4445 *

ROLE OF CURE ACCELERATORS

Jay B. Fox, Jr.
Eastern Regional Research Center[1]
Philadelphia, Pennsylvania 19118

When I was asked to speak on the role of cure accelerators, my first thoughts were of ascorbate and erythorbate, as well as acidifiers such as glucono-delta-lactone and sodium acid pyrophosphate. But on further contemplation of the subject I realized that the subject was much broader than the rather narrow consideration of compounds that speed up the color reaction. Cure acceleration is a matter not only of compounds, but also of processes interacting with each other as well as upon a wide variety of characteristics of the finished product. Many innovations have been made in the curing process that are better than reductants in accelerating the process. In many products color development is not the time limiting factor. I propose, therefore, to examine the process of meat-curing from beginning to end, from grinding in the machine to grinding in the teeth; to analyze the roles of additives, processes, and techniques with respect to time for cure and quality of product, and to correlate interactions among cure accelerators.

We cure meats today to change the taste of fresh meat to some flavor we enjoy as much or more. Our ancestors may have cured meats for preservation, but in this age of refrigeration we cure meats for flavor. As for preservation, most modern cured meat products are only slightly more stable than fresh meat.

In addition to flavor we have reaped other benefits from the curing process. Salt, nitrite and heat kill Clostridia and some other harmful pathogens. Nitrite plus reductants produce a pleasing color which also indicates whether the product is under or overprocessed, or has become bacterially or chemically contaminated. Nitrite appears to have something to do with texture, possibly producing protein crosslinks through its oxidative activity. Finally, nitrite also has an antioxidative activity, probably because its reduction product, nitric oxide, readily reacts with oxygen. We therefore look for cure-acceleration factors in terms of these functions: development of flavor, color, and texture, bacterial kill and product preservation, and rancidity prevention. Cure times and cure acceleration, for any given product, are determined by the time required for completion of the slowest of the foregoing processes.

The History

The examination of cure acceleration from an historical viewpoint not only gives a perspective to the process, but is also a logical way of treating the subject. Up to the turn of the century meats to be cured were either coated with salt and nitrate, soaked in brines, or mixed with salt containing nitrate. With time, slow penetration of salt into the meat and micrococcal reduction of nitrate to nitrite produced the characteristic cured meat flavor and color. Growth of acid-producing bacteria also contributed to flavor by producing an acid tang. The penetration of salt and reduction of nitrate took about 2 months for a ham and several weeks for bacon (Lewis *et al.* 1925; Kerr *et al.* 1926). Salt penetration required several days when mixed with chopped meat. This process was then followed by a period of smoking and aging of such a length as was deemed necessary to produce the desired flavor, surface and keeping qualities. The last process often lasted for months.

The first great acceleration of this process came in the 1920's with the introduction of the direct addition of nitrite to cures. The cure penetration process in whole meats was reduced from 2 to 1 month (Lewis *et al.* 1925); the subsequent smoking

[1]Agricultural Research Service, U.S. Department of Agriculture.

and aging times were not reduced. In meats mixed with nitrite, color developed in a day or two. Emulsified meat products benefited most from direct nitrite addition. While the actual development of meat emulsion products depended on the gradual improvement in meat choppers leading eventually to the present techniques of today, the modern process — in which all ingredients are mixed, emulsified, and cooked — could not be practiced without nitrite. Some other procedure using nitrate might be possible, but a curing period would still be required to reduce nitrate to nitrite.

In fermented meat products, nitrite plays a significant role only if lactobacilli starter cultures are used. Prior to the use of nitrite, two microbial growths had to occur in fermented meats; lactobacilli to produce the lactic acid for the tang and keeping qualities, and micrococci to reduce the nitrate to nitrite to develop color, flavor and keeping qualities. When lactobacilli starter cultures are used, cure times are too short for micrococcal growth and nitrite must be added. In Europe where nitrate is commonly added, micrococcal starter cultures are used.

While nitrate has a distinctive flavor, it has nothing to do with cured meat flavor. Its reduction product, nitrite, does, through reaction with meat components. The substitution of nitrite for nitrate made no difference in the basic flavor of cured meats. However, the shortened processing times, made possible by the use of nitrite, reduced the amount of other flavor components produced by other reactions, such as browning reactions, fat, sugar and protein oxidations, smoke component reactions and bacterial growth. To the extent that the latter contribute to the elusive characteristic of quality, nitrite addition may not have necessarily produced a better product.

Nitrite, and to a lesser extent, salt, is the primary factor in inhibiting the growth of *Clostridium botulinum.* The latter is not killed at 160°F, but in the presence of 150 ppm nitrite, is killed at even lower temperatures. In this respect, nitrite may be looked on as a cure accelerator as compared to nitrate, although botulinum kill has never been used a criterion of cure development.

The next cure accelerator, in the late 1930's was the technique of artery pumping of hams and stitch pumping of bacon and other whole meat products (Anonymous, 1948; Fields and Dunker, 1952). These techniques essentially eliminated the problem of cure penetration. Although some operators hold freshly pumped hams for a few hours or even soak them in brine before putting them in the smokehouse, it is possible to put them in directly with no cure penetration period. Mathematically, this is an infinite improvement in the process. Recently Rust and Olson (1973) reported that with Koch's[2] automatic multiple-needle stitch pumping machine cure distribution was so even that tempering periods were not needed before cooking. Since pumping is only a matter of cure distribution, it effects no changes in the finished product except uniformity. Pumping, like nitrite, shortens the cure period so that time is not allowed for any other flavor reactions to take place.

The next step in cure acceleration came in the early 1960's with the introduction of the reductants, ascorbate and erythorbate. Emulsified meat products gained most from this innovation, for the rapid processing techniques in use at the time sometimes led to poor color formation because of the relatively slow reducing capabilities of the endogenous reductants of meat. The addition of a faster reductant accelerated the formation of nitric oxide so that color developed by the time the cooking/smoking process was complete. The development of color can be divided into two phases, a lag phase during which oxygen is scavenged from the system, and a color-production phase in which the pink hemochrome is formed. We studied color formation in frankfurter emulsions (Fox *et al.* 1967) and found that the lag phase was about 300 minutes in

[2]Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

emulsion held at 100°F, 190 minutes if cysteine were added and 38 minutes if ascorbate were added. The corresponding times for the color-production phase were 8 hours, 25, and 25 minutes, respectively. Emulsifying under nitrogen or vacuum mixing eliminated the lag phase, and vacuum mixing also eliminated the color-production phase since the emulsion had over 50% pink hemochrome after the mixing. In this respect, vacuum mixing is also a cure acceleration process.

The use of ascorbate is less critical to whole meat products and is not necessary in fermented meat products. In these products, total tissue reductants and time of processing, determined by the time of cooking, are theoretically more than sufficient to develop color. However, there is frequently a gap between what ought to be and what is, and ascorbate acts as color insurance to produce maximal color every time.

Ascorbate, although added principally for color development, may have something to do with botulinum kill. Johnston and Loynes (1971) reported that 3500 ppm ascorbate, 2800 ppm cysteine and 17,500 ppm thioglycolate inhibited the outgrowth of botulinum spores. Although the effect of ascorbate on flavor is not known, there are some aspects of ascorbate-nitrite interactions that may affect flavor development. If nitrosation reactions with other compounds, such as amines or phenols, produce flavor components, ascorbate may interfere with flavor development since ascorbate has been shown to interfere in nitrosation of amines (Adriaanse and Robbers, 1969; Mirvish *et al.* 1972; Fiddler *et al.* 1973). The ascorbate-nitrite reaction is principally a reduction of nitrite to nitric oxide, which, while it is readily oxidized, is otherwise chemically inert. It is the readily oxidized characteristic of nitric oxide that probably accounts for the antioxidant role of nitrite in rancidity development. The reduction reaction of ascorbate and cysteine passes through the formation semi-stable nitroso intermediates, but none of these intermediates have any flavor identifiable as a cured meat flavor.

The next major step in cure acceleration came in the 1960's with the introduction of starter cultures for fermented meat products. The number of different processing techniques used to prepare fermented meats is almost as great as the number of plants making them. Suffice it to say that all nitrate- or nitrite-containing fermented sausages require a pan cure period of several days for bacterial growth, a period which may be shortened somewhat when nitrite is used. If starter cultures are used with added sugar from which to produce acid, and nitrite if only lactobacilli are added, this process may be shortened to a day or less. The process may be carried out in a cool smokehouse with smoke, followed by cooking, smoking and/or drying as desired. Starter cultures have one other cure acceleration benefit in dry sausages: the drying period may be reduced from about 2 months to 1 month. Fermented sausages made with starter cultures have the desired firm texture, satisfactory color and — a matter still under debate — the desired flavor.

Acidifying agents have been the most recently proposed innovations for cure accelerations, and I shall group glucono-delta-lactone and sodium acid pyrophosphate together. These compounds, added at normal levels, decrease pH a few tenths of a unit. This decrease, although small, is important. Some years ago, we (Fox and Thomson, 1963) studied the effect of pH on the formation of cured meat pigments from metmyoglobin, nitrite and ascorbate. From the data, we may calculate that a drop of 0.2 of a pH unit in meat doubles the rate of color formation. In a later study, however, we (Fox *et al.* (1967) found that under simulated processing conditions color development was essentially complete by the time the emulsions had reached 140°F, regardless of whether glucono-delta-lactone had been added or not. There was some acceleration with lactone, but the effect was slight. With a 45-minute processing cycle, full color development would be expected since the reaction at the normal pH of meat takes 20 to 30 minutes, even without acidifiers. We can only speculate on the effect of acidifiers on flavor. Nitrosation reactions are probably involved in flavor development, and lowering the pH would probably be beneficial since such reactions are generally faster at lower pH values. One interesting use of glucono-delta-lactone was recently suggested to me by Charles Everson[3] of Merck. Since a rapid drop in pH is beneficial in preventing growth of toxic and spoilage organisms, the initial rapid drop produced by glucono-delta-lactone may be an advantage.

We now come to the latest in the line of cure accelerators, in terms of commercial practice, liquid smoke. Although liquid smoke has been available for many years, its use is increasing because it is convenient and meats can be smoked without the neighbors complaining. In emulsified meat products, its use is primarily for convenience, because smoking with smoke is usually contained within the cooking period, even in the fast tunnel smokehouses of today. With liquid smoke, the predrying period before liquid smoke application, the spraying or atomizing, postapplication and cooking periods add up to 1.5 hours which is about usual smokehouse time. However, for those products where a smokier product is desired, hams, bacon, smoky links, etc., liquid smokes can accelerate the curing process. With liquid smokes, the concentration of smoke components can be controlled to produce smokier flavors as desired within the relatively short spraying or atomizing period. But with semidry or dry sausages, even though a heavy smoke is desired, conventional smoking periods fall within the lengthy times required for drying the sausage. Surface color and smoke flavor of liquid smoke-treated products are said to be indistinguishable from smoked products.

What does the future hold? One possibility is indicated by the work of Watanabe and Tape (1969) on the microwave processing of frankfurters. They used a tunnel microwave oven with a forced-air draft at 77°C to process a standard frankfurter emulsion. The emulsion was deaerated in a vacuum, stuffed, linked and dipped into liquid smoke. The frankfurters were then cooked by microwave energy in a special sequence designed to prevent bursting. The total time from linking to peeling was about 0.5 hour, which included a 15-minute holding period required for good color development. While less than one-half hour is fast, Dudley (Anon., 1966) described a high-efficiency smokehouse process of 40 minutes, and spoke of experimental smokehouse cycles of 20 to 25 minutes. Watanabe and Tape could not cook the weiners in one step, but had to divide the process into three phases to prevent bursting. First came a 42-second microwave cook, followed by a 2-minute equilibration period and a second 15-second exposure to microwaves; a total of 3 minutes' cooking. The question is to what extent all of the necessary reactions had occurred in this time period. Watanabe and Tape concluded that the microwave processed frankfurters were as good as commercial frankfurters, meaning they had, presumably, the same surface color and skin, flavor, color and texture. The use of liquid smoke plus vinegar was necessary to produce the surface characteristics of color, skin and peelability. Good color development may well have been due, with ascorbate, to the vacuum treatment since, as has been mentioned before, such treatment results in some color development immediately. Insofar as texture is concerned, Dudley (Anon., 1966) had raised the question of whether or not the emulsion would "set" under rapid processing conditions, But Watanabe and Tape's work shows that it can be set very quickly. What seems to me to be most remarkable is that they were able to develop flavor in such a short time.

Flavor, after all, is the primary reason for curing meats. Frankfurters are examples of the gustatory, not the ocular, art. And I would like to know something more about a hot dog than that it peeled well. I have stated that today we cure meats for flavor, and yet in the discussion of cure acceleration little was said about flavor. The problem is that we don't know what causes or produces cured meat flavor, or surprisingly enough, when the flavor is developed. If Watanabe and Tape's assessment of their frankfurters is correct,

[3]Personal communication.

development of flavor must be a fast reaction. To date it appears that no processing technique has been devised in which the product does not have at least an acceptable flavor.

The term "acceptable" bothers me. Far too often in the literature the term "acceptable compared to the commercial control," or some similar phrase is used. If acceptable should happen to be always just a few fractions of a unit lower on an hedonic scale, and today's products are the result of a long series of such comparisons, then today's product may have undergone a serious deterioration by comparison with the primordial product. At the Eastern Regional Research Center, we make frankfurters the old way: 10% weight loss, rich shiny, smokey, brown skin and all. They may not appeal to all people, but they have a quality that is no longer found in commercial frankfurters. If accelerated curing processes result in a loss of quality, has the product been improved? The manufacturers of Smithfield hams, Virginia bacon and Lebanon bologna would not think so.

I am not deploring the passing of the good old days and the good old products. Actually, the latter are still around. And I admit that in today's economy, if a faster cure produces a cheaper product that is still acceptable, it is difficult to criticize the technology. But I am not sure rapid processing is always justified. For example, one of the advantages cited for one rapid frankfurter-processing technique was that water loss was almost eliminated. So what of it? Water is necessary to life, but it hardly can be called nutritious. If water is lost, the protein content per unit weight is proportionally higher, and the frankfurter proportionally more nutritious per unit weight. That's no economic disadvantage; if it were, the potato chip would have disappeared long ago.

My final thought on cure acceleration is that someday I should like to see in the technological journals something like this, "Table X, shows that our technique reduced curing time by 13 minutes. On an hedonic scale, however, a trained panel rated the product low on texture and, therefore, inferior to the commercial control. We found that higher air velocities increased the rating to a level comparable to that of the commercial product. This change does not shorten the processing time, and adds 0.63 to the cost per pound of finished product. Because we consider quality more important than increased cost, we have included this modification in our recommended procedure (Figure Z)."

That will be the day!

Literature Cited

1. Adriaanse, A., and Robbers, J. E., 1969. J. Sci. Food Agr. 20:321.
2. Anonymous. 1948. Meat 28, 30 (May); 29, 36 (June); 29:31 (July).
3. Anonymous. 1966. Western Meat Industry, 12(3):12.
4. Fiddler, W., Pensabene, J. W., Kushnir, I., and Piotrowski, E. G. 1973. J. Food Sci. 38:714.
5. Fields, M. D., and Dunker, C. F. 1952. Food Tech. 6:329.
6. Fox, J. B., Jr., and Thomson, J. S. 1963. Biochemistry 2:465.
7. Fox J. B., Jr., Townsend, W. E., Ackerman, S. A., and Swift, C. E. 1967. Food Tech. 21:386.
8. Johnston. M. A., and Loynes, R. 1971. Can. Inst. Food Tech. J. 4:179.
9. Kerr, R. H., Marsh, C. T. N., Schroeder, W. F., and Boyer, E. A. 1926. J. Agr. Res. 33:541.
10. Lewis, W. L., Vose, R. S., and Lowry, C. D., Jr. 1925. Ind. and Eng. Chem. 17:1243.
11. Mirvish, S. S., Wallcave, L., Eagen, M., and Shubik, P. 1972. Science 177:65.
12. Rust, R. E., and Olson, D. G. 1973. Meat Curing Principles and Modern Practice. Koch Supplies, Inc., 1411 w. 29th St., Kansas City, MO. 64108.
13. Watanabe, W., and Tape, N. W. 1969. Can. Inst. Food Tech. J. 2:64; 2:104.