Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 17, No. (3) : 2015 : 763-774
© Global Science Publications
ISSN-0972-3005

FOODBORNE DISEASES, PROBIOTICS AND HEALTH

ALEJANDRO DE JESÚS CORTÉS-SÁNCHEZ*[1], MAYRA DÍAZ-RAMÍREZ[2], MARIA DE LA LUZ SÁNCHEZ-MUNDO[3], ALAN JAVIER HERNÁNDEZ-ALVAREZ[4] AND LIDIA R. BARRÓN-SOSA[1].

[1] Comisión Federal para la Protección contra Riesgos Sanitarios (COFEPRIS). Comisión de Control Analítico y Ampliación de Cobertura. Departamento de Microbiología. Calzada de Tlalpan 4492, Tlalpan, México D.F.
[2] Departmento de Ciencias de la Alimentoction, Division de Ciencias Biologicas y de la Salud, Universidad Autónoma. Hidalgo Poniente 46, Col. La Estaction, Lerma de Vellada Estado de Mexico. 52006, Mexico
[3] Instituto Tecnológico de las Choapas. Veracruz México. Departamento de posgrado e investigación. Carretera Las Choapas-Cerro de Nanchital Km 6 Col. J. Mario Rosado, Las Choapas Veracruz, México.
[4] Food Research and Development Centre, Agriculture and Agri-Food Canada, 3600 Casavant Blvd. W. St. Hyacinthe, QCJ2S 8E3, Canada.

Key words: *Probiotics, Foodborne diseases, Functional foods, Bacteriocins, LAB.*

Abstract–Foodborne Diseases (FBD) has arisen as an important cause of high morbidity and mortality, which is translated nowadays as a world public health issue. On the other hand, a social demand is increasing every time higher for nourishing, fresh foods and food safety, which could help to improve the life's quality of the consumer (preventing or reducing the risk of suffering a certain disease or simply by improving the health condition). To face these topics, a different variety of studies have been carried out focusing on the research of probiotics as an alternative to mitigate these social demands and public health problems; this by means of the use of microorganisms considered as probiotics such as lactic acid bacteria (LAB), or in respect to their natural protein metabolites (bacteriocins), in the production and/or conservation of a wide variety of foods. In the present review a general panorama of different foodborne diseases is exposed, as well as their causal agents, impact in México and different countries around the world. In addition the importance of food safety is assessed, and their relation with probiotics, the benefits to human health derived from their consumption and/or their employment in food shell-life.

INTRODUCTION.

Foodborne Diseases (FBD) are caused by food or beverages ingestion that contains pollutants (microorganisms or chemical substances) of endogenous origin, or as well as acquired during some point of their transformation or manipulation, in sufficient quantities which can affect the health's consumer in an individual or collective manner. There exists a wide variety of FBD's which present different symptomatology, depending on the type of pollution and the quantity of ingested food (Delgado *et al.*, 2003; Kooper *et al.*, 2009). There have been described approximately 250 producing agents of FBD's which includes bacteria, virus, fungi, prion parasites, toxins and heavy metals (Olea *et al.*, 2012). Between the most common symptoms are vomits and diarrhoeas even though other symptoms can be present such as abdominal pains, headache, fever, neurological symptoms, double vision, among others. Furthermore certain FBD's can produce long-term chronic diseases such as renal damages, arthritis, meningitis, and abortion and in severe cases death (Gonzalez and Rojas, 2005; Kooper *et al.*, 2009; WHO, 2014). The microbial and parasitic FBD's are those originated by the consumption of water and food contaminated with pathogenic microorganisms, parasites or toxins (Gonzalez and Rojas, 2005; Parrilla-Cerillo *et al.*, 1993). The FBD's are divided in food infections and food poisonings (Fig. 1) (Kooper *et al*., 2009).

Food infections are those diseases which are caused mainly by ingestion of foods that contains and transports live harmful microorganisms. Which once in the intestine are multiplied, lysate and *per se* generating toxins and/or invasion of the intestinal wall to reach other systems of the host, besides of showing long incubation times. Some well-known

***Corresponding author's email**: Alejandro De Jesús Cortés-Sánchez**,** alecortes_1@hotmail.com

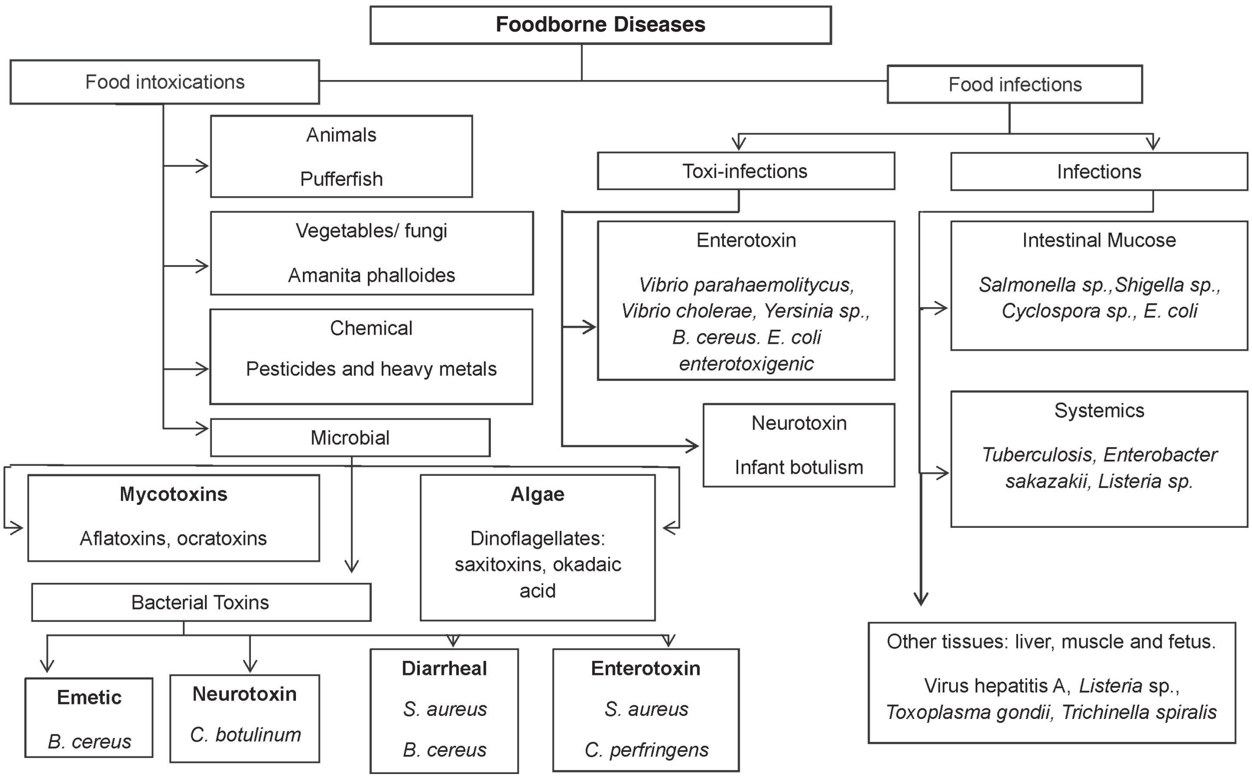

Fig. 1. Classification of foodborne diseases transmitted by foods (FBD) and most common causal agents (Kooper *et al.*, 2009).

food infections are the salmonellosis, listeriosis, trichinosis, hepatitis A and toxoplasmosis. On the other hand food poisonings are diseases generated by the consumption of foods in which the toxin is formed in the tissues of plants or animals or as a microorganism metabolite. Some food poisonings are the botulism, *Staphylococcus* poisoning or toxins produced by fungi or marine species such as ciguatoxine, saxitoxine, among others; likewise in this category the poisonings caused by chemical substances are also included, these could be added in the food by accidental or intentional means, like pesticides, heavy metals or others (Caballero, 2008; Kooper *et al.*, 2009).

In addition another type of FBD's exists which associates the poisoning with the infection and are known as toxi-infections, in which the infection period is generally minor to that of the infections but higher than that of the poisonings. These diseases are the result of food infections with a certain quantity of pathogenic microorganisms that once consumed are capable of producing or liberating toxins; the producing microorganisms (bacteria) are not of invasive character and produce toxins during its development in the host intestine (Kooper *et al.*, 2009).

FBD's are considered as a problem of public health importance due to a diversity of factors which involves the increase in incidents, generated deceases, the appearance of new ways of transmission, vulnerable population groups, the increase of the pathogens resistance to antimicrobial compounds used for treatments and the socioeconomic impact that they cause (Gonzalez and Rojas, 2005; Olea *et al.*, 2012). The appearance of these diseases is a direct indicator of the sanitary - hygienic quality of foods, showing that besides the fact that the pollution of these can happen along their processing or for the employment of contaminated raw material, since different human pathogenic bacteria are part of the normal poultry, porcine or bovine livestock destined to human consumption (Gonzalez and Rojas, 2005).

Some of the principal pathogenic microorganisms transmitted by food that can affect seriously any individual are: *Campylobacter jejuni, Clostridium botulinum, Clostridium perfringens, Escherichia coli (E. coli)* pathogenic, *Listeria* *monocytogenes*, *Norovirus* (Norwalk type virus), *Salmonella enteritidis*, *Salmonella typhimurium*, *Shigella spp.*, *Staphylococcus aureus*, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Vibrio vulnificus* and *Yersinia enterocolitica* where even some vulnerable groups such as pregnant women and babies are the most affected, some of these pathogens can be seriously harmful and even produce fatal consequences (FDA, 2014).

Foodborne diseases in México and different regions of the world

Estimations of the World Health Organization (WHO) reported 1500 million cases of diarrheas pear year (Olea *et al.,* 2012). In agreement with the information provided by The Pan-American Health Organization (PAHO) the FBD's are between the first 5 causes of deaths in 5-year-old children in the region and annually there's a clear high increase of morbidity and mortality, due to mentioned above, measures of diffusion have been implemented in the population to guarantee the hygienic food preparation and incidents reduction. In addition the Center for Disease Control (CDC) in the United States estimates that annually 76 millions of persons contract FDB's, where more than 300,000 require hospitalization and 5,000 American citizens passed away because of the above mentioned diseases generating a high cost for the health sector (Caballero,2008; Olea *et al.,* 2012). On the other hand the National Network of Epidemiological Vigilance of Spain registered for the 2004-2007 period a total of 3,511 outbreaks of diseases transmitted by food (excluding water sources), resulting in 2,965 hospitalizations and 35 deaths cases, being the principal causal agents the bacteria (generally the *Salmonellas* group) followed by virus, toxic substances and parasites, being the egg and egg products the main foods implied in such cases, including mayonnaises and meat (except poultry) (Martínez *et al.*,2008). In France and Germany in 2010 only a total of 503 and 392 FDB's outbreaks were reported respectively, whose etiological agent were bacteria giving place to a total of 311 hospitalizations in France and 236 in Germany, without any decease in both countries (Instituto Nacional de Salud Pública, 2014).

On the other hand during nine years in the Latin-American and Caribbean region it has been assessed 6,511 reports of FDB's outbreaks corresponding to 22 countries; where Cuba showed more than 54% of the total reports. Those outbreaks were reported as follows: 57 % was due to bacteria, 12% to virus, 21% marine toxins and 10% caused by parasites, chemical pollutants and vegetal toxins (Barreto *et al.,* 2010), in spite of the previous data there's still a lack of knowledge in respect to the real magnitude of FBD's due to the low index of patients who attends to welfare centers for consultation and/or prevention, being a small percentage of official reports due to gastrointestinal symptoms (Olea *et al.,* 2012).

In different industrialized nations, it has been observed an increase of incidents of this type of diseases. Besides that several microorganisms of pathogenic importance have been isolated from foods of which it was not thought that they would be able to proliferate, showing some resistance to different processing technologies and food storage, and furthermore for a long time were considered as safe, have generated so far an alert spot for the food processing industry. In countries with systems of epidemiological vigilance such as Mexico, only at the end of the 80's decade, barely 3,419 cases of brucellosis, 9,790 of shigellosis, 10,939 of typhoid, 30, 899 food poisonings not specified, 72,754 of salmonellosis and 1,948, 542 of other intestinal infections, which gives a total of 2, 076, 343 episodes related to foodborne diseases were reported (Parrilla-Cerillo *et al.,* 1993).

In 2001 the Secretary of Health in México reported that the gastrointestinal diseases originated by bacteria or parasites, occupied the fourteenth reason of national deceases, being the states of Chiapas, Oaxaca, Guanajuato, Veracruz, Puebla and Distrito Federal with the higher number of cases. And finally for 2003 a governmental study reported 4,556 deceases caused by intestinal infections (Hernández *et al.,* 2011) being foods such as eggs, meat, chicken, dairy products, vegetables, seafood, canned foods, among others, the principal sources identified as outbreaks of gastrointestinal diseases, at the end of the decade of the 80's as well as the first years of the 21st century; nevertheless it is necessary to highlight that the type of food as a source of disease varies in accordance to certain characteristics of each country/location and the patterns of consume and production among the population (Parrilla-Cerillo *et al.*,1993; Hernandez *et al.,* 2011).

Microorganisms involved in the development of diseases transmitted by food (FBD)

Public health statistics in the last years estimates that there are more than 30 different microorganisms capable of generating diseases to consumers after the consumption of contaminated foods. Several of these microorganisms are recognized as pathogenic, generating several diseases in the consumers for years and which are considered "traditional" such as: *Clostridium perfringens, Clostridium botulinum, Staphylococcus aureus, Bacillus cereus*, members of the genus *Shigella spp. y Salmonella spp*. Being the latter mentioned microorganisms responsible of the major number of infections caused by contaminated foods (Diez, 2012).

Nevertheless, it has been observed a several number of cases in which microorganisms that were not known as disease-causing agents transmitted through food ingestion, have arisen turning into an important area of attention for the public health agenda. These microorganisms are known as emergent pathogens giving place equally to FBD's of emergent character. This definition can be subjected to several interpretations, since some of these pathogens are completely new, others were already identified but now they possess new characteristics. On the other hand, they are considered to be as emergent for being responsible of diseases which their incidence in patients has increased during the last years or that might be increased in the near future, as well as being the new responsible of new diseases or diseases which are established with different clinical signs (Hernandez, 2010; Diez, 2012).

Between the pathogenic emergent microorganisms we can find *Escherichia coli* O157 enterohemorrhagic (capable of causing complications as the hemolytic uremic syndrome affecting kidneys, and causing death), *Listeria monocytogenes* (it causes infection in different organs in the body, including the nervous central system and in pregnant women it can cause spontaneous abortions, distinguished as the most lethal infection transmitted by foods), *Salmonella enteritidis* principally A fagotype though salmonellosis are catalogued as "classic" in recent years, some serotype have showed special properties that have turned them into etiologic agents of emergent salmonellosis, *Vibrio cholerae* O1 and O139, *Vibrio parahaemolyticus, Vibrio vulnificus, Cryptosporidium parvum, Giardia lamblia, Toxoplasma gondii, Cyclospora cayetanensis,* Norovirus, Rotavirus, Adenovirus, Saprovirus, Astrovirus, Coronavirus, Aichivirus, Virus of Hepatitis E and A, *Campylobacter jejuni*, *C. coli, Yersinia enterocolitica, Clostridium botulinum,* prions and recently or in the near future other *E. coli* enterohemorrhagic producers of Shiga toxin, as well as *Staphylococcus aureus* methicillin resistant, *Saccharomyces boulardii, Yersinia pseudotuberculosis, Arcobacter* spp., *Cronobacter* spp. Complex *Enterobacter cloacae, Bacteroides fragilis, Mycobacterium avium* subsp. *paratuberculosis* (Hernández, 2010; Diez, 2012; Quevedo, 2014).

It has been considered that multiple factors can boost the rise of FBD's pathogenic emergent generators, among some of them are: genetic resultant modifications of the acquisition of new genes and the loss of others, mechanisms of genetic recombination, horizontal transmission of virulence factors, antimicrobial agents resistance, new methods of processing and food storage and inadequate controls for the protection of public health, as well as demographic and nutritional behavior changes of the population with new nourishing habits based on the consumption of prepared and precooked meals and of services of collective restoration with the negative consequences in sanitation; derivate of mistakes during managing and control of the foods. In addition the incorporation of microbial inactivation processes in the food processing industry used for minimally processed foods has given place to diverse types of stress and sub-lethal treatments, which have facilitated microbial resistance to a certain stress conferring resistance to other microorganisms. A higher consumption of vegetables, fruits and juices has also enhanced an increase in the number of FBD's outbreaks, due to the possibility that some virus and members of the *Enterobacteriaceae* could remain in the agricultural land, by forming biofilms, internalizing and surviving in fruits and vegetables as well as a wide variety of preservative processes which enables avoiding cleanliness and disinfection treatments, promoting the outbreaks by the consumption of vegetables. On the other hand the globalization in the areas of commercialization and tourism has favoured the distribution and dispersion of pathogenic agents since the production and commercialization of foods on a large scale enables their diffusion and the possibility of cross-contamination. Likewise, the existence of other factors that contributes to the appearance of these diseases such as vulnerable groups (children and elderly), malnutrition, gestation stage, hospitalization, antibiotics consumption, alcoholism and the increase of a immuno-depressed population by diseases such as the acquired immunodeficiency syndrome (AIDS) or for immune-suppressants agents in therapies like cancer and organs transplants. Furthermore is important to take into account the fact that some microorganisms are responsible for permanent injuries or generation of sequels (Hernández, 2010).

The food processing industry therefore must be focused on the food production without health risks, adopting a food safety philosophy, throughout the application of a series of factors, procedures and conditions of safety such as the Hazard Analysis and Critical Control Points (HACCP) of compulsory use, the traceability, Codex Alimentarius, Good Agricultural Practices, Good Manufacture Practices, training of personnel dedicated to the production and food processing by governmental entities of the food and health agencies (Arispe and Tapia, 2007; Kooper *et al.,* 2009; Albo, 2010), the risks analysis, as well as the application of physical technologies (irradiation, electromagnetic waves, sonication, electrical intense pulses, use of high hydrostatic pressure), chemical, biological (organic acids and antimicrobial agents as protective cultures, probiotics, bacteriophages and/or bacteriocins) and the employment of multiple or combined barriers. All that reinforced in addition with the use of qualitative and/or quantitative detection systems for pathogens in a reliable and precise manner for the consumer safety and producing brand food prestige (Hernández, 2010; Diez, 2012; Quevedo, 2014).

The development of legal procedures for the prevention and microbiological quality control of foods can contribute to FBD's reduction due to bacterial organisms, although taking into consideration the consumers protection by means of the employment of vaccines, probiotics and functional foods, in which some of them should present certain molecules in their intrinsic composition showing proven biological activity as a potential prevention measure against FBD's pathogenic microorganisms (Hernández, 2010).

The intestinal human microbiota, probiotics and health

The man's gastrointestinal tract (GT) is a highly specialized ecosystem that it has evolved with time microbiologically as well as physiologically, is one of the most metabolically active systems and of high diversity in the human body. The intestine and the related microbiota cannot be analyzed as separated entities since it represents a dynamic system in co-evolution since birth. The GT is constituted of regions adapted for the mediation of diverse functions, many of which have shown a crucial effect in the health and well-being of the guest. The physiological characteristics in each region will be affected by the type of initial bacterial culture and bacterial strains colonizers; therefore causing different micro-atmospheres along the intestine that influence the metabolism, protection and immune stimulation, with effects both at local and systemic level due to the connection of the gastrointestinal system with the vascular, lymphatic and nervous system. This way the capacity of the intestines to form and maintain its beneficial microbiota against the pathogens and opportunistic bacteria in a beneficial communal structure is fundamental for the guest health and also to reduce the risk of diseases (Grady and Gibson, 2005; Sanz *et al.*, 2006).

The microbiota diversity as for type and proportion of the population in the GT is due to several factors such as crossing times, secretions and nutrients availability, besides the interaction between microorganisms and their environment to assure survival alongside possible competitors; this by means of different mechanisms as an increase of the anaerobic environment or a production of a wide variety of antimicrobial compounds (Grady and Gibson, 2005).

The gastrointestinal human microflora consists approximately of 300-500 bacterial species. In a healthy individual after the birth, the intestinal flora colonizes rapidly the food tract remaining the intestinal microflora relatively constant and even though its proportion and type depends on diverse factors, such as the use of antibiotics, the diet or different pathologies (diabetes, hepatic encephalopathy, cancer or atopia) it's not easy to modify it for a definitive manner (Lorente *et al.*, 2001; Guarner, 2002; Quera *et al.,* 2005). Among the different microorganisms found along different sites of the gastrointestinal system as the colon has been found anaerobic bacteria such as: *Bacteroides*, *Bifidobacterium*, *Clostridium*, *Eubacterium*, *Lactobacillus*, *Peptostreptococcus*, *Peptococcus*, *Porphyromonas*, *Ruminococcus*, facultative anaerobics like *Enterococcus*, *Escherichia coli Enterobacteriaceae* (*Escherichia coli*), *Staphylococcus*, *L. acidophilus*, *L. bulgaricus*, *L. casei (rhamnosus)*, *L. johnsonii*, *L. lactis*, *L. plantarum*, *L. reuteri*, *B. adolescentes*, *B. bifidum*, *B. breve*, *B. infantis*, *B. lactis*, *B. longum*, *Bacillus cereus*, *Enterococcus faecalis*, *Escherichia coli*, *Saccharomyces boulardii*, *Saccharomyces cerevisiae* and *Streptococcus thermophilus* (Quera *et al.,* 2005).

The ingestion of certain bacteria allows the maintenance of a certain type of microorganisms, in this context the concept of probiotic is born, which is defined as those microorganisms (bacteria and yeasts) pure or in mixed active cultures that when consumed in adequately quantities by human and animals can exert a beneficial effect in the guest health (Lorente *et al.*, 2001; Quera *et al.*, 2005; Anadón *et al.*, 2006; Ramírez *et al.*, 2011; Diosma *et al.*, 2013) (Table 1). Also the concept of "ideal probiotic" has been established, which is the one that would must present the majority of the following particularities: skill to adhere to cells, to multiply, and the ability to generate chemical compounds against the growth of pathogens (organic acids, bacteriocins, among others), GRAS, non-invasive, non-carcinogenic, non-pathogenic, and be capable to co-aggregate to form part of a normal well-balanced flora (Zamora-Vega *et al.*, 2014).

Several studies have shown the beneficial effects of probiotics in human health, through different mechanisms such as lumen acidification, synthesis of substances which inhibits the growth of pathogenic microorganisms (Lorente *et al.*, 2001; Castro and De Rovetto, 2006), adhesion interference and inhibition of pathogenic flora bacterial propagation, bacteriocins production, inhibition of bacterial translocation and increase of epithelial function through the boost of actin phosphorylation and tight junction occlusion. The probiotics have the ability to modulate the surface of dendritic cells as well as the release of cytokines, which could contribute in the treatment of intestinal inflammatory disorders (Quera *et al.*, 2005). Furthermore clinical analysis have evaluated their use in the prevention and treatment of gastrointestinal diseases, caused mostly by pathogenic microorganisms (virus and bacteria) or by an alteration of the characteristic microbiota, showing positive effects on health (Gonzalez *et al.*, 2006; Narayan, 2010).

Also probiotics have other properties with positive effects on human health such as reversion to symptomatology of low digestion (lactose intolerance) (Suarez, 2013), ulcerative colitis, diarrhea associated to rotavirus, antibiotics intake and *Clostridium difficile*, traveler´s diarrhea, child diarrhea, irritable bowel syndrome (IBS), pouchitis and Crohn´s disease (Quera *et al.*, 2005; Vidal, 2006). Likewise, probiotics possess immunomodulatory properties (Marquina and Santos, 2001) as modified the antigens response due to an increase of specific IgA secretion against pathogens such as rotavirus, it also facilitates the antigens uptake in the Peyer's plaque, produces hydrolytic enzymes and decreases intestinal inflammation. Otherwise, probiotics also help to avoid the growth of bacteria which has the ability to convert the pro-carcinogens into carcinogens (Lorente *et al.*, 2001; Anuradha and Rajeshwari, 2005), the pro-carcinogens enzymes intake or inhibitory substances production of these enzymes (glucosidase, β-glucuronidase, azoreductase and nitroreductase associated with the pre-carcinogens to carcinogens conversion) which probably reduce the development of certain tumors (Lorente *et al*., 2001; Castro and De Rovetto, 2006). Moreover the probiotics increase the bile salt hydrolases activity, which binds the cholesterol and facilitates its elimination, showing a hypocholesterolemic effect, through the production of short-chain triglycerides which inhibits

Table 1. Microorganisms considered and/or used as probiotics.

Microorganism	Genus and specie
Bacteria	*Bifidobacterium adolescentes, Bifidobacterium animalis subsp. Lactis, Bifidobacterium bifidum, Bifidobacterium brevis, Bifidobacterium infantis, Bifidobacterium longum, Lactobacillus acidophilus, Lactobacillus amylovorus, Lactobacillus casei, Lactobacillus crispatus, Lactobacillus delbrueckii subsp. Bulgaricus Lactobacillus delbrueckii subsp. Lactis, Lactobacillus fermentum, Lactobacillus gallinarum, Lactobacillus gasseri, Lactobacillus helveticus, Lactobacillus johnsonii, Lactobacillus paracasei, Lactobacillus plantarumLactobacillus reuteri, Lactobacillus rhamnosus, Lactobacillus salivarius, Enterococcus faecalis, Enterococcus faeciumLactococcus lactis subsp. Lactis, Streptococcus lactisStreptococcus cremoris, Streptococcus salivarius, Streptococcus intermedius, B. subtilis, Leuconostoc ssp., Pediococcus ssp., *Propionibacterium ssp.*
Yeasts and Fungus	*Saccharomyces boulardii, Saccharomyces cerevisiae, Aspergillus oryzae, Kluyveromyces ssp., Candida pintolopesii.*

**(potential candidate group to be used as probiotic).*Anadón *et al.*, 2006; Vidal, 2006, Rubio, 2008; Narayan *et al.*, 2010; Chukeatirote, 2003; Anuradha and Rajeshwari, 2005.

cholesterol synthesis, redistributing them from the plasma to the liver and via bile salts de-conjugation, the cholesterol is not re-absorbed and is used for the synthesis of *de novo* bile acids (Lorente *et al.*, 2001).

It is suggested that the probiotics could be effective in the immune response in order to prevent allergenic reactions in child and also could affect negatively the growth and survival of *Helicobacter pylori* (bacteria involved in the duodenal ulcer development and in gastric cancer risk factor) inhibiting the adherence of glycolipids receptors and reducing the urease activity (Castro and De Rovetto, 2006).

Nowadays there are many foods which are considered as a probiotics source and are commercial authorized (mainly as nutritional supplements specifically in countries like USA). Many of them containing viable cells of lactic acid bacteria being the dairy products the conventional vehicle to commercialize them such as yogurt, pickles, sausages, cheese, ice cream or butter, also it has been identified other food products as soy milk, mayonnaise, juices, peanuts, and soups (Vidal, 2006; Ramirez *et al.*,2011). However we have to consider that there are different factors which affect the viability and survival of probiotics cells as follows: pH, oxygen dissolved, antagonist interactions between species, chemical composition of the media culture, final sugar concentration, inoculation practices, temperature and duration of fermentation and storage product conditions (Olagnero *et al.*, 2007). Therefore, an efficient food vehicle of probiotics needs that the culture added during the process remains viable at high concentrations during its storage and through the gastrointestinal path to guarantee its potential benefic effect in the host. Some authors have proposed different concentrations from 10^6 to 10^{10} UFC/ g or mL per product to generate the proposed effects on the consumers health (Gonzalez *et al.*, 2006; Parra, 2010).

Probiotics safety

Many probiotics are commercialized like foodstuffs or drugs, being of vital importance the safety knowledge of their use. The safety of some traditional probiotics has been recognized though the experience, such as lactic acid bacteria (LAB) from *Lactobacillus*, *Leuconostoc*, and *Pediococcus* genres, which have been used in food processing along the human history while Biofidobacteria are present in natural form in the gastrointestinal tract of breast-fed infants. Until now, the safety of these microorganisms has not been questioned, they are generally well tolerated and they do not seem to be a risk for health; few harmful information about their use has been reported and rare adverse events such as endocarditis, fungemia, bacteremia, diarrhea had appeared but are extremely rare (Lorente *et al.*, 2001; Ishibashi and Yamazaki, 2001; Quera *et al.*, 2005). Otherwise species from *Lactobacillus*, *Leuconostoc, Pediococcus, Enterococcus* and *Bifidobacterium* genres have been isolated from a wide variety of different infectious lesions, questioning their safety as probiotics. There are many factors which have been considered in the probiotics evaluation safety (*in vitro*, animal and/or clinical studies), such as pathogenicity, non-infectious behavior and virulence, even though other factors such as toxicity, metabolic activity and intrinsic properties of these microorganisms have to be taken into account. Some researchers have supplied different methods to evaluate the safety of the acid lactic bacteria (ALB), indicating that some cultures considered like probiotics comply with the safety requirements. An assessment of pathogenicity and infectiveness are required for the probiotics safety but the isolation of lactic acid bacteria (LAB) from clinical infections, have increased the discussion about their security, however these LAB and Biofidobacteria have been considered non-infectious and with a low probability of general infectivity. The isolation of these bacteria from infections is probably the result of opportunistic infections. Therefore the increase of this type of isolations could be due to greater knowledge of their role in the cause of opportunistic infections (Ishibashi and Yamazaki, 2001).

The probiotics and the foodborne diseases

Among the microorganisms categorized as probiotics, are the group called lactic acid bacteria (LAB). Many of the LAB are considered commensal without pathogenic potential, gram positive prokaryotes, some genres are *Lactobacillus, Leuconostoc, Lactococcus, Bifidobacterium, Weissella, Streptococcus,* and *Enterococcus* (Chukeatirote, 2003; Neira, 2006; Castro and De Rovetto, 2006; Ramírez *et al.,* 2011). The LAB is a group of microorganisms which mostly grows at a pH of 4-4.5, the temperature is a key factor of their growth, being mesophiles (20-25°C) or thermophiles (40-45°C); furthermore they share morphological, physiological and biochemical characteristics (coccus or bacillus, width from 0.5 to 0.8 µm, nonspore, non-mobile, without cytochromes; anaerobic and microaerofilics, oxidase, catalase and bencidin negatives and they cannot reduce the nitrate to nitrite). They are generally used in the food industry in fermentation processes such as yogurt, cheese, pickles, sausage production and are also involved in beer and wine elaboration and used as food supplements, additionally are widely used in the livestock and farming industry to improve animal production (Parra, 2010; Ramírez *et al*., 2011), they are present in natural form in fruits, vegetables, milk products, meat and in fact in the digestive tract and reproductive systems (vagina) of mammals. In this way LAB are responsible for the fermentation of different foods as they facilitate their preservation/shelf-life by the production of different chemical compounds as CO_2, H_2O_2, bacteriocins, exopolysaccharides and lactic acid improving sensorial characteristics (odor, flavour and texture), nutritional quality, shelf-life and the safety of the final product (Neira, 2006; Parada *et al*., 2007; Rattanachaikunsopon and Phumkhachorn, 2010; Ramírez *et al*., 2011; Serna and Enríquez, 2013). The present interest in LAB, besides their fermentative and preservative effects in food, is more focused on human health aspects due to their antagonist effects (attributed to their metabolites products) against pathogenic microorganisms which contaminate foods (Neira, 2006, Serna and Enríquez, 2013) *per se* promoting a variety of illnesses when they are consumed.

According to their fermentative carbohydrates metabolism (glucose), LAB are classified in homofermentative and heterofermentative, in which in the first group their main product is lactic acid via Embden-Meyerhof, while in the second group which lacks the presence of aldolase and glucose isomerase enzymes, fermenting the hexoses to pentoses by means of 6-phosphogluconate phosphoketolase pathway producing besides lactic acid as final product different compounds such as propionic acid, acetates, succinates, ethanol and CO_2 (Parada *et al*., 2007; Parra, 2010; Ramírez *et al*., 2011).

The carbohydrates fermentation products from most of the LAB are organic acids as lactic, formic, propionic, butyric and acetic, furthermore other compounds such as H_2O_2, acetoin, acetaldehyde, di-acetyl, CO_2 and bacteriocins (Oh *et al*., 2000; Roos *et al*., 2002; Turgay *et al*., 2002; Neira, 2006; Reis *et al*., 2012), which promotes undesirable changes in the growth media (inhibition) of microorganisms responsible of the spoilage and development of pathogens in food (*L. monocytogenes, S. aureus, B. cereus. Enterococcus spp. y Cl. botulinum* (Davidson and Hoover, 1993; Roos *et al*., 2002; Soomro *et al*., 2002; Neira, 2006; Dicks and Botes, 2010; Reis *et al*., 2012) through a wide variety of action mechanisms (Table 2).

The LAB antimicrobial activity generated against Gram (+) bacteria mainly comes from the bacteriocins action, while the antimicrobial activity against Gram (-) bacteria is due to organic acids action and also to other compounds as hydrogen peroxide. Different authors acknowledge that the chemical composition of the cellular wall of Gram(-) bacteria is considered as a protection factor against bacteriocins since the external membrane of these microorganisms functions as a permeability barrier (Serna and Enríquez, 2013).

Bacteriocins and food safety

The bacteriocins are elongated or globular proteic molecules with antimicrobial activity derived from the LAB metabolism mainly in the growth logarithmic phase (Table 3) (Parada *et al*., 2007; Rojas and Vargas, 2008). The factors that activate and promote the synthesis mechanism of these molecules involve the presence of other competitive bacteria, thermal stress or pH 7 and a mechanism known as "*quorum sensing* or population census"

Table 2. Metabolites produced by LAB inhibition mechanism.

Metabolite	Inhibition mechanism
Lactic Acid	Cellular metabolism breakdown and cellular growth inhibition.
H_2O_2	Production of hydroxi-radicals with membrane lipids peroxidation and cellular proteins, and cell susceptibility.
CO_2	Anaerobic environment enhancement, pH reduction and wall and/or membrane cell disruption.
Di-acetyle	Interference in Arginine Metabolism.
Bacteriocins	Membrane cytoplasmatic disruption or cell wall synthesis inhibition.Alteration of the protons driving force necessary for energy production and protein and/or nucleic acid synthesis.

Roos *et al*., 2002; Gonzalez-Martínez *et al*., 2003; Neira, 2006; Ramírez *et al*., 2011.

Table 3. Some bacteriocins, LAB and activity spectrum.

Bacteriocin	Class	Activity spectrum	Microorganism
NisinLacticin 3147	I	Gram (+) including *Staphylococcus aureus* and *Listeria monocytogenes* preventing the sporulation and vegetative cells of *Bacillus spp* and *Clostridium spp.Clostridium sp, Listeria monocytogenes, Staphylococcus aureus, Streptococcus dysgalactiae, Enterococcus faecalis, Propionibacterium acne, Streptococcus mutans*	*Lactococcus lactis subsp lactis*
Pediocin PA-1	II	*Listeria monocytogenes*	*Pediococcus acidilactici Lactobacillusplantarum WHE92*
Sakacin P	II	*Listeria monocytogenes*	*Lactobacillus sake 706*
Curvacin A	II	*Listeria monocytogenes, Enterococcus faecalis*	*Lactobacillus curvatus LTH1174*
Mesentericin Y105	II	*Enterococcus faecalis, Listeria monocytogenes*	*Leuconostoc mesenteroides*
Pediocin A	II	*Lactobacillus, Lactococcus, Leuconostoc, Pediococcus, Staphylococcus, Enterococcus, Listeria, Clostridium*	*Pediococus pentosaceous*
Helveticin	III	*Lactobacillus bulgaricus, Lactococcus lactis*	*Lactobacillus helveticus*

Gonzalez-Martínez *et al*., 2003; Parada *et al*., 2007; Rojas and Vargas, 2007; Reis *et al*., 2012

(López *et al*., 2008). According to their molecular weight and heat stability, the bacteriocins are classified in three main groups, Class I: lantibiotics, low heat stability and polycyclic peptides <5KDa with modified amino acids for their presence of lantionin, β-methyllanthionine, dehydrated amino acids and D-alanine in some cases; Class II: small (<10 KDa) non-lantibiotics and heat stable; Class III: large peptides or molecules (>10 KDa) and heat unstable (Roos *et al*., 2002; Parada *et al*., 2007; Rojas and Vargas, 2008; Dicks and Botes, 2010). The Class I is the most studied and industrially explored, within this class is the Nisin which contains 34 amino acids and its molecular weight is <5 KDa. Its synthesis involves transcription processes, transduction and post-transductional modifications, secretion, processing and signal transduction. There are two types of nisin: A and Z, which differ among them in the 27 amino acid, histidin in A and asparagine in Z (Parada *et al*., 2007). This type is produced by strains of *Lactococcus lactis subsp lactis* and is the only considered as GRAS ("Generally Recognized As Safe") (Gonzalez-Martínez, 2003; Parra, 2010; De la Fuente and Barboza, 2010) and has the authorization of the Food and Drug Administration (FDA), to be applied commercially and is used in many countries as a natural preservative in food (biopreservation) with proven effectiveness. For this reason the incorporation of bacteriocins as the nisin in different food systems is a modern alternative in combination with physicochemical treatments and/or low concentration of some natural and traditional chemical preservatives to achieve food safety, reducing the proliferation and control of foodborne illnesses or food spoilage due to pathogenic microorganisms such as *Listeria monocytogenes, Clostridium botulinum, Yersinia enterocolítica, Staphylococus aureus, Escherichia coli, Salmonella typhimurium and Bacillus cereus*, just to mention some; enhancing the human health without altering the nutritional and sensorial characteristics of both raw material and final food products. Thus the process of biopreservation is defined as the procedure to extend the shelf life and safety of a certain food product through the use of natural or controlled microbiota and/or antimicrobial compounds; it`s considered as a green approach to eliminate the use of conservatives, improving safety, freshness or minimizing the process steps and lengthening the shelf life of foods (Parra, 2010; De la Fuente and Barboza, 2010; Reis *et al*., 2012;. Serna and Enriquez, 2013).

Furthermore, it has been reported that bacteriocins can exert a synergic effect with other non-thermal preservation food treatments which involves hydrostatic pressures (HP) and pulse electric fields, which in combination are effective against Gram (-) and Gram (+) bacteria control and *per se* in the preservation and food safety (Rojas and Vargas, 2008; Rattanachaikunsopon and Phumkhachorn, 2010). However we have to recall that bacteriocins antimicrobial activity in foods is highly influenced by different inherent factors such as the composition and interaction with other food components, bacteriocin stability, pH and storage temperature, therefore is especially important to identify if the bacteriocin selected can exert the preservation effect desired and the conditions in which the bacteriocin presents an optimal antimicrobial activity and therefore food safety concerns (Rojas and Vargas, 2008).

Some LAB uses and their inhibitory compounds.

The use of bacteriocins, such as nisin in foods, has been made mainly like a preservative in milk products for example in Gouda and Emmental cheeses, and in yogurt inhibiting the growth of *Cl. butyricum and Cl. tyrobutyricum* and in starting cultures (*Lactobacillus delbrueckii, bulgaricus and Streptococcus thermophilus)* showing in the last cases that not all bacteriocins cannot be used as preservatives in foods (Rojas and Vargas 2007). Otherwise the nisin has been used in the form of "nisaplina" (Danisco), a preparation with nisin (2.5 %), NaCl (7.5 %) and low fat skimmed milk (12 % protein and 6 % carbohydrates) (López *et al*., 2008).

In this sense, many vegetables during their field growth are frequently in contact with the soil promoting contamination at the surfaces, and then are necessary to eliminate or reduce the spoilage and pathogenic microorganisms using physical and chemical treatments by the food manufacturing industry; therefore the bacteriocins and other additives are used as protective agents in foods. Several studies have been carried out on the effectiveness of chlorine-nisin-EDTA mixtures in cantaloupes to reduce the native micro flora, as well as the combined effect of nisin-EDTA-sodium lactate and potassium sorbate to reduce *Salmonella* in cut pieces of fresh cantaloupe (Settanni and Corsetti, 2008). Also pediocin and nisin have been applied individually and mixed with sodium lactate, potassium sorbate, phytic acid and citric acid in sanitization processes to reduce the presence of pathogens as *L. monocytogenes* in vegetables (broccoli, cabbage and germinated kidney bean) (De la Fuente and Barboza, 2010). On the other hand Gámez *et al*., 2011 studied the biopreservation effect of grounded pork meat (hamburger type), with *Lactobacillus acidophilus* and *Staphylococcus carnosus*, showing that the microbiological analysis presented values of total and fecal coliforms of <3 UFC/g during 30 days at ambient temperature, this phenomena was promoted by the inhibitory action of lactic acid and other inhibitory compounds produced by LAB. Furthermore, both strains were acid pH resistant without antagonistic effect between them; these results propose the potential use of these strains as a preservation method and an alternative to the cold chain.

Whereas Salazar *et al.*, 2011 reported the evaluation of 10 antimicrobial extracts obtained from individual cultures and mixed cultures of LAB (*Lactobacillus plantarum, Pediococcus acidilacti and Leuconostoc mesenteroides*) and from isolated strains of fish, in order to reduce the microbial amount in fish fresh fillets of tilapia, which were packed in vacuum and stored in refrigeration. The extracts obtained from individual and mixed cultures of *L. plantarum* produced the higher inhibition against pathogen and spoilage bacteria isolated from the same product, showing up that after 10 days of storage at 8°C, with the use of the extracts on the fillets, the concentration of aerobic mesophilic and total coliforms were reduced in 2.8 and 1.6 logarithmic cycles, respectively, in respect to the control. Furthermore according to the simulations made with the Software Growth Predictor (Combase), this reduction in the microbial amount could mean an enhancement of three days more in the storage of the product. Suggesting an innovative option in the industrial fisheries sector with the implementation of bioactive packaging added with antimicrobial extracts of LAB.

CONCLUSION

Until now the studies carried out on the probiotics around the world, place them as a potential alternative in the antimicrobial traditional therapy due to consume availability and to the multiple action mechanisms with different beneficial effects on human health (Narayan *et al*., 2010). Furthermore the increase in the demand of fresh and food safety (without chemical preservatives) with lengthen shelf life, along with the constant population growth, puts the probiotics and their different metabolites (bacteriocins) as an important option as biopreservatives due to their inhibitory effect on many food pathogenic microorganisms that produce different foodborne illnesses. The pathway is open, however, it requires more research related to finding a wider variety of probiotic strains, generating *per se* more information about the synthesis mechanisms and the optimization of antimicrobial compounds and preservatives; also the safety and functionality issues as well as the knowledge of the use of these unique compounds and/or the cultures as ingredients in the formulation and development of new food products are required; this will contribute to satisfy the food demand of the population which claims more nutritive, appealing and safe food products with longer shelf-life.

REFERENCES

Albo, G. 2010. Health microbiological pig meat. Evaluation of the antimicrobial resistence of *Escherichia coli*. *Veterinaria Cuyana*. 5 : 7-28.

Anadón, A., Rosa Martínez-Larrañaga, M. and Aranzazu Martínez, M. 2006. Probiotics for animal nutrition in the European Union. Regulation and safety assessment. *Regulatory Toxicology and Pharmacology*. 45 : 91-95.

Anuradha, S. and Rajeshwari, K. 2005. Probiotics in Health and Disease. *Journal Indian Academy of Clinical Medicine.* 6 : 67-72.

Arispe, E. and Tapia, M.S. 2007. Inocuidad y calidad: requisitos indispensables para la protección de la salud de los consumidores. *Agroalimentaria*. 24 : 105-117.

Barreto, A.G., Sedrés, C.M., Rodríguez, T.H., Guevara, V.G. 2010. Agentes bacterianos asociados a brotes de Enfermedades Trasmitidas por Alimentos (ETA) aislados de coprocultivos. *REDVET. Revista electrónica de Veterinaria*. 11 : 1-15.

Caballero Torres Ángel, E. 2008. Temas de higiene de los alimentos. Editorial Ciencias Médicas. ISBN 978-959-212-363-2.

Castro, Luz A. and De Rovetto, C. 2006. Probióticos: utilidad clínica. *Colombia Médica*. 37: 308-314.

Chukeatirote, E. 2003. Potential use of probiotics. *Songklanakarin J Sci Technol*. *25*: 275-282.

Davidson, P.M. and Hoover, D.G. 1993. Antimicrobial components from lactic acid bacteria. In: Lactic Acid bacteria, Salminen, S. and Von Wright, A. (Eds) Marcel Dekker, Nueva York.

De la Fuente Salcido, N. M. and Barboza Corona, J. E. 2010. Inocuidad y bioconservación de alimentos. *Ciencia y Salud.* 20:43-52.

Delgado, R., Gutiérrez, C. and Hurtado, A. 2003. Enfermedades transmitidas por alimentos (ETA) de origen marino en Nueva Esparta II: características clínicas y etiológicas. *Rev. Inst. Nac. Hig*. 34: 11-16.

Dicks, L. M. and Botes, M. 2010. Probiotic lactic acid bacteria in the gastro-intestinal tract: health benefits, safety and mode of action. *Beneficial microbes*. 1: 11-29.

Diez González F. 2012. Patógenos emergentes. *Énfasis Alimentación*. 7:40-42.

Diosma, G., Romanin, D. E., Rey-Burusco, M. F., Londero, A. and Garrote, G. L. 2013. Yeasts from kefir grains: isolation, identification, and probiotic characterization. *World Journal of Microbiology and Biotechnology*. 30: 43-53.

Food and Drug Administration (FDA). *http://www.fda.gov/Food/ResourcesForYou/HealthEducators/ucm091976.htm.* Access 25th August 2014.

Gamez, H. J., Rodríguez, C. M., Toro, C. R. and Bolivar, G. 2011. Efecto de bioconservación de carne molida de cerdo, tipo hamburguesa con *Lactobacillus acidophilus* cepa ATCC 4356 *y Staphylococcus carnosus* NRRLO2. *Alimentos Hoy*. 16: 33-42.

González Flores T. and Rojas Herrera, RA. (2005). Enfermedades transmitidas por alimentos y PCR: prevención y diagnóstico. *Salud Pública de México*. 47: 388-390.

González Martínez, B.E., Jiménez Salas, Z., Heredia Rojas, N. L., Villarreal Treviño, L., García Díaz, G. and Gómez Treviño, M. 2006. Efecto de microorganismos probióticos sobre el crecimiento de *Salmonella enteritidis* var. *Typhimurium*. *Ciencia UANL*. *9*(4).

González-Martínez, BE., Gómez-Treviño, M. and Jiménez-Salas, Z. 2003. Bacteriocinas de probióticos. *Revista Salud Pública y Nutrición*. 4:1-8.

Guarner, F. 2002. El colon como órgano: hábitat de la flora bacteriana. *Nutrición Hospitalaria*. 17: 7-10.

Hernández Cortez, C., Aguilera Arreola, Ma. G. and Castro Escarpulli, G. 2011. Situación de las enfermedades gastrointestinales en México. *Enfermedades Infecciosas y Microbiología*. 31:137-151.

Hernández Cruza, P.E. 2010. Bacterias patógenas emergentes transmisibles por los alimentos. *Monografías de la Real Academia Nacional de Farmacia*. Pp.147-179.

Access: December 16 2014. *http://www.analesranf.com/index.php/mono/article/viewFile/1111/1128*

Instituto Nacional de Salud Pública (INS). República de Colombia. Vigilancia y análisis del riesgo en salud pública. Protocolo de vigilancia en salud publica enfermedades transmitidas por alimentos (ETA). pro-r02.001 versión 01 2014 – jun – 11.Página 1 de 33. Access: December 17 2014. *http://www.ins.gov.co/lineas-de-accion/SubdireccionVigilancia/sivigila/Protocolos%20SIVIGILA/PRO%20Enfermedades%20Trans.%20por%20alimentos.pdf*

Ishibashi, N. and Yamazaki, S. 2001. Probiotics and safety. *The American journal of clinical nutrition*. 73: 465s-470s.

Kopper, G., Calderon, G., Schneider, S., Dominguez, W., Gutiérrez, G., Rosell, C., Mejía, D. 2009. Enfermedades transmitidas por alimentos y su impacto socioeconómico. Estudios de caso en Costa Rica, El Salvador, Guatemala, Honduras y Nicaragua. Informe técnico sobre ingeniería agrícola y alimentaria. *Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO).* Editorial FAO. Series informes técnicos sobre ingeniería agrícola y alimentaria 6. ISBN 978-92-5-306153-2. *http://www.fao.org/docrep/011/i0480s/i0480s00.htm*

López, J. E., Ochoa, A., Santoyo, G., Anaya, J. L., Medina, E., Martínez, M. and Loeza, P.D. 2008. Bacteriocinas de bacterias Gram positivas: una fuente potencial de nuevos tratamientos biomédicos. *Revista Mexicana de Ciencias Farmacéuticas*. 39: 49-57.

Lorente, B.F. and Serra, J. D. 2001. Alimentos funcionales: probióticos. *Acta Pediatr Espan*. 59: 150-5.

Marquina, D. and Santos, A. 2001. Probióticos, prebióticos y salud. *Actualidad SEM*. 32: 24-27.

Martínez, E. V., Varela, M. C., Cevallos, C., Hernández-Pezzi, G., Torres, A. and Ordóñez, P. 2008. Brotes de enfermedades transmitidas por alimentos. España, 2004-2007 (excluye brotes hídricos). *Boletín epidemiológico semanal*. 16: 241-248.

Narayan, S. S., Jalgaonkar, S., Shahani, S. and Kulkarni, V. N. 2010. Probiotics: current trends in the treatment of diarrhoea. *Hong Kong Med J*. 16: 213-218.

Neria Pérez, A. 2006. Evaluación de la capacidad inhibitoria de cepas de bacterias acido lácticas aisladas de productos lácteos. (Dissertation thesis bachelor´s degree). dgsa.uaeh.edu.mx. Access: December 17 2014 : *http://dgsa.uaeh.edu.mx:8080/xmlui/bitstream/handle/231104/1711/Evaluaci%C3%B3n%20de %20la%20 capacidad%20 inhibitoria%20de%20cepas%20de%20bacterias%20acido%20l%C3%A 1cticas%20 aisladas%20de%20productos%20l%C3%A1cteos.pdf?sequence=1*

Oh, S., Kim, S. H. and Worobo, R. W. 2000. Characterization and Purification of a Bacteriocin Produced by a Potential Probiotic Culture, *Lactobacillus acidophilus* 30SC. *J Dairy Sci.* 83 : 2747–2752.

Olagnero, G., Abad, A., Bendersky, S., Genevois, C., Granzella, L. and Montonati, M. 2007. Alimentos funcionales: fibra, prebióticos, probióticos y simbióticos. *Diaeta*. 25: 20-33.

Olea, A., Díaz, J., Fuentes, R., Vaquero, A. and García, M. 2012. Vigilancia de brotes de enfermedades transmitidas por alimentos en Chile. *Rev Chilena Infectol* 29: 504-510.

Parada, JL., Rico y Caron, C.P., Medeiros Adriane, B. and Soccol, CR. 2007. Bacteriocins from Lactic Acid Bacteria: Purification, Properties and use as Biopreservatives. *Brazilian Archives of Biology and Technology*. 50 : 521-542.

Parra Huertas, R.A. 2010. Review. Lactic acid bacteria: functional role in the foods. *Facultad de ciencias agropecuarias*. 8 : 93-105.

Parrilla-Cerrillo, MC., Vázquez-Castellanos, J.L., Saldate-Castañeda, O.E. and Nava-Fernández, L.M. 1993. Brotes de toxiinfecciones alimentarias de origen microbiano y parasitario. *Salud Pública Méx*. 35 : 456-463.

Quera, R., Quigley, E. and Madrid, A.M.S. 2005. El rol de los prebióticos, probióticos y simbióticos en gastroenterología. *Gastr Latinoam*. 16: 218-228.

Quevedo, F. 2014. Enfermedades Emergentes y Re-Emergentes transmitidas por los alimentos. *Ciencia e Investigación*. 5 : 25-35.

Rattanachaikunsopon, P. and Phumkhachorn, P. 2010. Lactic acid bacteria: their antimicrobial compounds and their uses in food production. *Annals of Biological Research.* 1 : 218-228.

Reis, J. A., Paula, A. T., Casarotti, S. N. and Penna, A.L.B. 2012. Lactic Acid Bacteria Antimicrobial Compounds: Characteristics and Applications. *Food Eng Rev*. 4 : 124–140.

Rojas, C. and Vargas, P. 2008. *Bacteriocinas*: sustituto de preservantes tradicionales en la industria alimentaria. *Tecnología en Marcha*. *21-2:9-16.*

Ross, R. Paul, Morgan, S. and Hill, C. 2002. Preservation and fermentation: past, present and future. *International Journal of Food Microbiology*. 79 : 3-16.

Rubio, A., Hernández, M., Aguirre, A., and Poutou, R. 2008. Identificación preliminar in vitro de propiedades probióticas en cepas de *S. cerevisiae*. *Revista MVZ Córdoba*. 13 : 1157-1169.

Salazar, G. S., Uribe, A.E., Aguilar, R.C. and Klotz, C.B. 2011. Bioconservación de pescado fresco empacado al vacío mediante la utilización de extractos antimicrobianos de bacterias ácido lácticas. *Revista Alimentos Hoy.* 20 : 8-22.

Sanz, Y., Collado, M. and Dalmau, J. 2006. Contribución de la microbiota intestinal y del género *Bifidobacterium* a los mecanismos de defensa del huésped frente a patógenos gastrointestinales. *Acta pediatr Esp*. 64 : 74-78.

Serna Cock L. and Enríquez Valencia CE. 2013. Antimicrobial activity of *Weisella confusa* and its metabolites against *Escherichia coli* and *Klebsiella pneumonia. Rev. Colomb. Biotecnol*. 15 : 63-69.

Settanni, L. and Corsetti, A. 2008. Application of bacteriocins in vegetable food biopreservation. *International Journal of Food Microbiology.* 121: 123–138.

Soomro, A.H., Masud T. and Kiran, A. 2002. Role of Lactic Acid Bacteria (LAB) in Food Preservation and Human Health – A Review .*Pakistan Journal of Nutrition.* 1: 20-24.

Suárez, JE. 2013. Microbiota autóctona, probióticos y prebióticos. *Nutr Hosp*. 28: 38-41.

Turgay, E. O., Cetil, O. and Ergun, O. 2002. A study on metabolic and antimicrobial activities of *Pediococcus pentosaceus* isoled from fermented sausage. *Pakistan Journal of Biological Sciences.* 5: 594-596.

Vidal, D. R. 2006. Probióticos: aspectos microbiológicos y tecnológicos. *Alimentación Nutrición y Salud*. 13: 48.

World Health Organization (WHO) 2014. *http://www.who.int/topics/ foodborne_diseases/es/. Acceded 8 September 2014.*

Zamora-Vega, R., Martínez-Flores, HE., and Montañez-Soto, JL. 2014. Viability of *Saccharomyces boulardii* under acidic conditions *In vitro. Biotecnia*. XVI:2: 31-35.