Director's Digest
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STERILIZATION

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The most common method of killing microorganisms is to subject them to a heat treatment. The objectives for which heat is applied to various materials vary considerable. The minute living organisms, not visible to the naked eye, and classified as microorganisms are virtually everywhere. Those of primary medical interest are bacteria, viruses, spirochetes, rickettsia, molds and yeasts. Though there are innumerable genera and species of each class of microorganisms not all are of medical significance or involved in disease processes. In fact the predominance are composed of those that are necessary to food production, friendly environments and metabolic processes: examples being cheese/wine production, decomposition of organic matter and digestion of food. Therefore it is a fine line of differentiation in the utilization of heat or other controls of microorganisms by destruction processes. In food safety the goal or fine line is the destruction of pathogenic microorganisms below the concentration of their ability to produce disease. However heating by virtue of its effect on the finished product as well as microorganisms must be considered. The effect of heat on microorganisms is generally believed to be due to protein denaturation, enzyme inactivation or both. Thus it is important that foods are cooked sufficiently to destroy certain pathogenic organisms but they should not be heated to the extent the nutritional value is reduced significantly.

Sterilization is a term most frequently referenced in describing the destruction of microorganisms. Sterilization is, however, a process defined as the complete destruction of microorganisms either by heat, radiation or microcidal chemical compounds (bactericides or virocides). It is seldom achieved and in food and feed ingredient processes and preparation seldom attempted. Sterilization obviously becomes important in a number of procedures with surgery being most notable. Several surgical functions including the procedure, the tissue preparation and the preparation of the instruments are all-important steps in maintaining aseptic conditions. Most surgical packs are prepared using an autoclave which effects sterilization by using high temperature steam (250°F or 121°C) under pressure (15 psi). Sterile means free of life of every kind and is actually achieved under very limited conditions. The control of microorganisms in medicine, industry, sanitation, food and feed service involves the acceptance that sterilization is most often not achievable without destroying or severely damaging the product. However, acceptable numbers and types of microorganisms are controlled below any disease producing threshold. In the food service sector the term of commercially sterilized is used to describe non-sterile but safe product. Similarly pasteurization is a process of heating, usually to either 145°F (63°C) for thirty minutes or 161°F (72°C) for 15 seconds to kill pathogenic bacteria and inhibit total bacterial development. Pasteurization is a process that kills a percentage of the inherent microorganisms but is not a sterilization process. Rendering is a classic example of effective heat treatment to destroy microorganisms in mega numbers under controlled and specific processes. Rendering processes correlate quite closely to those used by the food industries. Thermal processing of any product is a percent kill. Consequently with higher initial populations, more rigorous heat processes are required (i.e.–increased temperatures and or time) to achieve commercial sterilization or desired uniform final microbial population. Heat sterilization is based on a statistical probability that the number of remaining viable microorganisms will be below a certain level after a particular heating time at a specific temperature. The specific requirement for heat is dependent upon a number of variables. The time the material is exposed to a specific temperature must be tested to determine the thermal conductivity or heat penetration. After the rate of heat penetration is known, the lethal effect of the heat can be determined. Thus time and temperature relationships are important in raising product temperature and then killing microorganisms. Moisture levels of the material are a definite influencing factor. Moist heat readily kills viruses, bacteria and fungi. There is a correlation between the % presence of water and the effectiveness of heat to kill microorganisms. In the presence of fats, there is a general increase in the heat resistance of some microorganisms. This is referred to as fat protection and is believed to increase heat resistance by directly affecting cell moisture. Other influencers include quantity (vessel size) particle size and consistency of material being processed. As an example, a vessel of green beans in a #10 size can requires nearly two times the commercial sterilization required as compared to a smaller #2 size can of green beans. Further, whole kernel corn requires nearly three times the value for each respective can size when compared to green beans.

As was referenced previously, there are several descriptions applied to the steps of thermal processing in order to quantify results. **Thermal Death Time** – This is the time in minutes necessary to kill a given number of organisms at the specified temperature. **D Value** – This indicates the time in minutes required to destroy 90% (or a one log cycle) of a population of cells at a given reference temperature. A one-log reduction is reducing the bacterial population by

90%. **z Value** – This is the temperature increase required to reduce the thermal death time by a factor of 10 (or a one log cycle). **F Value** – The process lethality. This is the time in minutes at a specified temperature required to destroy a specific number of viable cells having a specific z-value. The z value is a characteristic of each individual species of bacteria. More heat resistant bacteria that are more difficult to destroy have higher z values whereas heat labile bacteria that are readily destroyed with heat have lower z values. *Clostridium perfringens* is a well-known foodborne pathogen that is relatively heat resistant and has been determined to have a z value (°C) of 6 to 8. Thus a temperature increase of 6 to 8 °C is required to reduce a *C perfringens* organism count from 10,000 to 1,000 or 1,000 to 100 etc.

Thus the z value (temperature) inter-relates with the time (or the D value) for establishing processing conditions based on statistical lethality. In the canned food industry the concept of a 12D process has been developed. In a 12D process, sufficient thermal process (temperature and time) is provided to reduce the initial population by 12 log cycles or by 99.9999999999%. This level of safety has been established primarily due to the concern for the presence of *C. botulinum* [z value 10 (°C)] spores. D values vary according to the temperature, species of microorganisms, number of initial population and other factors that may affect thermal resistance.

In the rendering industry (food safety), the microorganisms of greatest concern are *Salmonella sp.*, *Clostridium perfringens, Staphylococcus aureus, Listeria monocytogenes, Campylobacter sp* and *E. coli* all of which have much lower z values and consequently should achieve a 12D process in a shorter time. *Bacillus stearothermophilus* is a non- pathogenic organism that has been shown to be one of the most heat resistant strains of bacteria known. This organism was used along with *C. perfringens* in a project conducted by Dr. Annel K. Greene, Clemson University that evaluated the thermal conductivity of nine mixtures of animal raw materials ranging in species origin and tissue type to achieve a 12D process. The procedures used were more consistent with that used by the food canning industries. Thus, the experiment subjected animal by-product materials to a worst case processing procedure since the material was not stirred or mixed within the heating chambers as is standard during the rendering process. In the experiment the following raw materials were inoculated with the spores of the test organisms (B stearothermophilus and C perfringes):

1. Primary beef bones
2. Primary Shop Fat and bones, beef and pork bones, beef offal
3. Tallow
4. Cattle offal
5. Feathers (ground)
6. Poultry offal
7. Whole Ground Chicken (WGC)
8. 50% WGC and 50% feathers (vol./vol.)
9. Pork offal with bone

Heating was then accomplished to describe the thermal processes and the thermal conductivity for all of the above samples. Linear and non-linear (logistical) analyses were determined on four replications for each of the above raw materials.

Though there have been many previous documentations of the time/temperature effectiveness of the rendering process with specific bacteria and viruses, this pioneering project established F values for each of the raw materials under a worst case experimental processing condition, using the most heat resistant bacteria known and a minimum 12D process. This project establishes thermal conductivity values for further modeling of given cooking cycles for specific variables. In this study heating curves with standard deviations are as follows:

Treatment	Mean f_H ± standard deviation*
1	31.51 ± 2.50^{a}
2	35.59 ± 5.32^{a}
3	2.58 ± 2.99^{c}
4	34.62 ± 8.87^{a}
5	8.39 ± 2.81^{c}
6	35.47 ± 4.13^{a}
7	29.07 ± 3.80^{a}
8	20.88 ± 2.29^{b}
9	34.39 ± 6.47^{a}
^{a,b,c}Means followed by same letter are not significantly different at alpha = 0.05	
*f_H describes the slope of the straight line portion of the heating curve.	

As would be expected, raw materials vary in heat penetration with tallow and feathers having the fastest. Treatments with soft tissue and bone were statistically similar in heating curves. Products containing increased level of bone were associated with greater variation (standard deviations) than other tissues. This work is preliminary and describes the rate of heating for unstirred raw material. As previously referenced, unstirred materials are known to heat much more slowly than stirred material as in standard rendering processes. This basic research is exclusive and is a scientific reference that is not available for any of the commonly cited alternatives for the rendering process.

The rendering industry is committed to processing animal and poultry by-products to produce microbiologically safe finished products. The thermal process of rendering being a very similar process (time/temperature) to that utilized by the food processing industry has been shown to be the most biosecure process. The thermal process relies on mathematical models to ensure the safety of the final product. Current rendering processes are closely monitored and controlled processes in which many are computer operated. Rendering temperatures and times have been developed using scientific knowledge of the lethality of microorganisms during its century plus service to animal agriculture. As the knowledge of microorganisms has expanded so has the technology of rendering. The Fats and Proteins Research Foundation Inc. and the allied industries have focused on product safety. This project and others completed, in progress and planned will continue to concentrate on this mission. Is rendering a sterilization process? No, but neither is any other food or feed processing procedure. Is rendering the safest process to convert animal by-products into resourceful alternative uses? A definite Yes!