Effects of Probiotics on Lipid Profile: A Review

1Aziz Homayouni, 2Laleh Payahoo and 3Aslan Azizi
1Department of Food Science and Technology, Faculty of Health and Nutrition, Tabriz University of Medical Sciences, Tabriz, Islamic Republic of Iran
2Department of Nutrition, Faculty of Health and Nutrition, Tabriz University of Medical Science, Islamic Republic Iran
3Department of Food Engineering, Iranian Agricultural Engineering Research Institute, Ministry of Jihad Agriculture, Karaj, Islamic Republic of Iran

Corresponding Author: Aslan Azizi, Department of Food Engineering, Iranian Agricultural Engineering Research Institute, Ministry of Jihad Agriculture, Karaj, Islamic Republic of Iran. Tel: +98-261-3202205 Fax: +98-261-2706277

ABSTRACT
Probiotics are live microorganisms which when consumed in enough amounts exert health effects on the host. Several animal and human studies showed that probiotics have beneficial effects in prevention and treatment of some diseases. In addition to improving gut health, immunity and protection against harmful microorganisms, antihypertensive and antioxidative effects, anticarcinogenic properties and prevention of cancer, improving of arthritis, reduction of dermatitis and allergic symptoms, protection against gastrointestinal disease, dental carries, osteoporosis and obesity, probiotics have also been studied for their cholesterol-lowering effects. The purpose of this study was to review recent researches into the lipid profile improving effect of probiotics in animal and human studies and brief explanation about functional probiotic foods. Probiotics can be found in dairy and non-dairy products. It has been shown that, probiotics exert lowering lipid profile through several mechanisms such as deconjugate bile acids through bile salt hydrolase catalysis, take up and assimilate cholesterol for stabilization of their cell membrane and binding cholesterol to cell walls of probiotics in intestine, conversion of cholesterol into coprostanol, inhibit hepatic cholesterol synthesis by short chain fatty acids such as propionate produced by probiotic bacteria and/or redistribution of cholesterol from plasma to the liver. Certain strains of probiotics have demonstrated cholesterol lowering properties while others did not. However, not all trials have yielded conclusive results. Thus, more properly designed in vitro trials may appear additional understanding to eliminate the controversies, to better understand the underlying mechanisms and for safety assessment prior to consumption.

Key words: Cholesterol lowering, lipid profile, probiotics

INTRODUCTION
Probiotics: It is becoming increasingly difficult to ignore the influence of live microorganisms in foods and understanding of their effect especially lactic acid bacteria, on human health that has a very long history. In a Persian version of the Old Testament, it is said that Abraham owed his longevity to the consumption of sour milk (Schrezenmeir and de Vrese, 2001). Metchnikoff (1908) stated that the longevity of the Bulgarians was in part related to their consumption of large quantities of fermented milk containing lactobacilli. The name probiotic comes from the Greek
'pro bios' which means 'for life' (Gismondo et al., 1999). Probiotics was first used by Lilly and Stillwell (1965) to describe the 'substances secreted by one microorganism that stimulate the growth of another'.

It is clear that, a number of definitions of the term 'probiotic' have been used over the years but the one derived by the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO, 2001; Homayouni, 2009) and approved by the International Scientific Association for Probiotics and Prebiotics (Reid et al., 2003) best exemplifies the breadth and scope of probiotics as they are known today: 'live microorganisms which, when administered in adequate amounts, exert health benefit on the host'. Use of probiotic term for microorganisms need criteria such as these microorganism must be capable of being prepared in a viable manner and on a large scale, during use and under storage, the probiotics should remain viable and stable, they are should be able to survive in the intestinal ecosystem and also the host animal should gain beneficially from harboring the probiotic (Ogueke et al., 2010). The first recorded probiotic was fermented milk for human consumption. After that, probiotics became popular with animal nutrition. Across the globe, about 20 probiotic strains, alone or in combination, mainly Lactobacilli such as L. acidophilus, L. casei, L. reuteri and others; Bifidobacteria, safe spore forming lactic acid producing bacteria (such as Lactospore; Bacillus coagulans also known as Lactobacillus sporogenes) and a probiotic yeast culture Saccharomyces boulardii, are used in dietary supplements and functional foods or in mainstream food products (Maity and Misra, 2009).

A considerable amount of literature has been published on the application of probiotic bacterium in animal and human studies. In addition to improving gut health (FAO/WHO, 2001; Homayouni, 2009) and immunity (Galdeano et al., 2007), protection against harmful microorganisms (Soccol et al., 2010), probiotics have been documented to exert other health promoting effects by several mechanisms. Some of other health benefits of probiotics are reduce the severity of infection (Shu et al., 2000), antihypertensive effects (Ye and Liong, 2010), anticarcinogenic properties (Bengmark et al., 1998; Mack et al., 1999) and prevention of cancer especially colon and bladder (Sanders, 2006), antioxidative effects (Songisepp et al., 2004), improving of arthritis (Baharav et al., 2004), reduction of dermatitis and allergic symptoms especially in infants and pregnant womens (Weston et al., 2005; Ouwehand, 2007), prevention against gastrointestinal disorders (Homayouni and Ehtahed, 2009) such as ulcerative colitis (Pronio et al., 2008) and Crohn’s disease (Vilela et al., 2008), prevention of dental carries (Haukiopa, 2010) improving of performance (Sultan et al., 2006) and prevention of osteoporosis (Lourens-Hattingh and Viljoen, 2001) and obesity (DiBaise et al., 2008). Probiotics have also been studied for their cholesterol-lowering effects (Ehtahed et al., 2011; Pereira and Gibson, 2002a). The purpose of this study was to review recent researches into the lipid profile improving effects of probiotics in animal and human studies. This study first gives a brief overview of the functional probiotic foods and then focuses on cholesterol-lowering effect of probiotic in animal and human studies.

**Probiotics in foods:** Probiotics can be found in dairy and non dairy products (Soccol et al., 2010). Functional foods, designer foods or medicinal foods are defined as: 'foods that contain some health-promoting component(s) beyond traditional nutrients'. Addition of probiotics is a way in which foods can be changed to become functional (FAO/WHO, 2001). Different types of food matrices have been used such as various types of cheese, ice cream, milk-based desserts, butter, mayonnaise, powder products or capsules and fermented foods of vegetable origin (Tamime et al., 2005). In the production of probiotics an important factor is the food substrate.
Besides buffering the bacteria through the stomach, it may contain functional ingredients that interact with the probiotics, altering their activities. Fat content, type of protein, carbohydrates and pH can affect probiotic growth and survival (Soccol et al., 2010).

**Probiotics in dairy foods:** Dairy products are mentioned as ideal vehicle for delivering probiotic bacteria to the human gastrointestinal tract. The matrices used most frequently are cheese, yoghurt, ice cream and other dairy products. The most common means to incorporate probiotics to fermented milk include: (1) addition of probiotics together with the starter cultures, (2) the production of two batches separately, one containing the probiotic microorganism in milk to achieve a high concentration of viable cells and another with starter cultures. When the fermentation stages are completed, the batches are mixed and (3) the use of a probiotic microorganism as a starter culture. In this situation, the time of fermentation is generally higher than traditional processes using non-probiotic starter cultures (Tamine et al., 2005). In this respect, it is necessary to consider the supplementation of the culture medium and the production conditions (e.g., incubation temperatures), since metabolites produced by probiotics can lead to off-flavours (Saarelta et al., 2000; Ostlie et al., 2003). In addition, the probiotic strains must be compatible with starter cultures, since the latter could produce inhibitory substances that damage the probiotics (Vinderela et al., 2000). Yoghurts with high fat content showed inhibitory effects against probiotic cultures, particularly *B. bifidum* BBI. The supplementation with vitamins (e.g., ascorbic acid) has been reported to improve the viability of *L. acidophilus* in yoghurts (Dave and Shah, 1997). The addition of substances such as whey protein may also enhance the viability of some probiotics, probably due to their buffering property. In addition, the employment of prebiotics in yoghurt formulations could stimulate the growth and activity of probiotics. In this regard, fructooligosaccharides showed to be most effective in maintaining the probiotic viability (Capela et al., 2006).

The utilization of probiotics in the cheese elaboration presents some challenges: low moisture content; presence of salt; starter cultures competing for nutrients and developing acid and flavour during the maturation stage; extended storage (over 3 months) which can influence biochemical activities, redox potential and alter the cheese structure. Moreover, probiotics should survive the entire shelf life of the cheese, not produce metabolites that affect the cheese quality and the starter culture activities and also, they should be able to grow in starter culture media (e.g., whey-based and phage inhibitory media). Tamine et al. (2005) reported that, Turkish white brined, Feta-type, Cheddar, Philippine white soft, Edam, Emmental, Domiati, Ras, Herrgard cheese, Quarg and cheese-based dips can be compared with yoghurts in delivering probiotics.

On the other hand ice cream and frozen dairy desserts are ideal vehicle to delivery of probiotics into human intestinal tract (Mountzouris and Gibson, 2003; Homayouni, 2008) that it refer to be stored at low temperatures which makes them less exposed to abusive temperatures having higher viability at the time of consumption (Cruz et al., 2009). Besides, they are consumed by people of all ages and are composed of milk proteins, fat and lactose as well as other compounds that are required for bacterial growth. However, some probiotic species showed a decrease in the viability during the manufacture and freezing of ice cream (Alamprese et al., 2002). So, selection of resistant probiotic strains and adjust the condition of production and storage for more survival rates (encapsulation) can be useful methods for increasing viability of them (Shah and Ravula, 2000; Homayouni et al., 2008). Selection of suitable probiotic strains depend on to probiotic ability to survive simulated conditions of ice cream (high sucrose concentrations, high oxygen, freezing and
storage tempreatures), gastric (acidic) and intestinal conditions (alkaline) (Homayouni et al., 2012). As well as some probiotics could be used to improve the characteristics of the probiotic ice creams. Inulin demonstrated to be beneficial to the firmness, melting properties and dripping time of the ice creams (Akalin and Erisir, 2008). Besides, the inulin level in ice cream enhanced the viability of L. acidophilus and B. lactis (Akin et al., 2007). The addition of oligofructose in low-fat ice cream also improved the survival of L. acidophilus La-5 and B. animalis ssp. lactis Bb-12 during storage (Akalin and Erisir, 2008). However, to efficiently produce probiotic ice cream, it is important to select oxygen-resistant strains since the incorporation of air (overrun) in the mixture occurs in the production process which is harmful to microaerophilic and anaerobic strains such as Lactobacillus sp. and Bifidobacterium sp. This type of challenge can be resolved by the use of microencapsulation technique.

As an alternative, dairy dessert (e.g., chocolate mousse) has also been used as a potential agent to deliver probiotics (Aragon-Alegro et al., 2007).

Probiotics in non dairy foods: Some limitations of the use of dairy products to deliver probiotics are the presence of allergens and requirement of cold environments. This fact has led to the launch of new products based on non-dairy matrices. Some claims related to probiotic products are lactose intolerance and fat content. Some matrices have been used in the development of non-dairy probiotic products such as fruits, vegetables, legumes and cereals.

Fruits and vegetables can be considered good matrices since they contain nutrients such as minerals, vitamins, dietary fibres and antioxidants. The development of different probiotic fruit juices has been studied (Yoon et al., 2004; Soccol et al., 2007). However, the incorporation of probiotics in fruit juices requires the protection against acid conditions. This can be achieved by microencapsulation technologies which allow the entrapment of cells into matrices with a protective coating (Soccol et al., 2010).

Probiotic strains usually found in vegetable materials are species belonging to Lactobacillus and Leuconostoc genera. L. plantarum, L. casei and L. delbrueckii, for example, were able to grow in cabbage juice. In addition, it was found that these same bacteria grew in beet juice (Yoon et al., 2005). Gelatin and vegetable gum have been demonstrated to provide a good protection for acid-sensitive Bifidobacterium and Lactobacillus (Sultana et al., 2000; O’Riordan et al., 2001).

In the case of cereals such as oat and barley, fermentation with probiotic microorganisms could be beneficial due to the decrease of nondigestible carbohydrates (polyand oligosaccharides), the improvement of the quality and level of lysine, the availability of the vitamin B group, as well as the degradation of phytates and release of minerals (e.g., manganese, iron, zinc and calcium) (Blandino et al., 2005). Oat-based substrates have proved promissory for the growth of L. reuteri, L. acidophilus and B. bifidum (Martensson et al., 2002). Boza, an acid and low-alcohol beverage produced in the Balkan Peninsula, is a fermented product based on maize, wheat and other cereals.

Malt, wheat and barley extracts as non dairy foods demonstrated to have a good influence in increasing bile tolerance and viability of L. acidophilus, L. reuteri and L. plantarum (55, 56). Fermented foods with probiotic strains had an increment in the content of the vitamin B complex (Soccol et al., 2010).

Soymilk is another non dairy product for delivery of probiotics. The survival of probiotics has been assayed in soymilk and this substrate has shown to be efficient for the growth of species such as L. casei (Garro et al., 1999), L. acidophilus (Wang et al., 2006), B. infantis and B. longum.
(Chou and Hou, 2000, 2002). The antioxidative activities of soymilk can be increased after fermentation by lactic acid bacteria and bifidobacteria (Dave and Shah, 1997). This has led to the designing of the probiotic soybean yoghurt (Wang et al., 2006).

HYPRELIPIDEMIA

Relationship between hyperlipidemia and CHD: Coronary Heart Disease (CHD) is one of the major causes of death and disability in industrialized countries (El-Shafie et al., 2009). In Iran, as many countries, CHD associated with hyperlipidemia (hypertriglyceridemia and hypercholesterolemia) are considered as the main cause of death (Fazeli et al., 2010). The world Health Organization (WHO) predicts that by the year 2020, up to 40% of all deaths will be related to cardiovascular diseases or disease of the heart. Although, cholesterol is an important basic block for body tissues, elevated blood cholesterol is a well-known major risk factor for CHD (Aloglu and Oner, 2006). The results from several epidemiological and clinical studies indicate a positive correlation between elevated total serum cholesterol levels, mainly reflecting the LDL-cholesterol fraction and risk of emergence of CHD (Lipid Research Clinics Program, 1984). It was reported that, hypercholesterolemia contributed to 45% of heart attacks in Western Europe and 35% of heart attacks in Central and Eastern Europe from 1999-2003 (Yusuf et al., 2004). The risk of heart attack is three times higher in those with hypercholesterolemia, compared to those who have normal blood lipid profile. Also each increase in the serum cholesterol concentration by 1% results in 2-3% increase in the risk of CHD (Davis et al., 1990; Manson et al., 1992).

EFFECTS OF PROBIOTICS ON LIPID PROFILE

Recent modalities for lowering blood cholesterol levels involve dietary management, behavior modification regular exercise and drug therapy (Dunn-Emke et al., 2001). Pharmacological agents are available for the treatment of high cholesterol, although they effectively reduce cholesterol levels, they are expensive and are known to have severe side effects (Bliznakov, 2002). Thereby use of probiotics for natural and safe properties and a low ability of triggering adverse effects can be useful strategy (Roberfroid, 2007).

Among the beneficial effects attributed to probiotics and probiotic-containing food products, the reduction of blood cholesterol is of particular interest (Cavallini et al., 2009). The first record of the influence of certain dairy products on blood lipids dates back more than 40 years. Shaper et al. (1963) and later Mann and Spoerry (1974) observed that men from the tribes of Samburu and Maasai warriors in Africa showed reduced serum cholesterol after consumption of large amounts of milk fermented with a wild Lactobacillus strain. The primary probiotic bacteria associated with cholesterol lowering have been lactobacilli and bifidobacteria, although, other lactic acid bacteria, such as enterococci, are able to produce this effect (Cavallini et al., 2009).

Probiotics in animal studies: Hyapolipidemic effects of several strains of probiotics have been demonstrated in many animal studies (Table 1). El-Shafie et al. (2009) showed the effect of lactic acid bacteria Lactobacillus plantarum NRRL B-4524 used as single or mixed with Lactobacillus paracasei and/or other strains of bacteria in rat diets (high fat and high cholesterol-enriched) in lowering blood serum cholesterol (El-Shafie et al., 2009).

Rossi et al. (1999) developed a soy yogurt, fermented by Enterococcus faecium CRL 188 (probiotic microorganism) and Lactobacillus helveticus ssp. jugurti 416 (Rossi et al., 1999).
<table>
<thead>
<tr>
<th>Table 1: Animal and human studies of probiotics in lipid profile levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probiotic strain</strong></td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td><em>Lactobacillus plantarum</em> NRRL B-4524 and <em>Lactobacillus paracasei</em></td>
</tr>
<tr>
<td><em>Lactobacillus plantarum A7</em></td>
</tr>
<tr>
<td><em>Lactobacillus plantarum PH04</em></td>
</tr>
<tr>
<td><em>Lactobacillus plantarum</em></td>
</tr>
<tr>
<td><em>Bifidobacterium longum</em> BB-46</td>
</tr>
<tr>
<td><em>Lactobacillus acidophilus</em> fermention rice bran</td>
</tr>
<tr>
<td><em>Lactobacillus sporogenes</em></td>
</tr>
<tr>
<td><strong>In human studies</strong></td>
</tr>
<tr>
<td><em>Lactobacillus bulgaricus</em> and <em>S. thermophilus</em></td>
</tr>
<tr>
<td><em>Lactobacillus acidophilis</em></td>
</tr>
<tr>
<td><em>B. longum BL1</em></td>
</tr>
<tr>
<td><em>E. faecium M-74</em></td>
</tr>
<tr>
<td><em>Streptococcus thermophilus</em> and <em>Lactobacillus bulgaricus</em></td>
</tr>
<tr>
<td><em>Lactobacillus acidophilus</em></td>
</tr>
<tr>
<td><em>Lactobacillus fermentum</em></td>
</tr>
<tr>
<td><em>Lactobacillus acidophilus</em></td>
</tr>
<tr>
<td><em>Lactobacillus acidophilus</em></td>
</tr>
<tr>
<td><em>Lactobacillus acidophilus</em></td>
</tr>
</tbody>
</table>

Fazeli et al. (2010) showed that the consumption of *L. plantarum A7* (10⁶ CFU mL⁻¹) for 14 days is effective in lowering serum lipid levels in rats (Fazeli et al., 2010).

In placebo-controlled studies (Park et al., 2007; Liang and Shah, 2006) have been evaluate the effects of probiotic strains on cholesterol metabolism in hypercholesterolemia-induced mice and rats. It was found in all these investigation that the serum cholesterol levels decreased in the rats fed with a diet supplemented with probiotics.

In a study evaluating the effect of *L. plantarum* PH04 (isolated from infant feces) on cholesterol, Nguyen et al. (2007) administered *L. plantarum* (4×10⁶ CFU mL⁻¹ dose per day in
mouse) to twelve male hypercholesterolemic mice for 14 days. The authors found a significant (p<0.05) reduction of total serum cholesterol (reduced by 7%) and triglyceride (reduced by 10%) compared to the control group. In another study, Abd El-Gawada et al. (2005) conducted a randomized, placebo-controlled and parallel designed study to assess the efficiency of buffalo milk-yogurts (fortified with Bifidobacterium longum Bb-46) in exerting a cholesterol-lowering effect. In the study, the authors fed forty-eight male albino hypercholesterolemic rats (average weight 80-100 g) with 50 g of yogurts (containing 0.07% (w/v) Bifidobacterium longum Bb-46) daily for 35 days. The administration of B. longum Bb-46-fermented buffalo milk-yogurt significantly reduced concentration of total cholesterol by 50.3%, LDL cholesterol by 56.3% and triglycerides by 51.2% compared to the control (p<0.05). In another study, Fukushima et al. (1999) found that, 73 hypercholesterolemic male Fischer 344/Jcl rats (8 week old) fed with 30 g kg⁻¹ of L. acidophilus-fermented rice bran significantly showed an improved lipid profile compared to the control (without L. acidophilus). In this 4 week study, the authors reported a significant (p<0.05) reduction in serum total cholesterol and liver cholesterol of 21.3 and 22.5%, respectively compared to the control.

Taranto et al. (2000) reported that, administration of Lactobacillus reuteri was effective in preventing hypercholesterolemia in mice. In addition, he observed a decrease in total cholesterol (22%) and triglycerides (33%), as well as a 17% increase in the ratio of HDL to LDL.

Gilliland et al. (1985) fed a strain of Lactobacillus (strain RP32) to pigs with a high-fat diet which induced any rise in serum cholesterol. Daniela CU Cavallini showed that probiotic microorganism E. faecium CRL 183 in rabbits could be used to improve lipid profile as an alternative or an adjuvant for drug therapy (Cavallini et al., 2009). In Hung et al. (2008) study, it has been shown that use of probiotic combination in fermented soybean meal resulted in reduction in TG, TC and LDL-C in forty-eight pigs (Hung et al., 2008).

Probiotics supplementation reduces cholesterol concentration in serum of chickens (Mohan et al., 1995). Arun et al. (2006) showed that dietary supplementation of Lactobacillus sporogenes (6×10⁸ spore per g) at 100 mg kg⁻¹ diet significantly lowered total cholesterol, VLDL cholesterol and triglycerides concentrations in the serum of broiler chickens. Supplementation of probiotics (Lactobacillus acidophilus, Bifidobacterium bifidum and Aspergillus oryzae) at 100 mg kg⁻¹ in the diet of broiler chickens significantly reduced the serum cholesterol concentration. Kalavathy et al. (2003) reported that, dietary supplementation of a mix culture of 12 strains of Lactobacillus at 1% in the basal diet of broilers resulted in higher body weight gain and lowered serum cholesterol concentration.

**Probiotics in human studies:** The hypocholesterolemic potential of probiotics has also been evaluated in human subjects (Table 1). In 1979, the first trial to evaluate the effects of lactic acid bacteria on serum cholesterol levels in humans was conducted. Fifty four volunteers participated in a randomized cross over trial; the results revealed reductions of 5-10% in serum cholesterol levels after several weeks of moderate consumption of yoghurt fermented with Lactobacillus bulgaricus and S. thermophilus (Schlaafsma et al., 1998).

A Dutch trial involving 30 healthy men also found that consuming yoghurt fermented with L. acidophilus cultures for several weeks decreased both total and LDL cholesterol levels by 4.4 and 5.4%, respectively compared with controls (Xiao et al., 2003). Xiao et al. (2003) evaluated the effects of a low-fat yoghurt containing 10⁹ CFU g⁻¹ of B. longum BL1 on lipid profile of thirty-two subjects (baseline serum total cholesterol 220-280 mg dL⁻¹, body weight 55.4-81.8 kg, aged 28-60 years old). Results from this randomized, single-blind, placebo-controlled and parallel study showed a
significant (p<0.05) decline in serum total cholesterol, LDL-cholesterol and triglycerides after 4 weeks. The authors also observed a 14.5% increase in HDL-cholesterol when comparing to the control (yoghurt without B. longum BL1; p<0.05) (Xiao et al., 2003).

Hivak et al. (2005) showed that, administration of the E. faecium M-74 as probiotic strain was associated with the reduction of serum cholesterol concentration by 12% after 56 weeks in 43 volunteers. Pawan and Bhatia (2007) showed that, probiotics given in the form of fermented milk product ‘Dahi’ and ‘Lassi’ in 60 male healthy volunteers had no significant reduction in cholesterol level and HDL-C in the human subjects. Ashar and Prajapati (2001) reported hypcholesterolemic effect of probiotic diet in humans and showed total cholesterol reduction to an extent of 12-21% by feeding on acidophilus milk. The lactic acid fermenters of yogurt can reduce the levels of total cholesterol, HDL-C and LDL-C, in a well-balanced way by assimilation of cholesterol by bacteria in yoghurt (in vitro). The effect of probiotic intake on cholesterol level on human subjects carried by Fabian and Elmadfa (2006) showed that, the consumption of fermented milk leads to decrease in cholesterolemia. Lewis and Burmeister (2005) showed that L. acidophilus in volunteers can not affect in serum lipids. Fabian and Elmadfa (2006) showed that, mean concentrations of total, HDL and LDL cholesterol in 33 female volunteers changed among the probiotic (n = 17) (enriched with Streptococcus thermophilus and Lactobacillus bulgaricus), as well as, the control (n = 16) group (S. thermophilus and L. bulgaricus). No relevant differences were observed between the two groups. The total/HDL and LDL/HDL cholesterol ratios improved in both groups. The authors found that L. acidophilus capsules did not significantly change plasma total cholesterol, LDL-cholesterol, HDL-cholesterol and triglycerides of the subjects. In a controlled trial lasting 6 weeks involving 78 healthy subjects which found that consumption of yoghurt fermented with L. acidophilus had no significant effect on serum cholesterol levels at all (De Roo et al., 1998). Human and animal studies of probiotics were summarized in Table 1.

Although, many studies have demonstrated convincing cholesterol-lowering effects of probiotics in both animals and humans, controversial results have been surfaced. A study by Hatakka et al. (2008) refuted the purported hypcholesterolemic effect of probiotics and reported that the administration of L. rhamnosus LC705 (10^10 CFU g^-1 per capsule; two capsules daily) did not influence blood lipid profile in thirty-eight men with mean cholesterol levels of 6.2 mmol L^-1 after a 4 week treatment period. In another study, involving forty-six volunteers (aged 30-75 years old), Simons et al. (2006) found that the consumption of Lactobacillus fermentum, (2×10^8 CFU per capsule; four capsules daily) did not contribute to any lipid profile changes after 10 weeks. Lewis and Burmeister (2005) conducted a randomized, placebo-controlled double blind and crossover designed study to determine the effect of Lactobacillus acidophilus on human lipid profile. In this study, eighty volunteers (aged 20-65 years old; baseline total cholesterol of >5.0 mmol L^-1; mean Body Mass Index of 27.8 kg m^-2) consumed two capsules containing freeze-dried L. acidophilus (3×10^10 CFU/kg capsules) three times daily for six weeks and crossed over for another six weeks after a 6 week washout period. These results may refer to semi-active properties of probiotic cells in capsules. Therefore, it can be concluded that probiotics may improve lipid profile in active form as are in functional foods.

MECHANISMS OF ACTION

Several mechanisms are suggested for cholesterol reducing activity of probiotics. These mechanisms including deconjugate bile acids through bile salt hydrolase catalysis. Since, cholesterol is the precursor for the synthesis of new bile acids, the use of cholesterol to synthesize new bile would lead to a decreased concentration of cholesterol in blood (Lye et al., 2009), to take up and
Fig. 1: Mechanisms of hypolipidemic effects of probiotics

assimilate cholesterol for stabilization of their cell membrane and binding cholesterol to cell walls of probiotics in intestine (Tanaka et al., 1999; Lepercq et al., 2004; Razin, 1975; Noh et al., 1997), conversion of cholesterol into coprostanol (Lye et al., 2010) and short chain fatty acids such as propionate produced by probiotic bacteria may also inhibit hepatic cholesterol synthesis and/or redistribution of cholesterol from plasma to the liver (Wolever et al., 1996; Delzenne and Williams, 2002; Pereira and Gibson, 2002b) hypocholesterolemic effect via altering the pathways of cholesteryl esters and lipoprotein transporters (Coi and Liong, 2010). Figure 1 shows mechanisms of hypolipidemic effects of probiotics.

CONCLUSION

This study has given an account of and the reasons for widespread use of probiotics for improving the lipid profile (total cholesterol, LDL-cholesterol, HDL-cholesterol and triglyceride) in animal and human studies. However, not all trials have yielded conclusive results. Certain strains of probiotics have demonstrated cholesterol lowering properties while others did not. Also, the matrix-as a probiotic carrier-may influence the cholesterol-lowering effect of probiotics. In order to justify the varying cholesterol-lowering effect exhibited by various strains of probiotics, researchers have endeavored to reveal the mechanisms of probiotics on hypocholesterolemic effect through in vitro and in vivo studies. Many of the proposed mechanisms and experimental evidence specifically targeting cholesterol-lowering effects remain controversial. Thus, more properly-designed in vivo trials may disclose additional understanding and knowledge to eliminate the controversies, to better understand the underlying mechanisms and for better safety assessment prior to consumption.

REFERENCES


