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Review

Potential of berry extracts to control foodborne pathogens

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A B S T R A C T

Globally, foodborne diseases continues to be a serious public health problem. Among the infectious bacteria implicated in these diseases, non-typhoidal *Salmonella enterica* (NTS) serovars are the major cause of hospitalization and death, followed by *Campylobacter*, *Clostridium perfringens*, *Escherichia coli* O157:H7, and *Listeria monocytogenes*. In addition, the emergence and spread of antibiotic-resistance strains among these bacteria is becoming a worldwide food safety issue. This rise of resistance led to the restriction of antibiotics use in animal productions in the European Union and application of a possible similar action in the North America. To limit the use of antibiotics in agricultures while satisfying the consumer demands, effective alternative approaches to maintain the animal health and productivity as well as to preserve food need to be explored. In this context, the plant-derived antibacterial compounds could provide novel approaches to control pathogenic bacteria in food industry. In this paper, we review the potential of three different berries (cranberries, blueberries and strawberries) extracts, as alternative antibacterial products against foodborne pathogens. These extracts show various antimicrobial activities against Gram positive (*Listeria*, *Staphylococcus aureus, and Clostridium perfringens*) and Gram negative (*Salmonella enterica*, *E. coli* and *Campylobacter* spp.) bacteria. Berry extracts seem to have a pleotropic mode of actions against foodborne bacteria. Several studies on proanthocyanidins from cranberry demonstrated its bactericidal action through anti-adhesion activities and free iron sequestration. Blueberry phenolics were reported to decrease cell auto-aggregation, motility and affect the cellular hydrophobicity. Similar action was observed with strawberry extracts due to their immobilizing capacity. Key research gaps include the effects of processing, bioavailability and detail mechanisms of action of berry compounds.

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1. Introduction

Healthy food-producing animals can carry many pathogenic bacteria, including *Salmonella*, *Staphylococcus aureus*, *Campylobacter* spp., *Clostridium perfringens*, *Listeria monocytogenes* and *Escherichia coli* O157:H7 which can contaminate the food chain at slaughterhouses and during processing. Despite substantial efforts, these bacteria continue to cause considerable economic losses for the food industry and serious public health issues (Scallan, Hoekstra, Mahon, Jones, & Griffin, 2015). According to the Center for Disease Control and Prevention (CDC), an estimated 48 million foodborne illnesses occur every year in the United States of America (USA), resulting in 128,000 hospitalizations and 3000 deaths (Robertson et al., 2016). In Canada, about 4 million (1 in 8) Canadians are affected by a foodborne illness every year (Thomas et al., 2013). While there is a considerable decline in the number of foodborne illnesses, rates of *Salmonella* outbreaks remained relatively unchanged. It is estimated that non-typhoidal *Salmonella enterica* (NTS) serovars are the most common cause of death and economic losses among all foodborne pathogenic bacteria (Hoffmann, Batz, & Morris, 2012). In humans, infectious foodborne diseases are generally contracted through the consumption of contaminated foods of animal origin (mainly eggs, meats and milk products); although various other non-animal derived foods, including green vegetables and nuts have also been implicated in these diseases (Callejón et al., 2015). *Salmonella*, for example, can pass through the entire food chain from animal feed, primary production, and make its way to food preparation steps in households or at the food-service establishments and institutions.

The use of antibiotics in agriculture and animal husbandry, not only for therapeutic purposes but also to increase animal productivity as growth promoters, has been reported to contribute to the emergence and spread of antibiotic resistant foodborne pathogens such as *Salmonella* serovars and *Campylobacter* spp. (Aarestrup, 1999). In the USA, 24.6 million pounds (9.9 million kg) of antimicrobials are used annually, mostly for nontherapeutic production in chickens, cattle, and swine. Approximately 88% of growing swine receive antibiotics such as tetracycline or tylosin in their feed for disease prevention and/or growth promotion (Landers, Cohen, Wittum, & Larson, 2012). In 2014, antibacterial resistance (ABR) surveillance of World Health Organization (WHO) from 129 Member States showed that resistance to common antibiotics has reached alarming levels in many parts of the world. For example, methicillin-resistant *S. aureus* (MRSA) proportions exceed 20% in all regions investigated by WHO; proportions of *E. coli* resistance to third-generation cephalosporins and fluoroquinolones were 85% and 90%, respectively in the investigated countries; *S. enterica* serotype Typhimurium, multi-resistant to ampicillin, chloramphenicol, streptomycin, sulfonamides and tetracycline present a serious public health concern (WHO, 2014).

Polyphenolics and non-phenolic constituents of berries, such as cranberry, blueberry and strawberry, have been found to disintegrate the outer membrane of Gram negative bacteria which in turn decrease their viability (Puupponen-Pimiä, Nohynek, Alakomi, & Oksman-Caldentey, 2005a; Wu, Qiu, Bushway, & Harper, 2008). It is well known that antibiotic treatments can have side-effects, such as diarrhea, which dis-equilibrate gut microbiota and result to the elimination of beneficial microbes and the selection of resistant strains among the target pathogens (Kim, 2015). In this context, the phytochemicals in berry fruits could confer antimicrobial activities while potentially limiting the development of antimicrobial resistance within the host (Vattem, Lin, Labbe, & Shetty, 2004). Moreover, producers and consumers are becoming increasingly health conscious and the presence of antibiotic or other chemical residues along with the antibiotic-resistant bacteria in food is receiving considerable attention raising the demand for organic and minimally processed food. The present review focuses on the increasing concerns of foodborne illness outbreaks along with the antibiotic resistance. In addition, we also describe the potential of berry products which could be developed as natural alternatives to antibiotics to control a wide range of foodborne pathogens. Consideration was limited to the American cranberry (*Vaccinium macrocarpon*), lowbush (*V. angustifolium*) and highbush (*V. corymbosum*) as well as other blueberries such as, *V. alaskaense, V. boreale, V. caesariense*, *V. constablaei* and strawberry (*Fragaria*, spp.) which are native to North America.

2. Foodborne diseases and their causal agents

Foodborne diseases have important negative public health consequences causing morbidity and mortality worldwide. However, the full extents and costs of unsafe food, and especially the burden arising from chemical and biological contaminants in food, are currently still unknown. Foodborne diseases can be caused by a broad group of pathogens. From the early 1990's until now, three major foodborne pathogenic bacteria (*Salmonella*, *Campylobacter* spp. and *E. coli*) have been the most-focused research subjects for both government agencies and food industries (Newell et al., 2010). Foodborne pathogens are emerging and re-emerging due to a number of factors. They (*E. coli* O157:H7 and *Salmonella*) are able to sustain their presence in human or animal reservoirs and can contaminate food (milk, meats, eggs) via the excreta of infected subjects or crops when contaminated manures are used as fertilizers.

Since the mid-1980s, *S.* Enteritidis has been a major cause of human salmonellosis in Europe and North America (Threlfall et al., 2014). Outbreak investigations and targeted studies implicated chicken and egg as sources of increasing incidences of infections due to this pathogen in human between 2005 and 2010. From February 3rd to October 14th, 2014, the largest live-poultry-associated salmonellosis outbreak in the USA was described with

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