Advances in and Aspects of Modified Atmosphere Packaging in Fresh Red Meats

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Introduction

The current marketing system in which red meats must be fabricated at the retail level appears to have substantial economic and marketing disadvantages. Very few, if any, other foods require the final manufacturing step to be conducted in the retail store by personnel that are not under the supervision of the food processor. For this reason, there has been keen interest in technologies which would allow centralized packaging of fresh red meats (FRM) in consumer-sized packages. Controlled/modified atmosphere packaging (C/MAP) appears to be such a technology. Several recent reviews of C/MAP of FRM and other related technologies have recently appeared (Young et al., 1988; Shay and Egan, 1987; Cole, 1986; Finne, 1982).

Controlled atmosphere packaging (CAP) can be defined as an active packaging system where a combination of initial atmosphere, product and/or microbial respiration, package permeability and the use of in-package gas absorbents combine to deliver an equilibrium gas mixture which stays constant during storage and extends the shelf life of the product. Modified atmosphere packaging (MAP) is a one-time alteration of the gases surrounding a product in a package. The gas mixture will change over time due to absorption by the product, permeation through the package and respiration by the product or the microorganisms on the product. MAP is widely used for a variety of products such as high moisture content pasta, cheeses and cooked meats. CAP is used to a very limited extent as a packaging technology but is widely used in the long-term storage of fruits and vegetables. In this paper, I will use the two terms interchangeably.

C/MAP has two effects on FRM. First, C/MAP influences the rate of growth of microorganisms which might be present on the surface of the FRM and also influences the types of microorganisms present. Secondly, C/MAP directly influences the oxidative state of the myoglobin. An absence of O_2 results in a purple myoglobin while high O_2 levels result in the bright red oxymyoglobin. Low (approximately 2%) levels of O_2 accelerate the formation of brown metmyoglobin (Livingston and Brown, 1981). These two effects combine to influence the shelf life of C/MAP meats. Careful selection of the variables or parameters can result in a 100% to 200% increase in shelf life. This is usually sufficient for centralized packaging and distribution.

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Variables in C/MAP

There are at least six variables to be considered in C/MAP. The most important is the nature of the product itself. Of primary concern for FRM is the product's myoglobin content. Chicken, for example, has a longer shelf life than beef under C/MAP because of its lower myoglobin content, which results in less concern about color stability. The pH of the FRM at the time of packaging will also influence both the microflora and the color stability of the myoglobin and so is an important product parameter. The types and quantity of microorganisms expected in the product will further affect shelf life under C/MAP.

The second variable is the gas or mixture of gases used in the package. While several gases have been experimented with, only homogenous gases or mixtures of O_2, N_2, and CO_2 are practical. Carbon monoxide (CO) would have some usefulness in meats due to its formation of a stable red complex with myoglobin but has been precluded from use by the FDA. Each gas has a specific function, N_2 is inert and has no biostatic activity beyond displacing O_2. It can keep packages from collapsing as other gases are absorbed by products and so is used as a balance gas in many C/MAP mixtures. O_2 has two functions; it inhibits the growth of pathogenic anaerobic organisms and it maintains the oxymyoglobin bloom of red meats. Co_2 selectively inhibits many gram negative psychrotrophic organisms which are responsible for the spoilage of many refrigerated foods.

The third variable is the package itself. There are several materials and design variables which must be considered in any C/MAP system. Primary is the barrier properties of the material from which the package is constructed. All plastics used in food packaging allow the permeation of gases in and out of the package. The differences between types of plastics is a matter of rate of transmission. Gas transmission rates (i.e., amount of gas permeating a given area of film per unit time) vary by as much as four orders of magnitude. In addition, the rate of permeation for CO_2 is 2 to 4 times greater than for O_2. This means the CO_2 which is injected into a package will, over time, permeate out of the package. The rate of gas loss will influence shelf life.

In addition to the permeation rate of the package, the amount of headspace influences the success of C/MAP for FRM. The headspace serves as the reservoir for the gases. It is the solubilization of the gases in the meats which allows an extension of shelf life. If those gases are lost through permeation, or by product and microbial respiration, then the enhancement of shelf life will be decreased. Trays or other forms of C/MAP should have ridges on the bottom to allow the gases to completely surround the product. Other design issues include the control of drip and the method of display. Meat products in trays with headspace will not display well if the trays are held vertically.

The fourth variable in C/MAP is the type of packaging equipment used to add the MA to the package. Chamber-type machines place the package inside a chamber which is evacuated and refilled with the desired MA. The package is sealed before the chamber is opened. This means that there is never a pressure differential across the barrier (nor on the product). This technique is best suited to semi-rigid containers such as trays. The alternative method uses a tube or snorkel to evacuate the air from within a flexible package and to reinsert the desired atmosphere. The snorkel is withdrawn and the package quickly sealed. In this method, the product is placed under vacuum (i.e., there is a pressure differential across the package) during the air evacuation process. While many products can withstand being vacuumed, other, more fragile products can not.

Another package design issue concerns consumer versus wholesale C/MAP systems. In wholesale systems, consumer cuts are packaged in low-barrier packages which are unitized into larger shipping units which are C/MAP in higher barrier bulk bags within boxes. This system has some advantages but the protective effects of the C/MAP are lost when the bulk system is opened and the consumer units removed.

The fifth variable in the C/MAP of FRM is the temperature at which products are stored. The effectiveness of C/MAP increases with decreasing temperatures. Decreasing the storage temperature has two effects. First, lower temperatures slow the growth of microorganisms in general, and secondly, increase the solubility of CO_2 in the meat (Ogrydziak and Brown, 1982). These two factors, combined with a high barrier film, can result in a very long shelf life for the storage of wholesale cuts of FRM.

Lastly, the use of additives can influence shelf life. For example, the addition of ascorbic acid by dips or sprays can add sufficient reducing equivalence to help delay the oxidation of myoglobin to metmyoglobin.

Color Stability

The color of FRM is of primary importance, especially to the retail consumer. The literature is ambiguous concerning the effect of C/MAP on color of FRM. Savell et al. (1981) found that MA of 75:25, O_2:CO_2 resulted in faster discoloration than PVC-wrapped meats held under simulated retail display. Seideman et al. (1979) found that beef packaged in a 50:50 blend of O_2:CO_2 deteriorated in color between 15 and 20 days where vacuum packaged controls were acceptable. On the other hand, Huffman et al. (1975) found that elevated (>20%) O_2 levels gave acceptable color for up to 4 weeks. Nearly all commercial systems which have used C/MAP for FRM have used levels of O_2 of 40% to 80% with the balance gas being CO_2. Seideman and Durland (1984) in reviewing C/MAP of FRM have suggested that more research needs to be conducted on the effects of C/MAP on myoglobin stability.

Microbial Effects

The scientific literature is much clearer on effects of C/MAP on the microbiology of meats. The ability of C/MAP to inhibit spoilage organisms has been documented in the literature over several decades (Genigeorgis, 1985). Much of this work has been done in FRM. For example, Clark and Lentz (1972) clearly showed that increasing the CO_2 content of the aerobic atmosphere surrounding meats from 0% to 20% increases the lag phase of psychrotrophic organisms, as well as decreasing the log growth rates. Enfors et al. (1979) demonstrated that the effect was due to the presence of CO_2 and not just to the displacement of O_2.

There has been some confusion about the amount of CO_2 necessary to inhibit spoilage. We (Hintlian and Hotchkiss, 1987) have shown that this is not a function of percent gas but more a function of the amount of CO_2 available. The amount of CO_2 available depends on both the concentration in the mixture and the amount of headspace in the container. A better measure than percent might be headspace to product ratio, or moles of CO_2 per kilogram of product. The CO_2 in the headspace serves as a reservoir for gas lost through permeation and absorption. Headspace ratios of >1.5 should be used with concentrations >60% CO_2 for maximum shelf life.

Safety Issues

The safety of C/MAP has been discussed by industry and regulatory groups at length but little direct research has been published. As is pointed out above, C/MAP has the ability to increase the time before FRM spoils by 2 to 4 times. However, the delay of spoilage does not necessarily mean a delay in the development of pathogenic microorganisms. Many pathogens do not spoil food in the sense that they do not always render foods inedible (Silliker and Wolfe, 1980).

The major safety question for C/MAP is whether or not pathogenic organism(s) will proliferate while the normal organisms that serve as indicators of spoilage are inhibited. This is probably the most hazardous of all situations because spoilage often warns consumers that a product might be dangerous.

We have explored this question for several years and believe that an understanding of the relationship between spoilage and pathogenicity of each individual product-package combination is important if the potential hazards of C/MAP are to be understood. Packaging technologies which inhibit spoilage yet allow or even promote pathogen growth should be carefully monitored.

For example, we (Wimpfheimer et al., 1989) have inoculated raw chicken meat with *Listeria monocytogenes* and followed the numbers of both spoilage and pathogenic organisms. Even at 4°C, which is considered adequate refrigeration, *L. monocytogenes* grew to high numbers within 20 days but the spoilage organisms remained nearly constant. This suggests that this pathogen must be carefully monitored in C/MAP of FRM.

Conclusions

C/MAP has several benefits for the centralized packaging and distribution of FRM: chief of which are the 100% to 200% increase in shelf life over conventional consumer packaging; an ability to brand label and advertise; higher efficiency and lower costs of centralized packaging through automation; and reutilization of retail space. The limitations appear to be increased capital cost for new packaging machinery, increased costs of packaging materials, some consumer resistance to the headspace and unsuitability for frozen storage.

The reluctance of the wholesale and retail food industry to use C/MAP appears to be due not to technical problems but rather to other economic and social concerns. The equipment and packaging materials are currently available for commercial C/MAP of FRM. Any FRM packer with sufficient capital who wanted to could enter the market with extended shelf life of C/MAP FRM.

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Discussion

Session One

R. Field: I have a question on something you just passed over. You indicated the FDA did not approve carbon monoxide for use, and I assume you're referring to just red meat. I'd like to hear your comment about carbon monoxide in produce, like the vegetables and perhaps some of the fruits. Is there any concern about safety in the vegetables as far as use of carbon monoxide? What level is it used at? How is it used there? My question is a concern, of course, because if we had that in red meat we could solve the color problem.

J. Hotchkiss: Something like 100 ppm has been addressed to FDA for red meat and they have specifically not approved it, not based on safety problems necessarily, but based on concern that that is a reconditioning process. In other words, it's something that might fool the consumer. It is specifically approved and used in cut lettuce. I don't know the exact process. As I understand it (it is a proprietary process), carbon monoxide is used at the 1% level. As you well know, carbon monoxide complexes iron stronger than oxygen, in addition to being red in color. It also inhibits cytochromes and will slow or inhibit respiration, which is a key element in produce. As I understand, the Techtrol Process is used by Transfresh in California for cut lettuce. I haven't seen the science on it to know. I worked a fair amount with cut lettuce, but we've never run across anything published that convinced us that it was very effective, but lots of people are buying it and using it. And I understand there is some work going on to expand its use to other cut products. Cut produce has problems because as soon as you cut it up, whatever you do, the respiration rates go through the roof, and so in order to get any kind of shelf life out of it, one of the things that you have to address directly is slowing that respiration down. And carbon monoxide will do that. It's in the Code of Federal Regulations as being approved for that, I'm quite sure. I don't think it will ever come for meats. It would certainly address the color issue; and what Excel is trying to do, for example, would become kind of moot. You wouldn't have to reeducate 240 million shoppers minus a few meat people.

D. Kropf: One comment first, Joe, and that is you are