Lactic Acid-Fermented Vegetable Juices – Palatable and Wholesome Foods

J. KAROVIČOVÁ and Z. KOHAJDOVÁ

Department of Food Technology, Faculty of Chemical and Food Technology, Slovak University of Technology, SK-812 37 Bratislava
e-mail: jolana.karovicova@stuba.sk

Received 27 October 2003

This paper describes the manufacture procedure of lactic acid-fermented vegetable juices, nutritional aspects of lactic acid fermentation, and wholesome effects of lactic acid bacteria that are used as starter cultures for preparation of lactic acid-fermented vegetable juices. The topic of antioxidants, sensory and biologically active compounds present in selected vegetables and current trends in manufacture of lactic acid-fermented juices are also discussed.

Fermented foods are of great significance because they provide and preserve vast quantities of nutritious foods in a wide diversity of flavours, aromas, and textures which enrich the human diet.

Fermentation can be defined as a desirable process of biochemical modification of primary food products brought about by microorganisms and their enzymes. Fermentation is carried out to enhance taste, aroma, shelf-life, texture, nutritional value, and other attractive properties of foods [1]. Fermented foods can be generally described as palatable and wholesome foods, prepared from raw or heated raw materials by microbial fermentation [2]. While there are 21 different commercial vegetable fermentations in Europe along with a large number of fermented vegetable juices and blends, the most economically relevant of these are the fermentations of olives, cucumbers (pickles), and cabbage (sauerkraut, Korean kimchi) [3].

The lactic acid fermentation of vegetable juices, applied as a preservation method for the production of finished and half-finished products, is again being ranked as an important technology and it is being further investigated because of the growing amount of raw materials processed in this way in the food industry. The main reasons for this interest are the nutritional, physiological, and hygienic aspects of the process and their corresponding implementation and production costs [4]. Therefore, in the recent years, several scientists deal with the field of lactic acid fermentation of vegetables or vegetable juices. Examples of various lactic acid-fermented vegetables and vegetable juices are presented in Table 1.

The purpose of this study was to describe process manufacture of lactic acid-fermented vegetable juices and nutrition and healthy effects of their consumption.

MANUFACTURE OF LACTIC ACID-FERMENTED VEGETABLE JUICES

In a lot of countries consumption of the lactic acid-fermented vegetable juices increases [19]. The Chinese cabbage, cabbage, pH-adjusted tomato (to pH 7.2), carrot, and spinach media gave relatively higher fermentability than other vegetables because they have more fermentable saccharides than other vegetables [13]. Lactic acid-fermented vegetable juices are produced mainly from cabbage, red beet, carrot, celery, and tomato [18].

The lactic acid fermented vegetable juices can be produced by two procedures: the vegetable is fermented by usual way and then it is processed by pressing the juice (manufacture from sauerkraut) or the vegetable is at first processed to mash or raw juice and it is consecutively fermented. There are three fermentation types of vegetable juices: spontaneous fermentation by natural microflora, fermentation by starter cultures which are added into raw materials, and fermentation of heat-treated materials by starter cultures [20].

Table 1. Examples of Lactic Acid-Fermented Vegetables and Vegetable Juices

Vegetable or vegetable juice	Microorganism	Ref.
Garlic	*Lactobacillus plantarum*	[5]
Carrot slices	*Lactobacillus sacei*	[6]
Lye-treated carrot	*Lactobacillus plantarum* or mixture culture *Lactobacillus plantarum* and *Saccharomyces cerevisiae*	[7]
Carrot, capsicum	Different *Lactobacillus* strains	[8]
Olives	*Lactobacillus pentosus*	[9]
Gourd, cabbage, celery	*Lactobacillus plantarum, Lactobacillus brevis, Lactobacillus pentosus*	[10]
Cucumber	*Lactobacillus plantarum*	[11]
Mixture of cabbage, carrot, onion, and red beet	Mixture starter cultures	[12]
Various vegetables	Lactic acid bacteria and bifidobacteria	[13]
Sauerkraut and sauerkraut juice	*Lactobacillus plantarum, Lactobacillus casei, Pediococcus pentosaceus, Enterococcus faecium*	[14]
Cabbage juice or cabbage-carrot juice	16 strains of *Lactobacillus* genera or *Lactobacillus plantarum*, mixture culture *Lactobacillus plantarum* and *Saccharomyces cerevisiae*	[15—18]

At the manufacture of lactic acid-fermented vegetable juices, the pressed juice can be pasteurized at first and consecutively it is inoculated by culture of selected lactic acid bacteria [19] at a concentration from 5×10^6 to 1×10^7 CFU cm^{-3}.

For fermentation of juices, of the highest importance are commercially offered strains such as *Lactobacillus plantarum, Lb. bavaricus, Lb. xylosus, Lb. bifidus, Lb. brevis* [21]. The desirable properties of fermented vegetable juices can be achieved by choosing *Lactobacillus* strains suitable for the lactic acid fermentation of individual raw materials. The criteria used for finding out a strain suitability are as follows: the rate and total production of acids, change of pH, loss of nutritionally important substances, decrease of nitrate concentration and production of biogenic amines [4, 8], ability of substrate to accept the starter culture, type of metabolism, and ability of culture to create desirable sensory properties of fermented products [22]. Bacteriocin-producing starter cultures have been suggested as a mean to obtain more controlled and reproducible vegetable fermentations [6, 23].

Enzyme mash treatment is a well-known modern process for gaining more juice from vegetable [24]. The enzyme decomposition is applied before the lactic acid fermentation of products to achieve a concentration of compounds that commonly remain in the pomace. It refers especially to some of mineral compounds, including calcium, phosphorus, and magnesium [19].

The fermentation is performed at the temperature about 20—30 ℃ [25]. For optimal course of lactic acid fermentation, the content of sugars in raw materials must be sufficient (at least 40 g kg^{-1}) and the content of proteins, that neutralize emergent acids must be minimal [19]. During fermentation, the pH of juices decreases from 6—6.5 to 3.8—4.5 [25]. A rapid decrease of pH in the beginning of fermentation is of great importance for the quality of the end product [26]. The rapid increase of acidity minimizes the influence of spoilage bacteria. In the slowly acidified environments the lactic acid fermentation can be suppressed by butyric bacteria [27]. The acidity below pH 3.6 is undesirable from the sensory point of view [28]. By the fermentation, the juices obtain pleasant acid taste and characteristic aroma. After fermentation, the juices can be filled into bottles and pasteurized or aseptically filled into bottles after previous filtration [29].

The current trends in manufacture of lactic acid-fermented juices are oriented to qualitative and quantitative development [19]. The high priority should be given to the research of the effect of lactic acid fermentation on the viruses, parasites, some bacteria and mycotoxins, risk assessment using HACCP approach, health education of the handlers and consumer perception of new fermented juices, characterization and optimalization of fermentation processes and development of appropriate starter cultures, and some physiological and nutritional effects of consumption of lactic acid-fermented vegetable juices [1, 22].

VEGETABLE JUICES AS SOURCE OF ANTIOXIDANTS

Vegetables as raw materials for manufacture of lactic acid-fermented vegetable juices are naturally low in fat, saturated fat, cholesterol, energy, and sodium and are rich in potassium, fibre, and vitamins [30—32].

Cao et al. [33] found that vegetables, such as kale, beets, broccoli, spinach, shallots, potato, carrots, and cabbage, have high antioxidant activities. Their study indicates that each type of vegetable has different antioxidant activity, contributed by different antioxidant components, such as α-tocopherol, β-carotene, vitamin C, selenium or phenolic compounds [34].

The importance of antioxidant constituents of vegetables in the maintaining of health and protection from coronary disease and cancer is also raising interest among scientists, food manufacturers, and consumers since the future trend is towards functional foods with specific health effects [35].

Sujatha and *Srinivas* [36] found that aqueous extracts of cabbage and onions inhibit lipid peroxidation by 65 % and 66 %, respectively. Carrot is a major source of β-carotene and the other carotenoids which are thought to scavenge free radicals and other oxidants involved in disease processes. The antioxidant action of β-carotene has been observed *in vitro* and *in vivo* [37, 38]. Organosulfur compounds of garlic inhibit the peroxidation of lipids and possess antioxidant and radical-scavenging activity [39]. Red beet is the most important source of betalaines. Betalaines are a class of compounds with antioxidant and radical-scavenging activities [40].

Sensory and Biologically Active Compounds Present in Selected Vegetables

Glucosinolates and their degradation products are responsible for the characteristic taste and odour of cabbage and *Brassica* vegetables (isothiocyanates are responsible for the bite and pungency) [41—45]. Nature of glucosinolate breakdown product formation in cabbage is strongly affected by pH and depends on the glucosinolate substrate, as well as on the presence of other enzyme inhibitors and activators, such as ascorbate [46]. *Kyung* and *Fleming* [47] documented that cabbage juice exhibited antibacterial activity against some bacteria strains, but that inhibition was eliminated when the cabbage was heated before juice extraction.

S-Methylmethionine present in fresh cabbage, cabbage juice, and sauerkraut reduces tumourigenesis risk in the stomach. The isothiocyanatans and indoles contained in cabbage account for anticancer effects. These compounds protect from cancer of colon, breast [19], lung, forestomach, and liver [48].

Carrot has a complex flavour. There is no single compound that accounts for a distinctively carrot-like flavour. Although there are many factors that influence carrot flavour, including nonvolatile chemical constituents, such as free sugars, phosphates and nitrogenous compounds, bitter compounds, phenolic compounds and organic acids, the characteristic flavour of carrot is mainly due to the volatile constituents which are mostly made up of terpenes and sesquiterpenes [49]. Carotenoids present in carrot may help reduce risks for developing tumours in various tissues [50] by interfering with the metabolic activation of such substances to the ultimate carcinogens, which damage DNA, proteins and lipids [33, 51]. Oxidative DNA damage is significantly reduced during carrot juice intervention. It is likely that the effect was partly due to carotene [33, 52].

Tertiarly alcohol geosmine is mainly responsible for earthy taste and odour of red beet [53]. Red beet has a beneficial health effect against tumour cells [54]. Extracts of this plant have been used for the therapy of liver, spleen, and skin diseases [55].

Health-related properties of garlic are attributable to the organosulfur compounds, particularly to allicine, the pungent-smelling compound [39]. Diallyl disulfide and diallyl sulfide also appear to be the bioactive components of garlic that exert the anticarcinogenic effects. These allylic compounds stimulate glutathione *S*-transferase activity in the liver. This transferase binds to and detoxifies potential carcinogens [48, 56]. Garlic is believed also to affect the microbial flora in two ways: by acting as an antimicrobial agent, in particular against gram-negative bacteria due to allicine and by stimulating the growth of lactic acid bacteria [57]. The antimicrobial activity may serve to inhibit the bacterial conversion of nitrate to nitrite in the stomach, thereby reducing the amount of nitrite available for reaction with secondary amines to form nitrosamines, which may be carcinogenic, particularly in the stomach [38].

Wholesome Effects of Lactic Acid Bacteria

Among bacteria associated with food fermentation lactic acid bacteria are of predominant importance. Their association with the human environment and their beneficial interactions, both in food and in the human intestinal tract, combined with the long tradition of lactic acid-fermented foods in many cultures, have led to the general conclusion that this group may be generally recognized as safe [2]. By definition, lactic acid bacteria are bacteria that ferment a sugar (*e.g.* glucose) predominantly to lactic acid [58]. Lactic acid production resulting in acidification to pH $<$ 4.2 contributes to a major safety factor. However, recent observations confirm that other metabolites with antimicrobial properties also contribute to the safety of lactic acid-fermented foods. Metabolic products of lactic acid bacteria with antimicrobial properties are presented in Table 2 [2].

Each of these properties and especially a combination of some of them, can be used to extend the shelf life and safety of food products [59].

Lactic and acetic acids are characteristic products of lactic acid fermentation [26]. The antimicrobial action of these acids is related to the ability of the undissociated acid molecules to penetrate through the bacterial plasma membrane as a function of their diffusion constant. In the cytoplasm, the acid dissociates to release protons and conjugate bases with higher pH, this disrupts the membrane proton-motive force, thus disabling the energy-yielding and transport process dependent upon it [60]. The lactic acid also forms the natural protection of the body against various infections, increases immunity and effects as physiological disinfection agent, improves digestion and acts at liver diseases [21].

Table 2. Metabolic Products of Lactic Acid Bacteria with Antimicrobial Properties

Product	Main target organisms
Organic acids	
Lactic acid	Putrefactive and gram-negative bacteria, some fungi
Acetic acid	Putrefactive bacteria, clostridia, some yeasts and fungi
Hydrogen peroxide	Pathogens and spoilage organisms, especially in protein-rich foods
Enzymes	
Lactoperoxidase system with H_2O_2	Pathogens and spoilage bacteria (milk and dairy products)
Lysozyme (by recombinant DNA technology)	Undesired gram-positive bacteria
Low-molecular-mass metabolites	
Reuterin (3-OH-propionaldehyde)	Wide spectrum of bacteria, moulds, and yeasts
Diacetyl	Gram-negative bacteria
Fatty acids	Different bacteria
Bacteriocins	
Nisin	Some lactic acid bacteria and gram-positive bacteria, notably endospore-formed
Other	Gram-positive bacteria, inhibitory spectrum according to producer strain and bacteriocin type

Table 3. Classification of Bacteriocins of Lactic Acid Bacteria

Class	Properties
I	Small membrane-active, heat-stable peptides ($M_r < 10^4$)
Ia	Lantibiotics
Ib	Nonlanthionine-containing peptides:
	Peptides active against Listeria (A-terminal sequence of consensus: -Tyr-Gly-Asn-Gly-Val-Xaa-Cys-)
	Bacteriocins the activity of which depends on the complementary action of two peptides
	Thiol-active bacteriocins requiring cysteine for their activity
II	Large heat-sensitive proteins ($M_r > 3 \times 10^4$)
III	Complex bacteriocins, requiring a nonprotein component (*e.g.* a carbohydrate or lipid moiety) for their activity

Carbon dioxide can directly create an anaerobic environment and is toxic to some aerobic food microorganisms through its action on cell membranes and its ability to reduce internal and external pH [3]. Carbon dioxide produced replaces air and provides anaerobic conditions favourable for the stability of ascorbic acid and the natural colour of vegetable products [61].

Hydrogen peroxide can accumulate and be inhibitory to some microorganisms. Inhibition is mediated through the strong oxidizing effect on membrane lipids and cell proteins [3].

Bacteriocins produced by lactic acid bacteria are peptides or small proteins that are frequently inhibitory towards many undesirable bacteria, including foodborne pathogens (*e.g. Listeria monocytogenes*) [62]. Classification of bacteriocins of lactic acid bacteria is presented in Table 3. An advantage of bacteriocins over classical antibiotics is that digestive enzymes destroy them. Bacteriocin producing strains can be used as part of, or adjunct to starter cultures for fermented foods in order to improve safety and quality [3].

Lactic acid bacteria are considered to have several beneficial physiological effects, such as antimicrobial activity, enhancing of immune potency [63] and ability to prevent cancer and lower serum cholesterol levels [64]. Proposed health and nutritional benefits of *Lactobacillus* species are [65] enzyme (lactase) presentation, colonization and maintenance of the normal microflora, competitive exclusion of undesirable microorganisms, microbial interference and antimicrobial activities, pathogen clearance, immuno-stimulation and modulation, cholesterol reduction/removal, deconjugation of bile acids, anticarcinogenic and antimutagenic activities, reduction of endotoxemia from alcoholic liver disease. Because lactic acid bacteria prohibit colonization by the invader and control the intestinal pH through the release of acetic and lactic acids, these bacteria could effectively prevent constipation and diarrhea caused by lactose intolerance or pathogenic bacteria. A synergistic effect of the dietary fibre and lactic acid bacteria for the improvement of the large intestinal health of the most may be achieved by providing a fermented fibre-rich natural plants to the host [13].

Several research studies confirm the ability of lactic acid bacteria to reduce the mutagenicity of intestinal contents by suppressing the levels of specific bacterial enzymes that promote the activation of procarcinogenic compounds [66]. Lactobacilli have been periodically associated with anticarcinogenic, antimutagenic, and antitumourigenic activities. These activities may occur *via* the following: binding, inhibition or inactivation of mutagens *in vitro*, reductions in carcinogen-generating fecal enzymes *in vivo*, stimulation of the immune system, suppression of tumour formation [65].

Progress in gene technology allows modification of lactic acid bacteria by introducing new genes or by modifying their metabolic functions. These modifications may lead to improvements in food technology (bacteria better fitted to technological processes, leading to improved organoleptic properties, improved product safety and quality), or to new applications including bacteria producing therapeutic molecules that could be delivered by mouth [67].

The implementation of carefully selected strains as starter cultures or co-cultures in fermentation processes can help to achieve *in situ* expression of the desired property, maintaining a perfectly natural and healthy product [68]. Examples are lactic acid bacteria that are able to produce antimicrobial substances, sugar polymers, sweeteners, aromatic compounds, useful enzymes, or nutraceuticals, or lactic acid bacteria with health-promoting properties, the so-called probiotic strains. This represents a way of replacing chemical additives by natural compounds, at the same time providing the consumer with new, attractive food products. It also leads to a wider applications area and higher flexibility of starter cultures [69].

Nutritional Aspects of Lactic Acid Fermentation

The nutritional value of a particular food depends on its digestibility and its content of essential nutrients. Both digestibility and its nutrient content may be improved by fermentation [59]. The different ways by which the fermentation process can affect the nutritional quality of foods include improving the nutrient density and increasing the amount and the bioavailability of nutrients [70].

Lactic acid fermentation leads to a decrease in the level of carbohydrates as well as some nondigestable poly- and oligosaccharides. The latter reduces side effects such as abdominal distension and flatulence [1]. The nutritional impact of fermented foods on nutritional diseases can be direct or indirect. Food fermentations that arise the protein content or improve the balance of essential amino acids or their availability will have a direct curative effect. Similarly fermentations that increase the content or availability of vitamins, such as thiamine, riboflavin, niacin or folic acid can have profound direct effects on the health of the consumers of such foods [71].

It was shown that lactic acid fermentation increases utilization of iron from food by breakaway of inorganic iron from complex substances under influence of vitamin C [72, 73].

Acid-fermented vegetables are important sources of vitamins and minerals [61]. Vitamin C is better preserved in lactic acid-fermented vegetable products, compared with those processed by alternative methods [1].

Fermented foods may reduce the serum cholesterol concentration by reducing the intestinal absorption of dietary and endogenous cholesterol or inhibiting cholesterol synthesis in liver [59].

CONCLUSION

Fermentation can have multiple effects on the nutritional value of food [1]. Lactic acid fermentation imparts attributes of robust stability and safety in the product, and thereby preempts disease infections, such as diarrhea and salmonellosis [74].

The fundamental reason for the development and acceptance of fermented foods can be variably ascribed to preservation, improved nutritional properties, better flavour/aroma, upgrading of substrates to higher value products and improved health aspects [59]. The assumption of the higher consumption of lactic acid-fermented food is the publicity. An important factor is also the supply of lactic acid-fermented vegetable juices with new quality characteristics, without application of preserving agents [19].

Acknowledgements. This work was supported by the Slovak Grant Agency for Science VEGA (Grant No. 1/0102/03) and National Program of Research and Development (Grant No. 749/s/2003).

REFERENCES

1. Nout, M. J. R. and Motarjemi, Y., *Food Control 8*, 221 (1997).
2. Holzapfel, W., *Food Control 8*, 241 (1997).
3. Caplice, E. and Fitzerald, G. F., *Int. J. Food Microbiol. 50*, 131 (1999).
4. Karovičová, J., Drdák, M., Greif, G., and Hybenová, E., *Eur. Food Res. Technol. 210*, 53 (1999).
5. De Castro, A., Montaño, A., Sánchez, A. H., and Rejano, L., *Int. J. Food Microbiol. 39*, 205 (1998).
6. Aukrust, T. W., Blom, H., Sandtorv, F., and Slinde, E., *Lebensm. Wiss. Technol. 27*, 337 (1994).
7. Montaño, A., Sánchez, A. H., Rejano, L., and De Castro, A., *Int. J. Food Microbiol. 35*, 83 (1997).
8. Karovičová, J., Drdák, M., and Polonský, J., *Potrav. Vědy 12*, 105 (1994).
9. Sánchez, A. H., De Castro, A., Rejano, L., and Montaño, A., *J. Agric. Food Chem. 48*, 5975 (2000).
10. Kuchta, T., Radošovská, R., Glončáková, B., Belicová, A., and Lopašovská, J., *Bull. PV 33*, 85 (1994).
11. Lu, Z., Fleming, H. P., and McFeeters, R. F., *J. Food Sci. 66*, 162 (2001).
12. Garden, N. J., Savard, T., Obermeier, P., Caldwell, G., and Champagne, C. P., *Int. J. Food Microbiol. 64*, 261 (2001).
13. Kim, H. Y., Min, J. H., Lee, J. H., and Ji, G. E., *Food Sci. Biotechnol. 9*, 322 (2000).
14. Kalač, P., Špička, J., Křížek, M., and Pelikánová, T., *Food Chem. 70*, 355 (2000).

15. Drdák, M., Karovičová, J., Greif, G., and Rajniaková, A., *Bull. PV 13*, 195 (1994).
16. Karovičová, J., Kohajdová, Z., Greifová, M., Lukáčová, D., and Greif, G., *Bull. PV 41*, 197 (2002).
17. Karovičová, J., Greif, G., Kohajdová, Z., and Hybenová, E., *Bull. PV 40*, 119 (2001).
18. Karovičová, J., Kohajdová, Z., and Hybenová, E., *Chem. Pap. 56*, 267 (2002).
19. Kopec, K., *Výživa a potraviny 3*, 93 (2000).
20. Hammes, W. P., *Food Biotechnol. 4*, 383 (1990).
21. Šulc, D., *Flüssiges Obst. 1*, 17 (1984).
22. Holzapfel, W. H., *Int. J. Food Microbiol. 75*, 197 (2002).
23. Ausco, M., Leal, V., Baras, M., Ruiz-Barba, J. L., Floriano, B., and Jimenez, R., *Int. J. Food Microbiol. 43*, 129 (1998).
24. Demir, N., Acar, J., Sar, K., and Mutlu, M., *J. Food Eng. 47*, 275 (2001).
25. Adams, M. R. and Nicolaides, L., *Food Control 8*, 227 (1997).
26. Viander, B., Maki, M., and Palva, A., *Food Microbiol. 20*, 391 (2003).
27. Kyzlink, V., *Bases of Food Preservation.* Nakladatelství technické literatury (Publishers of Technical Literature), Prague, 1980.
28. Lopatníková, J., *Nové postupy v konzervovaní rastlinnej produkcie.* (New Procedures in Preserving Plant Production.) Dom techniky ZSVTS, Bratislava, 1992.
29. Biacs, P., *Bull. PV 25*, 1 (1986).
30. Brandt, K. *et al.*, *Trends Food Sci. Technol. 15*, 384 (2004).
31. Graig, W. J., *J. Am. Diet. Assoc. 97*, 199 (1997).
32. Toit, R., Volsteedt, Y., and Apostolides, Z., *Toxicology 166*, 63 (2001).
33. Cao, G., Sofic, E. and Prior, R. L., *J. Agric. Food Chem. 44*, 3426 (1996).
34. Ismail, A., Marjan, Z. M., and Foong, Ch. W., *Food Chem.*, in press.
35. Amarowicz, R., Pegg, R. B., Rahimi-Moghaddam, P., Barl, B., and Weil, J. A., *Food Chem. 84*, 551 (2004).
36. Sujatha, R. and Srinivas, L., *Toxicol. in Vitro 9*, 231 (1995).
37. Anilkumar, K. R., Khanum, F., Sudarshanakrishna, K. R., Viswanathan, K. R., and Santhanam, K., *Nutr. Res.* (N. Y.) *20*, 893 (2000).
38. Steinmetz, K. A. and Potter, M. D., *J. Am. Diet. Assoc. 96*, 1027 (1996).
39. Rabinkov, A., Miron, T., Konstantinovski, L., Wilchek, M., Mirelman, D., and Weiner, L., *Biochem. Biophys. Acta 1379*, 233 (1998).
40. Strack, D., Vogt, T., and Schliemann, W., *Phytochemistry 62*, 247 (2003).
41. Jones, A. M. E., Winge, P., Bones, A. M., Cole, R., and Rossiter, J. T., *Insect Biochem. Mol. Biol. 32*, 275 (2002).
42. Rangkadilok, N., Nicolas, M. E., Bennet, R. N., Premier, R. R., Eagling, D. R., and Taylor, P. W. J., *Sci. Hortic.* (Amsterdam) *96*, 27 (2002).
43. Leoni, O., Palmieri, S., Esposito, E., Menegatti, E., Cortesi, R., and Nastruzzi, C., *Bioorg. Med. Chem. 5*, 1799 (1997).
44. Kassie, F. *et al.*, *Chem.-Biol. Interact. 102*, 1 (1996).
45. Stoewsand, G. S., *Food Chem. Toxicol. 33*, 537 (1995).
46. Tolonen, M., Rajaniemi, S., Pihlava, J. M., Johansson, T., Saris, P. E. J., and Ryhanen, E. L., *Food Microbiol. 21*, 167 (2004).
47. Kyung, K. H. and Fleming, H. P., *J. Food Sci. 59*, 1541 (1994).
48. Kris-Etherton, P. M. *et al.*, *Am. J. Med. 113*, 71 (2002).
49. Alasalvar, C., Grigor, J. M., and Quantick, P. C., *Food Chem. 65*, 391 (1999).
50. Desobry, S. A., Netto, F. M., and Labuza, T. P., *Crit. Rev. Food Sci. Nutr. 38*, 381 (1998).
51. Van Duyn, M. A. and Pivonka, E., *J. Am. Diet. Assoc. 100*, 1511 (2000).
52. Glei, M., Liegibel, U. M., Ebert, M. N., Bohl, V., and Pool-Zobel, B. L., *Toxicol. Appl. Pharmacol. 179*, 65 (2002).
53. Velíšek, J., *Food Chemistry 1.* OSSIS, Tábor, 1999.
54. Stintzing, F. and Carle, R., *Trends Food Sci. Technol. 15*, 19 (2004).
55. Stuppner, H. and Egger, R., *J. Chromatogr. 735*, 409 (1996).
56. Ankri, S. and Mirelman, D., *Microb. Infec. 2*, 125 (1999).
57. Paludan-Muller, Ch., Huss, H. H., and Gram, L., *Int. J. Food Microbiol. 46*, 219 (1999).
58. Liu, S. Q., *Int. J. Food Microbiol. 83*, 115 (2003).
59. Kalantzopolos, G., *Anaerobe 3*, 185 (1997).
60. Savard, T., Beaulieu, C., Gadren, N. J., and Champagne, C. P., *Food Microbiol. 19*, 363 (2002).
61. Lee, Ch. H., *Food Control 8*, 259 (1997).
62. Leroy, F., Degeest, B., and De Vuyst, L., *Int. J. Food Microbiol. 73*, 251 (2002).
63. Kullisaar, T., Yilmer, M., Mikelsaar, M., Vihalemm, T., Annuk, H., Kairane, C., and Kilk, A., *Int. J. Food Microbiol. 72*, 215 (2002).
64. Kaur, I. P., Chopra, K., and Saini, A., *Eur. J. Pharm. Sci. 15*, 1 (2002).
65. Klaenhammer, T. R., *Int. Dairy J. 5*, 1019 (1995).
66. Daly, Ch., Fitzerald, G. F., Conor, L., and Davis, R., *Int. Dairy J. 8*, 195 (1998).
67. Renault, P., *Biochimie 84*, 1073 (2002).
68. Leroy, F. and De Vuyst, L., *Trends Food Sci. Technol. 15*, 67 (2004).
69. Ruas-Madiedo, P., Hugenholtz, J., and Zoon, P., *Int. Dairy J. 12*, 163 (2002).
70. Svanberg, U. and Lorri, W., *Food Control 8*, 319 (1997).
71. Steinkraus, K. H., *Food Control 8*, 311 (1997).
72. Siegenberg, D., *Am. J. Clin. Nutr. 53*, 537 (1991).
73. Venkatesh, M. G., *Am. J. Clin. Nutr. 89*, 23 (1998).
74. Nout, M. J. R. and Ngoddy, P. O., *Food Control 8*, 279 (1997).