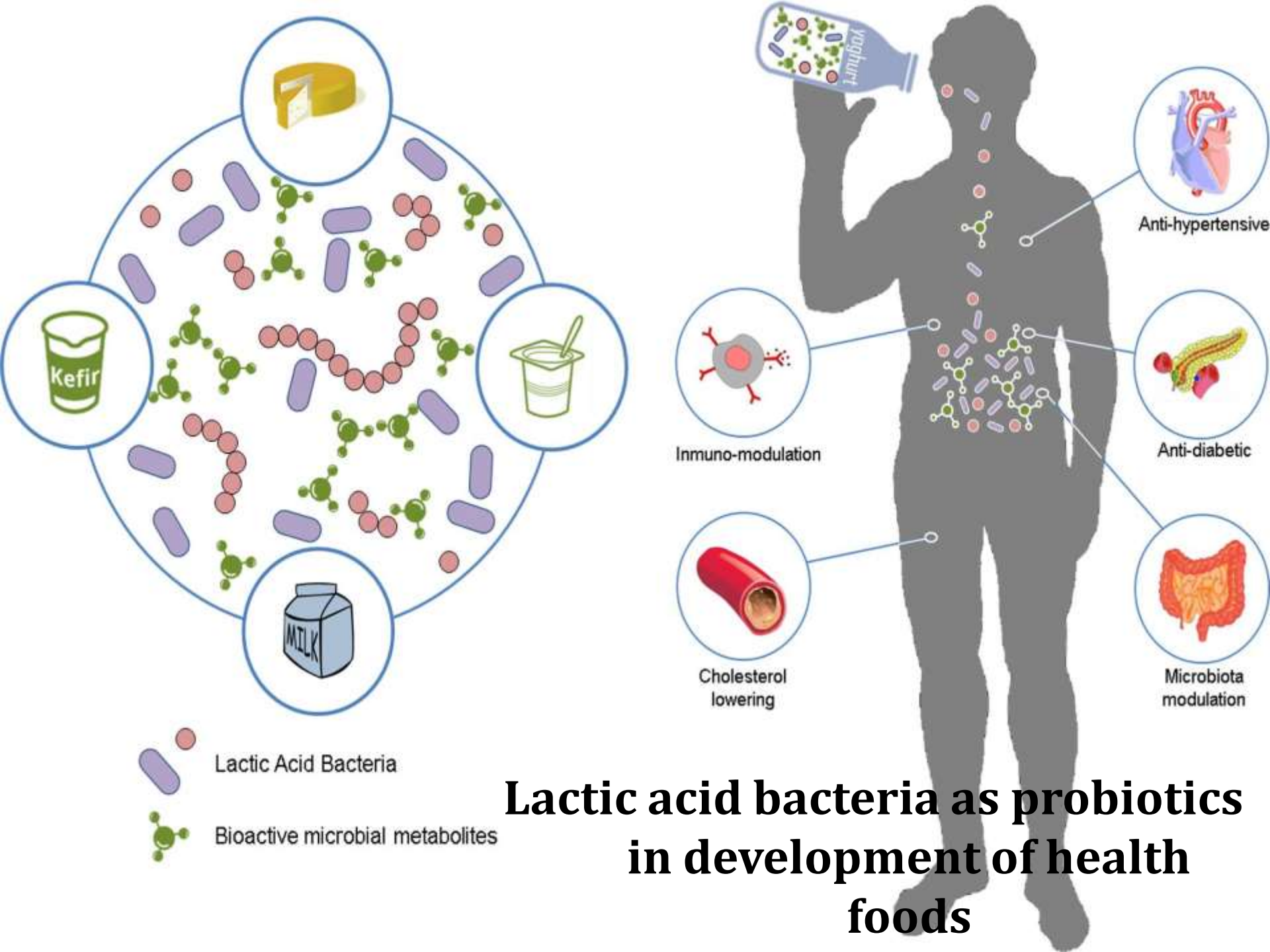
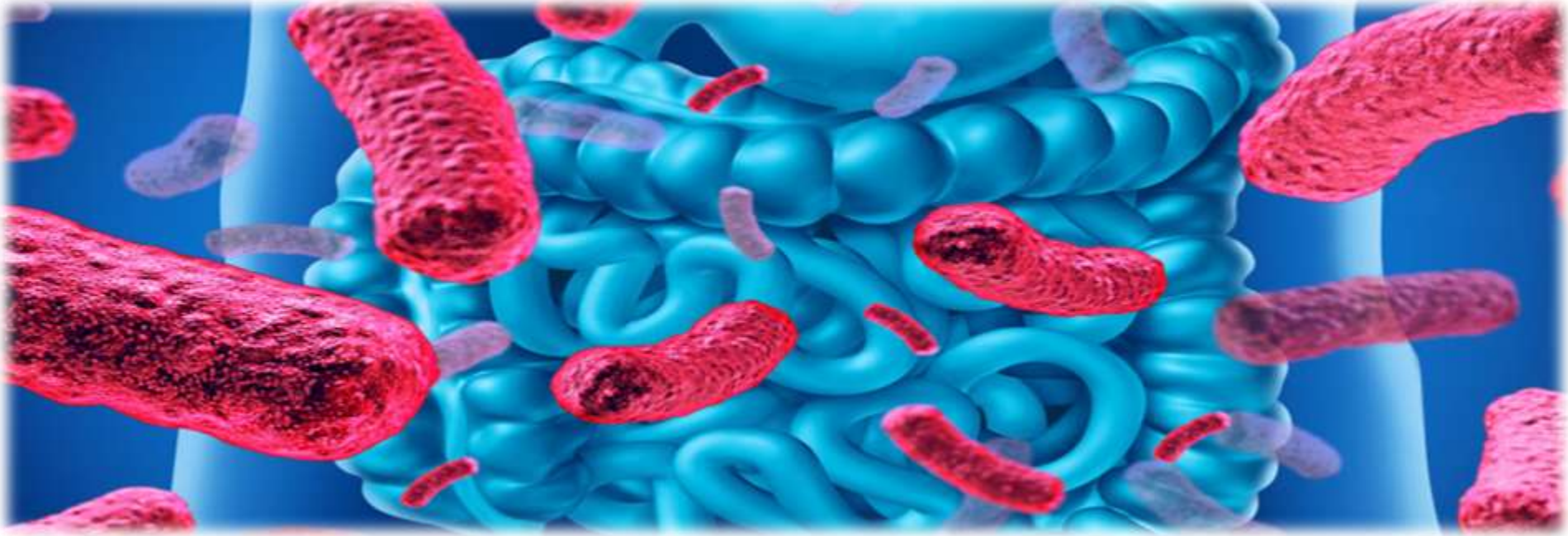


Lactic acid bacteria as probiotics in development of health foods

Probiotics

- Fermented milks and dairy products containing beneficial or "probiotic" cultures, such as lactobacilli and bifidobacteria, are currently among the best-known examples of functional foods.
- Defined as "Live microorganisms which when administered in adequate amounts confer a health benefit on the host".
- Propionibacteria, *Leuconostoc*, pediococci, and enterococci, are candidate probiotic cultures.



What makes a bacteria probiotic???

- Survive both stomach acids (pH as low as 1.5) and bile acids (pH as low as 2).
- Bacteria must arrive in the intestines in sufficient quantities to have an effect.
- Bacteria may need to adhere to the wall of intestine (i .e. “implant”) and colonize.
- Bacteria must possess beneficial effects on human health such as alleviation of lactose intolerance, prevention and treatment of diarrhea, maintenance of normal intestinal flora, antagonism against pathogens, stimulation of immune system, anticarcinogenic activity and reduction of serum cholesterol levels.

Key and desirable criteria for the selection of probiotics in commercial applications

General	Property
Safety criteria	Origin
	Pathogenicity and infectivity
	Virulence factors—toxicity, metabolic activity and intrinsic properties, i.e., antibiotic resistance
Technological criteria	Genetically stable strains
	Desired viability during processing and storage
	Good sensory properties
	Phage resistance
	Large-scale production
Functional criteria	Tolerance to gastric acid and juices
	Bile tolerance
	Adhesion to mucosal surface
	Validated and documented health effects
Desirable physiological criteria	Immunomodulation
	Antagonistic activity towards gastrointestinal pathogens, i.e., Helicobacter pylori, Candida albicans
	Cholesterol metabolism
	Lactose metabolism
	Antimutagenic and anticarcinogenic properties

Lactobacillus species		
Lb. acidophilus *Lb. amylovorus* *Lb. crispatus*	*Lb. gasseri* *Lb. johnsonni* *Lb. casei*	*Lb. paracasei* *Lb. rhamnosus* *Lb. plantarum*
Bifidobacterium species		
Bf. Lactis *Bf. longum* *Bf. adolescentis*	*Bf. Animalis* *Bf. bifidum*	*Bf. infantis* *Bf. Breve*
Other lactic acid bacteria		
Lc. Lactis *Ln. mesenteroides* *P. aciddilactici*	*St. diacetylactis* *St. intermedius* *St. thermophilus*	*En. Faecalis* *En. Faecium*

Species of lactic acid bacteria with probiotic activity

Lactobacillus **and** ***Bifidobacterium*** **are central to both probiotic and prebiotic (non-digestible food ingredients that stimulate the growth and/or activity of certain colonic bacteria) approaches to dietary modulation of the intestinal microflora.**

Association of these bacterial groups with human health

Presence in fermented foods

Regarded as safe (GRAS) status

Survival and antagonism effects of LAB in the gut:

1. **Probiotics should be viable at the time of ingestion to confer a health benefit. Survive GI tract passage and colonize the host epithelium.**
2. **Antagonize pathogenic bacteria by reducing luminal pH, inhibiting bacterial adherence and translocation, or producing antibacterial substances and defensins.**
3. ***Lactobacillus* produce antimicrobial compounds (bacteriocin) to contribute to their beneficial activity. Lacticin 3147 produced by *Lactococcus lactis* inhibits *Clostridium difficile* isolates in patients with IBD.**

LAB and mucous layer:

- Most mucosal surfaces are covered by a hydrated gel formed by mucins. Mucins are secreted by specialized epithelial cells, such as gastric foveolar mucous cells and intestinal goblet cells.
- Probiotics may promote mucus secretion as one mechanism to improve barrier function and exclusion of pathogens.

Bioactive Compounds produced by LAB

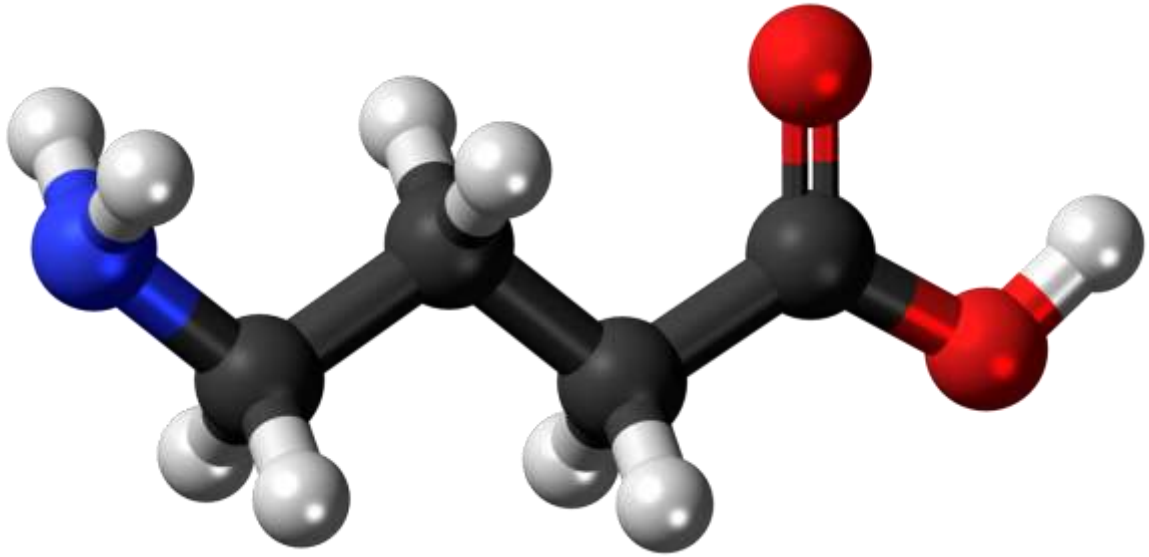
Vitamins:

- There are 13 vitamins that must be obtained exogenously due to the inability of humans to synthesize them thus; essential nutrients in the human diet.
- *Lactobacillus* and *Bifidobacterium* can provide an additional source of B vitamins (thiamine, riboflavin, cobalamin, folate, and biotin) during dairy fermentation.
- *L. casei* KNE-1 produce thiamine and riboflavin in fermented milk drinks.
- Folate is involved in vital processes and its deficiency is generally linked to neural tube defects and poor cognitive performance. Foods can be naturally fortified with folate synthesized by LAB and bifidobacteria during manufacture of fermented foods.

Bioactive	Producer strain	Food Product	Health effect
Thiamine (B_1)/Riboflavin (B_2)	*Lactobacillus casei* KNE-1	Fermented milk	Vitamin enrichment
	Bifidobacterium infantis CCRC14633	Fermented soymilk	Vitamin enrichment
	Bifidobacterium longum B6	Fermented soymilk	Vitamin enrichment
	Lactobacillus plantarum CRL 2130	Fermented soymilk	Vitamin enrichment
Biotin (Vitamin B_7)	*Lactobacillus helveticus MTCC5463*	Fermented milk	Vitamin enrichment
Cobalamin (Vitamin B_{12})	*Propionibacterium freudenreichii*	Kefir	Vitamin enrichment
	Bifidobacterium animalis Bb12	Fermented milk	Vitamin enrichment
	Lactobacillus reuteri ZJ03	Soy-yogurt	Vitamin enrichment
Folic acid (Vitamin B_9)	*Streptococcus thermophilus* CRL803/CRL415	Yogurt	Vitamin enrichment
	Lactobacillus bulgaricus CRL871	Yogurt	Vitamin enrichment
	Bifidobacterium lactis CSCC5127	Fermented milk	Vitamin enrichment
	Bifidobacterium infantis CSCC5187	Fermented milk	Vitamin enrichment
	Bifidobacterium breve CSCC5181	Fermented milk	Vitamin enrichment
	Lactobacillus amylovorus CRL887	Fermented milk	Vitamin enrichment

Gamma aminobutyric acid:

- ❑GABA is the main inhibitory neurotransmitter of the central nervous system.
- ❑Physiological functions of GABA: neurotransmission, induction of hypotension, diuretic effects etc.
- ❑Food-grade LAB exhibit GABA-producing ability (*L. brevis, L. paracasei, L. delbrueckii, L. plantarum*).
- ❑GABA has potential as a health-promoting bioactive component in foods.



Bioactive peptides:

- During milk fermentation, LAB make use of their proteolytic system to transform milk proteins into biologically active peptides (antimicrobial, antihypertensive, immunomodulatory, and antioxidative).
- Best known ACE-inhibitory biopeptides, Val-Pro-Pro (VPP) and Ile-Pro-Pro (IPP) have been identified in milk fermented by *L. helveticus*.
- Dairy starter cultures used in the manufacture of fermented dairy products (*L. helveticus, L. bulgaricus, L. plantarum, L. acidophilus, Lactococcus lactis, or S. thermophilus*) can generate bioactive peptides.

Enzymes:

- Lactic acid bacteria associated to dairy fermentations possess enzymes which can be produced *in situ* during fermentation of dairy foods.
- Hydrolytic enzymes exert potential synergistic effects on digestion and alleviate symptoms of intestinal malabsorption.
- β-galactosidase activity degrade lactose thus, improve health and reduce symptoms in lactose intolerant consumers.

Conjugated Linoleic Acid:

- Polyunsaturated fatty acid that can be biosynthesized by LAB and bifidobacteria through bioconversion of linoleic acid.
- Health-promoting properties of CLA include anticarcinogenic, anti-inflammatory, and antidiabetic activity as well as reduce body fat.
- An effective way to increase CLA uptake in humans is to increase CLA levels in dairy products by using strains with high production potential.
- Food-grade LAB and bifidobacteria produce CLA in milk products (*L. bulgaricus* LB430 and *S. thermophilus* TA040 are suitable for production of CLA-enriched yogurt).

Bacteriocins:

- Bacteriocins are ribosomally synthesized antimicrobial peptides produced by particular bacterium that are active against other competitor bacteria.
- These antimicrobial molecules are beneficial peptides synthesized by some LAB during milk fermentation and they have been traditionally used as naturally produced food biopreservatives.
- **Nisin** is the most well-known bacteriocin used as food preservative due to its antibacterial effect against *Listeria*, clostridia spores and LAB associated to spoilage.
- Nisin-containing Camembert and semi-hard cheeses with prolonged shelf-life were made using *Lactococcus lactis.*

Health Effects of Probiotics

Well-substantiated effects

- Alleviation of lactose maldigestion
- Prevention/treatment of infections
- Reduction of serum cholesterol
- Chemopreventative effects
- Modulation of the immune system

Potential effects

- Treatment/prevention of inflammatory bowel disease
- Alleviation of constipation
- Improvement of dermatitis
- Liver disease therapy

Bacteria	Probiotic effects	Properties	Use
Lactobacillus acidophilus (6 major species)	▪ may fight intestinal infection ▪ reduces intestinal transit time ▪ may prevent colon cancer ▪ may be hypocholesterolemic	Survives GI transit well. (Ability to survive varies between strains.) Adherence demonstrated in vitro but not yet demonstrated in vivo. Grows slowly in fermented products; doesn't survive well in fermented products.	Used in acidophilus milk and in kefir; may be used in yogurt.
Lactobacillus GG	▪ prevents growth of pathogens ▪ delays tumor development ▪ prevents traveller's diarrhea, ▪ antibiotic-associated diarrhea and infant diarrhea ▪ alters activity of intestinal microflora	Implants and colonizes the intestinal tract. However, the colonization isn't permanent. Research shows that probiotic bacteria should be consumed a few times a week to maintain their effect on intestinal flora.	Some new fermented dairy products using *LGG* are available in Europe. Minimum levels necessary for colonization are: ▪ 10^8 cells in milk, ▪ 10^9 cells in fermented milk or enteric tablets, ▪ 10^{10} cells in gelatin capsules.

Bacteria	Probiotic effects	Properties	Use
Lactobacillus casei	▪ can increase levels of immunoglobulins, γ-interferon, and phagocytic activity ▪ decreases activity of enzymes related to the risk of colon cancer ▪ alters composition of intestinal flora, possibly by restricting growth of pathogens	Some strains survive intestinal transit. Does not colonize.	Used in kefir and many cheeses, including parmesan and cheddar; also used in some new yogurt-like products.
Bifidobacteria (29 strains)	▪ reduces incidence and duration of diarrhea ▪ reduces intestinal transit time ▪ may reduce colon cancer ▪ increases production of secretory immunoglobulins	Some strains of Bifidobacteria survive intestinal transit well, but it is not clear whether they implant. Produce both lactic acid and acetic acid.	May be used in yogurt.