 4.47 showed high population of *S. thermophilus*, *B. animalis* and *L. rhamnosus* that increased ($p<0.05$) from 7.58, 8.13 and 6.91 log cfu ml^{-1} to 9.29, 8.05 and 8.11 log cfu ml^{-1}, respectively (Buriti et al., 2014). The addition of guava or soursop pulps had no significant effects on the population of *B. animalis* and *L. rhamnosus* in the whey-based goat milk beverages (Buriti et al., 2014). However, both probiotics maintained good viability in the presence of either guava or soursop pulps. Refrigerated storage of whey-based goat milk beverages in the presence of guava or soursop pulps reduced ($p<0.05$) the viability of *S. thermophilus* (0.5 log cycle) and *B. animalis* (1 log cycle) but not *L. rhamnosus* that showed stability during 21 days of storage. The author suggested that these beverages could have beneficial health effects in the gut since the populations of both *B. animalis* and *L. rhamnosus* were above the minimum recommended level 6 log cfu g^{-1} for health benefits (Kongo, Gomes & Malcata, 2006; Salva et al., 2011). Castro et al. (2013) investigated six strawberry-flavored probiotic dairy beverages fermented with yogurt bacteria and 2% v/v *L. acidophilus* and different levels of cheese whey (0, 20, 35, 50, 65, and 80%; v/v). Regarding to *L. acidophilus* counts, whey level did not interfere ($p>0.05$) in the viability of *L. acidophilus* in the dairy beverages (Castro et al., 2013). This indicated that the capacity of *L. acidophilus* has no limit to metabolize the peptides present in the whey. All beverages showed viability of >8 log cfu ml^{-1} with average pH varied between 4.09 and 4.14 (Castro et al., 2013). However, whey contents greater than 65% resulted in lower acceptance by consumers. A study has found that, the viability of *L. acidophilus* in fresh whey-pineapple juice blend (65:35) reduced significantly ($p<0.05$) from 3.8×10^7 cfu ml^{-1} to 1.1×10^7 cfu ml^{-1} during 28 days of storage at 5 °C with pH ranged

Table 1
Application of selected probiotic bacteria in fermented dairy based beverages with prebiotic.

Beverage	Probiotic bacteria	Prebiotic substrates	References
WPC35 (WPC containing 35% of proteins)-based beverage	*L. acidophilus* CRL 636	Peach juice or 2% (v/v) calcium lactate in peach juice	Pescuma et al. (2010)
Whey-based goat milk beverage	*S. thermophilus* TA-40, *B. lactis* Bb-12 and *L. rhamnosus* Lr-32	Guava or soursop pulps	Buriti et al. (2014)
Dairy beverages	*S. thermophilus*, *L. acidophilus* and *L. delbrueckii*	Strawberry flavored	Castro et al. (2013)
Whey beverage	*L. acidophilus*	Pineapple juice	Shukla et al. (2013)
Yogurt-like drink	*B. lactis* Bb-12 and *L. acidophilus* LA-5	Corn fiber or inulin	Allgeyer et al. (2010)
Yogurt-like drink	*B. lactis* Bb-12 and *L. acidophilus* LA-5	Polydextrose	Allgeyer et al. (2010)
Milk	*L. acidophilus* LA5, *L. plantarum*, *L. rhamnosus* GG and *B. lactis* Bb12	Carrot juice	Daneshi et al. (2013)