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Stress Responses of Foodborne Pathogens and Implications in Food Safety

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Abstract

Some microorganisms can induce adaptive responses to environmental stresses, which can enhance their tolerance to these stresses and may promote persistence under adverse conditions. Stress responses of foodborne pathogens can have profound effects on their survival in foods. Additionally, exposure to one sublethal stress may produce a spectrum of adaptive responses, cross-protecting microorganisms against multiple stresses. Understanding the mechanisms underlying the microbial responses to different stresses will improve the effective use of intervention strategies to inhibit the survival of pathogens in foods.

Keywords: Foodborne pathogen; Stress; Stress response; Cross-protection

Introduction

Foodborne pathogens face a broad spectrum of stresses in all links of the food chain [1]. During traditional food processing (e.g., pasteurization), microbial cells are more likely to be killed than injured or stressed [2]. Recently, some novel minimal processing techniques have been developed with less deleterious effects on food quality; however, they may constitute mild stresses, which are detrimental to most of the cells but may also enhance the generation of cells with increased resistance [3]. Microorganisms can tolerate small changes in environmental parameters through inducing adaptive responses [4]. Among the known foodborne outbreaks, there is an increasing involvement of stress-adapted strains, which are difficult to control with traditional intervention strategies [5]. Adaptive responses of foodborne pathogens to stresses are thus of paramount significance in food safety.

Stresses Encountered by Foodborne Pathogens

Microorganisms in the natural environment are exposed to a wide range of stresses. Pathogens in foods are also frequently exposed to stresses with varying magnitudes [6]. Stresses to these microorganisms in foods during processing include physical stresses, such as heat, high pressure, desiccation, and irradiation, chemical stresses, such as acids, salts, and oxidants, and biological stresses, such as microbial antagonism [7].

Stress Responses of Foodborne Pathogens

Once foodborne pathogens sense a certain stress, the microbial cells respond in various ways. Different microorganisms appear to have evolved different mechanisms to cope with environmental stresses [8]. Complicated changes in cell composition and physiological state may occur due to the exposure to stressful environments. Such responses enable foodborne pathogens to maintain their normal functions and thus survive in foods during processing. For example, most *Salmonella* strains possess the ability to form fimbria- and cellulose-mediated colony under some harsh conditions [9]. This multicellular phenomenon is termed the rdar morphotype (colonies are "red, dry, and rough" when grown on media containing Congo red), which can be isolated from poultry and produce [10]. The rdar morphotype can enhance the resistance of *Salmonella* to desiccation and starvation [11].

Heat treatment is one of the most commonly used food processing methods [12]. When properly used, heat can eliminate foodborne pathogens from foods. However, some microbial cells may become heat-shocked under sublethal heat stress [13]. In this case, microorganisms can synthesize heat shock proteins, which renders the cells more resistant to subsequent high temperatures normally considered to be lethal [14]. The heat shock response and induced thermotolerance have been reported in a wide range of foodborne pathogens [15]. Responses of foodborne pathogens to heat stress have been a concern, as the adapted pathogenic cells in foods surviving during thermal processing may pose potential health risks to consumers.

Cross-Protection of Foodborne Pathogens

Microbial cells adapted to a sublethal stress may exhibit enhanced survival on subsequent exposure to a different stress. This tolerance to multiple stresses after adaptation to an individual stress is called cross-protection [16]. Several stresses, such as heat stress, cold stress, acid stress, and osmotic stress, have been reported to induce cross-protection in microorganisms [3]. Cross-protection has been found to be mediated by the *rpoS* gene. In some bacteria, the *rpoS* gene encodes an alternative sigma factor (σ^S/RpoS) that acts as a master regulator needed for the survival under stressful conditions [17]. The *rpoS* gene has been identified to be involved in the cross-protection of desiccation-adapted *Salmonella typhimurium* against high temperatures [18].

The current trend toward the application of mild minimal food processing techniques may result in more stress responses of foodborne pathogens. In view of this, cross-protection has significant implications in ensuring food safety and establishing risk assessment programs, as it will markedly enhance the survival of foodborne pathogens during food processing containing multiple barriers.

Therefore, cross-protection of foodborne pathogens should be taken into consideration when assessing the effectiveness of different combinations of minimal food processing techniques.

Implications of Stress Responses of Foodborne Pathogens in Food Safety

Stress responses of foodborne pathogens have a much greater impact on food safety than has already been recognized. As the consumers demand foods with higher food quality, the food industry is applying cumulative mild processing steps for the control of pathogens in foods. In turn, this trend facilitates more frequent exposure of foodborne pathogens to sublethal stresses, potentially compromising food safety through inducing resistance responses and cross-protection.

Currently, most of the food processes are tested by inoculation with freshly harvested cells. However, many published studies have recommended that stressed cells should be used when performing challenge studies and validating food processing procedures [19-22], since the use of fresh cultures may not represent the actual survival characteristics under real-world environments.

Future research on the stress responses of foodborne pathogens could be conducted with advanced modern genetic tools. For instance, it is possible to create isogenic mutants of foodborne pathogens to identify the genes involved in specific or general stress responses. Moreover, there are available complete genome sequences and amino acid sequences of expressed open reading frames (ORFs) in foodborne pathogens [23]. This will enable the identification of genes and proteins involved in stress responses, as well as the evaluation of their importance in the physiology of these microorganisms.

References

1. Beales N (2004) Adaptation of microorganisms to cold temperatures, weak acid preservatives, low pH, and osmotic stress: a review. Compr Rev Food Sci Food Saf 3: 1-20.
2. Hurst A (1977) Bacterial injury: a review. Can J Microbiol 23: 935-944.
3. Capozzi V, Fiocco D, Amodio ML, Gallone A, Spano G (2009) Bacterial stressors in minimally processed food. Int J Mol Sci 10: 3076-3105.
4. Hill C, Cotter PD, Sleator RD, Gahan CG (2002) Bacterial stress response in *Listeria monocytogenes*: jumping the hurdles imposed by minimal processing. Int Dairy J 12: 273-283.
5. Samelis J, Sofos JN (2003) Strategies to Control Stress-Adapted Pathogens. In Microbial Stress Adaptation and Food Safety. Yousef AE, Juneja VK (edn) CRC Press, Boca Raton, FL.
6. Humphrey T (2004) *Salmonella*, stress responses and food safety. Nature Rev Microbiol 2: 504-509.
7. Wesche AM, Gurtler JB, Marks BP, Ryser ET (2009) Stress, sublethal injury, resuscitation, and virulence of bacterial foodborne pathogens. J Food Prot 72: 1121-1138.
8. Schimel J, Balser TC, Wallenstein M (2007) Microbial stressresponse physiology and its implications for ecosystem function. Ecol 88: 1386-1394.
9. Römling U, Sierralta WD, Eriksson K, Normark S (1998) Multicellular and aggregative behaviour of *Salmonella typhimurium* strains is controlled by mutations in the *agfD* promoter. Mol Microbiol 28: 249-264.
10. Solomon EB, Niemira BA, Sapers GM, Annous BA (2005) Biofilm formation, cellulose production, and curli biosynthesis by *Salmonella* originating from produce, animal, and clinical sources. J Food Prot 68: 906-912.
11. White AP, Gibson DL, Kim W, Kay WW, Surette MG (2006) Thin aggregative fimbriae and cellulose enhance long-term survival and persistence of *Salmonella*. J Bacteriol 188: 3219-3227.
12. Richardson P (2001) Thermal Technologies in Food Processing. Taylor & Francis Group, Abingdon, Oxford, UK.
13. Lindquist S (1992) Heat-shock proteins and stress tolerance in microorganisms. Curr Opin Genetics Dev 2: 748-755.
14. Schlesinger MJ (1990) Heat shock proteins. J Biol Chem 265: 12111-12114.
15. Lindquist S (1986) The heat-shock response. Annu Rev Biochem 55: 1151-1191.
16. Rodriguez-Romo L, Yousef A, Griffiths M (2005) Cross-Protective Effects of Bacterial Stress. In Understanding Pathogen Behaviour. Woodhead Publishing, Sawston, Cambridge, UK.
17. McMeechan A, Roberts M, Cogan TA, Jørgensen F, Stevenson A, et al. (2007) Role of the alternative sigma factors σ^E and σ^S in survival of *Salmonella enterica* serovar Typhimurium during starvation, refrigeration and osmotic shock. Microbiol 153: 263-269.
18. Chen Z, Jiang X (2017) Thermal resistance and gene expression of both desiccation-adapted and rehydrated *Salmonella enterica* serovar Typhimurium cells in aged broiler litter. Appl Environ Microbiol 83: e00367-17.
19. Leyer GJ, Wang LL, Johnson EA (1995) Acid adaptation of *Escherichia coli* O157:H7 increases survival in acidic foods. Appl Environ Microbiol 61: 3752-3755.
20. Leenanon B, Drake MA (2001) Acid stress, starvation, and cold stress affect poststress behavior of *Escherichia coli* O157:H7 and nonpathogenic *Escherichia coli*. J Food Prot 64: 970-974.
21. Wesche AM, Marks BP, Ryser ET (2005) Thermal resistance of heat-, cold-, and starvation-injured *Salmonella* in irradiated comminuted turkey. J Food Prot 68: 942-948.
22. Gruzdev N, Pinto R, Sela S (2011) Effect of desiccation on tolerance of *Salmonella enterica* to multiple stresses. Appl Environ Microbiol 77: 1667-1673.
23. Johnson EA (2003) Microbial Adaptation and Survival in Foods. In Microbial Stress Adaptation and Food Safety. Yousef AE, Juneja VK (edn) CRC Press, Boca Raton, FL.