Microbial Control Methods in Fresh and Processed Meats

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Microbial contamination and growth always will be a concern in fresh and processed meats due to the nature of the substrates involved and the inherent nature of the slaughtering process. Good Manufacturing Practices (GMP's) and the use of the Hazard Analysis Critical Control Point (HACCP) approach to the identification and control of critical elements of the respective processes reduces the magnitude of the problem, but even meat plants with the best hygienic practices do not totally eliminate microbial contamination and the occasional presence of food pathogens. These GMP's and HACCP procedures are well documented elsewhere and generally need only to be implemented in specific meat processing operations to reduce and control the initial microflora.

The focus of this presentation will discuss several emerging control mechanisms that have gained recognition and recent acceptance for the control of undesirable microorganisms in meat processing.

Live Meat

Ideally, the control of undesirable microorganisms in fresh and processed meats is a totally integrated program commencing with the birth of the respective animal that ultimately provides the meat. Minimizing the presence and controlling the proliferation of pathogenic and spoilage microorganisms in the live animal will result in reducing the "load" that enters the slaughtering facility as well as yielding a more desirable, healthy animal.

Optimal performance in the production of meat is closely linked to animal health. A healthy animal is more capable of resisting the challenge and colonization of undesirable microbes in the digestive tract, and this resistance inhibits their proliferation and ultimate spread to other animals. In recent years, it has become apparent that controlling the microflora of the digestive tract generally controls the colonization of pathogenic microbes. Conventional "performance enhancers," such as antibiotics and vaccines, only make a limited contribution to health with a positive effect on weight gain and feed utilization, but generally they do not lead to major reductions in loss rate. Additionally, these traditional "performance enhancers" are the subject of intense scrutiny and may not be as readily available in the future.

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In the healthy state, the main intestinal microflora (approximately 90%) is represented by partially anaerobic homofermentative or exclusively anaerobic heterofermentative lactic acid bacteria (*Lactobacillus* or *Bifidobacterium*) and exclusively anaerobic butyric acid and other volatile-fatty-acid-forming rod-shaped bacilli (*Bacteroides, Fusobacterium* and *Eubacterium*). The concomitant flora often accounts for only 1% of the total, consists of enterococci and *E. coli*. Other potentially pathogenic species for farm animals, such as clostridia, staphylococci, *Blastomyces, Pseudomonas,* and *Proteus* sp., constitute a residual flora.

In meat animals, any change in this ratio in favor of the residual or the concomitant microflora generally results in a lowering of the performance due to the undesirable microbial burden and, in the case of dominance by pathogenic species, a higher animal loss rate from intestinal infections.

The use of the socalled "probiotics" is gaining acceptance as a means to control the intestinal microflora and thus improve health by reducing the colonization and proliferation of undesirable species. Basically, this concept involves the addition of desirable, species-specific microorganisms to the animal feed, providing a constant source-inoculating the animal. This is especially important in newborns, in this age of "motherless rearing," where the establishment of the initial intestinal microflora is critical to subsequent health and thus performance. Numerous studies have demonstrated that comparable performance-enhancing effects, as achieved with the traditional methods, also can be achieved with specific probiotics. Various microbial species possess these "bioregulatory" capabilities, with their only common features being their ability to develop antagonistic properties, to adhere to the intestinal epithelial cells and to form a biofilm as a barrier providing resistance against potential pathogens penetrating from the outside. Various species of *Lactobacillus* and *Bifidobacterium* are the most commonly used for direct animal ingestion (probiotics) while *Lactobacillus, Pediococcus* and *Streptococcus* sps. are also used for improving the quality and safety in animal feed preparation (silage inoculants).

Recently, the concept of probiotics has expanded to the use of "super probiotics." This involves the concurrent feeding of specific antibodies, specific for microbial pathogens, along with the desirable microorganisms to aid in subsequent resistance. The specific antibodies prevent colonization and infection by attaching to the pathogenic microorganisms which are subsequently "flushed" from the system. These super probiotics now have the potential to "cure" infections with the reestablishment of the proper microflora. As shown,

animals challenged with *E. coli* can be cured of the infection with the concurrent reduction in the presence of the pathogen and a return to increased health and weight gain. The infection, presence of the pathogen and loss in animal weight persist in the non-treated animals.

Fresh Meat

Fresh meat spoilage generally is caused by psychroptrophic microorganisms – those capable of growth <5°C – since in most countries meat is at least kept cool with the majority refrigerated. Although different types of spoilage can occur, the most rapid and "offensive" meat spoilage is the production of malodorous sulfides, acids, esters, etc., from aerobic decomposition by specific types of microorganisms (*Pseudomonas, Alteromonas putrefaciens, Brochothrix thermosphacta* and *Enterobacteriaceae*). Although all microorganisms can produce visible colonies as slime if given the opportunity to proliferate to high numbers, the "characteristic meat spoilage microflora" are the main concern since relatively low numbers are required to yield undesirable product. This is due to the metabolic end-products which can result in green discolorations and offensive odors that are detectable in low concentrations.

An effective approach to control fresh meat spoilage is to reduce and alter the total microflora of the tissue. This is being accomplished and more widely accepted by the use of organic acid treatments, particularly lactic acid and acetic acid. Mild acid (1% to 2%) applications to the meat surface reduce the total microorganisms, particularly *Enterobacteriaceae* and *Salmonella*, with the subsequent enhancement of lactic acid-type microorganisms. This "microbial inversion" extends the lag phase for subsequent microbial growth, in addition to reducing the numbers of the undesirable types. Although "lactic acid microorganisms" also can spoil meat, this type of spoilage requires significantly higher numbers of microbes and is "less undesirable."

Fresh meat spoilage is considered a "surface phenomenon" since deep tissue from animals slaughtered under reasonably hygienic conditions generally is sterile. Organic acid application to the surface does not penetrate the tissue significantly and the surface pH returns to normal within 48 to 72 hr. The organic acid and the low surface pH demonstrate both a bacterocidal and bacterostatic effect, particularly with the typical spoilage microflora. In the case of natural lactic acid(L+), lactate concentrations in the tissue from the use of mild acid sprays are insignificant compared to the existing lactate content (ie. natural background), and is within the range of carcass-to-carcass variation.

The effect of organic acid treatment is dependent upon acid concentration, application time, temperature, the attachment of microorganisms to surfaces and the application method. Lactic acid is most effective when applied to the hot carcass, since the microorganisms probably are still in the waterfilm and have not yet become attached to the surface. Recommended application levels of a 1% to 2% lactic acid solution (depending upon animal species), generally do not alter quality attributes. Acid treatment is more effective on a clean carcass, free of organic matter. Consequently, a prewash is recommended prior to treatment. Application immediately after potential contamination (ie. hide removal, defeathering) minimizes the time for microbial attachment and reduces the number of microorganisms entering the further processing area. The effect of the lactic acid is enhanced with higher acid temperatures, with the minimum recommended temperature being that of the warm carcass. Natural lactic acid also has been applied post-evisceration and post-chilling, where it demonstrates the most residual effect. Additionally, the lactic acid has proven an effective treatment for organs, parts, and equipment/utensils.

Although sanitation and GMP's are still the most important factors in controlling microbial contamination ("defensive"), organic acid treatments offer the processor an additional, "offensive" means to reduce the presence and proliferation of food pathogens with an insignificant effect on quality and with common, widely-accepted food ingredients (lactic and/or acetic acid).

Processed Meats

In processed meats, a pH reduction via lactic/acetic acid is not always desirable with the exception of fermented or acidified products (ie. lactic and acetic, respectively). Natural sodium lactate, the neutral sodium salt of lactic acid, is emerging as an effective natural ingredient to prolong shelf-life and enhance flavor without affecting significantly other product characteristics (ie. pH). Although weak organic acids are more effective as antimicrobial agents in the undissociated form, natural sodium lactate demonstrates significant shelf-life extension by an, as yet, undefined mechanism. Although sodium lactate, as a hygroscopic salt, lowers water activity, a similar reduction via sodium chloride does not demonstrate similar shelf-life extensions. Possibly, natural sodium lactate may inhibit microbial growth through a "feedback inhibition" by the lactate ion and/or due to its ability to penetrate the cell membrane. Additionally, natural sodium lactate demonstrates broad-range microbial inhibition, with no apparent preferential selection of any microbial types.

Natural sodium lactate is a liquid product (60% solids) and is normally added to formulated meat products at 2% to 3.3%. The sodium lactate is slightly saline in flavor and occasionally the processor may reduce the sodium chloride levels to compensate. In addition to its antimicrobial properties, natural sodium lactate is widely recognized as a flavor enhancer.

Conclusion

The most effective concept in the control of microorganisms is the incorporation in the food product of multiple "barriers" to potential growth, in addition to reducing/selecting the initial microflora. It has become readily apparent that a greater understanding and implementation of "natural barriers" is essential in lieu of "foreign" chemical preservatives. Modern technology has focused on production yields, production capacity and sanitation, which can often create opportunities for undesirable microbial species. In the future, the use of desirable microorganisms and their metabolic products will become components of a totally integrated Microbial Control Program for meat products commencing with the birth of the animal and continuing to the ultimate consumption of the product.

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Discussion

G. Brotsky: Jim, you mentioned that acetic acid has similar anti-microbial properties to the lactic acid. Could you comment on the USDA's study on using acetic acid to try to control salmonella in chicken carcasses, which apparently wasn't very successful?

J. Bacus: I'm afraid I'd have to look at the study. I'm not familiar with all of them, but there's a lot of literature that shows that organic acids are not that effective. But in my experience, most of the people, when they've done this work, they've done it at levels less than a half percent as far as in the solution. And generally, they're doing it way down the processing line where the animal has been gutted and chilled, been through a chiller and is sitting there cold. They're applying the acid at that point. I believe that the problem there is the dwell time. Lactic or acetic acid will kill bacteria way down the line but the dwell time has got to be longer. And it's not practical. And I think that some of the failures have been too low an acid concentration and too far down the line. Whereas the control needs to be implemented back up right after the animal is killed.

In fact, there are studies out there now in poultry where lactic acid has been added to the chill water. And the poultry goes through four or five chill tanks on the tail end; you add it to the last tank or the first tank at a different temperature, so you have more dwell time and that's been very effective. I think that some of the failures in the past have been low levels because I know that with lactic acid you can go up to, depending on the beef carcass, you could be spraying 2% lactic acid on the beef carcass and you probably couldn't tell it walking through the plant, if it's done properly. Acetic acid needs to be done at lower concentrations, but it's a little more effective, and it probably needs a lower concentration. But it needs to be done under a warm set of conditions – either hot acid or at least acid comparable with the temperature of the carcass so you don't have cold material going on a warm carcass. Because I think what happens then is that you close the cells or the pores or whatever and that's it. It needs to be done early on.

J. Regenstein: Do you feel though that, in the future, some possibly stronger compounds will be used, such as ozone, or chlorine dioxide, things of that sort that people are beginning to play with toward this purpose?

Bacus: My feeling on those is that they're going to have a hard time ever getting approved because they're foreign compounds. In the case of lactic acid or even acetic acid, acetic's not that common in the muscle, but it's a widely recognized safe food ingredient. I think as long as we stick with those, it's going to be easier. I think if we go with higher chlorine, chlorine's not too bad, but that has some negative effects too. I just think that if we start going with these fancy chemical preservatives, I just don't see the public accepting it.

Regenstein: Well, but the tradeoff here is all three. Even in rinsing, you've got the salmonella or listeria, you've got all those organisms which are a lot more dangerous than some compounds of a more strong nature going through food approval and once it breaks down in ways that may be, in fact, better than the breakdown of traditional chlorine.

Bacus: I just personally feel that those are going to be harder to sell to the public and it's all going to depend on how the USDA accepts it as far as labeling it – that's what it's all about is the labeling. But I think that the USDA – any kind of compound like that, they're probably going to require labeling. Currently with these acids they don't require labeling.

Regenstein: I've been involved with one of these compounds with the USDA and its applications with new food items. It's not clear that they would require labeling, because they can be used in chill water or spray earlier on, depending on the processing aid type of situation.

Bacus: Yes, at least with lactic or acetic acid, if you spray it early on and then you go through a normal chilling process, they pretty much consider you're washing it off. But like I said, chemically you're hard pressed to say you're adding anything significant to that meat, in the case of lactic acid anyway. So I think they pretty much look at it as a treatment, but this is not in stone and it could go either way.

J. Quick: Maybe I could shed some light on some of these things. When the organic acid sprays are used and are later removed either by waiting 72 hours or just by a water spray, no special labeling is required. However, if somebody wanted to use the spray and move the product on out the door, then there would be an ingredient statement or a "sprayed with" kind of statement on the label. We would require that. I'd like

to make a comment too about the use of sodium lactate in the lower salt products. I think that people ought to be very careful about proposing this kind of thing because the amount of sodium in sodium lactate to get the equivalent saltiness of sodium chloride is much higher and for any kind of low salt/no salt statement, that would go on the label. There would have to be a sodium declaration. And I'm not sure that they'd allow that kind of thing if "a low salt product's or no-salt product's" line actually had more sodium than the regular product line.

You need to be careful about that because it's the kind of thing where you think "Oh, gee, this is salt." But at USDA with labeling, we always include sodium in addition to salt. So I just wanted to make sure everyone was aware of that.

Bacus: I'd like to add one thing and I don't know if I mentioned this. Sodium lactate added to a product is considered a flavoring but it still has to be labeled as sodium lactate.

Quick: The last comment that I'd like to make is that we have approved it as a flavoring because we can do that very quickly without going through a lot of administrative processes. But I'd also like folks to be aware that we have a regulation in development for the use of sodium lactate at higher levels than what are currently being used at the antimicrobial level. FDA has not approved it for that purpose, partially so you won't have to go through a proposed rulemaking rather than just issue a final regulation.