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# The Development of a Chemical Analogue of Thermal Destruction of Bacterial Spores

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## SUMMARY

A study has been made of methods in which chemical reactions are used to evaluate the total lethal effect of heat on the bacterial population in a sealed container of food material. The chemical reaction technique has also enabled a study to be made of the effect that the movement of the material within the container has on the lethality of the applied heat.

The relationship between the extent of a chemical reaction and the degree of destruction of bacterial spores is shown to depend both on the activation energies and decimal reduction times of the chemical and bacterial systems, and on the "heat penetration" characteristics of the material being processed.

Acid hydrolysis of sucrose, in buffered solution, was chosen as the model chemical reaction systems. It was used in the experimental study of two types of process, one with cans stationary, as in ordinary commercial batch retorts, and the other with the cans rotated "end-over-end" as in some commercial agitating batch retorts and continuous cooker-coolers.

The effect of convection on the extent of sucrose hydrolysis has been investigated. By combining records of can temperature with data on the rate of sucrose hydrolysis, the final concentration of sucrose has been calculated for a range of processes. These calculated values have been compared with those actually obtained in the can.

Theoretical considerations show that the effect of heat on bacterial and chemical systems as calculated from temperatures measured at points fixed with respect to the container, is not necessarily the same as that actually obtained in the container if convection takes place during the process. Simple convection models have been used to relate the extent of of sucrose hydrolysis calculated from the temperature data, to that actually obtained in the can. These convection models show that the temperature at the geometrical centre of the can could be considered typical of the whole can for both static and agitated can processes.

The degrees of destruction of two micro-organisms with different "heat-resistances" have also been calculated from the can temperature data. These have enabled relationships between the sucrose hydrolysis and the spore destruction to be established. The effects of the various processing factors on these relationships, and on the rate of heat transfer to the can have been studied. The factors investigated were processing pressure and length of process, for static can and agitated can runs, and type and speed of rotation for agitated can runs only. The processing pressure in the agitated can runs, and the length of the process in both agitated and static can runs do not appear to have significant effects, but the effects of all other factors studied are significant.

The concept of equivalent time difference, which arises from the relationship between the extent of a chemical reaction and the degree of spore destruction has been defined and examined. Model temperature vs time curves for a greater range of processes and can sizes than that used in the experiments have been calculated using heat transfer rate data based on the agitated can runs, and the dependance of the equivalent time difference on the type of process and on the size of can is discussed.

Multiple reaction systems in which measurements of the extents of several chemical reactions, each with different activation energies, are used to estimate the degree of destruction of spores have been investigated. The model temperature vs time curves, derived for the analysis of the equivalent time difference concept, were used with data on the rates of the sucrose hydrolysis reaction, which has an activation energy of 22.35 kcal/mole, and on the rates of two hypothetical reactions with activation energies of 30 and 45 kcal/mole. Estimation of the degree of spore destruction using reactions in pairs or in groups of three is discussed.

If a pair of reactions is used, a knowledge of rates of heat transfer to the can is required for satisfactory estimation of the lethal effect of heat. If three reactions are used, the lethality of the process can be estimated without heat transfer rate data.

Errors arising in the estimation of the lethal effect of heat on bacterial spores using chemical reactions singly, in pairs, or in groups of three are discussed. The maximum errors in the lethality of the process as estimated using the various chemical reaction techniques were found to be less than one quarter of those arising from the same sources in traditional process calculation methods, in quite a number of instances much less. It is also shown that uncertainties arising from the necessary experimental measurements can be evaluated much more readily with a chemical reaction technique, especially the three reaction system, than they can in other methods of process evaluation.

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