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Editorial

Exploration and Understanding of Beneficial Properties of Lactic Acid Bacteria: 10 years of experience in Applied Food Biotechnology

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Abstract

The scientific community is currently facing a more than exponential increase of knowledge in all areas and disciplines. In the last 10 years, the contribution of the journal *Applied Food Biotechnology* was eminent in distributing that knowledge by providing a tribune for researchers from different countries all over the world to share their ideas, observations, and hypotheses. With a focus on different aspects of applied and fundamental biological sciences, the journal *Applied Food Biotechnology* was established as a reference of the Iranian scientific community. In the last 10 years, the journal has been covering several topics related to exploring the beneficial properties of lactic acid bacteria (LAB) and their role in modern food technologies. LAB are already proven as a realization of Hippocrates' vision for the potential role of food in human and other animals' health. However, what will be the next frontier? What are the challenges in understanding the interactions between microbiota and host microorganisms? What will be the novel analytical tools, facilitating a new era of probiotic research? These were only a few research topics presented and discussed in *Applied Food Biotechnology* in the last decade. This editorial overview aims to celebrate the scientific contribution of *Applied Food Biotechnology* in the area of research associated with the beneficial properties of LAB, summarizing some of the studies published in the journal.

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1. Introduction

The utilization of food as a beneficial 'tool' for the well-being of humans and other animals was suggested in ancient Greece by Hippocrates, signifying that one day our medicine will be our food, and food will be the medicine. However, more than two millennia would pass before this idea would draw serious scientific interest, which can be said to have begun in the early 20th century when the Russian scientist Ilya Metchnikoff and his Bulgarian colleague Stamen Grigorov became interested in the beneficial health-promoting role of yogurt consumption and importantly, the lactic acid bacteria (LAB) contained within. Shortly after, the ideas of Metchnikoff/Grigorov were adopted by the scientific community, developed, and resulted in wide-ranging scientific research projects and commercial products associated with the application of LAB as health-promoting factors [1]. Also, different beneficial metabolites produced by LAB originating from a variety of different ecological niches (including various fermented foods, human and other animals' gastro-intestinal environment) were also identified, and their role as health-promoting metabolites was further elucidated over time [2] and have been suggested for use as preventive aids or as active pharmaceutical preparations for use in healthcare [3].

The specific objective of the present editorial is to focus on research papers published in the last few years within the Applied Food Biotechnology journal with a clear goal of promoting the beneficial role of LAB and their biologically valuable metabolites.

An important initial step in research on health-promoting microorganisms is the selection of appropriate strains of LAB for evaluation as potential probiotic cultures. Initially, it was suggested that in selecting new probiotics, priority should be given to strains associated with human and other animals GIT [4]. Arguments in support of that idea were often based on the assumption that such strains will most probably be better adapted to the environment where probiotics will need to perform their health-promoting benefits, and since most cultures were obtained from healthy individuals, they are most likely already acting as beneficial cultures [4]. However, reports show that different other sources [5] can be considered in the screening process for probiotic candidates. Fermented food products soon become one of the favorite sources for the selection of new probiotic candidates [4,5].

Machmoudi et al. [6] explored Iranian Jug cheese as a source for the selection of new lactobacilli strains with probiotic properties, focusing on the safety and functional properties of the investigated strains. According to the concept of "safety is paramount," the authors only selected strains with no evidence of hemolytic activity and that were considered as susceptible or intermediately susceptible to most tested antibiotics for future study. *Lactiplantibacillus plantarum* KMJC4, *Latilactobacillus curvatus* KMJC3, *Lactobacillus* (*L.*) *acidophilus* KMJC2, and *Levilactobacillus brevis* KMJC1 were evaluated regarding their ability to produce antimicrobials active against *Escherichia coli*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Bacillus cereus*, and *Salmonella enterica* subsp. *enterica* serovar Typhimurium strains and for their survival in GIT conditions and adhesion to HT-29 cells. The studied strains presented different behaviors in the applied tests, clearly showing species and strain specificity. Despite variations in the probiotic potential of the isolates, the present study clearly showed that new isolates could be identified as future probiotic strains from the microbial community of non-human/animal sources [6].

In a similar study, Nejati and Oelschlaeger [7] reported on the probiotic potential of *Lactococcus lactis* strains isolated from Iranian dairy products. Nejati and Oelschlaeger [7] assayed 8 *Lactococcus lactis* isolates for potential probiotic properties, including *in vitro* resistance to GIT conditions, adherence to Caco-2 cells and HT29-MTX-E12 cell lines, antimicrobial activity against *Staphylococcus aureus* and *Listeria monocytogenes*, hydrophobicity, and antibiotic susceptibility evaluated against gentamicin, ampicillin, ciprofloxacin, erythromycin, tetracycline, penicillin, kanamycin, and nitrofurantoin. The range of applied tests did not solely focus on the presence of beneficial properties but included potential safety issues. The results suggest that the evaluated lactococcal isolates may be considered potential probiotic candidates, based on comparative results using the well-known *Lacticaseibacillus rhamnosus* GG strain as a reference microorganism (positive control) [7].

Golshahi et al. [8] explored a somewhat different application of probiotics, going outside of the more "traditional" scenario that is focused on applications in the GIT and instead focusing on oral cavity health and combatting *Streptococcus mutans* PTCC1683. Out of 22 strains derived from Iranian dairy products (various yogurts, cheeses, fermented milk, doughs, kashks and tarkhinehs), four strains were selected as potential probiotic candidates, including one *Levilactobacillus brevis*, one *Lacticaseibacillus casei*, and two *Lacticaseibacillus paracasei* representatives. The four strains were evaluated as producers of antimicrobial metabolites and for inhibitory activity against *Streptococcus mutans*, which is generally resistant to oral lysozyme enzymes and has high mucosal adhesion properties. Importantly, the evaluated LAB were also able to decrease *Streptococcus mutans* attachment, interfering with its biofilm formation abilities. The studied *Levilactobacillus brevis*, *Lacticaseibacillus casei*, and two *Lacticaseibacillus paracasei* strains were evaluated as safe, as they were found to be susceptible to a variety of antibiotics (erythromycin, gentamicin, vancomycin, azithromycin, tetracycline, clindamycin, ampicillin, chloramphenicol, and ciprofloxacin), and no evidence for hemolytic activity was observed [8].

Ferdouse et al. [9] reported on *Pediococcus pentosaceus* and *Apilactobacillus kunkeei* strains isolated from natural Bangladeshi honey. In the selection process, out of ten LAB strains originally isolated from honey samples, two *Pediococus pentosaceus* and one *Apilactobacillus kunkeei* strains were identified based on 16S rRNA gene sequencing and demonstrated strong antimicrobial activity against several pathogens, including *Bacillus cereus, Staphylococcus aureus, Vibrio cholerae*, *Salmonella typhi*, and *Candida albicans*. The selected putative probiotic candidates were assessed under simulated GIT conditions and shown to be resistant to low pH, bile salts, and phenol. Moreover, good adherence, aggregation, and antioxidant properties were observed for the *Pediococus pentosaceus* and *Apilactobacillus kunkeei* strains [9]. Ferdouse et al. [9] suggested that honey, already known as a health-promoting natural product, might be an excellent potential source of beneficial LAB, which may partially explain the use of honey in traditional medicinal practices and long-held knowledge of honey health-promoting effects.

Probiotics can be delivered to consumers through a variety of different food products, where beneficial LAB are a part of the natural microbiota of those products [6-9]. Zendeboodi et al. [10] suggested that beer can be a suitable vector for the delivery of probiotic LAB, noting that production and storage processes for beer are favorable for maintaining the needed probiotic load. However, probiotic cultures must not interfere with the food product used as a vector for their delivery regarding organoleptic properties and the presence of other microbial cultures applied in the technological production process. Yousefi et al. [11] explored possibilities of the development of probiotic apple juice, where *Lactiplantibacillus plantarum* PTCC1058 and *Bifidobacterium bifidum* PTCC1644 were encapsulated in xanthan-chitosan based hydrogel to provide viable beneficial culture to the consumers.

Boosjun et al. [12] explored a more traditional food matrix in evaluating fermented dairy products as a delivery vector for mesophilic and thermophilic beneficial LAB. Fermented milk was produced using different levels of inoculum with both starter and probiotic cultures and then analyzed regarding the resulting physicochemical properties and microbial load of the products at up to 15 days storage at refrigeration conditions, with the intent of establishing optimal proportions between applied starter and probiotic cultures.

In a similar study, Sarvari et al. [13] evaluated the viability of *L. acidophilus* LA-5 and *Bifidobacterium lactis* BB-12 applied as probiotic cultures in combination with standard yogurt starter cultures, *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, over 21 days of yogurt stored at refrigeration temperature. All cultures showed viability throughout the evaluated period; however, *L. acidophilus* had better survival than *Bifidobacterium lactis*, while *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* did not show significant reductions in cell count.

Malganji et al. [14] explored the viability of non-dairy probiotic cultures added to grape juice and how LAB cultures influence the product's organoleptic properties during storage. *Lactobacillus delbrueckii*, *Lactiplantibacillus plantarum,* and *Lacticaseibacillus rhamnosus* (all from PTCC culture collection) were evaluated in this study as individual supplements to grape juice for four weeks at refrigeration conditions. *Lactiplantibacillus plantarum* and *Lactobacillus delbrueckii* had better levels of survival. Moreover, adding probiotics to the grape juice did not significantly alter organoleptic properties. On 14 days of storage, juice supplemented with *Lacticaseibacillus rhamnosus* showed better acceptance by the consumers, and even though the sensory evaluation panel suggested some alteration after 21 and 28 days of storage, the products did not fail to meet consumer expectations [14].

Assessing the shelf life and viability of probiotics in food products is critical in designing beneficial food products. This presents a challenge for the food industry since refrigeration conditions are often considered an essential step of the storage process. However, encapsulation of probiotic cultures is an approach that can modulate interactions between the probiotic culture and food matrix and will later protect the microbial culture from the low pH in the stomach and the action of bile salts in the upper GIT compartments. Foroutan et al. [15] reported on the isolation and identification of probiotic *Lacticaseibacillus casei* PM01 from dairy and its encapsulation within polysaccharides to improve bacterial viability. Foroutan et al. [15] performed a series of preliminary experiments confirming the probiotic potential of *Lacticaseibacillus casei* PM01, including evaluations of hemolytic activity, resistance to pepsin and trypsin, transferable antibiotic resistance genes, antimicrobial activity, ability to reduce pathogens adhesion to surfaces, cholesterol removal from blood serum, and bile salt hydrolase activity. However, the study focused on confirming whether or not encapsulation is an appropriate approach for increasing the survival and viability of the probiotic candidate.

An additional challenge is the production of probiotic cultures in sufficient quantity so that they can be applied as additives in the different food matrixes or commercialized as pharmaceutical preparations. Noori et al. [16] evaluated the optimization of fermentation processes to produce significant quantities of *Lactiplantibacillus plantarum* T5jq30-1796.1, a strain isolated from tarkhineh (a traditional Iranian fermented food product). Noori et al. [16] suggested that pH, glucose, and yeast extract concentrations were principal factors for the growth optimization of *Lactiplantibacillus plantarum* T5jq301796.1.

In some cases, the application of probiotic cultures can be enhanced by additional components, such as antibiotics, essential oils, different postbiotics, and microbial metabolites. Sadrizadeh et al. [17] studied the synergetic effects between the essential oil of *Teucrium polium* in combination with a probiotic strain of *Lacticaseibacillus casei* ATCC 3939 on *Escherichia coli* O157:H7 in kishk, a dehydrated fermented milk product that is consumed in Middle East and the Indian subcontinent. Combined application of *Teucrium polium* essential oils and *Lacticaseibacillus casei* ATCC 3939 effectively reduced the number of viable *Escherichia coli* O157:H7 cells during cold storage of kishk, compared to the individual application of either anti-*Escherichia coli* agent. Moreover, based on organoleptic analysis, the addition of up to 75 ppm of the essential oil did not influence customers' acceptance of the product [17].

Probiotics can be appropriate microbial cultures not only for improving food safety, where different antimicrobial metabolites can contribute to the reduction and even elimination of spoilage microorganisms and food-borne pathogens [2], but may also be practical components for antimicrobial therapy against relevant pathogens. Sadeghi et al. [18] suggested that the enrichment of probiotic yogurt containing a combination of *Bifidobacterium lactis* and *L. acidophilus* with broccoli sprout extract (prebiotic) can be effective in the control of *Helicobacter pylori*. Strikingly, the authors provided evidence that the applied broccoli sprout extract did not have an inhibitory effect against the studied probiotics (*Bifidobacterium lactis* and *L. acidophilus*), nor yogurt starter cultures but could inhibit the growth of *Helicobacter pylori*. Synergetic inhibitory properties were recorded when probiotics and broccoli sprout extract were applied against *Helicobacter pylori*. Moreover, with an increase in the concentration of the broccoli sprout extract, the number of probiotic bacteria increased in the experimental evaluated samples [18].

As a consequence of applying probiotics, some authors have suggested that cholesterol levels can be reduced [19,20]. Widodo et al. [20] suggested that consumption of milk fermented with LAB can help improve lipid profiles and lower cholesterol levels. Application of *Lacticaseibacillus casei* AG and *Lacticaseibacillus casei* AP showed that probiotic application could effectively reduce cholesterol levels in strain-specific manners. Widodo et al. [20] suggested that high cholesterol assimilations by *Lacticaseibacillus casei* AG might be associated with membrane attachment via resistance to bile acids. Moreover, milk fermented with *Lacticaseibacillus casei* AG can also be recommended for patients diagnosed with dyslipidemia.

LAB like other probiotics could be incorporated into the food matrix or as biofilm for their health potential benefits or antimicrobial properties [21]. Also, screening, characterization, incorporation in foods, as well as impact of the variable on probiotic survival are the major branch of research in this context [22]. Their great impact in the treatment and prevention of disease is attracting interest due to antimicrobial resistance [23]. Also, due to increasing contamination in the food chain due to industrial life, bio-decontamination role of probiotics could be the last chance to get rid of pollutants in food [24].

LAB are already proven as a realization of Hippocrates' vision for the potential role of food in human and other animals' health. However, what will be the next frontier? What are the upcoming challenges in understanding the interactions between microbiota and host micro-organisms? A step towards the next generation of probiotics [25] and their role in the balance of human (and other animals) health has already been taken, and several research teams are now evaluating interactions with more “exotic microbial species/strains” as potential health-promoting factors. Novel analytical tools are facilitating a new era of probiotic research, and the fruits of these innovative ideas will soon be scientific facts.

The scientific community is currently facing a more than exponential increase of knowledge in all areas and disciplines. Research projects from Asian countries are taking a leading role in these processes. Research groups from Iran and other Asian countries produced the majority of papers mentioned in this short editorial. High levels of research are coming from different countries all over the world, and the democratization and dissemination of 21st-century communications tools are further facilitating access to information and the sharing of our latest research discoveries.

2. Contribution

Concept: SDT, KKD; Literature analysis: SDT, KKD and MLC; Writing of the manuscript: SDT; Language editing: RW and MLC; Corrections and editing: SDT, KKD and MLC.

3. Finding

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کاوش و شناخت خواص مفید باکتری‌های لاکتیک اسید: ۱۰ سال تجربه در مجله زیست فناوری غذایی کاربردی

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چکیده

جامعه علمی در حال حاضر با افزایش بسیار تصاعدی دانش در تمامی زمینه‌ها و رشته‌ها مواجه است. در ۱۰ سال گذشته، سهم مجله *زیست فناوری غذایی کاربردی* در توزیع این دانش با ارائه تریبونی برای محققان از کشورهای گوناگون در سراسر جهان برای به اشتراک گذاشتن ایده‌ها، مشاهدات و فرضیه‌های خود برجسته بود. مجله زیست فناوری غذایی کاربردی با تمرکز بر جنبه‌های گوناگون علوم کاربردی و بنیادی زیستی به‌عنوان مرجع جامعه علمی ایران تأسیس شد. در ۱۰ سال گذشته، این مجله چندین موضوع مرتبط با کاوش در خواص مفید باکتری‌های لاکتیک اسید(LAB) و نقش آنها در فناوری‌های نوین غذایی را پوشش داده است. LAB قبلاً به عنوان تحقق دیدگاه بقراط برای نقش بالقوه غذا در سلامت انسان و سایر حیوانات ثابت شده است. با این حال، مرز بعدی چه خواهد بود؟ چالش‌ها در درک تعاملات بین میکروبیوتا و میکروارگانیسم‌های میزبان چیست؟ ابزارهای آنالیتیکال جدید، که دوره جدیدی از تحقیقات پروبیوتیک را تسهیل می‌کند، چه خواهند بود؟ اینها تنها چند موضوع تحقیقاتی بودند که در دهه گذشته در *زیست فناوری غذایی کاربردی* ارائه و مورد بحث قرار گرفتند. هدف این سرمقاله، تجلیل از سهم علمی *زیست فناوری غذایی کاربردی* در زمینه تحقیقات مرتبط با خواص مفید LAB است و برخی از مطالعات منتشر شده در مجله را خلاصه می‌کند.

تعارض منافع: نویسندگان اعلام می‌کنند که هیچ نوع تعارض منافعی مرتبط با انتشار این مقاله ندارند.

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