乳酸菌在食用农产品安全生产中的应用研究进展

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摘 要: 食用农产品作为食品加工的源头, 对食品的质量安全和品质起关键性的作用。作为食品安全的首要环节, 食用农产品的安全生产问题已成为近年来各国学者研究的热点。随着对乳酸菌生物特性和安全性能研究的深入, 利用乳酸菌减少生产中农药和化学肥料使用过程中带来的危害从而获得绿色食用农产品受到众多消费者的关注。当前, 乳酸菌在保障食用农产品质量安全领域发挥了越来越大的作用。本文综述了国内外有关乳酸菌在食用农产品拮抗致病微生物和腐败微生物、重金属和农药残留的去除、真菌毒素降解及果树病虫害防控等领域的最新研究进展, 旨在为促进乳酸菌在食用农产品中的应用发展和食用农产品加工质量控制提供新思路, 同时提出了乳酸菌未来研究的方向和可能面临的挑战。

关键词: 食用农产品; 乳酸菌; 质量安全; 应用研究

Research advances on application of lactic acid bacteria in safe production of edible agricultural products

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ABSTRACT: As the source of food processing, edible agricultural products play a key role on food safety and quality. Therefore, as the primary part of food safety, the safe production of edible agricultural products has become a research hot spot in recent years. With the development of researches on biological characteristics and safety of lactic acid bacteria, many consumers have increasingly concerned about the use of lactic acid bacteria to reduce the harm

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produced by pesticides and chemical fertilizers so as to obtain green edible agricultural products. Currently, lactic acid bacteria have played an increasingly important impact on ensuring the quality and safety of agricultural products. This paper mainly reviewed the latest research development of antagonistic action against pathogenic and spoilage microorganisms, heavy metals and pesticide residues removal, mycotoxins degradation and fruit pests prevention and control by lactic acid bacteria in edible agricultural product, which aimed to promote the application development of lactic acid bacteria in edible agricultural products and provide new ideas for the quality control of edible agricultural products, and the directions of further researches on lactic acid bacteria and the possible challenges were also proposed.

KEY WORDS: edible agricultural products; lacticacid bacteria; quality safety; application research

1　引　言

食用农产品是指供食用的源于农业的初级产品[1]，一般由生产者提供，包括农业源产品和基于农业源产品的加工制成品，对后续食品安全起基础和关键性的作用。近年来，食品安全问题依然是消费者持续关注和担心的焦点问题[2,3]。然而，随着农产品需求量的不断增长，农药、激素、化肥及兽药等被大量使用到农业生产中，人类生存所必需的粮、油、果、蔬等大宗农产品开始频繁出现腐败变质、农药残留超标、重金属及生物毒素污染等潜在安全问题[4-6]。因此，农产品从种植养殖环节到进入批发零售市场或生产加工企业前存在诸多安全隐患[7]，影响农产品质量安全的未知因素也较多[8]。目前国内外对于这些问题的关注点多集中在大范围的风险筛查、危害分析和评估模型建立等理论方面[9]，研究的侧重点多集中于外部法规和标准制定。因此，采用安全可靠的控制措施来保障食用农产品的安全生产显得尤为重要。

乳酸菌不仅具有产生抗菌物质的能力，而且菌体本身也可为动物生长发育提供多种营养。因此，乳酸菌被广泛应用在食品储存、加工、保鲜、乳制品发酵，新型饲料研发及医药工业等领域[10]。近年来，越来越多的乳酸菌株被发现，并在食用农产品安全生产领域取得了新进展[11,12]。本文主要综述了乳酸菌在食用农产品安全生产中的应用研究进展。

2　乳酸菌对食用农产品生产中致病菌和腐败菌的拮抗

在农产品种植、采摘、储运过程中，畜禽粪便及灌溉用水、环境条件、采收方式等都可能引起致病菌和腐败菌的滋生[13]。而乳酸菌能够抑制病原菌定植，对农产品的安全生产起到重要的作用[14-16]。研究表明，日常泡菜、酱菜、榨菜、酸奶和火腿中都可分离得到能够抑制典型腐败真菌的乳酸菌，如食窦魏斯氏菌(*Weissella cibaria*)、弯曲乳杆菌(*Lactobacillus curvatus*)、清酒乳杆菌(*L. sake*)、植物乳杆菌(*L. plantarum*)等[17,18]。王文婧等[19]以金黄色葡萄球菌(*Staphylococcus aureus*)、肠炎沙门氏菌肠亚种(*Salmonella enterica* subsp *enterica*)、荧光假单胞菌(*Pseudomonas fluorescens*)作为指示菌，证明乳酸菌与酵母菌的共生发酵液具有较强的抑菌能力；此外，杜静芳等[20]从鲤鱼肠道中筛选出了一株拮抗阪崎肠杆菌(*Enterobacter sakazakii*)的植物乳杆菌(*L. plantarum* LY-4)；任大勇等[21]选用植物乳杆菌(*L. plantarum*)、乳酸链球菌(*Streptococcus lactate*)对金黄色葡萄球菌(*S. aureus*)和鼠伤寒沙门氏菌(*S. typhimurium*)进行了体外抑菌实验，效果同样良好。

3　乳酸菌对食用农产品生产中重金属和农药残留的去除

3.1　重金属去除

重金属通过植物和动物体内累积进入食物链，进而对人体健康造成危害。常规的物理和化学修复法具有一定的不安全性，基于微生物的生物学特性而采用微生物修复已成为治理重金属污染的一种前沿修复方法[22]。而乳酸菌作为人与动物肠道内的一种益生菌，对食用农产品中重金属污染的修复更具意义[23]。近年来，人们发现乳酸菌不但具有金属结合能力，而且能有效清除液体中的重金属[24]，这一发现为乳酸菌作用于重金属的解毒功能提供了可行性的思路[25-28]。科学研究发现，植物乳杆菌(*L. plantarum*)和德氏乳杆菌(*L. delbrueckii*)分别对常见金属镉、铅具有一定的吸附去除效果[29,30]。马欢欢等[31]综述了食品中砷、镉、汞、和铅的污染来源、存在形式及对人类产生的危害，归纳总结了可应用在粮食、果蔬及水产等食品中的乳酸菌株种类，对利用乳酸菌生物制剂清除农产品中重金属的研究与应用具有借鉴与参考意义。

3.2　农药残留去除

化肥、农药和激素的大量使用导致部分区域的土壤和水体中累积了大量的有毒物质，经植物吸收后富集在农产品中，通过生物循环和食物链被人体摄入，最终影响消费者的身体健康。去除农药的常规方法有超声波技术、吸附、洗涤、水解、氧化分解和光化学降解等。其中，微生物降

解以种类多、数量多且降解过程不易造成二次污染等优点而备受关注[32-34]。毒死蜱(chlorpyrifos)是全球广泛使用的一种杀虫剂，Cho 等[35]研究了泡菜发酵过程中清酒乳杆菌(*L. sakei*)、植物乳杆菌(*L. plantarum*)、短乳杆菌(*L. brevis*)等对毒死蜱的降解作用，发酵 3 d 降解率可达 83.3%；发酵 9 d 可完全降解毒死蜱。Harishankar 等[36]研究了几种肠道细菌对毒死蜱的降解效率，发现肠道中乳酸杆菌对毒死蜱的降解优势更明显。Zhao 等[37]研究了几株乳酸菌对 7 种有机磷杀虫剂在脱脂牛奶中的降解作用，42 ℃条件下保加利亚乳杆菌(*L. bulgaricus*)和植物乳杆菌(*L. plantarum*)对供试杀虫剂具有更强的降解能力。

4 乳酸菌对食用农产品生产中真菌毒素的降解

真菌及其毒素对食用农产品的污染会造成巨大经济损失和资源浪费[38,39]。近年来，乳酸菌在食用农产品种植、加工及储运环节的真菌及其毒素安全防控过程中发挥了重大的作用[40]。王应东等[41]研究发现，植物乳杆菌(*L. plantarum*)对黄曲霉(*Aspergillus flavus*)、娄地青霉(*Penicillium roqueforti*)、草酸青霉(*P. oxalicum*)、柑橘青霉(*P. citrinum*)、烟曲霉(*A. fumigatus*)有不同程度的抑制作用，可延长酸奶和馒头的保质期。此外，乳酸菌及其代谢产物可有效吸附去除乳制品中黄曲霉毒素的生物防治作用，且经安全性评价证实，使用乳酸菌生物防治乳制品中的黄曲霉毒素污染具有可行性及现实意义[42]。真菌一方面通过自身的生长繁殖损耗农产品及各种食品的营养物质，降低他们的可使用性和营养价值，致其霉败变质；另一方面，黄曲霉和青霉等真菌在繁殖过程中产生黄曲霉毒素、青霉素、桔霉素、伏马毒素、赭曲霉毒素 A 和玉米赤霉烯酮等有毒代谢物危害人体健康。Elsanhoty 等[43]研究了 5 株乳酸菌对酸奶中黄曲霉毒素 M_1 的脱毒作用，结果表明乳酸菌具有较强的脱毒作用。Bovo 等[44]的研究也证实了乳酸菌的在食品脱毒方面的巨大潜力。刘丽娜等[45]比较了嗜酸乳杆菌(*L. acidophilus*)、鼠李糖乳杆菌(*L. rhamnosus*)、口乳杆菌(*L. oris*)作用于玉蜀黍赤霉菌(*Gibberella zeae* (Schwein.)Petch)菌丝的生长和孢子萌发，抑制效果良好。

5 乳酸菌对食用农产品生产中果蔬病虫害的防治

生物农药和生物肥料的使用可以有效提高农作物产量、降低食物中农药残留、改善作物品质，减少消费风险，增强其抵抗病虫害的能力[46-48]。郭娟华等[49]综述了利用拮抗微生物对柑橘采后病害进行防治的机理，并提出利用化学杀菌剂的替代物微生物来防治病害，是果蔬采后贮藏面临的一项紧迫任务。Roselló 等[50]研究了几株植物乳杆菌(*L. plantarum*)对苹果和梨火疫病(fire blight)病原菌的拮抗作用，结果表明一些植物乳杆菌可作为微生物农药的有效成分来防止火疫病的发生。闫艳华等[51]研究了植物乳杆菌(*L. plantarum* IMAU10014)对番茄的促生长作用、灰葡萄孢霉菌(*Botrytis cinerea*)的生防效果及对植株叶片几种防御酶活性的影响，表明其作为生物农药防治灰霉病有很大的潜力。马锞等[52]从荔枝果实发酵液中筛选出一株具抑菌活性的拮抗植物乳杆菌(*L. plantarum*)并研究了其对炭疽菌(*Colletotrichum gloeosporioides*)和荔枝霜疫霉菌(*Peronophythora litchii*)的影响，为荔枝的生物保鲜提供了新思路。

6 结 论

乳酸菌作为公认的安全微生态制剂，在食用农产品安全生产应用中取得了阶段性的研究成果。目前，很多科学家开始转向探索不同物质与乳酸菌相互配伍使用，旨在提高乳酸菌的防控作用效果。然而，随着研究的不断深入，乳酸菌的安全性问题已经初露端倪。比如某些乳酸菌属可能把自身携带的抗性基因转移至病原微生物或者产生生物胺等有害代谢产物。此外，还有一些实验菌株具有体外降解粘蛋白的能力，这些问题都需要进一步的科学体外安全性评估实验来证实和解决。

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