THE HOT DOG: ANATOMY OF AN AMERICAN CLASSIC

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The conference today brings together representatives from a relatively small processor, Ter Beke, and a large processor, Oscar Mayer, to compare manufacturing of processed meats. While significant differences certainly exist, two similarities must be kept in mind.

First, the ultimate goal of both companies is to provide their consumers with consistent, high quality processed meats.

Second, with minor variation, the basic meat processing techniques, grinding, mixing, emulsification, smokehouse processing, etc. are similar. Beyond these similarities, it can be assumed that the small processor strives to deliver specialized products to the market or to satisfy the needs of a specific, localized group of people at a reasonable cost. The large processor, on the other hand, strives to deliver consistent products to a larger and more diverse group of people in the most economical manner possible. Both types of manufacturers serve significant, but very different populations in employing meat to "fortify the quality of life." This presentation will discuss the formulation and production of the "typical" American processed meat - hot dogs.

How typically American are hot dogs? Hot dogs owe their origin to Johann Lahner, the inventor of the Viennese Frankfurter (Reuter, 1972). In the United States (US) today, the terms wiener, frank, frankfurter, and hot dog are used synonymously. Clark (1994), in a popular article, indicated that 16 billion hot dogs are eaten in the US each year. He calculated this to be approximately 80 hot dogs for each man, woman, and child. Hot dogs are closely associated with several enjoyable facets of US life including summer, barbecues, children, and the American institution - baseball. From the industry's perspective, if we assume the average hot dog weighs 45.4 grams (22 hot dogs per kg, a very conservative estimate), 16 billion hot dogs translates into approximately 726,000 metric tons of finished hot dogs or 878,000 metric tons of hot dog batter to be made each year.

There are several variations of hot dogs based on specific characteristics of the meat component, such as meat type or fat content. For this discussion, however, we will concentrate on the most popular hot dog of all, the pork, poultry, and beef hot dog.

INGREDIENTS: MEAT COMPONENT

The ingredients and composition of hot dogs are closely regulated by the government. As a result of the regulations and efforts to control formula costs, the basic formulations among processors are similar. The differences between products are primarily the result of specific flavorings and smoke profiles, and texture differences resulting from variations in processing methods. Hot dogs are classified by the USDA (United States Department of Agriculture) as "cooked sausages." As such, their maximum permitted fat content is 30%, with a concurrent maximum added water of 10%. (Added water is calculated as follows: % Moisture - (4 * % protein) = USDA Added Water). Six years ago the USDA (USDA, 1988) permitted the total added water and fat to equal 40%, with the fat maximum at 30%. This regulation cleared the way for lower fat hot dogs containing, for example, 15% fat and 25% added water or 3% fat and 37% added water.

The meat component for a "typical" hot dog consists of pork, beef, and usually either chicken or turkey meat. The amount of the three meats in the formula is highly variable. It is possible, however, to get an estimate by keeping two rules in mind. First, if the package has a meat inspection legend, the meat portion must contain over 50% pork and beef. A poultry inspection legend, distinguished by the words "for wholesomeness", means the meat portion contains over 50% poultry. Second, if two meat items are connected by the word "and", they must adhere to a 70/30 rule. For example, the term "Pork and Beef" indicates that one of the two meats must be at least 30% or more of the total pork and beef portion. Since beef is currently more expensive than pork, it is likely that "Pork and Beef" means 70% pork and 30% beef. Hot dogs specifically designated "Beef", "Pork", "Turkey", or "Chicken" consist of one meat specie, unless a qualifier is added.

The poultry portion of the meat component is meat recovered from the carcass of the trimmed bird. The use of turkey or chicken meat became possible twelve years ago when the USDA permitted its use in processed meats (USDA, 1982). Between two and three years ago, its use became more widespread when processors learned how to use poultry with no loss of hot dog quality.

INGREDIENTS: NON-MEAT

Three non-meat ingredients are universally included in US hot dogs. They are water/ice, sodium chloride, and sodium nitrite. Water/ice is added for cost savings, for juiciness, and to control temperature rise during batter formation. The amount of added water/ice is regulated as previously discussed. Sodium chloride is added to extend shelf life, to increase food safety, to extract salt-soluble muscle proteins duringemulsion formation, and to flavor the product. Sodium chloride is typically added from 2.0-2.6% of the final product. Sodium nitrite is added for four classical purposes, including cured meat flavor formation, cured meat color development, reduction in fat oxidation, and prevention of *Cl. botulinum* growth and toxin production. Sodium nitrite is permitted up to 220 ppm, but an unspoken target of 156 ppm or less is usually followed. No nitrates are used in hot dog production.

Nearly all hot dogs contain either sodium ascorbate, ascorbic acid, or sodium isoascorbate (labeled sodium erythorbate). These ingredients accelerate the rate of nitric oxide formation from nitrite. (The actual rate of increase depends on several factors, including pH and temperature of the system.) In some applications, members of the ascorbate family also help to maintain final product color. Sodium erythorbate is used most frequently (60-70% of the time) due to its lower cost. Processors, however, who use sodium ascorbate or ascorbic acid are permitted to list vitamin C on the label. Sodium erythorbate has minimal vitamin C activity. Sodium ascorbate may be used at up to a level of 550 ppm, but there is no minimum requirement in hot dogs.

Sodium phosphates (primarily sodium tripolyphosphate) are currently added to approximately 50% of the US hot dogs. Sodium tripolyphosphate is added as a means of increasing water binding and overall product stability. It functions by increasing the meat pH and by assisting sodium chloride in solubilization of muscle proteins. Phosphates are permitted at up to 0.5% of the formula, but will typically be used at between 0.25% and 0.3% of the meat weight.

The remaining non-meat ingredients can be divided into two main categories. These are ingredients which contribute flavor and ingredients which bind fat or water. The most commonly used flavoring agents in US hot dogs are sweeteners - corn syrup and dextrose. Corn syrup is permitted at a maximum 2% of the formula, while dextrose is permitted at levels sufficient for purpose. (Typically dextrose will be added at between 1.25 and 1.75%.) The sweeteners function to sweeten the product, to reduce the harshness associated with sodium chloride, and to lower formula cost. One sweetener, sorbitol, is used in hot dogs intended for roller grilling (such as in airports or fast food restaurants) where Maillard browning is not desirable. Sorbitol may be used at up to 2%, but it may not be used together with corn syrup. All of the sweeteners must be labeled using their common names.

The word "flavoring" is seen on nearly every US hot dog label. Flavoring can consist of one or more of the following: spice, spice extractives, garlic powder, onion powder, or celery powder. The mostcommonly used flavorings are spices, mustard flour, and garlic powder.

Smoke, both natural and artificial, is often a characterizing flavor for hot dogs. If smoke from smoldering wood is applied or if a concentrated smoke extract is sprayed on the surface of the casing, the product is said to be smoked. If the smoke extract is added as an ingredient in the batch, then the product must be labeled as smoke flavor added.

Some ingredients classified as flavorings play dual roles in hot dogs. It has become standard practice for processors to add 1% non-meat protein to hot dogs for flavor and as a replacement for 1% meat protein in the USDA added water calculation (USDA, 1990). Proteins typically used in this manner include hydrolyzed milk protein, hydrolyzed vegetable protein, beef stock, and autolyzed yeast. If more than 1% protein is added from all non-meat sources, the amount over 1% must be subtracted from the total protein before added water is calculated. It is currently economical to add 1% non-meat protein when red meat protein is replaced. It is not economical to replace poultry protein. (Costs of use will depend on local prices and availability of materials.) These ingredients must be labeled using their common names.

Several water binders or formula extenders, including unmodified food starch, modified food starch, isolated soy protein, and assorted milk proteins are permitted for use in hot dogs. Depending on the ingredient either a 2% or 3.5% level of use is permitted. Binders and extenders have not become popular for use in 30% fat products.

PROCESS: GENERAL CONCEPTS

While formulation specifics vary between the US and non-US producers, mainly due to regulations, the processing of hot dog-style, linked, processed meats varies more between small and large processors than between countries. There are several basic principles which impact modern large scale production. To optimize production efficiency, some of the most important are as follows:

1. Maximize production throughput.
2. Balance process stages.
3. Maximize batch size.
4. Minimize labor.
5. Maximize objective, continuous monitoring of routine production.

The first four principles are obvious. The last may be less so. As processing rates and amounts continue to increase and manufacturing continues around the clock, it becomes virtually impossible for a few individuals to monitor every step. It is more effective to use highly trained individuals to develop products and processes and to function as consultants for routine manufacturing. The more objective measures built into the process, the easier it is to put in place continuous monitors and the easier it is to evaluate the process over time. Lord Kelvin stated, "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind." (Barlow, 1989) Computers are perfect in the role of continuous monitors. The increased use of computers to objectively monitor production is perhaps the greatest area of process change in recent years.

PROCESS: RAW PRODUCT HANDLING

Raw product handling impacts the sensory quality, stability and economics of the final product. It includes the formulation which impacts flavor, texture, and cost, the batter formation which primarily impacts product texture and stability, and the efficiency of production which influences consumer cost.

After a new product or process is commercialized, day-to-day conditions arise to which production must respond. One such condition is variation in the cost and availability of raw materials. The most common means of responding to raw material changes is through the use of least cost formulation. Least cost formulation systems require two basic types of information - the costs and availability of raw materials and the desired characteristics or constraints for the final product. The program uses linear regression to determine which combination of materials meets the final product characteristics at the optimum cost. Least cost formulation systems have been developed which can optimize from a wide range of raw materials and for various production levels from one batch to an entire company's production. The cost of the programs varies depending on their complexity, but systems are available which can be afforded by even the smallest processor.

After the optimum formula is determined, the next process step is batching. While a few continuous systems do exist, mixing in distinct, individual batches is still the rule. Within reason, increasing the size of the batch reduces variation. If you are making 10,000 kg of hot dog batter, there is less likelihood for variation between two batches of

5,000 kg than between five batches of 2,000 kg. (Of course, a 5,000 kg mistake is bigger than one of 2,000 kg.) The specific mixingprocess will vary depending on the manufacturer. Since this step is often the last non-continuous process, it is an ideal time to ensure that the composition of the batter is correct.

For all practical purposes, the silent cutter or chopper is no longer used by large US processors for making meat emulsions. The cutter exposes a relatively small amount of batter repeatedly to a small number of knives and takes too long for a large processor. Even worse than the time required to form the emulsion is the time lost loading and unloading the cutter at 180 kg per container. Cutters also provide too much opportunity for operator-induced variability. By using an emulsion mill, the batter is exposed to a specific plate and knife combination exactly once. Assuming the plate and blades are in proper condition and the mixing temperature is correct, proper emulsion formation can be continuously monitored by measuring temperature of the batter. For example, a hot dog batter should rise approximately 14°C during emulsification, whereas a beef frankfurter batter should reach 22-23°C. The primary disadvantage of a mill compared to the cutter is in those products containing a particulate phase (called a show phase) suspended in the batter. In those cases, the show phase must be added after emulsification using a second mixer.

Transport of the finished batter from the emulsifier to the stuffing equipment is a critical step due to the sensitivity of the batter to stress. Over short distances, transport by conveyor or pump is more efficient than unloading into tubs, pushing to another machine, then filling the other machine. When pumping is used, however, it is important to minimize the angles and T-joints through which the batter must travel. Sharp change in direction significantly increases stress on the batter. Ideally, flat belt conveyors should be used to transport the batter over short distances. Flow meters and thermometers can also be put in place to continuously monitor batter conditions. It should be remembered that using mechanical means of transport may limit the ability to use the production equipment for less stable batters developed in the future.

The most common equipment used for stuffing and linking frankfurters is the Frank-O-Matic_. Since time spent loading the casing onto the stuffing horn is not productive, the length of the casing, and thus the amount of meat stuffed without pause should be maximized. The length of the casing used is ultimately determined by either the method used to physically load the stuffed batter into the smokehouse, or the length of the stuffing horn over which the casing must fit. Natural casings are not used for efficient large scale production of hot dogs due to their variability in diameter and strength. Since collagen casings also tend to slow the rate of stuffing and linking and, more importantly, because the US consumer is most familiar with skinless hot dogs, cellulose casings are used by major producers.

PROCESS: THERMAL PROCESSING AND COOKED PRODUCT HANDLING

Like the earlier processes, thermal processing and cooked product handling are important for delivering optimum flavor, texture and economics to the consumer. Even more importantly, however, these steps are crucial to delivering microbiologically safe final products to the consumer.

In a batch smokehouse, the product is loaded by the operator to a fixed site in the house. The product is processed as desired and then removed from the smokehouse by the operator to have its casing removed and be packaged. In a continuous smokehouse, strands are loaded onto a continuous chain, or other carrier, which moves the product through the smokehouse where they are smoked, cooked, and chilled. The finished hot dogs are then automatically delivered out of the other end, ready to have their casings removed and be packaged.

The exact distribution of batch versus continuous smokehouses in the US is debatable. In general, small processors use batch houses due to their overall flexibility, while the most efficient cooking process for large volumes of similar products is in continuous smokehouses. Regardless of which smokehouse is used, three basic objectives are desired from the cooking process. The first is heating to set the skin and internal protein gels to develop texture. The second is heating and smoking to develop the appropriate color and flavor. These two objectives primarily impact the sensory quality of the hot dogs and can be achieved through a number of different temperature and relative humidity settings. The third objective is to reduce the number of viable bacteria in the final product. This objective can also be met using various processing cycles, but the ultimate target in the US is to achieve a temperature of at least 68°C at the center (core) of the hot dog.

In addition to these three objectives, however, there is a need to be as consistent during manufacture as possible. Two key areas of variability can be better controlled in continuous smokehouses. The first is cycle variability. In a batch smokehouse, the introduction of heat, moisture, smoke, and during chilling, cold vary depending on which part of the cooking cycle is taking place. This means that during one cook cycle, the smokehouse must frequently make significant adjustments in temperature and humidity. In the continuous smokehouse, each portion of the smokehouse is assigned one specific temperature and humidity which can be stabilized, then monitored. The second area of variability is product location within the smokehouse. All smokehouses, both batch and continuous, are notorious for variations in temperature at different locations within the house. The differences are caused primarily by the pattern of airflow in the chamber and are further increased by the quantity and location of the product in the house. Continuous smokehouses can have as much or more variation than that seen in a batch house. The difference is that in continuous houses, all of the hot dogs travel through the entire smokehouse so each hot dog is exposed to each variation. Overall, the hot dogs are cooked more uniformly. In addition to reducing variability, continuous smokehouses improve efficiency by eliminating the loading and unloading steps and the need to make small changes in the cycle to accommodate underfilled houses.

While the continuous smokehouse is a big efficiency improvement for large processors, it makes the overall processing line extremely inflexible. Without major modifications, once a continuous smokehouse for hot dogs is in place, it can only be used for products of similar shape and size with essentially the same cooking demands as hot dogs.

Packaging is, to a large processor, the means of getting the hot dogs to the customer in the best condition economically possible. There are essentially two hot dog packaging and distribution systems in place in the US. For consumer sales, hot dogs are packaged in formed plastic packages. Maximum shelf life is achieved: by keeping the packaging line clean; by keeping the product cold; by sealing in the most cost-effective plastic film which minimizes air and water movement through it; and by not handling the hot dogs until after they are in the package. The large processor uses a mechanical delivery system to transfer hot dogs from the smokehouse to the package.

In the second packaging and distribution system, for restaurant or other food service outlets (for example, airports, baseball parks, bowling alleys, etc.), hot dogs are usually delivered frozen. This essentially eliminates the microbial quality issues. The hot dogs are typically packaged in boxes lined with plastic and are kept frozen until use. Final quality is dependent upon the efficiency of initial freezing, on the ability to maintain a low temperature during distribution and storage, and the length of frozen storage before use.

FUTURE PERSPECTIVES

This paper has been an introduction to the basic principles of hot dog manufacture by large scale meat processors. The large processor optimizes formulation and manufacturing within the framework of government regulations in order to deliver safe, high quality, consistent, convenient, and economical hot dogs to the consumer. Even so, the hot dog has faced many challenges to its popularity recently. These have included cholesterol, sodium, and nitrite issues over the past two decades, and the fat issue of today. Largeprocessors have responded to the consumer concern by making available hot dogs containing reduced fat and sodium levels.

The future will undoubtedly see many changes to the formula and processing of hot dogs. Perhaps the hot dogs made from non-meat ingredients, such as soy or seafood, will become more popular. Certainly processing techniques will increase the rate and efficiency of manufacture, while further reducing manufacturing costs. It is easy to imagine that someday we will cook hot dogs in a fraction of the current time, we will not use a casing that we have to dispose of before selling, and we will no longer burn wood for smoke flavoring. Perhaps someday it will be commonplace to cook hot dogs with a non-heat energy source such as electrical current. Eventually, the product itself may inhibit microbial growth well enough to make extra packaging unnecessary.

Ultimately, however, it seems unlikely that anything in the future will match the enjoyment of that first bite into the warm, juicy hot dog at the baseball game, or the convenience of eating a hot dog with one hand while carrying your coat and briefcase to a waiting plane. For these, and many other reasons, the hot dog appears destined to "fortify the quality of US life" for many years to come.

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