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Review

Bioprotectives and probiotics for dry sausages

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Abstract

The microbial stability of dry sausages is determined by the combination and timing of different factors referred to as the hurdle-concept. However, the hurdles present in dry sausage are not sufficient to prevent the survival of *Listeria monocytogenes* or enterohemorrhagic *Escherichia coli* O157:H7. Recently bioprotective lactic acid bacteria, which in addition to the production of antimicrobial lactic acid, have been found to contribute to the safety of the dry sausage by producing antimicrobial peptide, i.e. bacteriocins and other low-molecular-mass compounds. Furthermore, the possibilities to use probotics in dry sausage manufacturing process has been addressed recently. As one possible mode of action for probiotics is the production of antimicrobial compounds, lactic acid bacteria may act as both probiotic and bioprotective culture as well as fermenting agent in meat product, such as dry sausage.

Keywords: Dry sausage; Probiotic; Bacteriocin; Bioprotective culture

1. Introduction

Today the increase in knowledge of nutrition has led to the development of foods which have health benefits beyond adequate nutrition. These functional foods are becoming scientifically better documented and also the trend is food for special health use, with the aim to promote the health and well-being of the consumers (Salminen et al., 1998a). Some dairy products—especially fermented milk and yoghurt—are produced by viable probiotic lactic acid bacteria (LAB) with scientifically proven health effects and safety (Salminen et al., 1998b). Dry sausages are non-heated meat products, which may be suitable carriers for probiotics into the human gastrointestinal tract. The idea of using probiotic bacteria as fermenting agents in meat products is beginning to develop and the idea of using antimicrobial peptides, i.e. bacteriocins, or other antimicrobial compounds as an extra hurdle for dry sausage safety has been introduced. However, the full utilization of this concept has not been developed. The present study provides an insight into the technology and microbiology of North European dry sausage fermentation with both probiotic and bioprotective LAB.

2. Dry sausage manufacturing process

Dry sausage material is made from a mixture of frozen pork, beef and pork fat (Buckenhüskes, 1993).

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In addition, it contains sugars, salt, nitrite, and nitrate, ascorbates and spices. The raw sausage material is stuffed into casing material of variable diameters and hung vertically in fermentation and ripening chambers for several weeks.

Salt acts as one of the first hurdles against the growth of unwanted microorganisms. It also induces the solubilisation and diffusion of myofibrillar proteins from muscle forming a gel between meat and meat as well as meat and fat particles of the raw sausage material. Salt (NaCl 2.5–3.0% (w/w), initial value) is also an important flavour component of the end product (Lücke, 1985). Nitrite acts as an other hurdle against the growth of pathogens which may be introduced with the raw meat material. It also contributes to the formation of the typical cured meat colour. Ascorbates enhance the colour formation (Puolanne, 1977). Spices, such as pepper, cardemum and garlic, have an impact on flavour and they may also have antioxidative and antimicrobial effects (Hammer, 1977). Furthermore, smoke, consisting of phenols, carbonyls and different organic acids, contributes to inhibition of different bacteria on the surface of the sausages (Tóth and Blaas, 1972).

Sugars are added as fermentable substrates for LAB (inoculation of 6–7 log cfu/g) and staphylococci (6 log cfu/g) used as starter cultures (Fig. 1). Catalase produced by staphylococci degrade hydrogen peroxide produced by LAB (Katsaras and Leistner, 1988). In addition, staphylococci reduce nitrate into nitrite (Niinivaara, 1955; Pohja and Niinivaara, 1957; Nurmi, 1966) and have an impact on flavour (Selgas et al., 1988; Comi et al., 1992; Berdagué et al., 1993; Stahnke, 1994; Montel et al., 1993; 1996). LAB decrease the pH of the sausage close to pH-value 5.0 in first few days, which acts as a hurdle for several Gram-negative bacterial species (Leistner, 1995). While the pH of the sausage (e.i. salt–meat mixture) decreases and approaches the isoelectric point, the water holding capacity of the sausage decreases (Hamm, 1962). This favours the drying and consequently the weight losses of sausage, which result in the

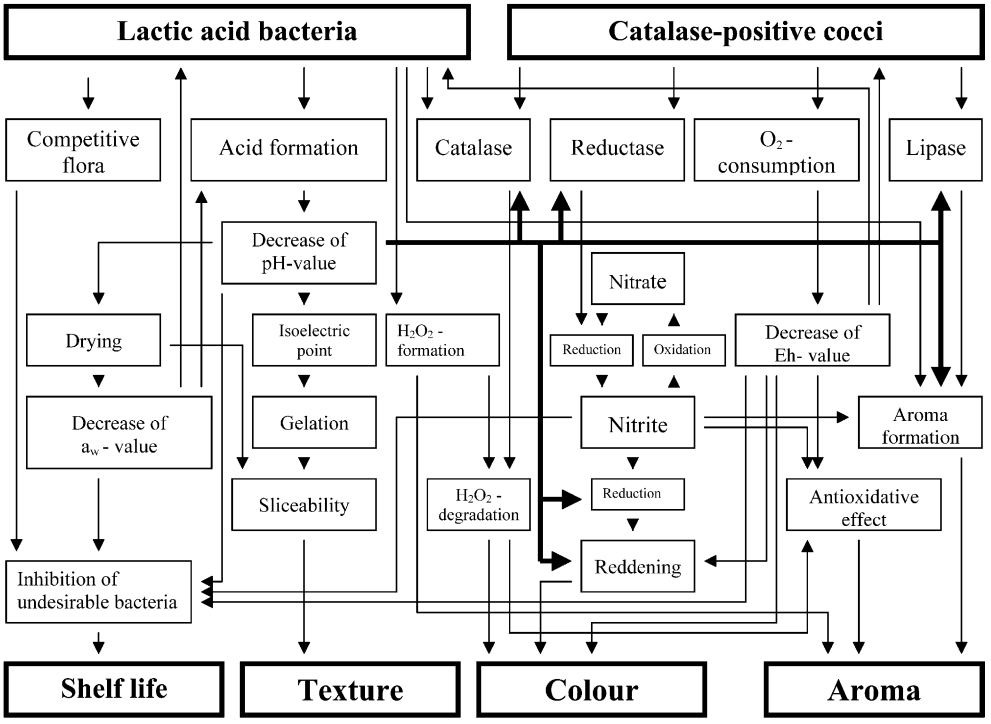

Fig. 1. Interactions during the fermentation of sausages caused by the action of lactic acid bacteria and catalase-positive cocci (Buckenhüskes, 1993).

firm texture and sliceability of the end product (Buckenhüskes, 1993).

3. Lactic acid bacteria currently used in the fermentation of meat

According to the definition of Hammes (1996), meat starter cultures are "preparations which contain living or resting microorganisms that develop the desired metabolic activity in the meat". As a rule, they are facultatively heterofermentative strains, which produce lactic acid from hexoses, such as glucose and lactose, as their only metabolic product (via glycolysis). As there is no sufficient glucose in meat to markedly reduce the pH, glucose is added at 0.4–0.7% (w/w) to the sausage matrix. For lactose fermenting LAB, such as *Lactobacillus sakei*, lactose may also be used (0.5–1.0%) (Pyrcz and Pezacki, 1981; Wirth, 1984). However, not all LAB can easily ferment lactose and especially some probiotics, such as *Lactobacillus rhamnosus* GG, are not able to utilize lactose. Thus, the starter culture properties have to be taken into account prior to planning new applications. From pentoses, such as arabinose and xylose, meat starter LAB produce both lactic acid and acetic acid (via part of the 6-phosphogluconate/phosphoketolase pathway) (Kandler, 1983; Axelsson, 1998). The amount of acetic acid is typically 1/10 of the amount of lactic acid (Deketelaere et al., 1974). As indicated in commercial catalogues LAB strains currently most employed in meat starter cultures are *Lactobacillus casei*, *Lactobacillus curvatus*, *Lactobacillus pentosus*, *Lactobacillus plantarum*, *L. sakei*, *Pediococcus acidilactici* and *Pediococcus pentosaceus*.

4. Safety and shelf-life of dry sausage

4.1. Hurdle concept

The microbial stability of dry sausages is determined by the combination and timing of different factors referred to as the hurdle-concept (Leistner, 1995). The safety of dry sausage material, which is actually raw meat kept at room temperature for several days, is based on the migration of salt into meat before the temperature of the meat rises above 10 °C and the addition of nitrite. Salt decreases the initial water activity inhibiting or at least delaying the growth of many bacteria while favouring the growth of starter LAB and starter staphylococci. Nitrite as in the form of undissociated nitrous acid (HNO_2) is able to pass the ion barrier of bacterial cell wall and disturb the function of bacterial enzymes and therefore bacterial growth (Cook and Pierson, 1983; Pierson and Smooth, 1987).

During the first day of fermentation the growth of microbes in sausage material uses up all the oxygen mixed in the sausage matrix during the chopping. This reduces the redox potential ($E_h = 100-200$ mV) making the nitrite more effective and restricts the growth of aerobic spoilage bacteria (pseudomonads) derived from the raw meat (Lücke and Hechelmann, 1987; Kröckel, 1995).

After few days of fermentation, the high amounts of LAB have produced high amounts of lactic acid resulting in a low pH value (5.0) of dry sausages (Lücke and Hechelmann, 1987). The lower external pH disturbs the homeostasis of different pathogens (e.g. *Salmonella* spp., *Clostridium* spp.) as well as spoilage bacteria, e.g. pseudomonads and enterococci (Leistner, 2000). In a solution, weak acids exist in pH-dependent equilibrium between undissociated and dissociated state (lactic acid $pK_a = 3.86$). The low pH favours the uncharged undissociated state of the molecule, which is able to penetrate the target cell membrane. Therefore, the lower the pH the stronger the inhibitory effect (Davidson, 1997; Leistner, 2000). However, at the pH values typical for dry sausage (4.8) only 10% of lactic acid is undissociated, resulting in a fairly moderate inhibitory effect (Lueck, 1980; Cherrington et al., 1991).

The final and most important hurdle for the growth of other bacteria than LAB and staphylococci is the low water activity of the dry sausage (Kröckel, 1995). The low pH value decreases the water holding capacity of meat increasing the rate of the drying process. The drying of sausages in ripening chamber leads to the final water activity < 0.90 of the product (Stiebing and Rödel, 1987; Lücke, 1985).

4.2. Inhibition of pathogens by hurdle concept

The growth of several bacterial species is inhibited by nitrite, low oxygen level, pH and water activity

(Leistner, 1995). The growth of *Bacillus* and *Clostridium* spores, which may be derived from spices (and to lesser extent from meat) are controlled by low pH and water activity (Nordal and Gudding, 1975). *Staphylococcus aureus* is tolerant for dry sausage environmental factors, but it is a fairly poor competitor to starter LAB and starter staphylococci at fermentation temperatures 20–25 °C commonly used in North Europe (Hurst and Collins-Thompson, 1979; Metaxopoulos et al., 1981a,b). However, the hurdles present in dry sausage are not sufficient to prevent the survival of *Listeria monocytogenes* (Farber and Peterkin, 1991; Varabioff, 1992) or *Escherichia coli* O157:H7 (Reed, 1995).

L. monocytogenes is a Gram-positive non-sporulating food pathogen. It is specially dangerous for very young (children), old, pregnant and immunocompromized persons (Farber and Peterkin, 1991). Despite the various hurdles in dry sausage manufacturing process it is able to survive the commercial dry sausage manufacturing process (Varabioff, 1992; Gahan et al., 1996). An additional hurdle to reduce the risk of *L. monocytogenes* in dry sausage is to utilise specific bacteriocin producing starter cultures in dry sausage manufacturing (Berry et al., 1990; Foegeding et al., 1992; Campanini et al., 1993; Elsser, 1999; Työppönen et al., in press).

E. coli O157:H7 is highly adapted to acidic conditions and due to its very low infectious level it poses a serious risk for the consumers (Doyle, 1991; Bolton et al., 1996). Its acid tolerance is inducible and involves the synthesis of acid shock proteins, activation of metabolic enzymes to maintain homeostasis, and the increased corporation of cyclopropane fatty acids in the cytoplasmic membrane (Leyer et al., 1995; Bearson et al., 1997; Brown et al., 1997). In 1994, in Washington and California 18 people were infected by *E. coli* O157:H7 derived from dry sausage. Therefore, United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) required the processors of dry and semidry sausage to validate at least a 5-log-unit reduction in numbers of *E. coli* O157:H7 cells in dry sausages (Reed, 1995). Several studies concerning the survival of *E. coli* O157:H7 in non-heated dry sausage manufacturing process with starter LAB have shown that the number of *E. coli* O157:H7 can be reduced by 1–3 log units (Hinkens et al., 1996; Clavero and Beuchat, 1996; Calicioglu et al., 1997; Faith et al., 1997, 1998; Yu and Chou, 1998; Erkkilä et al., 2000).

4.3. Protective culture concept

In recent years, there has been a considerable increase in studies of the natural antimicrobial compounds on and in food produced by LAB, referred as bioprotective cultures (Table 1). Bioprotective cultures may act as starter cultures in the food fermentation process, such as dry sausage manufacturing process, or they may protect foods without any detrimental organoleptic changes.

Bacteriocins are peptides or proteins, which due to their proteinaceous nature are readily degraded after human digestion to common nutrients (Sanders, 1993; Vandenbergh, 1993). The well-known bacteriocin nisin (Group I) (E234) dissipates the proton motive force of the target cell by forming a pore through the cytoplasmic membrane which causes the flux of essential energy (ATP) and different ions from the cell (Moll et al., 1996; Brötz et al., 1998). The bacteriocins of group II (Klaenhammer, 1993; Nes et al., 1996; Ennahar et al., 2000) are the most interesting for meat industry. For example curvacin A (Tichaczek et al., 1992) and sakacin A, P and K (Holck et al., 1992; Tichaczek et al., 1992; Hugas et al., 1995) produced by *L. curvatus* and *L. sakei* strains, respectively, are isolated from meat and they are mainly active against other LAB and *L. monocytogenes* while pediocin PA-1/AcH produced by *P. acidilactici*, *P. parvulus* and *L. plantarum* inhibit the growth of *S. aureus*, *L. monocytogenes* and *Clostridium perfingens* (Bhunia et al., 1988, 1991; Christensen and Hutkins, 1992; Ennahar et al., 1996; Luchansky et al., 1992; Klaenhammer, 1993; Eijsink et al., 1998). In dry sausages the utilization of bacteriocin producing *P. acidilactici* JD1–23, *P. acidilactici* PAC 1.0 and *L. plantarum* MSC as fermenting agents resulted 1–2 log units lower number of *L. monocytogenes* per gram dry sausage than in the control sausages (Berry et al., 1990; Foegeding et al., 1992; Campanini et al., 1993).

In contrast to Gram-positive bacteria, Gram-negative bacteria, such as *E. coli* O157:H7, possess in addition to an inner membrane an outer membrane

Table 1
Antimicrobial products of lactic acid bacteria (LAB) with broad inhibitory spectrum

Product	Producer	Reference
Lactic acid	All LAB	Axelsson (1998)
Acetic acid	Heterofermentative LAB	
Hydrogen peroxide	All LAB	
Alcohols	Heterofermentative LAB	
Carbon dioxide	Heterofermentative LAB	
Other low-molecular-mass compounds		
Diacetyl	*Lactococcus* spp.	Jay (1982)
Reuterin	*Lactobacillus reuteri*	Chung et al. (1989)
Bacteriocins		
Class I bacteriocins		
Nisin	*Lactococcus lactis*	
Class II bacteriocins		
Sakacin P	*Lactobacillus sake*	Holck et al. (1994)
Sakacin K	*Lactobacillus sake*	Hugas et al. (1995)
Curvacin A/sakacin A	*Lactobacillus curvatus*	Tichaczek et al. (1992, 1993)
Carnobacteriocin A	*Carnobacterium piscicola*	Worobo et al. (1994)
Pediocin AcH/PA-1/SJ-1	*Pediococcus acidilactici*	Gonzalez and Kunka (1987)
	Pediococcus parvulus	Bennik et al. (1997)
	Lactobacillus plantarum	Ennahar et al. (1996)
Leucosin A/B-Talla	*Leuconostoc gelidum*	Hastings and Stiles (1991)
	Leuconostoc carnosum	Felix et al. (1994)
Mesentericin Y105	*Leuconostoc mesenteroides*	Héchard et al. (1992)
Enterocin A	*Enterococcus faecium*	Aymerich et al. (1996)
Enterocin P	*Enterococcus faecium*	Cintas et al. (1997)
Enterocin B	*Enterococcus faecium*	Casaus et al. (1997)

through which the hydrophobic bacteriocins are not able to penetrate (Nikaido and Vaara, 1985; Helander et al., 1997). As suggested by Helander et al. (1997), food grade permeabilizers, such as lactic acid or citric acid (Cutter and Siragusa, 1995b; Alakomi et al., 2000; Helander and Mattila-Sandholm, 2000), in combination with bacteriocins would be ideal as part of the hurdle concept in inhibiting Gram-negative bacteria in foods.

Non-proteinaceous low-molecular-mass (LMM) compounds are known to possess a wide antimicrobial spectrum concerning both Gram-positive and Gram-negative bacteria (Table 1). Currently LMM compounds are poorly characterized due to difficulties in purification as described by Niku-Paavola et al. (1999). The typical LMM compounds are small hydrophobic heterocyclic or aromatic structured compounds similar to benzoic acid ($pK_a = 4.19$), active at low pH and stable in heat processing (Brul and Coote, 1999). However, these compounds most probably do not contribute to the safety and shelf-life of dry sausage due to their extremely low concentrations produced during dry sausage manufacturing process. Furthermore, e.g. diacetyl (Jay, 1982) and reuterin (Chung et al., 1989) are produced by heterofermentative LAB, which also produce carbon dioxide and high amounts of acetic acid (Axelsson, 1998) not desired in dry sausage due to quality defects.

In order to fully utilise the antimicrobial metabolites of LAB a few challenges have to be overcome in future. Bacteriocins may bind to the food fat or protein particles or the food additives, natural proteases or other inhibitors may inactivate them (Jung et al., 1992; Degnan and Luchansky, 1992; Leroy and De Vuyst, 1999). In addition, the effect may be seen only in a narrow pH range, which excludes their utilisation in many food products (Yang and Ray, 1994; Cutter and Siragusa, 1995a, Mortvedt-Abildgaard et al., 1995; Gänzle et al., 1999b). In case of dry sausage the concentrations produced by LAB in situ may be affected by the low carbohydrate content and low ripening temperature (Vogel et al., 1993; Hugas et al., 1995). Different weight losses and consequently in different salt contents may also have an effect on antimicrobial activity. Especially high salt content may decrease the activity of the bacteriocins, and furthermore, salt may prevent the growth and consequently the production of bacteriocins (De Vuyst et al., 1996; Gänzle et al., 1996; Nilsen et al., 1998; Leroy and De Vuyst, 1999; Työppönen et al., in press). However, many bioprotective cultures are known to produce several antimicrobial compounds,

which act in cooperation (Hanlin et al., 1993; Niku-Paavola et al., 1999).

5. Probiotics

Probiotics are live microbial food ingredients that are beneficial to health (Salminen et al., 1998a, 1999). Probiotics are lactic acid bacteria or bifidobacteria, currently mainly of *Lactobacillus* species (Table 2). Also other species have been introduced including enterococci, propionibacteria and even clostridia (Sanders and Huis in't Veld, 1999; von Wright and Salminen, 1999).

The ability to produce different antimicrobial compounds, such as bacteriocins and/or low-molecular-mass antimicrobial compounds, may be one of the critical characteristics for effective competitive exclusion of pathogens and survival in the intestine to express probiotic effect to the host (Ouwehand, 1998; Salminen et al., 1998a). The acidic conditions in the stomach may even enhance the activity of these antimicrobial compounds (Gänzle et al., 1999a,b). Furthermore, the probiotic effect of LAB may partly be based on the production of relevant concentrations of lactic acid in the microenvironment, which in combination with detergent like bile salts inhibit the growth of Gram-negative pathogenic bacteria (Alakomi et al., 2000). In fact, the exact mechanism by which a probiotic strain interacts with other bacteria in the gastrointestinal tract or with the mucus of gastrointestinal tract itself is not known (Havenaar et al., 1992; Fuller, 1992; Playne, 1995; Berg, 1998; von Wright and Salminen, 1999). However, several clinical studies concerning gastrointestinal disorders, food allergies and inflammatory bowel diseases have provided evidence for the claimed health effects (Isolauri et al., 1999; Ouwehand et al., 1999; von Wright and Salminen, 1999). Gastrointestinal disorders mainly covers diarrhoea caused by pathogens (Oksanen et al., 1990; Perdigón et al., 1990; Hilton et al., 1997), antibiotics (Arvola et al., 1999) and rotavirus (Saavedra et al., 1994). Furthermore, probiotics are known to promote the immune function (Perdigón et al., 1995; Schiffrin et al., 1995; Pelto et al., 1998; He et al., 2000). Recently, probiotics have been used for alleviation of symptoms of food allergy in infants and adults as well as prevention of atopic diseases in infants (Isolauri et al., 1999; Kalliomäki et al., 2001).

Table 2
Some commercially used probiotic lactobacilli and bifidobacteria and reported clinical effects in humans (modified from Sanders and Huis in't Veld, 1999; von Wright and Salminen, 1999; Mattila-Sandholm and Saarela, 2000)

Strain	Company	Reported clinical effects in humans
L. rhamnosus GG	Valio, Finland	Adherence to human intestinal cells, lowering faecal enzyme activities, prevention of diarrhoea, immune response modulation, prevention and treatment of food allergies
L. johnsonii La1	Nestle, Switzerland	Modulation of intestinal flora, immune enhancement, adjuvant in *Helicobacter pylori* treatment
L. casei Shirota	Yakult, Japan	Modulation of intestinal flora, lowering faecal enzyme activities, prevention of occurrence of superficial bladder cancer
L. reuteri SD2112	BioGaia, USA	Colonisation of intestinal tract, treatment of diarrhoea
L. plantarum 299V	Probi, Sweden	Adherence to human intestinal cells, modulation of intestinal flora
B. lactis Bb-12	Chr. Hansen, Denmark	Treatment/prevention of diarrhoea, modulation of intestinal flora, improvement of constipation, modulation of immune responces, alleviation of symptoms of food allergy

The utilisation of health aspects of food products in their marketing began in the 1960s and in the 1970s the trend was to remove unhealthy components, such as salt, sugar or fat. The trend continued by removing some of the additives in 1980s and finally in 1990s more healthy components, such as vitamins, antioxidants, fiber and probiotic LAB, were added to the food products. In the 2000s specific functional food products have scientifically proven to benefit the health and well-being of consumers. Proposed functional foods in Europe include 60% of dairy products, 25% of fat-based spreads, 10% of bakery and cereal products, and 5% of drinks (Young, 2000). The concept of probiotic foods being part of the concept of a functional food is due to the successful cooperation of food industry and research in food science and technology as well as in clinical nutrition. Probiotics have been applied mainly

in dairy products, such as yoghurt and other cultured milk products but also in cereal products. For example *L. rhamnosus* GG has been applied to normal and drinking yoghurts, fermented milks, pasteurised milk, dairy-based drinks, fermented whey-based drinks as well as juices (Saxelin, 2000).

The target products in meat processing are the various dry sausages which are processed by fermenting without heating. Arihara et al. (1996, 1998) have shown that the potentially probiotic strain *Lactobacillus gasseri* JCM1131 is applicable for meat fermentation to enhance product safety, and Sameshima et al. (1998) have demonstrated the usefulness of the potential probiotics *L. rhamnosus* FERM P-15120 and *Lactobacillus paracasei* subsp. *paracasei* FERM P-15121 in meat fermentation. Erkkilä et al. (2000, 2001a,b) used probiotic *L. rhamnosus* GG and potentially probiotic *L. rhamnosus* LC-705 and VTT-97800 for dry sausage manufacturing and Andersen (1998) fermented dry sausages succesfully using a mixture of the traditional starter culture Bactoferm T-SPX (Chr. Hansen) and a potentially probiotic culture of *L. casei* LC-01 or a mixture of the same starter and the probiotic *Bifidobacterium lactis* Bb-12.

However, human clinical studies documenting health promoting effects of dry sausage do not exists. At this point, it could be speculated that since the bacteria in general are sensitive to low pH values in the stomach (Conway et al., 1987; Berrada et al., 1990; Hammes et al., 1997; Erkkilä and Petäjä, 2000), it is most important that probiotics are consumed within a food matrix. Bacteria can survive acidic conditions in vitro when inoculated onto the surface of solid food, whereas the same level of acidity is lethal to the inoculum in an acidified broth environment. Milk has been shown to be an excellent vehicle for probiotic bacteria probably due to its high buffering capacity (Saxelin, 1996). Meat acts also as a buffer in an acidic environment and therefore may also protect bacteria from hostile environment. The protective effect of some solid foods may be due to the raising the pH of microenvironment of the bacteria on the surface of the food (Waterman and Small, 1998). Furthermore, meat has been found to protect LAB against the lethal action of bile (Gänzle et al., 1999a). In fermented sausages LAB grow in nests (Katsaras and Leistner, 1991) and they are therefore "encapsulated" by the sausage matrix consisting of meat and fat. Thus they may survive better the critical passage through the stomach and the small intestine compared to their unprotected exposure to low pH and bile salts. Furthermore, it has been argued by Tannock (1999) that food components (meat and fat particles) that have escaped digestion may act as an energy source for the bacteria in the intestine.

The minimum dose of daily ingestion of probiotic bacteria is not known, but it is estimated to be 10^{9-10} viable microbes in order to show a health effect and temporary colonisation as measured by levels of 10^{6-8} viable microbes/g faeces. For a dry sausage containing 10^{8} viable microbes/g the minimum dose therefore could be 10–100 g sausage per day. However, the minimal dose is dependent on several factors, such as individual person, strain and food product. Since the exact mechanism by which a probiotic strain interact with other bacteria in the gastrointestinal tract or with the mucus of gastrointestinal tract in itself is not known (Havenaar et al., 1992; Fuller, 1992; Playne, 1995; Berg, 1998), no direct extrapolations of how a strain would affect a host can be made (Mattila-Sandholm et al., 1999). It can also be speculated that a strain particularly well-suited to survive through the gastrointestinal tract could be provided in lower numbers than a poorly adapted strain (Conway et al., 1987; Berrada et al., 1990). Finally, the food product itself is highly important. The number of viable probiotics in the product is effected by several factors, such as temperature, moisture, fat content and levels of different chemicals (Sanders and Huis in't Veld, 1999; Hammes and Hertel, 1998).

6. Conclusions

LAB have been used for dry sausage manufacturing process since 1950s in order to ensure the safety and quality of the end product. Furthermore, by selecting bacteriocin and low-molecular-mass antimicrobial compounds producing strains for dry sausage fermenting process the risk for low numbers of *L. monocytogenes* or *E. coli* O157:H7 derived from raw dry sausage material may be further reduced. As discussed by Gänzle et al. (1999a) bioprotective LAB derived from food may also be useful in the small intestine against food pathogens—as long as they are able to survive the environment of gastrointestinal tract. Likewise, pro-

biotic strains with antimicrobial effects on food act similarly and therefore might be more successful than commonly used food fermenting bacteria. It could be concluded that dry sausage is suitable carrier for probiotic and bioprotective bacteria. However, human clinical studies are needed before the final answer concerning the health promoting effects of probiotic dry sausage.

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