Impact of Microbiology on Safety and Shelf Life of Processed Meats

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R.B. Tompkin

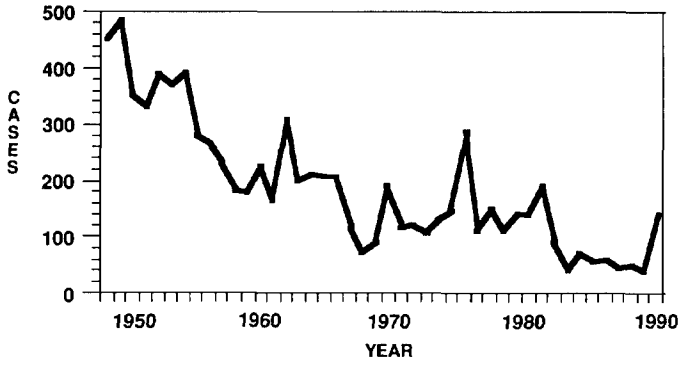
During the time available to me, I will present a variety of topics which are intended to stimulate your thinking and, thereby, provide some ideas for discussion.

I will begin with showing you some slides that show trends in the microbiological safety of meat products. The first slide (Figure 1) tracks the number of cases of trichinosis in the United States from 1947 to 1990. This is a very favorable downward trend. You can see certain peaks related to new immigrants who are not familiar with the necessity to cook pork adequately before consuming.

The second slide (Figure 2) relates to the incidence of *E. coli* in precooked roast or corned beef. This is a compilation of USDA data from 1984 through 1989. The trend is definitely downward. These data are from freshly produced products which have been sampled by the USDA to determine whether *E. coli* is present or not. These data are from an ongoing program which has been in place since the USDA-FSIS implemented the roast beef regulations. The *Salmonella* problem of the early 1980s was corrected as a result of the new cooking/cooling regulations for roast beef. The straight line is intended to show the overall decreasing trend in the data. This figure is interesting in that there is a seasonal effect with a higher incidence of *E. coli* through the summer months. These data are being used by the USDA as a measure of general sanitation and microbial control in the producing plants. The precooked roast beef/corned beef segment of the industry has been doing a better job of reducing post-process contamination.

Figure 1

Reported Trichinosis Cases– United States, 1947-1990*



* 1987 - 1990 PRELIMINARY DATA

The third slide (Table 1) is another summary of data from the USDA. The salmonellae testing program has been in place since 1983. This table summarizes data for various categories of ready-to-eat meat products and poultry which has been sampled since that time. The USDA had analyzed over 26,000 samples and found 14 positives during that time period. The majority of the positive roast beef samples were detected shortly after the new regulations were implemented and not all producers had their processes under control. One

Figure 2

Escherichia coli in Roast/Corned Beef

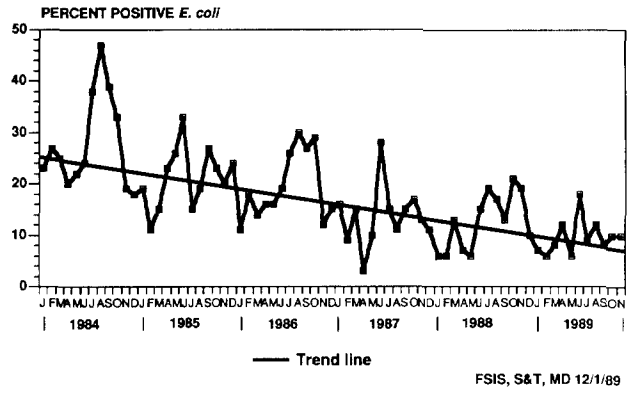


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Table 1. USDA Salmonella Results 1983 - 1990.

	No. Of Samples	*No. Positive*
Cooked Sausage	8870	2
Roast/Corned Beef	7923	9
Cooked Poultry	3643	2
Salads/Spreads	3333	1
Prosciutto	714	0
Sliced Canned Ham	721	0
Jerky	704	0
Imported Products	112	0
	26,020	14 (0.05%)

of the cooked sausage samples was very likely a raw sausage product. These data demonstrate that salmonellae are no longer a problem today in precooked, ready-to-eat meat and poultry products. Assuming $25 per sample for shipping and analysis, the cost would have been about $46,500 for every positive sample found.

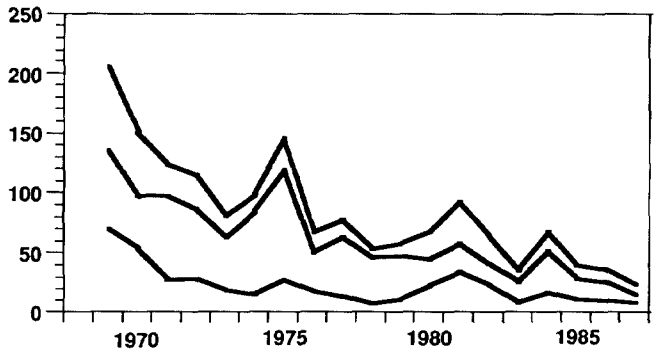
The fourth slide (Figure 3) has been prepared from data from the Center for Disease Control and is a summary of the number of outbreaks of foodborne illness in each year from 1969 through 1987. The top line is the sum of all outbreaks from meat or poultry products. The middle line is red meat and the bottom line is poultry products. These data show a favorable declining trend in the number of reported outbreaks in the United States. It is generally understood that not all outbreaks of foodborne illness are reported to the CDC. If it can be accepted that there is a comparable amount of underreporting each year, then these data can be accepted as showing a favorable trend for meat and poultry products.

Another USDA-FSIS program which has been in place to complement salmonellae monitoring is the sampling of meat and poultry products for *Listeria monocytogenes*. Since the USDA initiated its sampling of ready-to-eat products for *L. monocytogenes*, about 2% of the samples have been positive. All of the data presented for trichina, *E. coli* and salmonella basically show a positive, successful effort through the collective efforts of the USDA and industry toward improved microbial control.

The majority of outbreaks of foodborne illness occur due to mishandling errors in food service establishments and in the home. We heard this morning that only 3% of foodborne illnesses are due to errors within processing establishments. Most of the errors involve time/temperature abuse. Raw meat and poultry provide a significant source of pathogens in food service establishments and the home. This must be addressed.

Figure 3

Outbreaks of Foodborne Illness Attributed to Meat & Poultry



There are other microbiological issues which are of concern. The two most pressing issues involve *E. Coli* 0157:H7 in ground beef and *Campylobacter jejuni* in raw poultry.

I would like to next cover some general issues at this point. Perhaps they will help to stimulate discussion. The USDA has assumed a new position relative to the importance of refrigerating raw meat to assure microbiological safety. The USDA proposal for the manufacture of precooked meat patties, which was published in the *Federal Register*, basically states that fresh meat which is in excess of 40°F is unsafe for use in precooked meat patties. This is a radically new position which has very significant implications in how we handle raw meat. This is a position that I do not support.

Another issue is that of *Listeria monocytogenes*, its virulence and zero tolerance. Are all *Listeria monocytogenes* virulent? The answer appears to be yes, they are all potentially virulent. The National Advisory Committee on Microbiological Criteria for Foods has reviewed and discussed the questions of infectious dose and the zero tolerance. A final report from the National Advisory Committee will be available in July. The report will include a recommendation to the Federal agencies to focus upon those foods which have been involved in foodborne illness and in which *L. monocytogenes* can multiply.

The *Listeria monocytogenes* control programs that have been implemented over the past five years have had significant impact upon the shelf life of perishable ready-to-eat meat and poultry products. Customers (e.g., grocery chains) have been asking for and obtaining a minimum of 30 days remaining on the code when they receive products for their sale. Some are now asking for 40-45 days shelf life at the time they receive it. This has always been the case — everyone wants a longer shelf-life product. Industry must continue to strive for products with even longer shelf lives.

The National Academy of Sciences Committee on Microbiological Criteria for Foods recommended the adoption of a Hazard Analysis Critical Control Points (HACCP) system as a better approach to assuring the microbiological safety of foods than establishing microbiological criteria. This is one reason there is stronger interest in HACCP in this country. The real question is: Will HACCP survive the USDA multi-year program to implement HACCP? HACCP is an excellent management tool to prevent problems and minimize product loss. From an industry perspective, we should be implementing HACCP. Some companies have raised questions about whether the adoption of HACCP will increase their costs. We have not experienced an increased cost through the implementation of HACCP.

As I mentioned earlier, fresh meat and poultry products can be a significant source of pathogens for food service establishments and homes. This problem has been recognized for decades. Neither industry nor government has been effective in implementing a program that will minimize the risk of pathogen contamination on raw meat or poultry. There have been isolated attempts to decontaminate raw

meat and poultry through the use of organic acid sprays. Industry and the USDA should encourage the development of these methods. We must develop effective, safe procedures to minimize the levels of enteric pathogens on raw meat and poultry products.

Finally, the technical strength within the meat industry has severely eroded over the past 30 years. Two major factors seem to be primarily responsible. First, there were new aggressive companies which did not have the burden of a large corporate staff which included research scientists. These companies also promoted change through some very successful ideas and lower labor costs. The second major factor was the impact of buyouts, mergers and reorganizations. Collectively, these factors led to a reduction in the number of research scientists in the meat industry. The shift has been from research and development to technical services, from longer-term planned research to short-term problem solving. Considering the lack of technical strength in the meat and poultry industries, there is a significant void which must be filled by research at the universities and by government.

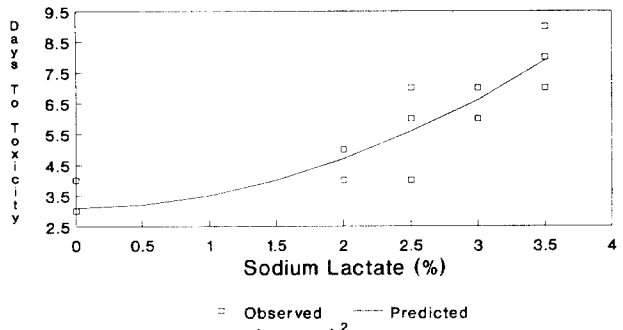
L.L. Borchert

Today, I want to talk about one element of food safety. That is the control of *Clostridium botulinum* in meat and poultry products. First, I want to talk about the anti-clostridial effects of sodium lactate. Dr. Melanie Maas, who is in my group at Oscar Mayer, coordinated this research with the Food Research Institute at the University of Wisconsin where the actual inoculation and abuse studies were conducted. The objective was to insure that our products are safe.

Uncured, cook-in-bag turkey breast products or roast beef products are potentially susceptible to the growth of and toxin production by *C. botulinum* if they are thermally abused. These products are made without sodium nitrite, low salt, no carbohydrate and have a pH that is near neutral. The competitive vegetative microorganisms have been destroyed by the heating process. The cook-in-the bag package is anaerobic. Although millions of pounds of these products have been made with no problems, our company is concerned that refrigeration is the only barrier we have to prevent botulism from occurring.

Fortunately, refrigeration has worked quite well over the years; however, the meat industry is not content to rely solely on that in the future. Thus, we conducted this research to determine the effectiveness of sodium lactate to prevent or inhibit toxin production by *C. botulinum* in cook-in-bag turkey. We varied the sodium lactate levels from 0% to 3.5% but maintained the salt level at 1.4%. The pH was 6.3 and the turkey was inoculated with 14 *C. botulinum* spores per gram.

Figure 1
Botulinal Toxin Production in Uncured Turkey Breast at 80°F Salt Content = 1.4%



Days to Toxicity = $3.13 + 0.39(\text{Lactate})^2$
$R^2 = 0.80$

After vacuum packaging and cooking, the product was abused at 80°F. The days required to produce toxin were noted. The control, with no sodium lactate and 1.4% salt, was toxic in 3 to 4 days (Figure 1).

As the lactate level was increased, the days to toxicity also increased. While this increase was only 2 to 3 days, this additional safety margin means a great deal to the industry.

We then conducted a second study looking at two variables in a cured poultry product: (1) the salt concentration and (2) the lactate concentration. Many people say "if it's cured, isn't it safe forever?" As with uncured, cook-in-bag turkey breast products, our company is very concerned about the safety of cured meat products with low salt levels. The cured products, however, have sodium nitrite as a second hurdle toward *C. botulinum*.

In this study, the sodium lactate and salt levels ranged from 0.0% to 3.0%. The inoculum was a little higher than the first study; 35 spores per gram. We used a response-surface experimental design with four internal replicates which gave us the statistical confidence that was needed to do modeling work with this product. The product was made with the treatments shown in Figure 2.

The combined effect of sodium lactate and salt on the toxin production by *C. botulinum* is shown in Figure 3. With 0.5% salt and 0.5% sodium lactate, the product was toxic in 4 days. When using the response surface curve shown in Figure 3, we can predict it will be 50 days before toxin will be produced in product containing 3.0% sodium lactate and 3.0% salt. This study demonstrated that sodium lactate has an effective role in low salt, cured cook-in-bag product. We

Figure 2
Response Surface Design for Clostridium Botulinum Abuse Test in Cooked, Cured Turkey Breast

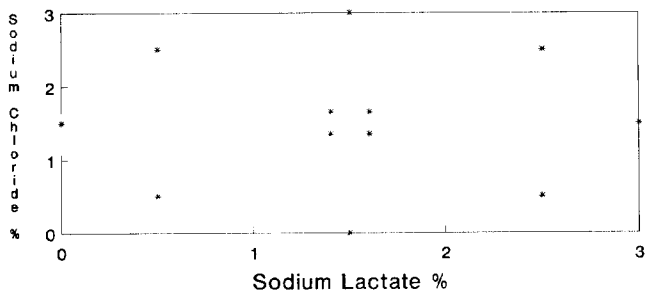
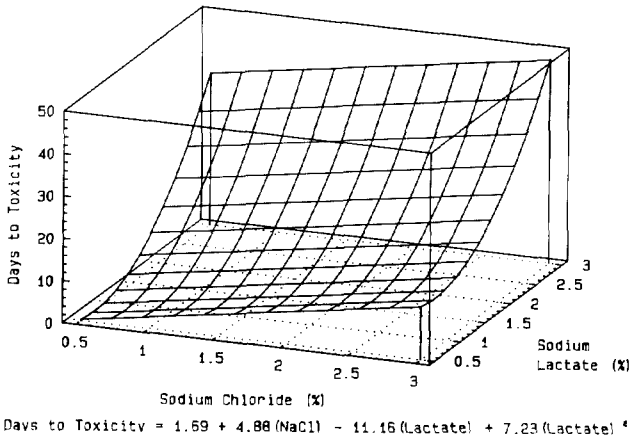


Figure 3
Botulinal Toxin Production in Cooked Cured Turkey Breast at 80°F



can improve our safety margins many-fold by just increasing sodium lactate to 3.0%.

Unfortunately, marketing does not want to use sodium lactate in cook-in-bag products because at levels of 2.5% or higher plus some low level of salt, there is a discernible salty taste that consumers find unacceptable. Therefore, our next approach was to look at abuse indicators which would alert the consumer if the product had been held unrefrigerated for some length of time. We wanted a two-phase system where the integrity of the abuse indicator could be maintained for 90 days at 40°F but if the product were abused for 48 hours, there would be a change in the indicator to warn the consumer.

There are several commercially available indicators, but none met our specific needs. I think one of the reasons is that they are primarily being designed by chemists who do not understand the true marketing needs of cook-in-bag roast beef or turkey breast products. We established the following guidelines for our abuse indicator:

- it must be compatible with the current packaging system
- temperature sensitive
- it must have a very distinct endpoint so that the retailer can accurately discern abuse or non-abuse
- inexpensive

We decided upon a two-color system. A green color would indicate that the product was OK to be used. A red color would indicate that the product had been temperature abused and, therefore, should not be used. We also wanted the color change from green to red to be very fast so a buffering system which allowed the whole transition in color to take place in a matter of hours was developed. Currently, the indicator system is in a test market. It is being used on one cook-in-bag turkey breast product. We are now waiting for feedback from marketing to determine if there are any problems.

Discussion

J. Sebranek: Do you have any reaction from retailers concerning the use of freshness indicators?

L. Borchert: We have two types of reactions. One reaction from the retailer is very ambivalent. For example, one retailer, that we are testing the indicator with, does not care if we are in their store with this technology. On the other hand, another retailer knows about the indicator and is very anxious to bring it into their store. In fact, the retailer has asked us to reposition the sensor on the package so that when the package is sitting unopened in the deli case, the sensor is at the front of the case. The prospective customer then can see the indicator and can tell that there is something on there. On one hand, we think that the latter retailer is treating this technology like we want them to, while the other one is what we are going to commonly see until this technology really catches on.

R. Benedict: Bruce and his co-workers have done a lot of work on the action of nitrite and the mechanisms of how nitrite inhibits microbial out-growth. Do either one of you want to comment on the possible mechanism of how lactic acid is limiting microbial growth? Might it be due to the action of lactic acid as an α-hydroxyl acid or is it a function of the pK_a and pH of the acid?

Borchert: As far as I am concerned, we do not have a definitive answer to your question, Bob. The work that we and others have done leads me to believe that it is the common ion effect. The concentrations of the lactate that we have seen outside of the bacterial cell are much higher than the physiological levels that are normally within the cell. We feel that the cells work themselves to death trying to pump their own lactate up hill against the lactate concentration gradient. That is my theory.

B. Tompkin: We have not really studied it. What we have read and in doing a literature search, there is a water activity effect. It does lower the water activity. Lactate does something beyond that but nobody knows what.

R. Henrickson: Bruce, why did the incidence of trichinosis increase in '90 or since '90?

Tompkin: The spikes or peaks in outbreaks were primarily due to increased numbers of certain immigrants entering into the U.S. who were eating raw pork.

Henrickson: Larry, temperature abuse in meat occurs either by it being too cold or too hot. How does the indicator work in both situations?

Borchert: Relative to the cold temperature abuse of this indicator, the stability of the indicator is held by refrigerated and/or frozen conditions. Therefore, it is quite stable in systems we are using it in. In fact, the stability of the indicator is probably less susceptible to frozen temperature damage than the product.

M. Westendorf: Larry raised the water activity question. We have found at Iowa State University that in low-salt, low-fat frankfurters, there was no effect on water activity. I think we are all too quick to jump on that water activity band wagon for a mechanism for lactate. Any comment on that?

Tompkin: There is a water activity effect. You can measure it or you can calculate a reduced water activity. Type E *Clostridium botulinum* have a high threshold for water activity. They shut off at much higher water activity than the proteolytic bacteria.

Borchert: We were not working with type E *C. botulinum*, and our measure of water activity was probably not as sophisticated as Bruce's technique. We did not actually see measurable levels of water activity change in the product that we were working with. I am not as strong a proponent as Bruce on the role of water activity. However, water activity has gotten a lot of press. Water activity has prevented us from getting a patent on sodium lactate in red meat products, because someone had made that suggestion 15 or 20 years ago in the area of red meat.

R. Terrell: There was some research done by the Korean Fisheries Association about 10 to 15 years ago. In order to show the effect of lactate on water activity, you have to go up to a 7% to 10% addition. This was in a fish paste. No question that at those levels, you could probably see a reduction in water activity. At the levels we commonly use and with the added water and moisture levels that we are working with in turkey and sausage products, you probably can not measure it.

N. Webb: Bruce, I wonder if you could elaborate a little on the temperature 40° or 45°F that was in your initial talk.

Tompkin: In the proposals that were submitted by the USDA and published in the Federal Register on pre-cooked meat patties, they conveyed the impression that raw meat must not exceed a storage temperature of 40°F for the meat to be considered safe and acceptable for producing that product. They did not say what you are to do with the meat if the meat exceeded 40°F, but that it was unacceptable. They also did not say anything about the age of the meat. The regulations covered only the meat at the time it was in the plant. I think that they are thinking that the longer the meat is 40°F, that the level of *Listeria monocytogenes* would be higher, because of growth. The process for pre-cooked meat patties, which is a high temperature short time process, might not be able to eliminate high *Listeria mono.* levels. Up until now, if the meat was held too long in the 40° to 45°F range, it would spoil. Now, it is being proposed that it is not just spoiled, it is unsafe. I do not believe that.

R. Cassens: I hear and read a lot about endogenously produced inhibitors, a topic neither speaker mentioned. Could you give us the current status?

Tompkin: There is a lot of interest in the use of bacteriocins for inhibiting microbial growth, particularly *Listeria mono.*. There is a fair amount of research currently being done, some of which is being supported by the National Live Stock and Meat Board. The intent would be to use these materials in processed meats where the growth of *Listeria mono.* could be a greater concern. There also is some interest in the development of starter cultures for dry sausage production with bacteriocin-producing capability. There are results at the university level that are positive, but in terms of there being anything commercially available, there is nothing that has been brought to my attention that has held up.

Kauffman: Larry, I would like to ask you about the device that you passed out. Did you have any reluctance from retailers to use this. Additionally, you said that you did not get any feedback as far as the red light, but the red indication. Are there circumstances where it turns red and it is still perfectly all right? Have you tested it from that point of view?

Borchert: The first part of the question is what I said to Joe. There were mixed reactions from the retailers. Some are waiting anxiously to put it on more products. Others are more ambivalent about it. With regard to false positives, on the bench top in the laboratory we have not had any problems. It works perfectly. We are very much concerned about the types of handling that it could undergo in the retail. If someone is a little long on Louis Rich Turkey, a hair blower will turn this thing red over night or in a couple of hours. There are ways to abuse it, and right now we are treading very cautiously. Currently, we have it only in one small market test. We are not going to expand that market test very rapidly until we get the answers on false positives and false negatives.

J. Johnson: Recently at ASM and at IFT, even though I did not attend either meeting, Felix Leistner from Germany had presented some ideas. His idea of getting around part of the *Listeria mono.* problem was a second pasteurization in the bag for ready-to-eat products. Would either of you have any comments?

Borchert: I can comment on our experience in raw fermented sausages. When we first discovered that *Listeria mono.* could survive the fermentation process and that it was not inactivated by traditional temperature regimens, we simply changed the temperature to inactivate the microorganisms. In that kind of a product, there is a relatively high acid content. The temperature change that was required was not severe enough to change the external character of the product. I think what he is talking about is a doable system. If it is practical, I really do not know.

Tompkin: I think that it depends on the product. It would not work well with sliced products or with franks in a package. It would really be geared towards a repackaged product where you would have cooked the product, taken it out of the bag and then repackaged the product. You use it as an insurance policy. The effectiveness would depend on the type of product. There are some situations where it can be very beneficial. As a means to assure a *Listeria mono.* negative product, the primary defense is through sanitation and avoiding the contamination. That in itself can be very effective, perhaps more so than other methods. If you are really concerned, I think that it has value.

R. Benedict: You mentioned *Listeria mono.* at refrigerated temperatures. Many people have reported that it will not increase in population if it is kept below 5°C. It will not increase in meat, but it will increase in milk. Nobody seems to have the explanation as to the reason why. If you had a product that contained both meat and milk, would *Listeria mono.* growth be a problem? Do you think that the meat would inhibit the growth or would the milk products increase the potential for growth in the meat product?

Tompkin: I do not have any answer for that one.

T. Vosen: You showed a slide that illustrated a higher

occurrence of foodborne illness from red meat versus poultry. Was this difference a function of the pure volume of red meat eaten over the past 20 years, or was it an inherent problem with sanitation in red meat plants?

Tompkin: The data is just a summary of the CDC reports. In terms of why red meat had a higher incidence than poultry, there is no explanation given. It is a matter of coming up with your own ideas. I have heard one person suggest that in the case of chicken broilers, individuals or small families are involved and do not get reported to CDC. In the case of roast beef, it may be served at institutions or social gatherings where larger numbers are involved. Whether that has anything to do with it or not, I do not know.

J. Sofos: Right now there is 0 tolerance for *Listeria mono.* in processed foods. There was a change in Germany where they have a higher tolerance now. Should we also change and what needs to be done before the change happens?

Tompkin: I think that in Germany they have been more conservative. I think that the Europeans, in general, have been more conservative. At this point, it is possible that a change may occur relative to the 0 tolerance for certain types of foods. For example, I do not know if FDA will reevaluate its position on ice cream, but there have been no cases of illness associated with ice cream. Of course, *Listeria mono.* will not grow in a frozen product. It is hard to say how that will shake out. In products such as hard cheeses where growth can not occur, and there is no evidence of illness, the zero tolerance is not necessary. In the case of certain soft cheeses, Brie or Camembert, there would be a continued 0 tolerance in effect for those products, because they have been involved in illness and growth can occur. It will depend on the type of product. I do not know whether a number (100 or 1000/g) will be adopted in the U.S.

P. Ahmed: Could you comment on the problems that you had with the other three types of indicators. You briefly said they were not satisfactory. Why did you decide on this particular type of indicator?

Borchert: Many of those other indicators are physical. They rely on melting of a capsule or they rely on defusion of a dye. You would think that most of these would be very linear or very highly correlated with temperature. On the other hand, in the case of a food product like we were talking about, we are really not concerned with linear temperature changes. We want the indicator to be stable under varying time and temperature conditions that occur in normal circumstances, but still be responsive in abuse cases. A perfectly integrated system would be a system that takes into account any degree of time and temperature. For example, if this indicator was held at 50 or 53°F for the full length of time, it would still work for *Clostridium bolulinum* strains that we are concerned about. We are not overly concerned about the long-term growth at those temperatures, but it will still spike off. The other indicators did not give the response until later in the shelf-life period that we have tested.

S. Raharjo: This quality freshness indicator, how much does it cost?

Borchert: We are still assessing that. We are not marketing it, and we are not being held for any firm price. It is going to be low enough that we can justify putting it on products that are cheaper than the 9-pound catering turkey breast product. I am not in a position to give a firm number.

D. Buege: A large amount of meat products are sold through service deli's. From your experiences, with what you have seen in those situations where products are handled a lot, are you satisfied with the food safety training and the conditions in those kinds of retail operations?

Borchert: Just from my observation, we have seen problems in the service deli. For example, we sell a sea food analog, Kemp's Imitation Crab meat. We often see that precooked product being thrown in the same case as the raw fish. We are very much concerned about the kind of abuse, which indicates that the operators are not fully aware of the problems of cross-contamination. I think that I can use that as one example. More needs to be done in training the deli operators.

R. Cassens: Could hygiene be improved to the point that flavor would be affected?

Tompkin: This is not really a direct answer to your question. We now have some perishable luncheon-type meat products that do not spoil bacteriologically, but flavor deteriorates over time. With improvements in hygiene, we have reached a semi-perishable state where with certain products under certain circumstances, flavor is no longer affected microbiologically. Can you make something too clean? Certainly in dry sausage, we have seen many cases where the level of hygiene can definitely impact the flavor quality of a fermented product.

M. Westendorf: We think there might be some synergism with sodium lactate and curing agents. Have you seen that?

Borchert: I guess that I am not in a position to respond, because synergism to me is $1 + 1 = 3$. With our two-dimensional, two-variable studies, we really kept the level of sodium nitrite constant. I can not say that there really would be a measurable synergism.

Tompkin: We have not looked at the interaction between lactate and nitrate.

W. Means: With some of these "ultra-clean products" that we may be seeing in the future and perhaps some exterior indicators of the safety of that product, are you somewhat concerned that consumers may look at the indicator, disregard it, and open that product. By not having the spoilage organisms there and in the absence of normal spoilage aromas, could consumers eat the product even though it is unsafe? Would this indicate that maybe we need to add some organisms back in a controlled fashion that would spoil the product?

Tompkin: A number of things have happened over the years. In the past, there was always a lactic spoilage, particularly in products with a traditional salt content, or which were basically cured. We now have more and more products with lower salt and we have an increased quantity and variety of poultry products which are low-salt, no-nitrite. This spoilage pattern for these products is quite different from the traditional product. I think in the past we have had the benefit of a lactic spoilage flora with a decreasing pH, in the event of temperature abuse. In a low-salt, no-nitrite product, you may not get a lactic spoilage and a decrease in pH. We may not have the level of protection we have had in the past. I think from an industry standpoint, perhaps we are approaching more situations of this nature. The mixes are changing and have changed in the past 10 years. We could very well be at the point where there is an increased risk relative to spore-

forming pathogens, which survive the process, and which grow-out in a product that is temperature abused.

D. Buege: I was thinking of these lower fat, cooked sausages, such as frankfurters, that have more water in them and lower salt content. Would you comment on if this really changes things along the terms of their shelf-life or making them so clean that it is not that big of an issue?

Tompkin: I have seen a lot of changes in terms of shelf-life. I can remember when we were struggling to get 45 days consistently. It was not that many years ago. What we are seeing now is that the chain store is asking a minimum of 30 days but would prefer 40 to 45 days. I have been impressed in the last five years by how much can be accomplished with an entirely different approach and attitude towards sanitation. Low-salt products, which I thought would spoil quickly, actually do not. They are more vulnerable and the shelf-life results show that they have a lower shelf-life, but we are obtaining a longer shelf-life than I ever thought possible.

Borchert: Just to say in a different way what Bruce has said, indeed the fat had a protective effect. If the salt is concentrated in the water phase, there was a protective effect from the fat. If the marketing people continue to listen to the consumer and want to drive down the percent salt, that is all going in the direction of shorter shelf-life. Those two things appear to be causing problems, but I think the industry has risen to the occasion to try to preserve the product. In some cases, marketing is demanding even longer shelf-life. I think that we were able to do it through extraordinary sanitation practices. I still think we have a long way to go to improve sanitation where we can not help our shelf-life any more.

D. Pilkington: In the earlier discussion, we were talking about bacteriocins for control of *Listeria mono.*. Do you feel that bacteriocins are not going to be or do not function right in this particular system? Where do they play a role? Is there a future for bacteriocins?

Borchert: There is a fair amount of activity going on in the area of bacteriocins. I do not see a lot of serious interest in putting bacteriocins into products. It may be nice. We have other avenues of protecting the product or making the product last longer, rather than putting in a bacteriocin.

Kauffman: Your slides indicated by trends that sooner or later we are not going to have a problem. I realize that you made a point that there were certain ones that were causing problems and have gone up. In your life time or ours, do you think that we will see a time when there will be none? In other words, will there be 0 outbreaks, 0 problems as far as sanitation and microbiological health problems concerning the meat industry?

Tompkin: I think that there will always be something new. While the trend is favorable in terms of the data that were presented by CDC, again this is what is reported to CDC. It looks like it is disappearing. Of course, there are many more outbreaks and illness within the U.S. than certainly showed up on that slide. That is just an assumption. There will always be microbiological problems with perishable products, they may just change.

Borchert: I think that Bruce's slides show that we have a very safe food supply and one we can be very proud of. You asked about things that have happened in our life time. We can all remember the days when we did not know what *Listeria mono.* even was. Now we are seeing, at least in Washington D.C., *Campylobacter* in poultry, which is becoming the buzz word. We are always going to see new organisms coming to the forefront. The bottom line is that we still have an extremely safe food supply. We may be getting into the range of finding microorganisms just to keep microbiologists in business.

Tompkin: One of the purposes in presenting that slide is to show you that not all the news we hear is bad. There is some good news. We are making progress. I think that cooperatively, USDA, the industry and the universities have really been working together quite well. As problems have occurred, they have been identified and strategies have been put into place to correct them. To assume that there is an ongoing chronic problem that is not being addressed, certainly in the case of ready-to-eat products, is not true. The one nagging problem that is not being adequately addressed is the presence of enteric pathogens on raw meat and poultry products. We have not really done that work.

A. McCurdy: We have not said a lot about temperature today. With fresh meats, temperature is the major effect in the extension of shelf-life. Could either one of you comment on your corporate ideas on temperature for processed meat storage?

Tompkin: As a company, we have placed greater emphasis on having a lower temperature going into the shipping carton on the packaging floor with our products. Is that what you mean?

McGurdy: For fresh meat, we are talking about -1°C as the normal storage temperature until the product gets to the retail outlet. Have the processed meat products been lowered down to that range?

Tompkin: Very selectively, and I would prefer not to discuss which ones and why.

Borchert: I am not going to get into any more detail than Bruce did. During my tenure in the meat industry, I can remember a campaign that we had at Oscar Mayer in the early 60's. We had a little brochure that we passed around that stated that life begins at 40°F. Our trend was to try and get our processed meat products into the shipping cooler and handled at lower than 40°F. I can say with great assurance and without fear of disclosure, we have gone a lot lower than that. We are being selective and we are going very low.

Cassens: I have been interested in the very positive comments about the effect of sanitation and hygiene. Could you expand that a bit further and comment more specifically about the slaughter, fresh meat trade, and the processed meat manufacturing segments?

Borchert: My experience in the fresh meat industry is in the turkey slaughter business and in the area of merchandising raw turkey products. We have been extremely concerned about ways to get the pathogen levels down to lower levels. I am not saying that we have achieved 0 pathogen levels or anything like that. From a sanitation point of view and from an internal control point of view, I think this is on the front of everyone's mind. Realistically, we have made quite a bit of progress. I am only speaking for our company, but I believe that the whole poultry industry, and from what I know from the red meat industry, there is a lot of work going on in that area.

Tompkin: My experience in the last five years has been with processed meats. I would say that what was acceptable

from a sanitation standpoint five years ago, is nowhere near acceptable today.

M. Miller: For fresh meat, saying that sanitation, shelf-life, and microbiological contamination have improved, is there a dollar assessment for longer shelf-life? Is it more valuable to the processor to be able to pay more to a particular slaughter operation to produce products that are free or low in pathogens?

Tompkin: I am not aware that anything is going on to reduce cost. If anything, it could increase the cost, in terms of sprays. However, if you match it with an overall program, that may not be the case. You probably have heard Rod Bowling discuss what they have done in their particular situation by marrying a different management system with carcass sprays. They have been able to make modifications that can at least pay for itself, or perhaps reduce the cost. You saw this morning a slide showing the reductions in pathogens and in total plate count.

D. Bartholomew: With your abuse indicator, what is the principle again on pH? Would you elaborate a little?

Borchert: I can not elaborate too much, especially to you, Darrell. It is a biological indicator. It has microbial components and enzymatic components. They are poised so that they can give you this type of very fast color conversion, like traditional pH indicators. That is about as far as I can go. The product is in the patent process. It is safe to go on the market, but I still do not want to get into much detail.

J. Acton: In your cooked, cured, ground turkey formulation, you had the nitrite level at 47 ppm. You did not show an accelerator or anything like that in the brine formulations. Is the residual nitrite level in that product higher after cooking than if you had an accelerator in there?

Borchert: I am speaking for Melonie Maas. I am recalling what logic she used for that level. That is the normal level that we would find in a cured turkey product after cooking, after cooling, and within a logical time after processing. I do not know that it is the ultimate level that we would get down to. It sure is getting in that range. We did not put any accelerator in there. There is no ascorbate in there.

Acton: So the data you showed was for post-cooked product?

Borchert: Yes.

Acton: 47 parts per million residual.

Borchert: Right.

Acton: But you used no accelerator in manufacturing this product?

Borchert: Not in this test product.

Acton: That meant that it was a barrier. Is it a barrier if it is not there? In other words, if you had a cured system that after a few days had 5 ppm nitrite or none, although you used nitrite initially in the system, is it still a barrier?

Borchert: What this is showing is that at extremely low sodium chloride levels, nitrite, even at 47 ppm, is not the barrier that we were looking for.

Bartholomew: What kind of level of botulism spores would you expect in fresh meat?

Borchert: What Dick Greenburg said 30 years ago was that we could expect 1 spore in each 9 to 10 pounds of meat. I think that is still the rule of thumb today. It is variable.

Audience Participant: You mentioned the USDA *Salmonella* results for cooked poultry, I would like to know if the results are for fresh or raw poultry.

Tompkin: I do not have the summary on the incidence of *salmonella* in a raw meat or raw poultry. They do have a program for following the trends, and the data are available on a quarterly basis. Those data can be obtained from USDA. Ralph Johnston, who is Director of the Microbiology Division, could help you.

N. Marriott: I have a question regarding HACCP. I guess that I would start by saying that it is my conviction that although it is a viable management tool, as you indicated, it is only an interim step. We should be going beyond HACCP. My question to you is - what is beyond HACCP and what do you see as the next step?

Tompkin: It is very compatible with a Total Quality Management Program. Ideally, they should be married. The two systems provide methods for different people within a company to interact. If we interact in a positive manner, then we are working toward a common goal. HACCP is a system for identifying problems and arriving at strategies to prevent those problems from occurring. They fit well together. What will happen beyond HACCP in a Total Quality Management Program, I do not know. We have yet to really bring those to fruition. We have not fully developed them yet.

J. Price: This question came to my mind as the previous speaker was talking. I would like to get your ideas on it. He brought up the question about nitrite as a barrier, particularly for botulism. I was just wondering if you would revisit the question - how much confidence can we have in nitrite as an effective barrier? One time the thinking was that it was the amount that was put in at the time of heat processing that had the greatest effect. What is your view now on how much of a barrier nitrite is?

Tompkin: I think that we have to be careful in terms of over-estimating the value of nitrite for preventing botulism or botulinal out-growth. At one point, it was commonly stated that if it was cured, it has nitrite, then it is safe. That is an over-statement. In fact, it is going the wrong direction. The addition of nitrite will delay the out-growth of *Clostribium botulinum* and many other microorganisms. It can then enhance the safety, but nitrite in itself is not going to prevent out-growth. There are a number of factors that enter into that situation, the age of a product at the time of abuse, the residual nitrite and whether you have competitive flora which may drop the pH.

Bartholomew: What kind of measurements do you see for meat that will be effective in a HACCP program? What kind of measurements do you see being used to monitor Critical Control Points?

Tompkin: For monitoring, the measurements have to be rapid. If the measurements are not quick, then you do not have the opportunity to make an adjustment to the process to maintain control. They have to be procedures such as a pH measurement, a rapid salt measurement, or color indicators on retort tags. It also depends on how fast the production process is developing. For example, if it is dry sausage, you have more time. For dry sausage, a sample can be taken and analyzed for moisture:protein ratio. If the results meet your requirements, then you end the drying period. If the results do not meet your requirements, then you extend the drying

cycle. Normally, they are going to be rapid measurements. Many of them either are going to be visual or how the product would feel, in the case of dry sausage. It will depend on the process and how long the process is stretched out.

Acton: I have two questions. My question is - if irradiation is not here today, we know it still has possibilities. Will it be here sometime in the future, particularly for raw products? The other question is what about the use of competitive flora as in an inoculation procedure? There have been some studies in the past, most of them point to bacteriocins, but my question is - can it take care of a mixed flora?

Tompkin: Irradiation can effectively eliminate enteric pathogens on raw meat and poultry. The question is - when will irradiation become acceptable to the consumer. I have no way of predicting when consumer acceptance will occur. It will not be in the near future. We can not rely upon radiation as a means to minimize enteric pathogens. I think we should approach it from other directions. When irradiation comes along, we should take advantage of it. As far as the competitive flora question, there are a lot of food microbiologists who have spent their lives trying to eliminate the competitive flora or the spoilage flora. The spoilage flora has been a positive protective agent for us. While our products have normally spoiled within a certain length of time, the pH has decreased, we have had a high acid content, and it has been an obvious spoilage. Concerning the use of bacteriocins to control *Listeria mono.*, there are a number of groups looking at that. There is nothing currently available that I am aware of. We have not been approached by a commercial company that has a culture, or an extract of a culture, that would prevent the growth of or elimination of *Listeria mono.* in a product.

Acton: Do you think that it is a possibility down the road?

Tompkin: I think that it is possible. Again, I think there are other ways of approaching the *Listeria mono.* issue other than to rely on a bacteriocin-producing culture. There is a question - do we really want to be adding cultures or extracts of cultures to our commercial products? Is that really a desirable thing to do? I think that from a *Listeria mono.* standpoint that we can be effective in preventing contamination. That is the direction that we have taken and a number of other companies have taken. Quite a bit can be accomplished in terms of minimizing the risk of *Listeria mono.* contamination through sanitation. Is it cost effective to throw on top of that the cost of a bacteriocin?

R. Usborne: With respect of the *E. coli* serotypes, like 0157:H7, you mentioned that it was a new bacterium. Has not our methodology improved? As we move ahead, we are able to identify specific serotypes and relate them to different pathogenic conditions? That is more of a comment. My second question is, you mentioned in your other general issues that meat raw material held above 40°F is objectionable for pre-cooked patties. What kind of regulations, if any, can be used to put that in place? As a follow-up to that, is our rapid methodology for bacteria good enough to make decisions on rejection of raw materials to send them back to suppliers?

Tompkin: In terms of the latter, the answer is no. I do not think that current rapid methodologies are good enough or quick enough. We have looked at a lot of different rapid methods over the years. We have not found one yet that is satisfactory. Most of them are based on a total plate count. As far as *E. coli*, I am merely parroting what I heard at an IFT symposium last week. It was a symposium devoted to the virulence of various pathogens. The person making that presentation stated that this is not something that has been around before, this is something that is new, and it is beginning to spread. You had another comment?

Usborne: The 40°F requirement.

Tompkin: The 40°F requirement has been proposed by the USDA with the idea that if the raw meat exceeds 40°F, then it is unsafe for the production of pre-cooked meat patties. This is a very different attitude. It really stems from the USDA concern relative to *Listeria mono.* and perhaps for *Yersinia spp.*, but primarily for *Listeria mono.* There is a question about whether *Listeria mono.* will grow well in raw meat? That depends upon the circumstances and the type of meat. I do not know of any data, in foodborne outbreaks where raw meat held up to 50°F has been the cause for illness. In outbreaks, temperatures of 60, 70 or 80°F and higher are involved. When I think of raw meat being held at 50°F and below, I think of spoilage. It is really a quality issue and not a food safety issue. I disagree that there is a food safety issue with raw meat held at 45°F.

N. Marriott: Since being involved with *Listeria* hysteria, we have seen even more emphasis on the use of quats as sanitizers. Also, we are aware of the fact that they do have limitations as to the spectrum of microorganism that they will destroy. My question to you is - is this concern justified and are we leaning too heavily on the quats now? If in fact it is true, what do you suggest that we do about it?

Tompkin: I do not think that we should rely on any one sanitizer. I think that we should be rotating sanitizers. We have seen in one plant that was using a quat exclusively for a number of years, a fairly high population of quat-resistant organisms. It did not cause spoilage, because it was not a lactic, but there were high counts on the product.

Bartholomew: With the USDA guideline, would we have 8 hours to get the meat down to 40°F? Do they specify time?

Tompkin: No. The 40°F versus 45°F that I was discussing, was for the raw meat prior to being cooked.

Bartholomew: After kill, what kind of time do they indicate?

Tompkin: They did not say anything about that. There was a time limit in terms of when you received the meat into your plant and when you had to use it. If you were preparing cooked meat patties, you had to move it through your plant within a certain time period and that meat should not exceed 40°F. There was no consideration of whether fresh meat was 5 to 7 days old before it got into your plant.

Bartholomew: Also, on the pH issue, how would you use pH? Normally glycogen levels would be minimal, or not there, after rigor mortis in the meat. How could pH increase or what would you be looking for? Can pH be used as a HACCP indicator?

Tompkin: I really would not use pH in the case of raw meat or poultry. pH can be used. It depends on the food system. pH is an important criterion for the production of dry fermented sausages or an acidulated product. I do not know of any other meat or poultry product where you would be using pH as a criterion for CCP.

Bartholomew: This is a follow-up on microbiological testing in HACCP. You do not believe that it has any part as far as a Critical Control Point measurement at any point in HACCP?

Tompkin: Microbiological testing has no immediate value for monitoring. Monitoring is that testing which is done within a time that will allow you to adjust the process and maintain control. Microbiological testing is very helpful for verification in a HACCP plan and that is the collection of samples of various types. For example, samples could be swabs from equipment, product samples, or they could be the first product through the plant on a given production day, or it could be shelf-life evaluations. There are a number of ways to collect microbiological data. All those require time to get the answer. That information can be used to verify that in making your original assessment of control during monitoring, that in fact you were correct.

P. Sleper: I realize that you did not talk about sodium lactate, but maybe you can answer some questions for me. I saw in an recent trade magazine that there was a comment about sodium lactate being an inhibitor for *Clostrium botulinum* and *Listeria mono.*. Can you comment on that or do you have any experience with that? We are being asked to reduce sodium in a lot of our products, so we would like to look at a reduced salt pepperoni product. Would sodium lactate be necessary to add so that we would have a safety element? Is a level of 2.5% to 3% of sodium lactate really necessary?

Tompkin: Sodium lactate has a lot of potential in a variety of products. We have not really taken advantage of sodium lactate's capabilities. Initially, they have been used in non-cured poultry products. That has been their primary use. Sodium lactate has been effective, as I understand with talking with others throughout the industry, at a level of about 2%. Sodium lactate has been beneficial in terms of extending the acceptable shelf-life of these non-cured products. When lowering the salt in a product and replacing the salt with sodium lactate, the sodium lactate can be very effective. It also could be of value in a pepperoni formulation. It is a matter of trying it and seeing how it works. It is a means of reducing the sodium chloride content. I think that it still offers microbiological control advantages.

P. Sleper. Since we are trying to get rid of the sodium, can we also use potassium lactate?

Tompkin: It would seem reasonable, but whether it is suitable for the product in question, you would have to test it.

Sleper: Do you have any information on the inhibitory effects of sodium lactate on *Listeria mono.*?

Tompkin: I have heard that is effective, but we have not been looking at sodium lactate as a means to minimize the *Listeria* risk. For that reason, I really do not have the data to make a comment.

J. Carpenter: I would like you to repeat the observation you made during the last session concerning sanitation today as opposed to five years ago.

Tompkin: The *Listeria mono.* issue has been with us for at least five years. With the concern for *Listeria mono.* in ready-to-eat meat and poultry products, a number of companies have undertaken extensive efforts to minimize the risk of *Listeria mono.* contamination. Probably 75% of my time, and the time of the people working for me, has been devoted simply to *Listeria mono.* control in our products and plants. As a result of that effort, we have learned quite a bit more than I had thought was possible, relative to microbial control and spoilage. There has been tremendous progress in the past five years towards up-grading the level of sanitation within the plants.