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Classification, Antimicrobial Potential, Industrial Applications and Probiotic Capability of Lactic Acid *Bacteria*: A Review Article

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Abstract: Lactic Acid *Bacteria* (LAB) are economically important organisms and existed in foods, soil, intestinal gut of animals, used as starter cultures for food fermentations such as yoghurt, cheese, pickles, sausages, fermented fish and fermented fruits. LAB are gram positive, catalase negative and non-spore forming rods or cocci. LAB include recently many genera such as Lactobacillus, Lactococcus, Leuconostoc, Carnobacterium, Streptococcus, Enterococcus, Vagococcus, Pediococcus, Allojococcus, Tetragenococcus and Weisella. A key for differentiation of LAB into genera is illustrated in this review and is based on easily determinable characteristics allowing a rapid assignment of a new isolate to any LAB genera. LAB produce organic acids, diacetyl, H_2O_2, ethanol, acetaldehyde, bacteriocins and antifungal substances. They are recently used as starter cultures for food fermentations with their use as probiotics, since, they were approved recently to tolerate acidic conditions of stomach, tolerate bile acids and bile salts of intestine and attach smooth human tissues. The medicinal uses of probiotics are discussed in the present review.

Key words: Lactic Acid *Bacteria* (LAB), probiotics, starter, culture, industerial importance, produce organic

INTRODUCTION

Lab are a group of gram-positive, non-spore forming, cocci or rods which produce lactic acid as the major end product from carbohydrate fermentation. They consisted of many genera including Aeorcoccus, Alloiococcus, Garnobacterium, Enterococcus, Lactobacillus, Lactococcus, Leuconostoc, Pediococcus, Streptococcus, Tetragenococcus, Vagococcus and Weissells (Stiles and Holzapfel, 1997). LAB produce several compounds such as bacteriocins, H_2O_2, diacetyl, acetaldehyde, ethanol, antifungal proteins and CO_2 that can inhibit pathogenic and food spoilage *Bacteria* and improve the smell, colour and texture throughout food fermentations (Caplice and Fitzgerald 1999; Ross *et al*., 2002). The antifungal agents produced by lAB can reduce the problem of toxinogenic moulds (Batish *et al*., 1997). These microorganisms have beneficial effects in human health such as treating allergy, increasing immune system, reducing urogenital infections, treating the ulcers, preventing the initiation of colon cancer, decreasing the cholesterol level in the blood, treating the cases of diarrhea and constipation and treating lactose-intolerance cases (Holzapfel and Schillinger, 2002).

LAB and their classification: LAB are gram-positive catalase negative rods their primary mentabolite is lactic acid. LAB are commonly found in foods including fermented vegetables, fruits, beverages and dairy products. Currently, LAB comprise the Genera Lactobacillus, Leuconostoc, Pedicoccus, Carnobacterium, Lactococcus, Enterococcus, Aerococcus, Vagococcus and Streptococcus (Nettle and Barefoot, 1993).

Lactobacilli: Lactobacilli include 3 groups: group 1, the obligately homo-fermentative lactobacilli which degrade hexose but not pentose, group 2, the facultatively hetero-fermentative lactobacilli which ferment hexose almost exclusively to a lactic acid, acetic acid and ethanol, group 3, the obligately hetero-fermentative lactobacilli. They ferment both hexoses and pentoses to lactic acid and ethanol (Enan *et al*., 1996). Lactobacillus (L) plantarum is a versatile and industrially important lactic acid bacterium which can be found in fermented pickles (Zago *et al*., 2011a, b). It shows probiotic capabilities (Hebert *et al*., 2000). The porbiotic properties are resistance to biological barriers, the antimicrobial activity and cholesterol-lowering effect (Hebert *et al*., 2000). The antimicrobial activity enable this bacterium to protect

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the produced pickles this antimicrobial activity of *L. plantarum* is due to its secretion of lactic acid and bacteriocin (Enan *et al*., 1996; Enan, 2006a-d; Enan *et al*., 2013a-c, 2014a- c).

Leuconostoc: Cells of Leuconostocs are spherical or lenticular and occur in pairs or chains. They are facultative anaerobes. Leuconostocs are morphologically different from Lactobacilli (Garvie, 1986). However, physioldgically they are quite similar to the gas-producing hetero fermentative Lactobacilli (Holzapfel and Schiliinger, 1992). The classification and identification of the *Leuconostoc* spp. has therefore been equivocal. A polypbasic approach for their classification and identification is necessary (Fantuzzi *et al*., 1992). The studies of DNA: DNA homology and rRNA similarity (Martinez-Murica and Collins, 1990, 1991a, b) differentiated the Leuconostoc species from lactobacilli. These studies added two new genera: *Leuconostoc paramesenteroides* and Leuconostoc oenes to the Genus Leuconostoc (Martinez-Murica and Collins, 1991b). The Genus Leuconstoc comprises the following species: *Leuconstoc mesenteroides*, *Leuconstoc dextranicum* (Beijerinck, 1972); *Leuconstoc cremories* (Knudsen and Sorensen, 1929); *Leuconstoc lactis* (Garvie, 1967); *Leuconstoc mesenteroides* subsp. amelibiosum (Hoover, 2000; Kandler, 1970); *Leuconstoc gelidum* and *Leuconstoc carnosum* and *Leuconstoc fallax* (Martinez-Murica and Collins, 1991a). *Leuconstoc amelibiosum* (Schillinger *et al*, 1987) which was formerly *Levconstoc mesenteroides* subsp. amelibiosum. Both *Leuconstoc dextranicum* and Leuconstoc *cremoris*-are now considered to be subspecies of *Leuconostoc mesenteroides* (Pot *et al*. 1994).

Carnobacterium: The Genus Carnobacterium was proposed by Collins *et al*. (1987) to accommodate species of non-aciduric *Lactobacillus piscicola* and *Lactobacillus divergens*. The latter 2 species (atypical lactobacilli) were differentiated from *Lactobacillus* spp. by their inability to grow on acetate agar, the growth at high pH values of 8.5-9.5 and the synthesis of oleic instead of cis-vaccenic acid produced by Lactobacilli (Collins *et al*., 1987). Based on these biological characteristics these two atypical Lactobcilli were allocated in a new genus, Carnobacterium as *Carnobacterium divergens* (formerly called *Lactobacillus divergens*) and *Carnobacterium piscicola* (formerly called *Lactobacillus piscicola*). Collins *et al*. (1987) created two new species, *Carnobacterium gallinarum*. Carnobacterium vmobile. The above four species of Carno*Bacteria* showed a high degree of rRNA sequence similarity with each other and formed a phylogenetically coherent group, quite from all LAB (Wallbanks *et al*., 1990). From the recommendations reported by Collins *et al*. (1990), it is obvious that *Carnobacterium piscicola, Lactobacillus piscicola* (Hiu *et al*., 1984) should be replaced by *Carnobacterium maltaromicus Lactobacillus maltaromicus* (Miller *et al*., 1974) as both species showed 100% r RNA sequence similarity and because maltaromicus species was described earlier than *Lactobacillus piscicola*.

Streptococcus: The genus Streptococcus is reserved for non-spore forming coccoid or coccobacillary chemo-organotrphic microorganisms, arranged in pairs or chains. The Streptococcus species ferment carbohydrates to lactic acid as amajor end-product and are generally aerotolerant. The optimum temperature for growth of these organisms is usually about 370°C but maximum ahd minimum temperatures vary among species. The species of the genus Streptococcus can roughly be divided into hemolytic species and the oral (viridans) species (Pot *et al*., 1994).

Enterococcus: The genus Enterococcus includes the Enterococcal group of Streptococci (formerly faecal streptococci), possessing the group D antigal (Schleifer and Kilpper-Balz, 1984). Numerous species of the genus Streptococcus have been classified as enterococcal organisms belonging to the enterococcal group (Jones *et al*., 1972). DNA: DNA and DNA; rRNA hybridization experiments (Kilpper-Balz *et al*., 1982). Proved the identification of two species of the genus Enterococcus as *Enterococcus faecalis* and *Enterococcus faecium*, respectively (Schleifer and Kilpper-Balz, 1984). Since, this renaming in 1984, 17 other species have been included in the genus Enterococcus, either by transfer or by new valid description (Pot *et al*., 1994).

Vagococcus: Sequence analysis of 16 SrRNA performed on Lactococci, Enterococci and motile N strains (Collins *et al*. (1989) showed a separate position of the Enterococci which are some what closer to strains of Listeria and Bacillus than to the Streptococci. From this study, it was shown that a motile group N Streptococcal strain seemed to branch as one single lineage with the Enterocci. This strain was isolated from chicken faeces (Hashimoto *et al*., 1974) and reacted with group N antiserum and was further allocated to the so-called new genus Vagococcus and designated *Vagococcus fluvialis* (Collins *et al*., 1989a). Asecond species, *Vagococcus salmoninarum* isolated from Salmonid fish has been described (Wallbanks *et al*., 1990).

Pediococcus, Aerococcus, Tetragenococcus and Alloiococcus: Cells of these genera are morphologically similar. The spherical, divide in 2 planes at right angles to form tetrads, gram positive, non-motile, facultatively anaerobic and require a rich medium, containing complex growth factors to grow. All species of these genera grow at 300°C but optimum temperatures range from 25-400°C (Garvie, 1986; Pot *et al*., 1994). At present, the genus Pediococcus includes eight species. However, Aerococcus comprises only one species, *Aerococcus viridans* (Pot *et al*., 1994). The differentiation between the members of both genera equivocal by simple morphological or physiological tests. *Aerococcus viridans* and *Pediococcus urinaequi*, for example, are phenotypically very similar and DNA: DNA hybridizations (Dellaglio *et al*., 1981) showed intrageneric relationships. The placement of *Pediococcus halophilus* in the genus Pediococcus has also been controversial as it phenotypically resembles Aerococcus viridans more closely than the Pediococci. DNA: DNA hybridizations (Dellaglio *et al*., 1981), however, showed no intrageneric relationships. Collins *et al*. (1990) clarified this taxonomic problem by comparison of 16S rRNA sequence for all species of Aerococcus and Pediococcus (except *Pediococcus inopinatus*) and *Pediococcus halophilus* was transferred to the new genus Tetragenococcus as *Tetragenococcus halophilus* (Pot *et al*., 1994). The genus Alloiococcus is one of the most recently described genera of LAB, created for an unknown bacterium isolated from middle ear fluids of children with persistent otitis. Only one species of this genus was desribed *Alloiococcus otitis* (Aguirre and Collins, 1992).

Weisella: Weisella belongs to the group of *Bacteria* known as LAB. They are gram-positive, catalase-negative, non-endospore forming cells and with cocci or rod shaped. Weisella species are obligatly heterofermentative they can ferment carbohydrate and produce end products such as lactic acid, acetic acid, ethanol and CO_2. Weisella species generally, difficult to be distinguished from other heterofermentative cocci (Leuconostoc) or rod (Lactobacillus) strains on the basis of phenotypic or biochemical properties alone, so, the accuret identification of weisella strains occur by molecular biological methods such as sequencing of 16SrRNA or other house keeping genes, DNA: DNA hybrdization and by rep-PCR or fAFLP. Methods. phylogenetically, the Weisella belong to frimicutes, class: Bacilli, Order: Lactobacillales and Family: Leuconostoceae. They require complex nutritional requirements and need peptides, amino acids, fermentable carbohydrates, nucleic acids, fatty acids and vitamins for growth. All species can grow at 15°C and some can grow upto 42-45°C. There are 19 species of Weisella they found in vareity rang of habitats such as on the skin in the milk and feces of animals. They have been isolated from saliva, breast milk, vagina of humans from plants and vegetables such as European and African traditional fermented foods. Weisella act as probiotic *Bacteria* where *W. cibaria* have ahigh probiotic potential for controlling diseases. Morever, *W. confusa* and *W. cibara* strains are producing amount of polymers such as oligopolysaccharides and extracellular polysaccahrides mainly dextran that play major role in industerial applications such as beverage fermentation. Other strains of *Weisella* species such as *W. viridescens*, *W. cibaria* and *W. confusa* are pathogenic *Bacteria* causing infections to human suh as bactermia, Endocarditis. While *W. ceti* strains act as etiological agent of "Weissellosis" which is adisease affecting farme rainbow trout (Fusco *et al*., 2015).

Key for differentiation of the genera of LAB: The LAB can be characterized as gram-positive. non-sporing microaerophilic *Bacteria* whose main fermentation product from carbohydrates is lactate (Kandler, 1983). Currently, they are subdivided into the genera Lactobacillus, Carnobacterium, Leuconostoc, Streptococcus, Lactococcus, Enterococcus, Vagococcus, Pediococcus, Aerococcus, Tetragenococcus and Alloiococcus (Pot *et al*., 1994). A key for differentiation of LAB into genera is illustrated in Fig. 1. It is based on easily determinable "characteristics allowing a rapid assignment of a new isolate to any of the genera of LAB. This key is a modification of the differentiation scheme for LAB which has been laid by Schillinger and Lucke (1987). It includes the recent LAB genera: Carnobacterium, Vagococcus. Aerococcus, Tetragenococcus and Alloiococcus . It is also inserted additional physiological criteria for differentiation of lactobacilli. Gas production from glucose is used as a first step in the differentiation of LAB. For a classification of the homofermentative lactobacilli producing no gas from glucose their grow temperature (Schillinger and Lucke, 1987) and their ability to ferment pentoses (Pot *et al*., 1994) were used as taxonomic criteria. The facultatively homofermentative strains (formerly called Streptobacteritun) grow at 15°C and ferment pentoses whereas the obligately homofermentative strains (formerly called Thermobacterium) can't do so. The Carnobacterium species (the atypical Lactobacilli) grow on acetate agar where as Lactobacillus species do not. The heterofermentative Lactobacilli (formerly called Betabacterium) can be differentiated from Leuconostocs by producing Ammonia from rginine (exceptions, *Lactobacillus fructosus, Lactobacillus viridescens,*

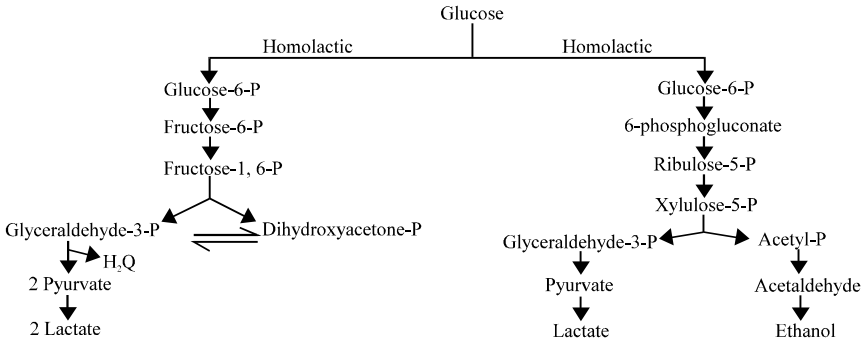

Fig. 1: Generalized scheme for the fermentation of glucose to lactic acid *Bacteria* (Caplice and Fitzgerald, 1999)

Lactobacillus sanfrancisco) and by forming DL lactic acid from glucose (exceptions, Lactobacillus divergens, Lactobacillus carnis both form L-lactic acid) whilst Leuconostocs don't hydrolyze arginine and form only D-lactic acid (Schillinger and Lucke, 1989). Growth at 450 or 10°C and on media supplemented with 6.5% NaCl are taxonomic criteria used for differentiation of Streptococcal genera (Fig. 1). Reaction with group N antiserum is used to the allocate thenew genus Vagococcus from the genus Enterococcus. An unknown strain, Pediococci like-strain is classified to the new genus Alloioococcus. The cells are further differentiated by 16S rRNA sequence analysis to the genera Pediococcus, Aerococcus and Tetragenococcus. The genus Bifidobacteriunt is not included in this key, since, its identification and its taxonomic position as a LAB are still unreliable (Pot *et al*., 1994). However, few researchers recommended the classification of Bifidobacterium as LAB (Mitsuoka, 1984). Cultural characteristics and physiology of these *Bacteria* are similar to other *Bacteria* (Lactobacillus, Corynbacterium and Actinomyces). For more details about the taxonomic position of the Bifidobacterium, the reader is referred to the reports of many researchers viz. Biavati *et al*. (1991), Yaeshima *et al*. (1991) and Pot *et al*. (1994).

LAB AND THEIR USES IN FOODS

LAB are industrially important organisms recognized for their ability of fermentation due to their health and nutritional benefits (Gilliand, 1990). Species that belong to genera Lactobacillus, Lactococcus, Streptococcus, Pediococcus, Leuconostoc and newly recognized Carnobacterium are involved in fermentation processes. These organisms are isolated from dairy and meat products, grains, plants, vegetables and the mucosal surfaces of animals (Lindgrea and Dobrogosz, 1990). They are used as starter cultures in the dairy, baking, meat, vegetables and alcoholic beverages industries. They produce compounds during lactic fermentations such as lactic acid, acetic acid, bacteriocins, diacetyl, ethanol and hydrogen peroxide (Lindgren and Dobrogososz, 1990). Not only this, compounds have beneficial effects for food taste, smell, color and texture but they also inhibit growth of pathogens and undesirable microflora (Rattanachaikunsopon and Phumkhachorn, 2010).

Using LAB as starter cultures for food fermentations: Starter cultures are defined as microbial preparation of one or more micro organisms that are supplied to a raw material to produce afermented foods (Ray, 1992; Caplice and Fitzgerald, 1999). Commercial starter cultures are used currently in industrial fermented foods and are available as frozen and freeze dried concentrates or lyophilized preparations (Sandine, 1996). These functional starter cultures that are used in food and beverage fermentation improve also the fermentation process, enhancing the quality of the end product (Leroy and De Vuyst, 2004). Selected starter cultures can remove formation of D-lactic acid or aracemate of lactic acid (Dl) or the formation of biogenic amines (Leroy and De Vuyst, 2004; Joosten *et al*., 1995).

Starter cultures and functional starter in fermentation of foods: LAB act as starter cultures in fermented foods and beverages because they can improve nutritional, organoleptic, technological and shelf-life characteristics of these foods (Wood and Holzapfel 1995; Leroy and De Vuyst, 2004). LAB produce various organic acid from

carbohydrates by it's initiation of rapid and adequate acidification of raw materials. The main acid produced by LAB are lactic acid followed by acetic acid; LAB can also produce ethanol, aroma compounds, Bacteriocins, exopolysaccharides and some enzymes (De Vuyst and Leroy, 2007). The production of fermented foods and beverages was based on a spontaneous fermentation that occur by LAB. The addition of selected starter cultures to food matrix cause the high degree of fermentation process and the stability of the final product (Enan *et al*., 2013b).

Starter cultures as probiotics: Successful starter cultures of LAB showed beneficial effects on human health through the consumption of yoghurts and fermented milk (Metchnikoff *et al*., 1910). Yoghurt is manufactured using *Streptococcus thermophilus* and *Lactobacilus delbrueckii* ssp. *bulgaricus* as starter cultures (Shah, 2007). A manufacturer's selection of starter cultures strains occur by checking the following aspects (Tamine *et al*., 2005; Enan *et al*., 2014).

The ability of probiotic to show fast growth in medium to increase cell count. The ability of microorganisms to tolerance the freezing and drying stages of preparation. Tolerance of *Bacteria*l stains to bile salts and the gastric acid during their passage through gastrointestinal tract, so, the probiotics must be stable for achieving health benefits (Tamine *et al*., 2005). Resistance to antibiotics to allow growth in food preserved by either biocides or antibiotics and to resist antibiotics in vivo if they are ingested by humans as aprobiotic capability and resistant to be lysed by bacteriophages.

Lab as starter cultures for making fermented dairy products: LAB are used as starter cultures in fermentation of dairy products. The main LAB that are used in dairy products fermentation are Lactobacillus spp. (*L. acidophilus*, *L. lactis*, *L.casei*, *L. plantarum*, *L. rhamnosus*, *L. reuteri*, *L. delbrueckii* ssp. bulgaricus) and the Enterococcus spp. (*E. faecalis*, *E. faecium*). *Carnobacterium* spp. and *Leuconostoc* spp. were also involved slowly in dairy products making (Shah, 2007; Tamine *et al*., 2005). Dairy products are considered as ideal vehicles for delivering probiotics to the human gut such as Yoghurt, followed by cultured butter milk, cheeses, kefir, ice cream (Shah, 2007; Soccal *et al*., 2010; Tamine *et al*., 2005) or frozen desserts as chocolate mousse (Aragon-Algero *et al*., 2007). Moreover, proteolytic strains of LAB provide probiotics by releasing bioactive peptides called angiotensin and inturn enzyme inhibitors which are examined for their hypotensive role (Conlin *et al*., 2000).

FUNCTIONAL STARTER CULTURES IN FERMENTED NON-DAIRY PRODUCTS

Fermented meat and meat products: The preservation of meat and meat products by fermentation were based on natural meat microorganisms. Pure strains of LAB meat starter cultures were used by Erkkila (2001) and are belong to *Pediococcus cerevisiae*. It was used for the immediate and rapid production of organic acids during fermentation process, resulting in shift of pH value towards acidic levels where palthogenic *Bacteria* will not grow (Ammor and Mayo, 2007). Therefore, the original characteristics of the produced foods and end- products are improved. The meat LAB starter cultures belong to the Lactobacillus, Pediococcus and carnobacterium strains which isolated from dry sausages (Ammor and Mayo, 2007). Selected previous strains have the best survival activity under acidic conditions and high levels of bile salts. The starter cultures play an important roles by preservation of foods by inhibiting activity of pathogens and spoilage via. production of bateriocin and biogenic amines (Ammor and Mayo, 2007).

Fermented vegetables: Fermentation of vegetables are commonly occurred by LAB strains that consume carbohydrates and fermenting them with production of organic acids. Usually fermented vegetable juices are produced from cabbage, red beet, carrot and tomato (Buruleanu *et al*., 2010). LAB play an important role in pickles and table olives fermentation, affecting the final flavour and shelf-life (Fleming, 1984; Medina *et al*., 2010).

Starter cultures in silages: Under anaerobic conditions, LAB can ferment carbohydrates into organic acids, mainly lactic acid or acetic and formic acids. LAB are added into silage to enhance lactic acid fermentation under anaerobic conditions. This can decrease pH to acidic levels where pathogenic *Bacteria* can't grow and can preserve the nutritional value and palatability of the forage (Broberg *et al*., 2007). Among genera of LAB that are used in silage *Lactobacillus plantarum*, *Enterococcus faecium*, *Pediococcus acidilactici*, *Pediococcus pentoseceus* and *Lactobacillus acidophilus* (Weinberg *et al*., 2004).

Effect of both pH value and temperature on growth of LAB: Growth of LAB at wide pH and temperature ranges is an interesting property for use of these *Bacteria* in food industry. A LAB growing at acidic, neutral and alkaline pH value is better than the one which can grow

only at acidic pH. This enables the LAB starter culture to ferment different food types (Adamberg *et al*., 2003). In addition, growth of LAB in broth media and in fluid foods such as pickles brine, juices of fruits and even in solid food systems are occurred wherein they consume carbohydrates and ferment them, producing lactic acid and other organic acids. In such acidic conditions,

pathogenic *Bacteria* can't grow (Vandenberg, 1993). The
growth of LAB at wide temperatue range is interest to enable such LAB strain to be used in food fermentation at wide temperature range. For instance, *Lactococcus lactis* and *Streptococcus thermophilus* grew well at 20-40°C with optimum temperature at 40°C with making of yoghurt as a useful food product (Beal *et al*., 1989). Thus, ability of certain LAB to grow at wide pH and temperature range is of interest in food fermentation. Most of LAB that were used on starter cultures for food fermentations were selected basically to full fill many criteria such as fast growth at wide pH and tempratue ranges. Of these LAB strains, *Lb. acidophilus* for milk fermentation at un-controlled pH, *Lactococcus lactis* and *Streptococcus thermophilus* for yoghurt making, *Lb. fermentum* and *Lb. plantarum* for sausage making, *Lb. plantarum* for pickles making, *Carnobacterium piscicola* for fermented beef meat and fish and heuconostoc mesentroides for fermented meat and vegetable products (Gupta *et al*., 1996).

Acid and bile tolerance: Probiotic LAB affected by various environmental conditions upon ingestion by the host and during transit in the GIT. Firstly, to survive in stomach they need to survive acidic conditions of stomach and still alive to transit to small intestine. Bile tolerance is one of the essential criteria for surviving and selecting of aprobiotic strain, it is necessary for any LAB to be probiotic to still alive in small intestine and in turn can flocculate lipids by its ability to secrete cholesterol oxidase enzyme. Bile acids are synthesized in the liver by cholesterol and are secreted from the gall-bladder then generating into duodenum. It plays an important role in emulsification of lipids die to the bile arrive duodenum from gall-bladder via. bile duct. Bile acids are surface active, amphipathic molecules (having hydrophilic and hydrophobic part) with potent antimicrobial activity and act as detergents, damaging biological membranes and disrupt cellular homeostasis. Therefore, the ability of LAB to tolerate bile is important for their surviving in the GIT (Begley *et al*., 2005). It was observed that the *Bacteria*l stress originated by low pH may be overcome after the subsequent treatment in presence of bile (Charteris *et al*., 1998). The bile concentration of about 0.3% is usually used for screening bile tolerant strains and this is considered as an average intestinal bile concentration of the human GIT (Gilliland *et al*., 1984). For instance *L.rhamnosus* that was isolated from infant feces is Gram+ve catalase negative, non-motile and non-sporing. *Lb. rhamnosus* survives as probiotic strain by having the ability to grow in 0.4% phenol and still viable in 0.6% phenol, atoxix metabolite produced by intestinal

Bacteria during putrefaction in the GIT (Khedekar, 1988) and it possesses the ability to grow in 6% NaCL (Jacobsen *et al*., 1999). The ability of *Lb. rhamnosus* to grow and survive in the presence of bile, Nacl and phenol can help them to grow, survive and effect beneficially to the host by flocculation of lipids in duodenum and secretion of protease, lipase and amylase, production of lactic acid and production of antimicrobial proteins (Pithva *et al*., 2012).

Production of enzymes: LAB have been found to produce a diverse types of enzymes which may influence the compositional, processing and organoleptic properties and quality of foods and feeds, production of such enzynes into the gastrointestinal tract that occur potential synergistic effects on digestion, giving good digestion and decreasing malabsorption of intesting (Naidu *et al*., 1999). These beneficial organisms may be used as an alternate source for the preparation of enzyme extracts that are able to do functions under the environmental conditions of fermentation (Tamang, 2011). The enzymatic activity has been studied mainly in LAB isolated from wine or other fermented foods as cheeses of yoghurt (Mtshali, 2007). Well defined species of the LAB Lactobacillus, Lactococcus, Pedicoccus and Bifidobacterium existed in fermented foods were found to produce carbohydrate degracling enzymes as amylases, xylanases and glucosideses and enable them to be used in improvement of bread texture, fermentation of fruit juices to beneficial products such as wine and beer they produce aroma and flavor for fermented products. Many strains of LAB were found also to produce certain peptides to improve quality of cheese and proteolysis and their lipolysis provide flavor of the produced cheese (Guldfeldt *et al*., 2001; Gonzalz *et al*., 2010). It was high level and other proteases help in digestion of proteins they were found to produce lactase enzyme which can prevent the lactose-intolerance case at old people. Enzymes of LAB play major role to produce by fermentation associated enzyme activities and wine flavor were improved. LAB grow in wine during malolactic fermentation following alcoholic fermentation, while abroad range of secondary modifications improve the taste and flavor of wine (Matshali, 2007).

Antimicrobial potential of LAB: LAB produce antimicrobial compounds such as hydrogen peroxide, carbon dioxide, diacetyl, lactic acid and other

organic acids, acetaldehyde, ethanol and bacteriocins (Mobolaji and Wuraola, 2011; Abdel-Shafi *et al*., 2013). These are discussed in the following:

Lactic acid: The primary antimicrobial effect exerted by LAB is the production of lactic acid (Mobolaji and Wuraola, 2011; Enan *et al*., 2012). Lactic acid is the major organic acid of LAB fermentation. Lactic acid exists in undissociated and dissociated forms and the extent of the dissociation depends on pH (Ammor *et al*., 2006). Lactic acid can be produced in L-or D-isomer form. The L-lactic acid is more inhibitory than the D-lactic acid (Papagianni, 2012). Antimicrobial activity of lactic acids is occurred throughout maintenance of cell membrane potential, inhibiting active transport, reducing intracellular pH and inhibiting a variety of metabolic activity (Rattanachaikunsopon and Phumkhachorn, 2010). At low pH, lactic acid is in alarge amount and undissociated form. It was inhibitory towards spore forming *Bacteria* and is not effected against yeasts and moulds (Yang, 2000).

Diacetyl: Diacetyl is certain product of LAB fermentation that is important flavoring compound in dairy products. The strains of *Lactococcus lactis* ssp. *lactis biovar*, *diacetylactis* and some species belonging to Leuconostoc and Weissella these Genera are used as diacetyl producers. Diacetyl inhibits strains of Listeria, Salmonella, Yersinia, *Esherichia coli* and Aeromonas (Yang, 2000, Ammor *et al*., 2006; Abdel-Shafi *et al*., 2016).

Hydrogen peroxide: Hydrogen peroxide (H_2O_2) is used in foods, dental products and environmental products. H_2O_2 is involved in oxidation and biochemical processes (Abbas *et al*., 2010). H_2O_2 is produced by LAB and acts as antimicrobial product that cause denaturation of enzymes leading to peroxidation of lipids membrane that increased permeability of membrane and production of bactericidal free radicals such as superoxide (O^{-2}) and hydroxyl group (OH^-) which can damage DNA (Yang, 2000; Ammor *et al*., 2006; Sunil and Narayana, 2008). H_2O_2 is produced by using enzymes as the flavor protein oxidoreductases, NADH peroxidase, NADH oxidase and α-glycerophosphate oxidase (Rattanachaikunsopon and Phumkhachorn, 2010). The synthesized H_2O_2 inhibits growth of pathogenic microorganisms that cause food spoilage at cold temperatures. Some food borne pathongens as *Aromonas hyolrophila*, *Listeria monocytogenes* and *Clostridium botulinum* type E can grow at thus, low temperatures up to 5°C (Ismaiel *et al*., 2014).

Reuterin: Reuterin is antimicrobial compound produced by a number of lactobacilli, produced under anaerobic conditions and in presence of glycerol. It is able to inhibit the growth of Aspergillus and Fusarium and plays a role

in preventing formation of mycotoxins in fermented foods. It is active against (G+ve and G-ve) *Bacteria* as yeasts, protozoa, fungiand viruses (Nes *et al*., 2012). Many spoilage organisms are sensitive to reuterin such as Salmonella, Shigella, Clostridium, Staphylococcus, Listeria, Candida and Trypanosoma (Yang, 2000).

Bacteriocins: Bacteriocins are antimicrobial proteins produced by *Bacteria* they are heat resistance and could be sensitive to protease enzyme and some bacteriocins contain lipid and/or carbohydrate moieties in their molecule. Bacteriocins are stable at acidic pH levels, however, few bacteriocins are active also at pH 7.0 and slightly alkaline levels. They inhibit (G+ve and G-ve) *Bacteria* as well as some fungi. Bacteriocin compounds are classified as follows:

Group 1: It included Lantibiotics that contain lanthionine amino acid in its active molecules. The bacteriocin nisin acid is a typical example of this group and was produced by *Lactococcus lactis* ssp. *lactis* and reffered the term GRAS (Generally Regarded As Safe) by WHO in 1988 and approved to be used as antilisterial and anti-clostridial for preservation of meat and dairy products (Brink *et al*., 1994; Enan *et al*., 1994a; Eckner, 1992; Nettles and Barefoot, 1993; Vuyst and Vandamme, 1994).

Group 2: It is a large group of small-heat stable proteins. That are subdivided into three groups: (Montville and Winkowski, 1997):

- Subgroup 1; Members of this group are bavarcin Mn, Curvacin
- Subgroup 2; Require for peptides for activity and member of this groups are lactococcins G and M and lactacin F
- Subgroup 3; Consists of lactacin B that require reducing cysteines for activity

Group 3: It was classified into larger heat labile proteins as helveticins J and V and lactacins A and B:

Group 4: Bacteriocins of this group have lipid or carbohydrate moieties in their molecules such as leuconocins, lactocin 27 and pedicin SJ-1 (Yang *et al*., 2014). The bacteriocin nisin is commercially available and added to milk, cheese, dairy products and baby foods since 1988. Bacteriocins are recently considered as safe

food additives after intake by the gastrointestinal system (Yang *et al*., 2014) due to their sensitivity to some proteases, so, their harmless are possibly digested. (Cleveland *et al*., 2001; Bernbom *et al*., 2006; Enan and Amri, 2006).

Antifungal agents: Some strains of LAB inhibited yeast, some Ascomycetes, Zygomycetes and some imperfect fungi. For instance, *L. lactis* subsp. *lactis biovar diacetylactis* and *Streptococcus thermophilus* produced antagonistic substances that inhibited *Aspergillus Fumigatus* and Rhizopus spp. (Batish *et al*., 1989); Leuconostoc oenes showed inhibitory activity against Saccharomyces cerevisiae *L. plantarum* and Pediococcus strains were found to be inhibitory towards Fusarium ssp. (Niku-Paavola and Haikara, 1992). The inhibitory substance was purified by gel filtration and had a molecular mass of about 100-400 and contained amino groups and phenolic hydroxyl or aromatic ring structures (Enan *et al* ., 2016).

Non-identified agents: Several strains of LAB were described to produce a number of low molecular mass non-proteinaceous substances that exhibited broad spectrum of activity against Gram-positive and Gram-negative *Bacteria*. These substances were distinguishable from other inhibitory agents produced by LAB they are still non-identified. The reports on these substances have been published by many researchers (Hamden and Mikolajik, 1974; Branen *et al*., 1975; Reddy and Ranganathan, 1983a, b, 1987; Lewus *et al*., 1991; Skytta *et al*., 1993).

Inhibition of fungal toxin biosynthesis: It was found recently that many strains of LAB inhibited fungal growth. The inhibitory activity was attributed mainly to organic acids such as lactic acid, diacetyl, ethanol and acetaldehyde. Also, some published results have showed that the antifungal activity of LAB was attributed to antimicrobial proteins bacteriocins (Sanchez *et al*., 2017).

Inhibition of mycotoxins biosynthesis by LAB: Mycotoxins are secondary metabolites produced by a wide variety of fungi, including Aspergillus, Fusarium and Pencillium. They cause nutritional losses and represent unsafed to the food and feed chain. Humans have long been exposed to mycotoxins directly, via. foods of plant origin including cereals by air (both indoors and outdoors) or indirectly, via. food of animal origin. The most economically important mycotoxins occurring in food and feed are a flatoxins, ochratoxin A, patulin and the Fusarium toxins (Zearalenon, Trichothecenes, Fumonisins etc.) (Chassy, 2010). There are 3 possibilities to avoid the harmful effect of contamination of food and feed caused by mycotoxins:

- Prevention of contamination
- Decontamination of mycotoxin-containing food and feed
- Inhibition of absorption of mycotoxin content of consumed food into the digestive tract (Halasz *et al*., 2009)

Inhibition of mycotoxin biosynthesis by LAB have focused on aflatoxins (Thyagaraja and Hosono, 1994). LAB can release molecules during cell lysis this molecules can inhibite mould growth and loss the accumulation of their mycotoxins (Gaurama and Bullerman, 1995). This "anti-mycotoxinogenic" metabolites that inhibits aflatoxins accumulation are found in Lactobacillus cell-free extracts (Gourama, 1991). This is due to aheat stable, low-molecular-weight inhibitory compound such as organic acids which make a strong acidic environment wherein fungi grow slowly or can't grow, antifungal substances, H_2O_2, ethanol and diacetyl (Luchese and Harrigan, 1990).

LAB as probiotics: The beneficial *Bacteria* are recognized as Probiotics. Probiotics (derived from Latin and Greek) means "for life" is defined according to FAO/WHO (2001) as: Live microorganisms which when administered in adequate amounts confer a health benefit on the host. Some substances such as oligosaccharides serve as substrates for Probiotics and they are important for their growth. These are called prebiotics. Prebiotics are those substances that aren't used or metabolized by non-probiotic *Bacteria* like Bacteroides spp. and *E. coli*. Breast milk and some vegetables are sources for prebiotics (Hamilton-Miller, 2004). There are different kinds of *Bacteria* that can be used as Probiotics, e.g. Lactobacilli and Bifido*Bacteria* (Macfarlane *et al*., 2004). These *Bacteria* show symbiotic relationship with human. They are found in the mucus membrane present on epithelial cells of the gut (Holzapfel and Schillinger, 2002) where they inhibit the growth and attachment of harmful *Bacteria* by producing bactericidal chemicals against these *Bacteria*. With the development of evidences regarding usefulness and safety of probiotics these *Bacteria* are replacing the traditional prophylactic and treatment regimes (Enan *et al*., 2013).

Sources of probiotics: Yogurt is known to be the most popular source of probiotics. Yogurt is prepared from milk fermented by *Bacteria* that modify lactose into lactic acid. Lactic acid is responsible for giving yogurt its characteristics (sharp taste usually changed into good taste by using sweeteners and flavouring) and also denatures and precipitates casein, resulting in a semisolid consistency. ''Bioyoghurts'' are formed by a similar method but *Bacteria* used for fermentation are of different strains, usually *L. acidophilus*. Medically, probiotics can

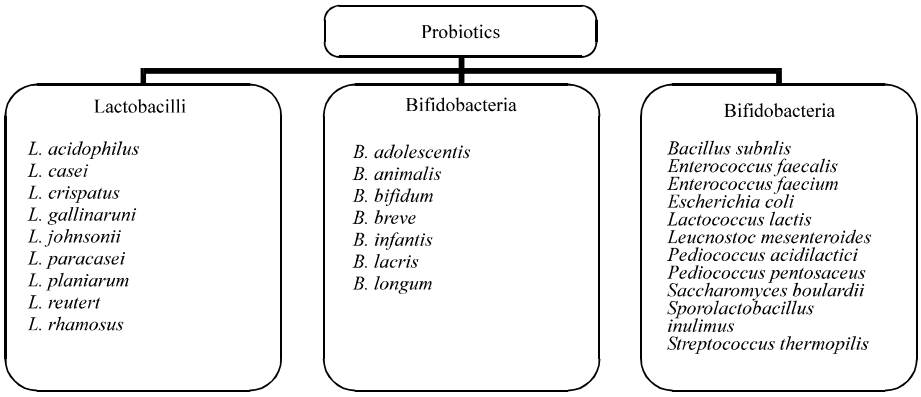

Fig. 2: Different types of *Bacteria* which are recognized as probiotics (Furrie, 2005)

be available in supplements consisting of freeze dried *Bacteria* in tablets, capsules and powders. Thousands strains of probiotics are easily obtainable now and all of them show different beneficial effects Many *Bacteria* used as probiotics are given in Fig. 2.

Mechanism of action of probiotics: The mechanisms by which probiotics exert biological effects are still poorly understood but the non specific terms such as colonization, resistance or competitive exclusion are often used to explain their mode of action (Elo *et al*., 1991). Colonization resistance or competitive exclusion describes a phenomenon whereby the indigenous anaerobic flora limits the concentration of potentially pathogenic (mostly aerobic) flora in the digestive tract (Vollaard and Clasener, 1994). The concept of competitive exclusion was first developed during the early 1970s when it was discovered that the administration of mixed adult intestinal microorganisms conferred adult type resistance against Salmonella infection to newly hatched chicks (Nurmi *et al*., 1992). Oelschlaeger (2010) reported that the effects of probiotics may be classified in three modes of action:

Probiotics might be able to modulate the host's defences including the innate as well as the acquired immune system. This method is most probably important for the prevention and therapy of infectious diseases and treatment of chronic inflammation of the digestive tract or parts thereof. This probiotic action could also be important for the eradication of neoplastic host cells.

Probiotics can also have a direct effect on other microorganisms, commensal and/or pathogenic ones. This mode of action is important for the prevention and therapy of infections and restoration of the microbial equilibrium in the gut.

Probiotic effects may be based on actions affecting microbial products like toxins and host products such as bile salts and food ingredients. These actions may lead to inactivation of toxins and detoxification of host and food components in the gut. The type of actions a certain probiotic finalizes relies on its metabolic properties, the molecules presented at its surface or on the components secreted. DNA or peptidoglycan of the *Bacteria*l cell might be important for its probiotic effectiveness. The individual combination of such properties in a certain probiotic strain determines a specific probiotic action and as a consequence its effective application for the prevention and/or treatment of a certain disease.

Safety considerations: Probiotics are live microorganisms and therefore, it is feasible that they could infect the host. First selection criteria mentioned that a probiotic supplement has to be Generally Regarded As Safe (GRAS) microorganisms (Reid *et al*., 2003; Cabana *et al*., 2006). Different species of Lactobacillus and Bifidobacterium are normal residents of the gastrointestinal and/or vaginal microbiota and do not exert infectivity or toxicity. The risk of infection with these microorganisms is lower (Gupta and Garg, 2009) Probiotics are safe for using in healthy people but should be used with caution in high risk cases such as: immunocompromised patients and premature infants. Current WHO/FAO guidelines (2001) recommend that, before using probiotic strains, a number of parameters should be assessed to prevent health damages, including antibiotic susceptibility patterns, toxin production, metabolic and haemolytic activities, infectivity in immunocompromised animal models, side-effects and adverse incidents in humans (Senok *et al*., 2005).

Medicinal role of probiotics

Diabetes: Diabetes is a chronic disease that occurs when the pancreas doesn't produce enough insulin or when the body cannot effectively use the insulin it produces.

Hyperglycemia is a common effect of uncontrolled diabetes and over time leads to serious damage to many organs and systems. Recent researches illustrated that there is a connection between *Bacteria*l population in gut and metabolic diseases in human (especially, diabetes). These studies showed that there is a relationship between the composition of the intestinal microbiota and metabolic diseases like obesity and diabetes (Larsen *et al*., 2010). Probiotics are supposed to treat diabetics via balancing microbial gut flora. It is also suggested that the use of probiotics, e.g. Bifidobacterium spp can decrease the insulin resistance and can also lower the incident hypertensive conditions tat are closely related to diabetes (Cani and Delzenne, 2011).

Inflammation: Some strains of LAB may decrease the inflammation by modulating inflammatory and hypersensitivity responses. This effect may be accomplished by regulation of inflammatory mediator called cytokines (Reid *et al*., 2003).

Peptic ulcer: Some strains of LAB may control Helicobacter pylori infections (cause of peptic ulcers) in adults when given concomitantly with standard medical treatments. Lactobacillus, Bifidobacterium and Saccharomyces are suggested to be adjuncts to antibiotics for the treatment of *H. pylori* infections.

Hypertension: The incidence of increased blood cholesterol has been increased in adults, children and adolescence. Hypertension can occur due to lipid abnormality, hypercholesterolemia and obesity (Yekeen *et al*., 2003). Mann and Spoer (1974), illustrated that lactobacillus-fermented milk has hypocholesterolemic effects. Bifido*Bacteria* can also cause a significant reduction in serum cholesterol when it elevates. Most of the cholesterol is synthesized and absorbed in the intestine so intestinal micro flora has shown to affect on cholesterol level in blood. Probiotics have been proved to be beneficial in lowering hypertension by decreasing blood cholesterol level and increasing resistance of LDL to oxidation (Goel *et al*., 2006).

Halitosis: Halitosis is the unpleasant odour exhaled in breathing. It is not considered a disease but is caused by some other diseases like periodontitis. Probiotics can be used in treatment both GIT and mouth mediated halitosis (Delanghe *et al*., 1997).

Oral candidiasis: Some strains of probiotics as *L. rhamnosus* strain and propionibacterium freudereichii are effective in reducing the Candida yeast count (Haukioja, 2010).

Viral infection: Probiotics are useful against many viral diseases. It is known that probiotics do not exert antiviral effect by direct action on viruses but do so by the mechanism of immunostimulation (De Vrese and Schrezenmeir, 2002). Such probiotics which exercise immunostimulation also exhibit potential antiviral effect. Species that thrive at relatively high temperatures have some antiinfluezal effect and can also exhibit anti herpetic effect when administered to guinea-pigs (Liaskovs *et al*., 2007).

Lactose intolerance: Lactose intolerance means the inability of adults to digest lactose due to lack of lactose metabolizing enzyme lactase. Approximately most people deficit in lactase generally tolerates lactose better from yogurt than from milk. Lactose is the sugar found in milk products. Kim and Gilliland (1983) found that feeding fermented milk to lactose intolerant subjects resulted in a significantly lower level of hydrogen in the breath when compared to the hydrogen level for subjects fed unfermented milk. Hydrogen in the breath is a marker for *Bacteria*l metabolism of lactose in the large bowel. A lower hydrogen level indicates that lactose has been metabolized prior to entering the large intestine.

Atopic diseases: Atopic dermatitis is the first symptom of atopic disease and it is a chronic skin condition associated with inflammation and pruritis (Simpson, 2010), eczematous papules, itch and plaques. It is one of the most prevalent skin diseases. There is a high risk of developing atopic disease in children whose mother is atopic. Probiotics may play a considerable role in reducing occurrence of atopic diseases. The risk of occurrence of eczema during first 2 years of infant life was reduced significantly in those whose mother received probiotics as compared to those whose mother takes placebo (Rautava *et al*., 2002).

CONCLUSION

The prime objectives of this review was to give an overview about classification of lab their antimicrobial potential and their use in food industry and their probiotic capability.

REFERENCES

Abbas, M.E., W. Luo, L. Zhu, J. Zou and H. Tang, 2010. Fluorometric determination of hydrogen peroxide in milk by using a Fenton reaction system. Food Chem., 120: 327-331.

Abdel-Shafi, S., A. Osman, G. Enan, M. El-Nemer and M. Sitohy, 2016. Anti*Bacteria*l activity of methylated egg white proteins against pathogenic G^+ and G^- *Bacteria* matching antibiotics. SpringerPlus, Vol. 5. 10.1186/s40064-016-2625-3

Abdel-Shafi, S., S.M. Ouda, I. Elbalat and G. Enan, 2013. Characterization and identification of multidrug resistant *Bacteria* from some Egyptian patients. Biotechnology, 12: 65-73.

Adamberg, K., S. Kask, T.M. Laht and T. Paalme, 2003. The effect of temperature and pH on the growth of lactic acid *Bacteria*: A pH-auxostat study. Intl. J. Food Microbiol., 85: 171-183.

Aguirre, M. and M.D. Collins, 1992. Phylogenetic analysis of *Alloiococcus otitis* gen. nov., sp. nov., an organism from human middle ear fluid. Intl. J. Syst. Evol. Microbiol., 42: 79-83.

Ammor, M.S. and B. Mayo, 2007. Selection criteria for lactic acid *Bacteria* to be used as functional starter cultures in dry sausage production: An update. Meat Sci., 76: 138-146.

Ammor, S., G. Tauveron, E. Dufour and I. Chevallier, 2006. Anti*Bacteria*l activity of lactic acid *Bacteria* against spoilage and pathogenic *Bacteria* isolated from the same meat small-scale facility: 1-Screening and characterization of the anti*Bacteria*l compounds. Food Control, 17: 454-461.

Aragon-Alegro, L.C., J.H. Alarcon-Alegro, H.R. Cardarelli, M.C. Chiu and S.M.I. Sadd, 2007. Potentially probiotic and symbiotic chocolate mousse. LWT-Food Sci. Technol., 40: 669-675.

Batish, V.K., S. Grover and R. Lal, 1989. Screening lactic starter cultures for antifungal activity. J. Cultured Dairy Prod., 24: 21-25.

Batish, V.K., U. Roy, L. Ram and S. Grover, 1997. Antifungal attributes of lactic acid *Bacteria*. A review. Crit. Rev. Biotechnol., 17: 209-225.

Beal, C., P. Louvet and G. Corrieu, 1989. Influence of controlled pH and temperature on the growth and acidification of pure cultures of *Streptococcus thermophilus* 404 and *Lactobacillus bulgaricus* 398. Appl. Microbiol. Biotechnol., 32: 148-154.

Begley, M., C.G.M. Gahan and C. Hill, 2005. The interaction between *Bacteria* and bile. FEMS Microbiol. Rev., 29: 625-651.

Beijerinck, M.W., 1912. [The slimy wall fabrics produced by cane sugar *Bacteria* (In German)]. Folia Microbiol., 1: 377-408.

Bernbom, N., T.R. Licht, C.H. Brogren, B. Jelle and A.H. Johansen *et al*., 2006. Effects of *Lactococcus lactis* on composition of intestinal microbiota: Role of Nisin. Applied Environ. Microbiol., 72: 239-344.

Biavati, B. and P. Mattarelli, 1991. *Bifidobacterium ruminantium* sp. nov. and *Bifidobacterium merycicum* sp. nov. from the rumens of cattle. Intl. J. Syst. Evol. Microbiol., 41: 163-168.

Biavati, B., V. Scardovi and W.E.C. Moore, 1982. Electrophoretic patterns of proteins in the genus Bifidobacterium and proposal of four new species. Intl. J. Syst. Evol. Microbiol., 32: 358-373.

Branen, A.L., H.C. Go and R.P. Genske, 1975. Purification and properties of antimicrobial substances by streptococcus diactis and *Leuconostoc cirovorum*. J. Food. Sci., 40: 446-450.

Brink, B.T., M. Minekus, J.M.B.M. van der Vossen, R.J. Leer and J.H.J.H. Intveld, 1994. Antimicrobial activity of lactobacilli: Preliminary characterization and optimization of production of acidocin B, a novel bacteriocin produced by *Lactobacillus acidophilus* M46. J. Applied Bacteriol., 77: 140-148.

Broberg, A., K. Jacobsson, K. Strom and J. Schnurer, 2007. Metabolite profiles of lactic acid *Bacteria* in grass silage. Appl. Environ. Microbiol., 73: 5547-5552.

Buruleanu, L., C.L. Nicolescu, M.G. Bratu, I. Manea and D. Avram, 2010. Study regarding some metabolic features during lactic acid fermentation of vegetable juices. Rom. Biotechnol. Lett., 15: 5177-5188.

Cabana, M.D., A.L. Shane, C. Chao and M. Oliva-Hemker, 2006. Probiotics in primary care pediatrics. Clin. Pediatr., 45: 405-410.

Cani, P.D. and N.M. Delzenne, 2011. The gut microbiome as therapeutic target. Pharmacol. Ther., 130: 202-212.

Caplice, E. and G.F. Fitzgerald, 1999. Food fermentations: Role of microorganisms in food production and preservation. Intl. J. Food Microbiol., 50: 131-149.

Charteris, W.P., P.M. Kelly, L. Morelli and J.K. Collins, 1998. Development and application of an *in vitro* methodology to determine the transit tolerance of potentially probiotic *Lactobacillus* and *Bifidobacterium* species in the upper human gastrointestinal tract. J. Applied Microbiol., 84: 759-768.

Chassy, B.M., 2010. Food safety risk and consumer health. N. Biotechnol., 27: 534-544.

Cleveland, J., T.J. Montville, I.F. Nes and M.L. Chikindas, 2001. Bacteriocins: Safe, natural antimicrobials for food preservation. Int. J. Food Microbiol., 71: 1-20.

Collins, A., E. Nicola, L.A.M. Kirschner and V. Holy, 1991. Characterization of Bacillus isolates from ropey bread, bakery equipment and raw materials. South Afr. J. Sci., 87: 62-66.

Collins, M.D., A.M. Williams and S. Wallbanks, 1990. The phylogeny of Aerococcus and Pediococcus as determined by 16S rRNA sequence analysis: description of Tetragenococcus gen. nov. FEMS. Microbiol. Lett., 70: 255-262.

Collins, M.D., C. Ash, J.A.E. Farrow, S. Wallbanks and A.M. Williams, 1989. Ribosomal ribonucleic acid sequence analyses of Lactococci and related taxa. Description of *Vagococcus fluvialis* gen. nov., sp. nov. J. Appl. Bacteriol., 67: 453-760.

Collins, M.D., J.A.E. Farrow, B.A. Phillips, S. Ferusu and D. Jones, 1987. Classification of *Lactobacillus divergens*, *Lactobacillus piscicola* and some catalase-negative, asporogenous, rod-shaped *Bacteria* from poultry in a new genus, Carnobacterium. Intl. J. Syst. Evol. Microbiol., 37: 310-316.

Conlin, P.R., D. Chow, E.R. Miller, L.P. Svetkey and P.H. Lin *et al*., 2000. The effect of dietary patterns on blood pressure control in hypertensive patients: Results from the Dietary Approaches to Stop Hypertension (DASH) trial. Am. J. Hypertens., 13: 949-955.

De Vrese, M. and J. Schrezenmeir, 2002. Probiotics and non-intestinal infectious conditions. Br. J. Nutr., 88: s59-s66.

De Vuyst, L. and F. Leroy, 2007. Bacteriocins from lactic acid *Bacteria*: Production, purification and food applications. J. Mol. Microbiol. Biotechnol., 13: 194-199.

Delanghe, G., J. Ghyselen, D. van Steenberghe and L. Feenstra, 1997. Multidisciplinary breath-odour clinic. Lancet, 350: 187-187.

Dellagilo, F., L.D. Travateli and P.G. Sara, 1981. Deoxyribonucleic acid homology among representative strains of the genus, Pediococcus, Zentrabl-Bakteriol, Parasitenked, Infekionskr. Hyg. Streptococcus Abt. Orign., C2: 140-150.

Eckner, K.F., 1992. Bacteriocins and food applications. Dairy Food Environ. Sanit, 12: 204-209.

Elo, S., M. Saxelin and S. Salminen, 1991. Attachment of *Lactobacillus casei* strain GG to human colon carcinoma cell line Caco-2: Comparison with other dairy strains. Lett. Appl. Microbiol., 13: 154-156.

Enan, G. and A.A. Al Amry, 2006. Novel plantaricin UG1 production by *Lactobacillus plantarum* UG1 in enriched whey permeate in batch fermentation processes. J. Food Agric. Environ., 4: 85-88.

Enan, G., 1995. Physiology and molecular genetics of lactic acid *Bacteria*, used for industrial fermentations. Ph.D. Thesis, Zagazig University, Egypt-Gent University, Belgum, EU.

Enan, G., 2006. Behaviour of *Listeria monocytogenes* LMG 10470 in poultry meat and its control by the bacteriocin Plantaricin UG1. Intl. J. Poult. Sci., 5: 355-359.

Enan, G., 2006. Inhibition of *Clostridium perfringens* LMG 11264 in meat samples of chicken, Turkey and beef by the bacteriocin Plantarcin UG1. Intl. J. Poult. Sci., 5: 195-200.

Enan, G., 2006. Nature and phenotypic characterization of plantaricin UG1 resistance in *Listeria monocytogenes* LMG 10470. J. Food Agric. Environ., 4: 105-108.

Enan, G., A.A. El-Essawy, M. Uyttendaele and J. Debevere, 1996. Anti*Bacteria*l activity of *Lactobacillus plantarum* UG1 isolated from dry sausage: Characterization, production and bactericidal action of plantaricin UG1. Int. J. Food Microbiol., 30: 189-215.

Enan, G., A.R. Al-Mohammadi, G. El-Didamony, M.E.F. Abdel-Haliem and A. Zakaria, 2014. Antimicrobial activity of *Enterococcus faecium* NM_2 isolated from urine: Purification, characterization and bactericidal action of enterocin NM_2. Asian J. Applied Sci., 7: 621-634.

Enan, G., J. Debevere, M.A. El-Sayed and A.A. El-Essawy, 1994. Production and characterization of a bacteriocin from *Lactobacillus plantarum* UG1. Mededelingen Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen., Vol. 1,

Enan, G., K.A. Shaaban, A. Askora and M. Maher, 2013. Evaluation of the use of novel coliphages to control *Escherichia coli* W_1 and *Escherichia coli* W_2. Res. J. Applied Sci., 8: 486-493.

Enan, G., M.E. Abdel-Haliem and E. Tartour, 2014. Evaluation of the antimicrobial activity, starter capability and technological properties of some probiotic *Bacteria* isolated from Egyptian Pickles. Life Sci. J., 11: 976-985.

Enan, G., N. Awny, A.A.A. Zeid and M.A. Abdou, 2012. Incidence and virulence of Bacillus cereus isolated from Egyptian foods during four seasons. Afr. J. Microbiol. Res., 6: 4816-4824.

Enan, G., S. Abdel-Shafi, M.E.F. Abdel-Haliem and S. Negm, 2013. Characterization of probiotic Lactic acid *Bacteria* to be used as starter and protective cultures for dairy fermentation. Int. J. Probiotics Prebioics, 8: 157-164.

Enan, G., S. Abdel-Shafi, S. Ouda and S. Negm, 2013. Novel anti*Bacteria*l activity of *Lactococcus lactis* Subspecies *Lactis* Z_{11} isolated from Zabady. Int. J. Biomed. Sci., 9: 174-180.

Enan, G., S. Abdel-Shafi, S. Ouda and S. Negm, 2014. Novel anti*Bacteria*l activity of *Lactococcus lactis* subsp. Lactis Z11 isolated from Zabady. Intl. J. Biomed. Sci., 3: 174-180.

Enan, G., S. Abdel-Shafi, S.M. Ouda and I. El-Balat, 2013. Genetic linkage of the antibiotic resistance ability in the *Escherichia coli* UR_4 strain isolated from urine. J. Med. Sci., 13: 261-268.

Enan, G., S. Hamdy, S. Abdel-Shafi and A. Al-Mohammadi, 2016. Biological characteristics and inhibition by both natural agents and antibiotics of *Streptococcus pyogenes*. Res. J. Med. Sci., 10: 573-586.

Enan, G.E., 2006. Control of the regrowing bacteriocin resistant variants of *Listeria monocytogenes* LMG 10470 *in vitro* and in food by nisin-plantaricin UG1 mixture. Biotechnology, 5: 143-147.

Erkkila, S., 2001. Bioprotective and probiotic meat starter cultures for the fermentation of dry sausages. Master Thesis, Department of Food Technology, University of Helsinki, Finland.

FAO/WHO, 2001. Health and nutritional properties of probiotics in food including powder milk with live lactic acid *Bacteria*. Report of a Joint FAO/WHO Expert Consultation on Evaluation of Health and Nutritional Properties of Probiotics in Food Including Powder Milk with Live Lactic Acid *Bacteria*. Cordoba, Argentina.

Fantuzzi, L., L.M.T. Dicks, M. Du Toit, R. Reniero and V. Bottazzi *et al*., 1992. Identification of Leuconostoc strains isolated from argentine raw milk. Syst. Appl. Microbiol., 15: 229-234.

Furrie, E., 2005. Probiotics and allergy. Proc. Nutr. Soc., 64: 465-469.

Fusco, V., G.M. Quero, G.S. Cho, J. Kabisch and D. Meske *et al*., 2015. The genus Weissella: Taxonomy, ecology and biotechnological potential. Front. Microbiol., Vol. 6,

Garvie, E.I., 1967. *Leuconostoc oenos* sp. nov. Microbiol., 48: 431-438.

Gilland, S.E., 1990. Health and nutritional benefits from lactic acid *Bacteria*. FEMS Microb. Rev., 87: 175-188.

Gilliland, S.E., T.E. Staley and L.J. Bush, 1984. Importance of bile tolerance of *Lactobacillus acidophilus* used as a dietary adjunct. J. Dairy Sci., 67: 3045-3051.

Goel, A.K., N. Dilbaghi, D.V. Kamboj and L. Singh, 2006. Probiotics: Microbial therapy for health modulation. Defence Sci. J., 56: 513-529.

Gourama, H. and L.B. Bullerman, 1995. Inhibition of growth and aflatoxin production of *Aspergillus flavus* by *Lactobacillus* species. J. Food. Prot., 58: 1249-1256.

Gourama, H., 1991. Growth and aflatoxin production of *Aspergillus flavus* in the presence lactobacillus species. Ph.D. Thesis, University of Nebraska-Lincoln, Lincoln, Nebraska.

Guldfeldt, L.U., K.I. Sorensen, P. Stroman, H. Behrndt and D. Williams *et al*., 2001. Effect of starter cultures with a genetically modified peptidolytic or lytic system on Cheddar cheese ripening. Intl. Dairy J., 11: 373-382.

Gupta, P.K., B.K. Mital and S.K. Garg, 1996. Characterization of *Lactobacillus acidophilus* strains for use as dietary adjunct. Int. J. Food Microbiol., 29: 105-109.

Gupta, V. and R. Garg, 2009. Probiotics. Indian J. Med. Microbiol., 27: 202-209.

Halasz, A., R. Lasztity, T. Abonyi and A. Bata, 2009. Decontamination of mycotoxin-containing food and feed by biodegradation. Food Rev. Int., 25: 284-298.

Hamdan, I.Y. and E.M. Mikolajcik, 1974. Acidolin: An antibiotic produced by *Lactobacillus acidophilus*. J. Antibiot., 27: 631-636.

Hamilton-Miller, J.M.T., 2004. Probiotics and prebiotics in the elderly. Postgraduate Med. J., 80: 447-451.

Hashimoto, H., R. Noborisaka and R. Yanagawa, 1974. Distribution of motile streptococci in faeces of man and animals and in river and sea water. Jpn. J. Bacteriol., 29: 387-393.

Haukioja, A., 2010. Probiotics and oral health. Eur. J. Dent., 4: 348-355.

Hebert, E.M., R.R. Raya and G.S. De Giori, 2000. Nutritional requirements and nitrogen-dependent regulation of proteinase activity of *Lactobacillus helveticus* CRL 1062. Applied Environ. Microbiol., 66: 5316-5321.

Hiu S.R, R.A. Holt, N. Sriranganathan, R.J. Seidler and J.L. Fryer, 1984. *Lactobacillus piscicola*, a new species from salmonid fish. Int. J. Syst. Bacteriol., 34: 393-400.

Holzapfel, W.H. and U. Schillinger, 1992. The Genus Leuconostoc. In: The Prokaryotes-A Handbook on the Biology of *Bacteria*: Ecophysiology, Isolation, Identification, Applications, Balows, A., H.G. Truper, M. Dworkin, W. Harder and K.H. Schleifer (Eds.). Springer, New York, USA., pp: 1508-1534.

Holzapfel, W.H. and U. Schillinger, 2002. Introduction to pre-and probiotics. Food Res. Intl., 35: 109-116.

Hoover, D.H., 2000. Microorganisms and their Product in the Preservation of Foods. In: The Microbiological Safety and Quality of Food, Lund, B.M., T.C. Baird-Parker and G.W. Gould (Eds.). Aspen Publisher, Gaithersburg, Maryland, pp: 251-276.

Ismaiel, A.A.R., A.E.S. Ali and G. Enan, 2014. Incidence of Listeria in Egyptian meat and dairy samples. Food Sci. Biotechnol., 23: 179-185.

Jacobsen, C.N., V.R. Nielsen, A.E. Hayford, P.L. Moller and K.F. Michaelsen *et al*., 1999. Screening of probiotic activities of 47 strains of *Lactobacillus* sp. by *in vitro* techniques and evaluation of the colonization ability of five selected strains in humans. Applied Environ. Microbiol., 65: 4949-4956.

Jones, D., M.J. Sackin and P.H.A. Sneath, 1972. A numerical taxonomic study of streptococci of serological group D. Microbiol., 72: 439-450.

Joosten, H.M., P. Gaya and M. Nunez, 1995. Isolation of tyrosine decarboxylaseless mutants of a bacteriocin-producing *Enterococcus faecalis* strain and their application in cheese. J. Food Prot., 58: 1222-1226.

Kandler, O., 1970. Amino acid sequence of the murein and taxonomy of the genera Lactobacillus, Bifidobacterium, Leuconostoc and Pediococcus. Intl. J. Syst. Evol. Microbiol., 20: 491-507.

Kandler, O., 1983. Carbohydrate metabolism in lactic acid *Bacteria*. Ant. V. Leuwenhoek, 49: 209-224.

Khedekar, C.D., 1988. Characterization of human strains of *Lactobacillus acidophilus* isolates for their suitability in preparation of milk beverage and their anti*Bacteria*l cum therapeutic ability. MSc Thesis, Anand Agricultural University, Anand, India.

Kilpper-Balz, R. and K.H. Schleifer, 1984. Nucleic acid hybridization and cell wall composition studies of pyogenic streptococci. FEMS. Microbial. Lett., 24: 355-364.

Kilpper-Balz, R., G. Fischer and K.H. Schleifer, 1982. Nucleic acid hybridization of group N and group D streptococci. Curr. Microbiol., 7: 245-250.

Kim, H.S. and S.E. Gilliland, 1983. *Lactobacillus acidophilus* as a dietary adjunct for milk to aid lactose digestion in humans. J. Dairy Sci., 66: 959-966.

Larsen, N., F.K. Vogensen, F.W.V.D. Berg, D.S. Nielsen and A .S. Andreasen *et al*., 2010. Gut microbiota in human adults with type 2 diabetes differs from non-diabetic adults. PloS One, 5: e9085-e9085.

Leroy, F. and L. De Vuyst, 2004. Lactic acid *Bacteria* as functional starter cultures for the food fermentation industry. Trends Food Sci. Technol., 15: 67-78.

Lewus, C.B., A. Kaiser and T.J. Montville, 1991. Inhibition of food-borne *Bacteria*l pathogens by bacteriocins from lactic acid *Bacteria* isolated from meat. Applied Environ. Microbiol., 57: 1683-1688.

Lindgren, S.E. and W.J. Dobrogosz, 1990. Antagonistic activities of lactic acid *Bacteria* in food and feed fermentations. FEMS. Microbiol. Lett., 87: 149-164.

Macfarlane, S., E. Furrie, J.H. Cummings and G.T. Macfarlane, 2004. Chemotaxonomic analysis of *Bacteria*l populations colonizing the rectal mucosa in patients with ulcerative colitis. Clin. Infect. Dis., 38: 1690-1699.

Mailander-Sanchez, D., C. Braunsdorf, C. Grumaz, C. Muller and S. Lorenz *et al*., 2017. Antifungal defense of probiotic *Lactobacillus rhamnosus* GG is mediated by blocking adhesion and nutrient depletion. PloS One, 12: e0184438-e0184438.

Mailander-Sanchez, D., C. Braunsdorf, C. Grumaz, C. Muller and S. Lorenz *et al*., 2017. Antifungal defense of probiotic *Lactobacillus rhamnosus* GG is mediated by blocking adhesion and nutrient depletion. PloS One, 12: e0184438-e0184438.

Mann, G.V. and A. Spoerry, 1974. Studies of a surfactant and cholesteremia in the Maasai. Am. J. Clin. Nutr., 27: 464-469.

Martinez-Murcia, A.J. and M.D. Collins, 1991. A phylogenetic analysis of an atypical leuconostoc: Description of Leuconostoc fallax sp. nov. FEMS. Microbial. Lett., 82: 55-59.

Martinez-Murcia, A.J. and M.D. Collins, 1990. A phylogenetic analysis of the genus Leuconostoc based on reverse transcriptase sequencing of 16 S rRNA. FEMS. Microbiol. Lett., 70: 73-83.

Martinez-Murcia, A.J. and M.D. Collins, 1991. Enterococcus sulfureus, a new yellow-pigmented Enterococcus species. FEMS. Microbiol. Lett., 80: 69-74.

Medina, E., C. Gori, M. Servili, A. De Castro and C. Romero *et al*., 2010. Main variables affecting the lactic acid fermentation of table olives. Intl. J. Food Sci. Technol., 45: 1291-1296.

Metchnikoff II, C. and P. Mitchell, 1910. Nature of Man or Studies in Optimistic Philosophy. Kessinger Publishing, Whitefish, Montana, USA.,.

Miller III, A., M.E. Morgan and L.M. Libbey, 1974. *Lactobacillus maltaromicus* a new species producing a malty aroma. Intl. J. Syst. Evol. Microbiol., 24: 346-354.

Mitsuoka, T., 1984. Taxonomy and ecology of bifido*Bacteria*. Bifido*Bacteria* Microflora, 3: 11-28.

Montville, T.J. and K. Winkowski, 1997. Biologically Based Preservation Systems and Probiotic *Bacteria*. In: Food Microbiology Fundamentals and Frontiers, Doyle, M.P., L.R. Beuchat and T.J. Montville, (Eds.), American Society for Microbiology Press, Washington DC, pp: 557-577.

Mtshali, P.S., 2007. Screening and characterisation of wine related enzymes produced by wine associated lactic acid *Bacteria*. Ph.D Thesis, Stellenbosch University, Stellenbosch, South Africa.

Naidu, A.S., W.R. Bidlack and R.A. Clemens, 1999. Probiotic spectra of Lactic Acid *Bacteria* (LAB). Crit. Rev. Food Sci. Nutr., 39: 113-126.

Nes, I.F., M. Kjos and D.B. Diep, 2012. Antimicrobial Components of Lactic Acid *Bacteria*. In: Lactic Acid *Bacteria* Microbiological and Functional Aspects, Lahtinen, S., A.C. Ouwehand, S. Salminen and A.V. Wright (Eds.). CRC Press, Boca Raton, Florida, USA., pp: 285-311.

Nettles, C.G. and S.F. Barefoot, 1993. Biochemical and genetic characteristics of bacteriocins of food-associated lactic acid *Bacteria*. J. Food Protect., 56: 338-356.

Niku-Paavola, M.G., A. Laitila, T. Mattial-Sandholm and A. Haikara, 1999. New types of antimicrobial compounds produced by *Lactobacillus plantarum*. J. Applied Microbiol., 86: 29-35.

Nurmi, E., L. Nuotio and C. Schneitz, 1992. The competitive exclusion concept: Development and future. Intl. J. Food Microbiol., 15: 237-240.

Oelschlaeger, T.A., 2010. Mechanisms of probiotic actions-A review. Int. J. Med. Microbiol., 300: 57-62.

Omemu, A.M. and O.W. Faniran, 2011. Assessment of the antimicrobial activity of lactic acid *Bacteria* isolated from two fermented maize products-ogi and kunnu-zaki. Malaysian J. Microbiol., 7: 124-128.

Papagianni, M., 2012. Metabolic engineering of lactic acid *Bacteria* for the production of industrially important compounds. Comput. Struct. Biotechnol. J., Vol. 3. 10.5936/csbj.201210003.

Rattanachaikunsopon, P. and P. Phumkhachorn, 2010. Lactic acid *Bacteria*: Their antimicrobial compounds and their uses in food production. Ann. Boil. Res., 1: 218-228.

Rautava, S., M. Kalliomaki and E. Isolauri, 2002. Probiotics during pregnancy and breast-feeding might confer immunomo dulatory protection against atopic disease in the infant. J. Allergy Clin. Immunol., 109: 119-121.

Ray, B. and M. Daeschel, 1992. The Need for Food Biopreservation. In: Food Biopreservatives of Microbial Origin, Ray, B. and M. Daeschel (Eds.). CRC Press, Boca Raton, Florida, ISBN:9780849349430, pp: 1-23.

Reddy, N.S. and B. Ranganathan, 1983. Nutritional factors affecting growth and production of antimicrobial substances by *Streptococcus lactis* subsp. diacetylactis S1-67/C. J. Food Prot., 46: 514-517.

Reid, G., J. Jass, M.T. Sebulsky and J.K. McCormick, 2003. Potential uses of probiotics in clinical practice. Clin. Microbiol. Rev., 16: 658-672.

Ross, R.P., S. Morgan and C. Hill, 2002. Preservation and fermentation: Past, present and future. Int. J. Food Microbiol., 79: 3-16.

Saavedra, J.M., N.A. Bauman, J.A. Perman, R.H. Yolken and I. Oung, 1994. Feeding of *Bifidobacterium bifidum* and *Streptococcus thermophilus* to infants in hospital for prevention of diarrhoea and shedding of rotavirus. Lancet, 344: 1046-1049.

Sandine, W.E., 1996. Commercial Production of Dairy Starter Cultures. In: Dairy Starter Cultures, Cogan, T.M. and J.P. Accolas (Eds.). Wiley-VCH, New York, pp: 191-206.

Schillinger, U. and F.K. Lucke, 1987. Identification of lactobacilli from meat and meat product. Food Microbiol., 4: 199-208.

Schleifer, K.H. and R. Kilpper-Balz, 1984. Transfer of *Streptococcus faecalis* and *Streptococcus faecium* to the genus Enterococcus nom. rev. as *Enterococcus faecalis* comb. nov. and *Enterococcus faecium* comb. nov. Intl. J. Syst. Evol. Microbiol., 34: 31-34.

Senok, A.C., A.Y. Ismaeel and G.A. Botta, 2005. Probiotics: Facts and myths. Clin. Microbiol. Infect., 11: 958-966.

Shah, N.P., 2007. Functional cultures and health benefits. Int. Dairy J., 17: 1262-1277.

Simpson, E.L., 2 010. Atopic dermatitis: A review of topical treatment options. Curr. Med. Res. Opin., 26: 633-640.

Skytta, E., A. Haikara and T. Mattila-Sandholm, 1993. Production and characterization of anti*Bacteria*l compounds produced by *Pediococcus damnosus* and *Pediococcus pentosaceus*. J. Appl. Microbiol., 74: 134-142.

Soccol, C.R., L.P.S. Vandenberghe, M.R. Spier, A.B.P. Medeiros and C.T. Yamaguishi *et al*., 2010. The potential of probiotics: A review. Food Technol. Biotechnol., 48: 413-434.

Stiles, M.E. and W.H. Holzapfel, 1997. Lactic acid *Bacteria* of foods and their current taxonomy. Int. J. Food Microbiol., 36: 1-29.

Sunil, K. and B. Narayana, 2008. Spectrophotometric determination of hydrogen peroxide in water and cream samples. Bull. Environ. Contam. Toxicol., 81: 422-426.

Tamime, A.Y., M. Saarela, A.K. Sondergaard, V.V. Mistry and N.P. Shah, 2005. Production and Maintenance of Viability of Probiotic Micro-Organisms in Dairy Products. In: Probiotic Dairy Products, Tamime, A.Y. (Ed.). Chapter 3, Blackwell Publishing, Oxford, UK., ISBN-13: 978-1405121248, pp: 39-72.

Thyagaraja, N. and A. Hosono, 1994. Binding properties of lactic acid *Bacteria* from Idly towards food-borne mutagens. Food Chem. Toxicol., 32: 805-809.

Vandenbergh, P.A., 1993. Lactic acid *Bacteria*, their metabolic products and interference with microbial growth. FEMS Microbiol. Rev., 12: 221-238.

Vollaard, E.J. and H.A. Clasener, 1994. Colonization resistance. Antimicrob. Agents Chemother., 38: 409-411.

Vuyst, L.D. and E.J. Vandamme, 1994. Bacteriocins of Lactic Acid *Bacteria*: Microbiology, Genetics and Applications. Blackie Academic & Professional, Glasgow, Scotland, UK., ISBN:9780751401745, Pages: 539.

Wallbanks, S., A.J. Martinez-Murcia, J.L. Fryer, B.A. Phillips and M.D. Collins, 1990. 16S rRNA sequence determination for members of the genus Carnobacterium and related lactic acid *Bacteria* and description of *Vagococcus salmoninarum* sp. nov. Intl. J. Syst. Evol. Microbiol., 40: 224-230.

Weinberg, Z.G., R.E. Muck, P.J. Weimer, Y. Chen and M. Gamburg, 2004. Lactic acid *Bacteria* used in inoculants for silage as probiotics for ruminants. Applied Biochem. Biotechnol., 118: 1-9.

Yaeshima, T., T. Fujisawa and T. Mitsuoka, 1991. Differential characteristics of *Bifidobacterium longum* and *Bifidobacterium animalis*. Syst. Appl. Microbial., 14: 169-172.

Yang, S.C., C.H. Lin, C.T. Sung and J.Y. Fang, 2014. Anti*Bacteria*l activities of bacteriocins: Application in foods and pharmaceuticals. Front. Microbiol., 5: 1-10.

Yang, Z., 2000. Antimicrobial compounds and extracellular polysaaharides produced by lactic acid *Bacteria*: Structures and properties. MSc Thesis, Faculty of Agriculture and Forestry, Department of Food Technology, University of Helsinki, Helsinki, Finland.

Yekeen, L.A., R.A. Sanusi and A.O. Ketiku, 2003. Prevalence of obesity and high level of cholesterol in hypertension: Analysis of data from the university college hospital, Ibadan. Afr. J. Biomed. Res., 6: 129-132.

Zago, L., M. Petit and N. Joliet, 2011. Microbiological status of pickles and starter evaluation of *Lactobacillus plantarum*. J. Food Prot., 15: 860-868.

Zago, M., M.E. Fornasari, D. Carminati, P. Burns and V. Suarez *et al*., 2011. Characterization and probiotic potential of *Lactobacillus plantarum* strains isolated from cheeses. Food Microbiol., 28: 1033-1040.