

POTENTIAL ROLE OF PROBIOTICS FOR SUSTAINABILITY IN RURAL INDIA

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Abstract

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Probiotics (greek "for life") have been recognized and explored for over a century. Metchnikoff's pioneering work was converted into commercial reality in the 1950s, and since then many probiotics' benefits have been described. Nowadays they have already found place as a food supplement and as a preventive or curative drug. The term probiotic describes a variety of microorganisms which can colonize the host and have health improving effects on it. Since it is a natural and comparably affordable product even for people with low incomes, it could be introduced into the diet of people living in the Indian rural areas. The biggest obstacles for this are education about their use and technology to prepare them in a convenient form for domestic use. Regular use could improve the quality of live and reduce the dependence on drugs and medical expenses.

Keywords

probiotics, sustainability, India

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1. Introduction

Probiotics are dietary supplements of live microorganisms thought to be healthy for the host organism when administered in adequate amounts. Their beneficial effects to the host are beyond those of basic nutrition. At first, probiotics were thought to beneficially affect the host by improving its intestinal microbial balance, thus inhibiting pathogens and toxin producing bacteria. Today specific health effects are being investigated and documented including alleviation of chronic intestinal inflammatory diseases, prevention and treatment of pathogen-induced diarrhea, urogenital infections, atopic diseases etc. A recent research also provides data on anti-cancer and hypocholesterolemic effects of probiotics (reviewed in Gupta and Garg 2009). The most common types of probiotic strains are *Lactobacillus*, *Bifidobacteria*, but also certain yeasts and bacilli are available (Singhi and Baranwal 2008).

Poor sanitary conditions and limited health facilities are common in rural India. Unavailability of modern medicine with concomitant outbreaks of intestinal diseases is calling for an additional simple and accessible method to improve the quality of these economically challenged people. The acceptability of probiotic dairy products in India is high because people already consume a lot of curd, milk and cheese. In the southern parts of India traditional dairy products such as rasam are prevalent since ancient times (http://www.indiaday.com/info_milk_products_dairyproducts.html). These are good for general nutrition but have a limited role in the improvement of digestion or serious disorders, since the bacterial strains are not selected. In the present paper we focus on health improving properties of probiotics, for which they could be recognized to find place in the diet of Indian rural people.

2. Intestinal tract and bacterial colonization

The intestinal mucosa surface exceeds 300 m², and to ensure normal functions regulated homeostasis is necessary. It requires a complex interplay between the intestinal epithelial monolayer and the underlying mucosal immune system. The intestinal epithelial barrier is a dynamic system composed of a single layer of densely packed enterocytes along the villous axis of the crypt (Thomson et al 2003b; Thomson et al 2003a). Tight junctions between the cells prevent leakage through the layer. Enterocytes are highly polarized cells with apical (towards the intestinal lumen) and basolateral part (towards the body) of the membrane, the organisation which controls selected and directional transport of substrates while maintaining a barrier to pathogens (Snoeck et al 2005). The mucosal immune system provides tolerance to food antigens along with protection against pathogens. This autologous synergistic concept was recently expanded to include intestinal commensal microorganisms, which are believed to be the third and indispensable player for the normal intestinal balance (Hooper and Gordon 2001; Sansonetti 2004). Intestinal microbiota interact with the epithelial cell barrier and the mucosal immune system and it can be modulated by the use of probiotics to increase their potential in preventing and curing of diseases (Nissen et al 2009). The interaction between them has been studied using *in vivo* and *in vitro* models (Botic et al 2007).

3. Health-improving potential of probiotics

3.1 Modulation of the immune system

Many studies are showing immunomodulatory effects of probiotics *in vitro*. The

response of the immune system to probiotics is weaker than in the presence of other gram positive pathogens (Veckman et al 2004). Generally, they suppress the formation of proinflammatory IL-12 while maintaining high production of immunosuppressive cytokine IL-10 (Braat et al 2004; Hart et al 2004; Lammers et al 2003). They can also elicit non-specific immune response, like production of oxygen species and NO (Pipenbaher et al 2009). Most of the studies focused on short-term effects, while long-term consumption of probiotics has not been assessed in details with regard to sustained improvements of the immune system.

3.2. Treatment and prevention of infectious diseases

In addition to strong physical epithelial barrier, gut has additional chemical antibacterial mechanisms to control growth of potential pathogens. Plasma cells in intestinal submucosa secrete pIgA as a part of adaptive immune response (Macpherson and Uhr, 2004). Epithelial and immune cells secrete cationic antibacterial peptides: α - and β -defensins and cathelicidins (Cunliffe and Mahida 2004).

Despite the sophisticated innate and adaptive immune response, pathogens still manage to destroy or traverse the epithelial barrier and invade the host. Various *in vitro* experiments and clinical trials showed positive effects of probiotics in prevention and cure of intestinal pathogen induced diseases. Probiotics compete with pathogens for adhesion sites, strengthen the epithelial barrier by preservation of tight junction protein expression between enterocytes (Parassol et al 2005) and inhibition of epithelial cell apoptosis (Yan and Polk, 2002). Alternatively, they may enhance mucosal IgA-mediated immune response to pathogens (Rautava et al 2006). Furthermore, probiotics are known to secrete antimicrobial molecules. Currently, most beneficial effects of probiotics have been observed in studies on diarrhea, in particular rotavirus watery diarrhea (Szajewska and Mrukowicz 2005).

Our results showed efficacy of probiotics in other viral food and water born infectious diseases, like hepatitis viruses (unpublished results). Reports also suggest protection against *Listeria monocytogenes*, *Salmonella enterica* and reduction of *Helicobacter pylori* load (Lin et al 2009), the infection which leads to chronic gastritis and increased risk of gastric malignancies. Little or no knowledge is available about the potential role of probiotics to prevent infection by uncommon enteroviruses like poliomyelitis (Palacios and Oberste 2005) and meningoencephalitis (Antona and Chomel 2005), the outbreaks of which are generally more frequent in the developing world.

3.3 Probiotics and prevention of necrotizing enterocolitis

Neonatal necrotizing colitis (NEC) is a challenging clinical disease entity, which is a complication of very low birth weight infants and is often fatal. The etiological cause for the disease is not understood, but it is generally accepted that the normal intestinal functions are underdeveloped in the newborn and therefore it can not deal with the challenges of dietary and microbial antigens (Lin and Stoll 2006). Several clinical studies showed that the use of probiotics significantly reduces mortality (Hunter et al. 2008, Lin et al 2008). In rural India, where pregnant women often deliver at home or in inadequately equipped facilities (Iyengar et al 2008), the use of probiotics could reduce the incidence of death along with the severity of symptoms.

3.4 Prevention of allergies and inflammatory bowel diseases

Allergies and inflammatory diseases are typical western diseases closely linked to unhealthy lifestyle (hygiene hypothesis; Garn and Renz, 2007). These diseases are significantly less common among rural Indian people, also due to prevalent vegetarian food, a lot of exercise, breastfeeding and early contact with bacteria and domestic animals. These diseases are rising due to globalization in India as well. The potential role of probiotics to treat patients with allergic diseases like atopic eczema, food allergies and atopic dermatitis has not been clinically evaluated yet in detail (Bunselmeyer 2006), but reports suggest that intestinal microbiota and its diversity are different between healthy and atopic eczema affected patients (Penders et al 2007). Several lines of evidence suggest that a loss of immunological tolerance to intestinal microbiota is a major component in the etiology of inflammatory bowel diseases, like Crohn disease and perhaps also ulcerative colitis and pouchitis (Korzenik and Podolsky 2006). The most convincing data of probiotics' benefit is linked to the treatment of pouchitis (Lammers et al 2005), but little is known about treating other above mentioned diseases.

3.5 Reduction of cancer and malignant diseases

Chemical industry produces xeno-compounds with mutagenic properties, which have found numerous use in our daily-life. Since their use is widespread, they can also be detected in the food-chain. Probiotics were shown to possess antimutagenic and anticarcinogenic activity against well-known mutagens and promutagens, although the mechanisms are still unknown (Rafter 2002). They can decrease levels of cellular enzymes responsible for the activation of procarcinogens. Alternatively, microbes can be involved in the metabolism of substances or into the prevention of their binding to the cell surface (Rafter 2002).

3.6 Lactose intolerance

Although general nutrition of Indian rural population is vegetarian-based, they traditionally consume a lot of milk and milk products as an important source of proteins. Cow milk contains lactose, which is degraded after consumption into monosaccharides by β -galactosidase. The level of endogenous enzyme declines over age and causes lactose intolerance especially in the aged people, and the condition manifests with clinical symptoms such as bloating, flatulence, nausea, abdominal pain and diarrhea. Probiotic strains may decrease the symptoms by producing their own secreted β -galactosidase or by consumption of lactose during the fermentation. Dairy products could thus stay in the normal diet of the majority of population without posing the risk of health problems.

4. Sources of probiotics

Probiotics have been lately exploited extensively by the dairy industry as a tool for development of new competitive functional products. Traditionally, probiotics have been incorporated into yoghurt; however, a number of additional carriers appear on the market including mayonnaise, edible spreads and meat. A wide variety of species could be considered potential probiotics, but commercially used strains should have several desirable criteria: safety (lack of pathogenicity and toxicity), tolerance to harsh conditions along the digestive tract, adhesion to mucosal surface, validated and documented health effects (Morelli 2000).

Fermentation of milk in a natural way with non-selected bacterial strains would not provide substantial health benefits as described above. Since already fermented dairy products are difficult for distribution in rural India due to unreliable cold distribution chain, it would only be possible to provide people with lyophilized or spray-dried bacterial strains. To prepare an affordable and effective bacterial strain is not of interest for the industry - moreover, there are technological challenges to prepare them and to be effective starters of fermentation in the hands of final consumers.

5. Status of probiotics in India

Functional dairy products with probiotics are promising in the Indian market, as major players such as Amul, Yakult, Mother Dairy and Nestle launch more health drinks and yoghurts in the country (2008). The market for products containing probiotics is expected to grow as Indians become more aware of natural, healthy ingredients in foods. Probiotics are available for purchase mainly in big cities (Delhi, Bombay). According to estimates by Dairy India, the size of the dairy market is expected to grow at almost 40% annually or even more, reaching Rs 5,20,780 crores (\$122,825 million) by 2011 (2008).

Currently, probiotics are often used as animal feed supplements for cattle, poultry and piggery. This requirement is also met by importing probiotics from other countries. The most commonly found commercial probiotic drinks for human consumption are found in the form of probiotic drinks, icecreams and frozen desserts. The latest and recent addition to the list of probiotics in India is ViBact (which is made up of genetically modified *Bacillus mesentericus*), which acts as an alternate to B-complex capsules (Sonal et al 2008). Probiotic products are gaining acceptance mostly in urban areas. The Indian market is big, but difficult to reach since cold storage and cold distribution chain are underdeveloped in India, especially in the rural areas. In the future, it is important to increase the awareness of the country people and to educate them about the probiotics' benefits.

6. Conclusion

Probiotics are food preparations of live bacteria, which are beneficial for health. Since they have already been known for more than 100 years, they are proved to be safe, natural and effective. The general knowledge about them has not reached the Indian rural areas and additional education of the country people is needed to boost their use. Probiotics could be used as prevention against diseases and to improve the quality of life of rural people. Moreover, lower dependence on expensive chemical drugs and scarce medical facilities would improve sustainability of the Indian rural countryside.

References

- APV, 2008: India's Probiotics Market Set to Grow. Asia food journal, September.
- Antona, D., Chomel, J. J. 2005: Increase in viral meningitis cases reported in France. Summer 2005. Euro Surveill, 10, E050908 1.
- Botic, T., Klingberg, T. D., Weingartl, H., Cencič, A. 2007: A novel eukaryotic cell culture model to study antiviral activity of potential probiotic bacteria. Int J Food Microbiol, 115, p. 227-34.
- Braat, H., De Jong, E. C., Van den Brande, J. M., Kapsenberg, M. L., Peppelenbosch,

- M. P., Van Tol, E. A., Van Deventer, S. J. 2004: Dichotomy between *Lactobacillus rhamnosus* and *Klebsiella pneumoniae* on dendritic cell phenotype and function. *J Mol Med*, 82, p. 197-205.
- Bunselmeyer, B. 2006: Probiotics and prebiotics for the prevention and treatment of atopic eczema. *Hautarzt*, 57, p. 785-91.
- Cunliffe, R. N., Mahida, Y. R. 2004: Expression and regulation of antimicrobial peptides in the gastrointestinal tract. *J Leukoc Biol*, 75, p. 49-58.
- Garn, H., Renz, H. 2007: Epidemiological and immunological evidence for the hygiene hypothesis. *Immunobiology*, 212, p. 441-52.
- Gupta, V., Garg, R. 2009: Probiotics. *Indian J Med Microbiol*, 27, p. 202-9.
- Hart, A. L., Lammers, K., Brigidi, P., Vitali, B., Rizzello, F., Gionchetti, P., Campieri, M., Kamm, M. A., Knight, S. C., Stagg, A. J. 2004: Modulation of human dendritic cell phenotype and function by probiotic bacteria. *Gut*, 53, p. 1602-9.
- Hooper, L. V., Gordon, J. I. 2001: Commensal host-bacterial relationships in the gut. *Science*, 292, p. 1115-8.
- Hunter, C. J., Podd, B., Ford, H. R., Camerini, V. 2008: Evidence vs experience in neonatal practices in necrotizing enterocolitis. *J Perinatol*, 28 Suppl. 1, p. 9-13.
- Iyengar, S. D., Iyengar, K., Martines, J. C., Dashora, K., Deora, K. K. 2008: Childbirth practices in rural Rajasthan, India: implications for neonatal health and survival. *J Perinatol*, 28 Suppl. 2, p. 23-30.
- Korzenik, J. R., Podolsky, D. K. 2006: Evolving knowledge and therapy of inflammatory bowel disease. *Nat Rev Drug Discov.*, 5, p. 197-209.
- Lammers, K. M., Brigidi, P., Vitali, B., Gionchetti, P., Rizzello, F., Caramelli, E., Matteuzzi, D., Campieri, M. 2003: Immunomodulatory effects of probiotic bacteria DNA: IL-1 and IL-10 response in human peripheral blood mononuclear cells. *FEMS Immunol Med Microbiol*, 38, p. 165-72.
- Lammers, K. M., Vergopoulos, A., Babel, N., Gionchetti, P., Rizzello, F., Morselli, C., Caramelli, E., Fiorentino, M., D'Errico, A., Volk, H. D., Campieri, M. 2005: Probiotic therapy in the prevention of pouchitis onset: decreased interleukin-1beta, interleukin-8, and interferon-gamma gene expression. *Inflamm Bowel Dis*, 11, p. 447-54.
- Lin, H. C., Hsu, C. H., Chen, H. L., Chung, M. Y., Hsu, J. F., Lien, R. I., Tsao, L. Y., Chen, C. H., Su, B. H. 2008: Oral probiotics prevent necrotizing enterocolitis in very low birth weight preterm infants: a multicenter, randomized, controlled trial. *Pediatrics*, 122, p. 693-700.
- Lin, P. W., Stoll, B. J. 2006: Necrotizing enterocolitis. *Lancet*, 368, p. 1271-83.
- Lin, W. H., Lin, C. K., Sheu, S. J., Hwang, C. F., Ye, W. T., Hwang, W. Z., Tsen, H. Y. 2009: Antagonistic activity of spent culture supernatants of lactic acid bacteria against *Helicobacter pylori* growth and infection in human gastric epithelial AGS cells. *J Food Sci*, 74, p. 225-30.
- Macpherson, A. J., Uhr, T. 2004: Induction of protective IgA by intestinal dendritic cells carrying commensal bacteria. *Science*, 303, p. 1662-5.
- Morelli, L. 2000: In vitro selection of probiotic lactobacilli: a critical appraisal. *Curr Issues Intest Microbiol*, 1, p. 59-67.
- Nissen, L., Chingwaru, W., Sgorbati, B., Biavati, B., Cencič, A. 2009: Gut health promoting activity of new putative probiotic/protective *Lactobacillus* spp. strains: A functional study in the small intestinal cell model. *Int J Food Microbiol*, 135, p. 288-94.
- Palacios, G., Oberste, M. S. 2005: Enteroviruses as agents of emerging infectious diseases. *J Neurovirol*, 11, p. 424-433.
- Parassol, N., Freitas, M., Thoreux, K., Dalmasso, G., Bourdet-Sicard, R. & Rampal, P. 2005: *Lactobacillus casei* DN-114 001 inhibits the increase in paracellular

- permeability of enteropathogenic *Escherichia coli*-infected T84 cells. *Res Microbiol*, 156, p. 256-262.
- Penders, J., Thijs, C., Van den Brandt, P. A., Kummeling, I., Snijders, B., Stelma, F., Adams, H., Van Ree, R., Stobberingh, E. E. 2007: Gut microbiota composition and development of atopic manifestations in infancy: the KOALA Birth Cohort Study. *Gut*, 56, p. 661-667.
- Pipenbahr, N., Moeller, P. L., Dolinsek, J., Jakobsen, M., Weingartl, H. & Cencič, A. 2009: Nitric oxide (NO) production in mammalian non-tumorigenic epithelial cells of the small intestine and macrophages induced by individual strains of lactobacilli and bifidobacteria. *International Dairy Journal*, 19, p. 166-171.
- Rafter, J. 2002: Lactic acid bacteria and cancer: mechanistic perspective. *Br J Nutr*, 88 Suppl 1, p. 89-94.
- Rautava, S., Arvilommi, H., Isolauri, E. 2006: Specific probiotics in enhancing maturation of IgA responses in formula-fed infants. *Pediatr Res*, 60, p. 221-224.
- Sansonetti, P. J. 2004: War and peace at mucosal surfaces. *Nat Rev Immunol*, 4, p. 953-64.
- Singhi, S. C., Baranwal, A. 2008: Probiotic use in the critically ill. *Indian J Pediatr*, 75, p. 621-7.
- Snoeck, V., Goddeeris, B., Cox, E. 2005: The role of enterocytes in the intestinal barrier function and antigen uptake. *Microbes Infect*, 7, p. 997-1004.
- Sonal, S. M., Suja, A., Lima, T. B., Aneesh, T. 2008: Probiotics: Friendly Microbes For Better Health. *The Internet Journal of Nutrition and Wellness*, 6.
- Szajewska, H., Mrukowicz, J. Z. 2005: Use of probiotics in children with acute diarrhea. *Paediatr Drugs*, 7, p. 111-22.
- Thomson, A. B., Drozdowski, L., Iordache, C., Thomson, B. K., Vermeire, S., Clandinin, M. T., Wild, G. 2003a: Small bowel review: Normal physiology, part 1. *Dig Dis Sci*, 48, p. 1546-64.
- Thomson, A. B., Drozdowski, L., Iordache, C., Thomson, B. K., Vermeire, S., Clandinin, M. T., Wild, G. 2003b: Small bowel review: Normal physiology, part 2. *Dig Dis Sci*, 48, p. 1565-81.
- Veckman, V., Miettinen, M., Pirhonen, J., Siren, J., Matikainen, S., Julkunen, I. 2004: *Streptococcus pyogenes* and *Lactobacillus rhamnosus* differentially induce maturation and production of Th1-type cytokines and chemokines in human monocyte-derived dendritic cells. *J Leukoc Biol*, 75, p. 764-771.
- Yan, F., Polk, D. B. 2002: Probiotic bacterium prevents cytokine-induced apoptosis in intestinal epithelial cells. *J Biol Chem*, 277, p. 50959-65.

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Summary

Probiotics have gained importance in the last decades mainly in the western world, but they are spreading in the third world as well. Their benefits are well documented and vary from protection against pathogens, alleviation of lactose intolerance, immune system modulation, prevention from inflammatory bowel disease and necrotising enterocolitis.

Intestinal bacteria are supposed to be one of the most important players in the gut. Intestinal commensal microorganisms interact with epithelia and the underlying immune system and all the three partners are indispensable for the intestinal balance. There are hundreds of different bacteria colonising the gut, but they are not selected with respect to the benefits they could provide for the intestine. Probiotics are selected strains of bacteria (mostly from genus *Lactobacillus* and *Bifidobacteria*), which are able to generate some of the properties described above. By consumption of probiotics, beneficial bacteria can colonize the gut and exert health improving actions in the intestine.

Indian rural inhabitants with poor incomes have limited access to medicines, besides; health facilities are scarce as well. Introduction of probiotics to these economically challenged people is a cost effective and natural way to improve their health conditions. Acceptability of dairy products (the most usual form of probiotics) in India is high since they have been consumed traditionally in the Indian subcontinent. There are obstacles in preparing them in a suitable form, since cold distribution chain and refrigerators are generally not available, education is poor, and technical problems exist to prepare them. By preparing them in a suitable form for domestic use we could improve the quality of rural inhabitants and enable sustainability in the Indian countryside.