

Influence of fat on the thermal destruction of bacteria in sausage products

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The effect of fat on thermal destruction of microorganisms was studied in emulsion sausages (frankfurters) and coarsely comminuted sausages containing within the range of 11% to 38% fat. Sausages were prepared from meat and fat containing high levels of either pseudomonads or micrococci. Time and temperature of heating was determined by an integration method designated degree-minutes. Plots of log surviving bacteria of different types versus degree-minutes with two types of sausages at various fat levels gave similar concave patterns. Statistical analysis of the linear portion of the plots where the log bacterial count was more than 2.0 indicated: (a) a greater sensitivity to heat for pseudomonads for micrococci, (b) a slightly deleterious effect of fat on bacterial survival during heating, and (c) very little difference between heat destruction of bacteria in frankfurters and in comminuted sausages.

Introduction

Study of thermal destruction of food-borne pathogens in a snack product was found that there was a large variation in fat content between commercial sausage and commercial snack sausages. Examination of the literature indicated inconclusive results concerning the effect of fat on the destruction of bacteria. Food technologists generally believe that fats protect bacteria from the deleterious effects of heat. There have been studies in which food products were utilized to investigate the protective effect of fat during the heating of bacteria. The effect of fat at destruction of bacteria or viruses has been studied in milk products (Brown and Peiser, 1916; Nichols, 1940; Kaplan and Melish, 1944; Lang and Dean, 1934), and meat (Zakula, 1969; Filippi and 1974). Other workers have tried to answer the question by utilizing culture tubes (Rogacheva, 1928; Rodenbeck, 1932; Jensen, 1946; Zuccaro et al., 1951). Examination of the data in the literature yielded conflicting evidence and thus, a reassessment of the role of fat on the thermal destruction of bacteria was warranted. Emulsion sausages (frankfurters) and coarsely comminuted sausages containing different levels of fat were used as model product to study the possible protective or deleterious effects of fat on the destruction of bacteria.

Materials and methods

Meat: Lean beef, lean pork, and pork fat were ground through a 1/8-inch (3 mm) plate, packed into Cry-O-Vac* bags and frozen at -27°C. Cooked, frozen meat and fat were thawed overnight at 10°C.

Incubation of meat-fat mixtures: Meat (beef and pork, frankfurters and 1:1 for coarsely comminuted sausages) and varying fat were ground through 3/32-inch (2.4 mm) plate with or without addition of NaCl. In Series A and C, meat-fat mixtures were comminuted with 15.1 and 30.0 g NaCl/kg, respectively, and incubated at 5°C for 24 hours. In Series B and D, meat-fat mixtures were incubated at 5°C for 24 hours in the absence of salt. Low temperature incubation of meat-fat mixtures in the presence of NaCl permitted a selective increase in the growth of micrococci; in the absence of salt, pseudomonads were the predominant microorganisms. The meat-fat mixtures of Series A and B were used to prepare frankfurters; those of Series C and D were used to prepare coarsely comminuted sausages.

Preparation of frankfurters (emulsion sausages): At the end of the incubation period, frankfurters were prepared (25.1 g NaCl was added to each kg of meat mixture in Series B) and processed according to the procedures of Palumbo et al. (1974), except that no smoke was used.

Smokehouse temperature control settings: For the operation of the smokehouse, the settings were: 130°F (54.4°C) dry bulb; 30 minutes at 150°F (65.6°C) dry bulb and 135°F (57.2°C) wet bulb; 45 minutes at 165°F (73.9°C) dry bulb and 160°F (71.1°C) wet bulb; and, finally at 190°F (87.8°C) dry bulb and 185°F (74.4°C) wet bulb until the internal temperature of the frankfurters reached 160°F (71.1°C). The internal temperature of the frankfurters was continuously monitored during heating by a thermocouple inserted into the center of the product and was recorded with a Honeywell Elektronik recorder.

Preparation of coarsely comminuted sausages (non-emulsion): After the curing period, curing agent (0.078 g NaNO₂/kg and commercial frankfurter seasoning (8 g/kg) were added to the meat-fat mixtures; in the case of frankfurters, 10.0 g NaCl/kg also was added. These sausage mixtures were packed into 55 mm fibrous casings (Union Carbide) to make sausages approximately 500 g in weight. The sausage were cooked in a smoke-

house with temperature controls set at 190°F (87.8°C) dry bulb and 140°F (60°C) wet bulb (without smoke). The internal temperature was monitored as described for frankfurters; the final internal temperature was 160°F (71.1°C).

Microbiological procedures: Samples for microbiological examination were assayed as follows: when the internal temperature of the product reached a predetermined point, a short strand of linked frankfurters or a comminuted sausage was removed from the smoke house. Fifty grams of the product was aseptically removed from the casing and placed in a cold, previously tared, sterile blender jar. Two hundred ml of sterile cold diluent (0.1% Difco peptone in distilled water) was added and the material blended at high speed for one minute. The blended mixtures were stored at 5°C until assayed (within 2 to 3 hours). Appropriate dilutions were pour-plated with Difco APT agar; colonies were counted after 5 days incubation at 25°C.

Fat analysis: The fat content of the uncooked comminuted sausages and frankfurters was determined by AOAC standard methods (1965).

Determination of degree-minutes: The degree-minute concept is an integration procedure which allows the calculation of the exposure of bacteria to lethal temperatures of 110°F (43.3°C) and above (Palumbo et al. 1974). Parameters for the integration were bound by the following lines on the recorder chart: (a) temperature-lines formed by the reference temperature (ice bath) and the product internal temperature; (b) time-lines formed from the time the product internal temperature reached 110°F (zero time) to the times needed for the product to reach preselected internal temperatures. Thus, the parameters describe a trapezoidal figure consisting of two parallel lines representing the time increment between the low and high temperatures extending at 90° angles from the base line temperature (ice bath) and terminating at the respective low and high points of the product internal temperature. Trapezoidal areas were traced onto tracing vellum, cut out and weighed. The weight in grams of the areas of paper represent degree-minute units which were plotted against the log of the number of surviving bacteria.

Results and Discussion

The microflora of meat and fat mixtures aged at 5°C in the presence or absence of NaCl differed. In meat incubated in the presence of NaCl, the microflora consisted mainly of catalase positive, gram positive cocci designated micrococci, whereas in the absence of salt, the microflora was primarily catalase positive, gram negative short rods designated pseudomonads. These designations are made for convenience only and are not taxonomic dicta. When the bacterial count of sausages prepared from meat incubated with or without salt was reduced to 10²/g or less during heating, surviving microorganisms consisted of micrococci and bacilli (catalase positive, gram positive sporeforming rods).

Pork fat was used to vary the fat concentrations of frankfurters and coarsely comminuted sausages described in this study; fat levels of the sausages in Series A, B, C, and D are shown in Table 1. Beef was an ingredient in both products and beef fat could have been used also. Zakula (1969) has shown that the thermal destruction of *Streptococcus faecalis* was similar in pork and beef with 10% to 40% added lard or tallow, respectively; therefore, the use of pork fat was considered to be adequate to demonstrate the effect of different fat concentrations on bacterial survival during heating.

Figure 1A shows the curves obtained with frankfurters when degree-minutes were plotted against log of bacterial survivors; the meat and fat were aged at 5°C in the presence of NaCl to enhance growth of micrococci. Figure 1B shows curves for frankfurters when meat and fat aged in the absence of salt to enhance growth of pseudomonads. Similar curves for coarsely comminuted sausages in which meat and fat were aged in the presence and absence of salt are shown in Figures 2A and 2B, respectively. The data in Figures 1 and 2 clearly indicate that the log of bacterial num-

* Union Carbide Research Service, U. S. Department of Agriculture.
No brand or firm name does not constitute endorsement by the U. S. Department of Agriculture over others of a similar nature not mentioned.

Content of frankfurters and coarsely comminuted sausages

Series	% fat present in uncooked product			
	Frankfurters		Comminuted sausages	
	Series A	Series B	Series C	Series D
	17.3	17.3	14.3	11.7
	25.6	25.7	17.4	17.3
	32.6	30.6	27.9	26.9
	37.2	36.2	33.4	37.4

Analysis of variance of log₁₀ viable bacteria

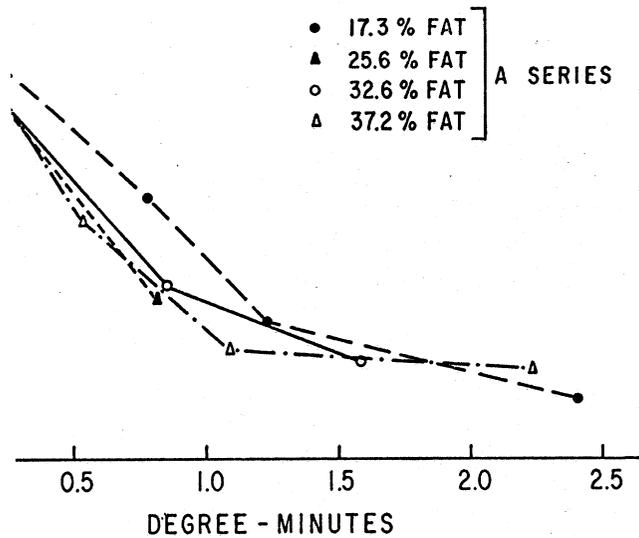
	Degrees of freedom	Sequential sum of squares	Mean square	F-value
X	1	222.237	222.237	564.63***
	1	7.846	7.846	19.93***
te	1	3.542	3.542	9.90***
	1	3.577	3.577	9.09***
K	1	1.848	1.848	4.70*
	45	17.712	0.394	
	50	256.763		

at 95% confidence level.

at 99.5% confidence level.

Effect of total heat treatment (degree-minutes) on the destruction of frankfurters of varying fat content

Series A



Series B

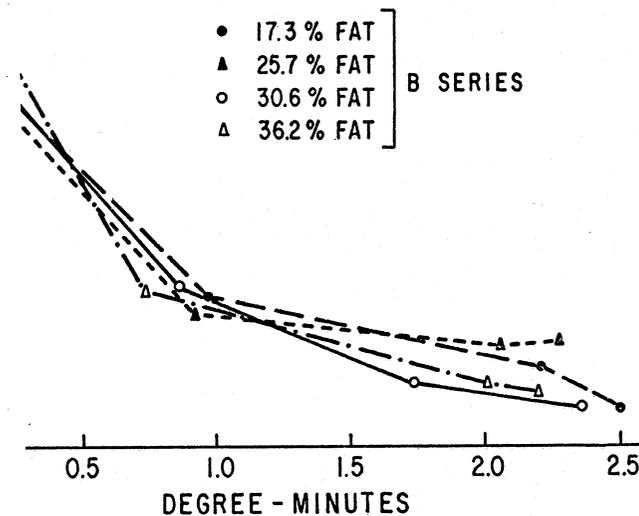
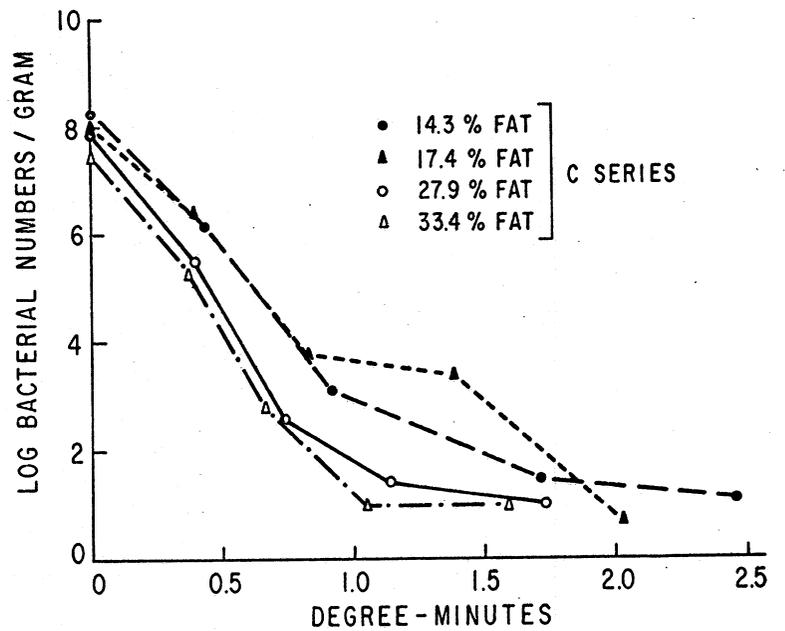
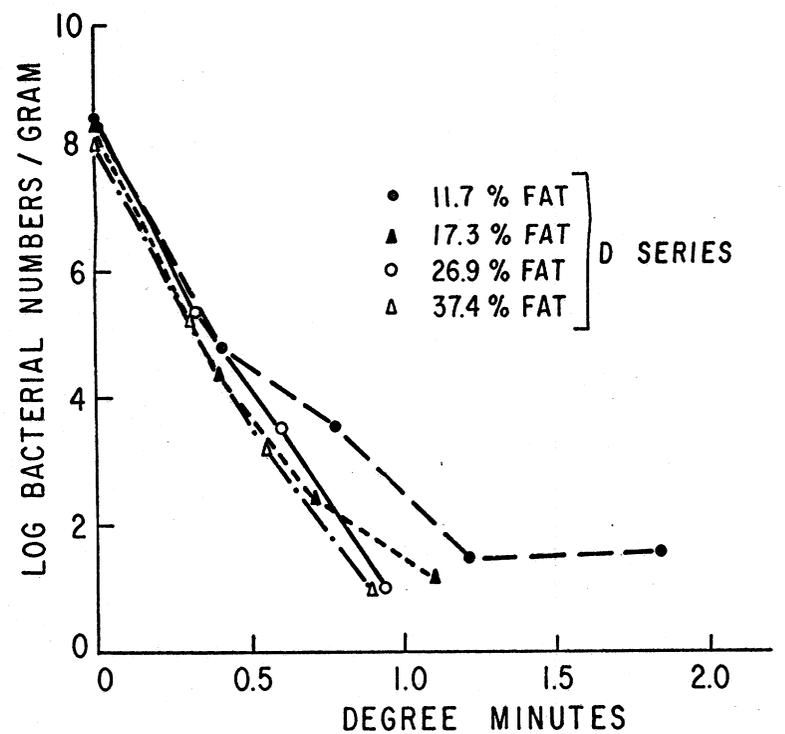


Figure 2. Effect of total heat treatment (degree-minutes) on the destruction of bacteria in coarsely comminuted sausages of varying fat content

a) data for series C



b) data for series D



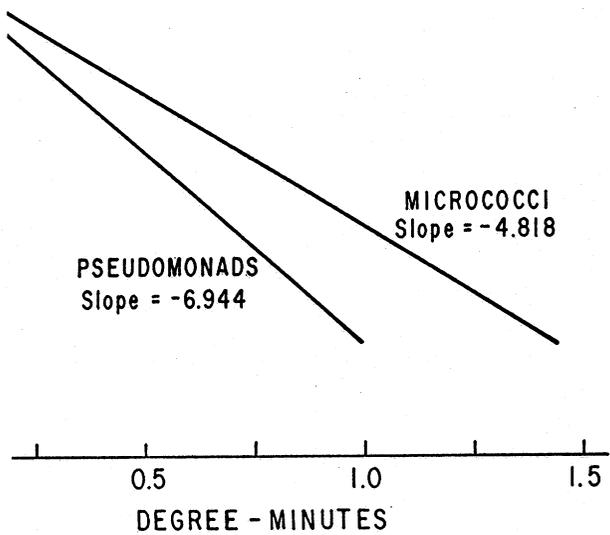
Log bacterial numbers are negatively related to degree-minutes. The regression analysis of the data in these figures was limited to the linear portion of the curves where the log of bacterial numbers were 2.0 or greater. The method of multiple regression analysis was used to relate log of bacterial numbers to the following factors and their interactions: degree-minutes, percent fat, bacterial type (micrococci or pseudomonads), and sausage type (frankfurters or coarsely comminuted sausages). Degree-minutes and percent fat were treated as continuous variables (covariates); the bacterial type and sausage type were treated as discrete variables. The analysis of variance (Table 2) shows the factors which were significantly related to the log bacterial numbers (significant at the 95% confidence level). The multiple correlation coefficient for the regression was + 0.965.

The results of the regression analysis are presented in Figures 3, 4, 5, and 6. The log bacterial survivors in heated sausages (Figure 3, data for both frankfurters and comminuted sausages combined) decreased linearly as the degree-minutes increased. Pseudomonads were more sensitive to heat than were the micrococci (Figure 3). The differences in heat sensitivity between pseudomonads and micrococci can be shown in two ways. The slopes were -6.944 and -4.818 for pseudomonads and micrococci, respectively. The greater negative slope for pseudomonads indicated that they were more heat sensitive than micrococci. The greater sensitivity of pseudomonads to heat is shown also by the fact that to reduce the bacterial count approximately seven log cycles, less heat treatment was required for pseudomonads (1.0 degree-minutes) than for micrococci (1.45 degree-minutes).

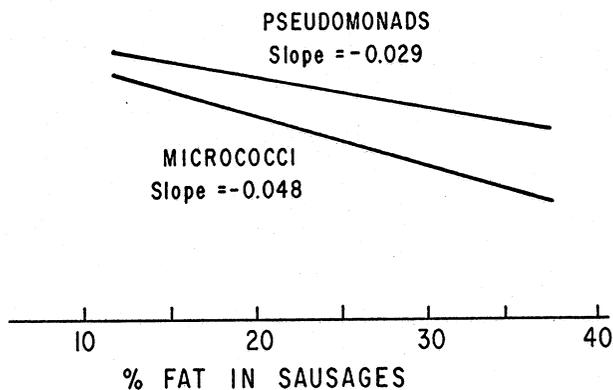
in Figure 4 suggest a slight deleterious effect of fat on the organisms during heating. However, the very small slopes (pseudomonads and -0.048 for micrococci) indicate that the effect of fat is not very important in a practical sense. The survival of the two organisms is so slight as to be unimportant technology.

little difference in the heat destruction of bacterial populations in frankfurters and comminuted sausages (Figures 5); the differences of -5.75 for frankfurters and -6.00 for comminuted

of cumulative heat treatment (degree-minutes) on the survival of bacteria in sausages (combined data for frankfurters and comminuted fat levels



of fat content of sausages (both frankfurters and comminuted) on the thermal destruction of bacteria at all degree-minutes



of cumulative heat treatment (degree-minutes) on the survival of bacteria in comminuted sausages and frankfurters

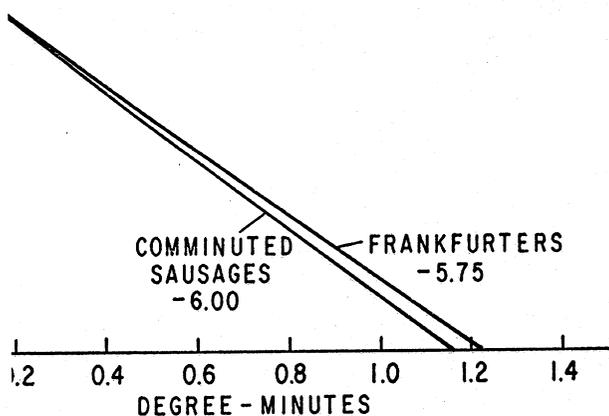
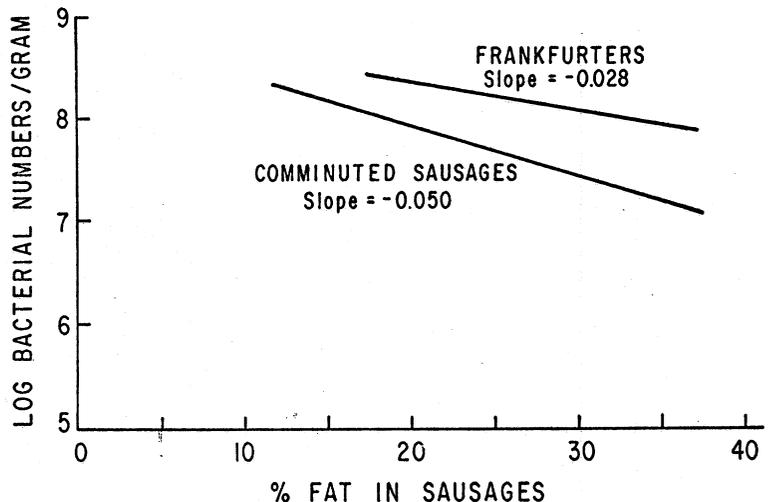


Figure 6. Effect of fat content of frankfurters and comminuted sausages on the thermal destruction of bacteria (both micrococci and pseudomonads) at all degree-minutes



sausages was not significant. The data in Figure 6 support the conclusions drawn for Figure 4: the minor decrease in the respective slopes indicate that fat has no protective effect for bacteria in either product and, in fact, it has a slightly deleterious effect on bacterial survival during heating. However, the small negative slopes (-0.028 and -0.050) indicate that this deleterious effect is minimal and is of doubtful significance in thermal processing of sausage products.

During this investigation, it was found that the time required for the sausage to reach a given internal temperature varied between production runs. This was attributed to differences in smoke house control and ambient atmospheric conditions. Since destruction of bacteria by heat can be described as a time-temperature phenomenon, the degree-minute concept devised by Palumbo, et al. (1974) was used for this purpose. Using this concept, slight variations in the heating pattern of the product in the smoke house between different experiments may be put on a quantitative basis in order to compare the cumulative effect of lethal temperature on destruction of bacteria. The data presented in this paper further validate the use of the degree-minute concept. The multiple correlation coefficient of the regression was $+0.965$ and the correlation coefficient obtained when log of numbers of survivors were plotted against degree-minutes (Figure 3) were close to unity (the simple correlation coefficient for pseudomonads was -0.964 and for micrococci, -0.930). Correlation coefficients close to unity indicate that there is a high degree of correlation between the two variables (degree-minutes and log of numbers of survivors) and thus the degree-minute concept is a good way to describe heat destruction in bacteria in frankfurters and coarsely comminuted sausages of different fat levels.

Much confusion exists in the literature concerning the influence of fat on thermal destruction of bacteria and yeast. Data in the literature suggest, in general, a protective effect of fat during heating of microorganisms. Although some workers reported that fat protects microorganisms from heat destruction, critical examination of the methods used in those studies indicates that methodology itself may be the origin of the difficulty. According to Jensen (1945) and Yessair, et al. (1946), dried micrococci were more resistant to heat in moist or dry fats than in broth. The resistance in anhydrous fat approached that of dry sterilization. It is not clear, however, why dried bacteria were used. Complete dryness of microorganisms (as well as the substrate) would rarely occur in actual food handling practice and the significance of the protection of dried bacteria from heat destruction by a dry fat is probably misleading. Rodenbeck (1932) pointed out that as little as 1% moisture in a pure fat or oil abolished the protective effect of fat against heat destruction of a sporeformer. Zuccaro, et al. (1951) found a ten-fold increase in the time necessary to kill yeast by heat when organisms were present in cottonseed oil as compared to phosphate buffer. These workers found that dried yeast would not disperse in oil, so they placed loopfuls of yeast in oil and left the loops in the oil during the heating period. At intervals, a loop was withdrawn and numbers of viable yeast determined. The control was phosphate buffer containing dispersed yeast (previously dried). It is difficult to compare the killing effect of heat on dispersed cells versus undispersed cells. A loopful of yeast would probably behave similarly to a large clump of cells; those cells in the center of the loop would be protected from the destructive effects of heat. Spores of *Clostridium botulinum* inoculated into tuna in cottonseed oil survived longer with heat treatment than when the spores were present in phosphate buffer (Lang and Dean, 1934). It is difficult to disperse organisms evenly in a food product, and the spores could have been protected from heat by being trapped between particles of tuna flesh. A more logical control would have been tuna suspended in buffer at a pH similar to tuna in oil. Their interpretation, that oil protected these spores from the destructive effect of heat, may not be correct. Methodology does not appear to explain the discrepancy between the work of Brown and

Peiser (1916) and Nichols (1940). Nichols (1940) found that increasing the butterfat content of milk did not increase the resistance of *Bacillus subtilis* spores to heat; with non-sporeformers, she found that heat resistance to be slightly less in cream than in either whole or skim milk. On the other hand, Brown and Peiser (1916) showed that microorganisms were more resistant to heat in cream than in whole or skim milk.

Thus, on the basis of data from the literature, it might be concluded that coarsely comminuted sausages or frankfurters containing 35% to 40% fat would require a greater input of heat energy to kill bacteria present in the products. However, the data presented here indicate that the fat content of sausage products played a minor role in heat destruction of bacteria.

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