NON-ISOTHERMAL KINETIC DATA GENERATION FOR FOOD CONSTITUENTS

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ABSTRACT. Two new non-isothermal methods for generating kinetic data for food constituents are examined. The first consists of a stirred batch reactor using linearly increasing temperature. The second employs a continuous flow reactor and a novel thermal evaluation method for defining the thermal treatment. The significance and implications of both methods are examined as related to each other and to classical data generation methods.

1. INTRODUCTION

Thermal processing produces physical, chemical and/or biological changes in food materials. The rates at which these changes occur are of primary importance in process design and evaluation. Methods for determining rate data with batch or continuous reactors should be critically evaluated as to their applicability to the real process environment. Classical batch methods for generating kinetic data may yield varying results due to the experimental design. Ideally, the sample is to be held for a constant time as a constant temperature (isothermal kinetic data generation). As the sample is heated to this design temperature, a thermal lag (time-temperature heating curve) is produced. This thermal lag must be accounted for in the overall heat treatment. As temperature increases, accounting for the thermal lag becomes more difficult. Data generated with batch type systems, generally, neglects this lag by providing as close to instantaneous heating as possible. In doing this, the experimental design requires small sample volumes, which may produce questionable data due to: variations with sample volume related to varying container dimensions; head space differences; heating and handling differences with viscous materials; dilution; heating variations due to container position to the heating source; and difficulties related to obtaining an adequate volume of properly heat treated material for many analytical methods.

In addition to the thermal heating lag, many microorganisms and their spores possess a protection effect or lag associated with their logarithmic destruction.

pattern. Consideration should be given to the questions: a) Does a constituent (i.e. spore) react the same to a thermal treatment instantaneously obtained as it does to an equal thermal treatment derived from a gradual heating process?, and b) When generating kinetic data, what role does the thermal history of the constituent in question play as we determine the rate of the reaction at the desired temperature -- the rate useful for design work?

Much discrepancy appears in the literature between constituent kinetics generated in a buffer solution and that generated in the actual product. Many of the current procedures for generating kinetic data are not designed to examine food constituents in the product of interest, during actual physical process conditions, and with the same thermal treatment level used in industry. Physical treatments such as high shear are not accounted for in static reactors, yet the data generated are readily used in designing systems with high shear. Although extrapolating results to temperatures higher than those used to generate the data is dangerous, the practice is still common, primarily due to the lack of methodology available for generating constituent usually designed as ideal reactors -- plug flow, no axial mixing and no radical gradients which, again, may or may not impart errors. Little or no data exist on the effects on kinetic parameters from mechanical factors that characterize real continuous flow systems (i.e. Residence Time Distributions (RTDs)).

This paper describes two new methods for generating kinetic data: a) a Linearly Increasing Temperature Method (LITM) designed for data generation of medium volume materials (< 0.3 liter) at low to moderate temperatures (30 - 100°C); and b) a Continuous Flow Method (CFM) designed for data generation of medium to large volume materials (> 0.3 l/min) at moderate to high temperatures (60 -160°C).

2. METHODS

2.1 Linearly Increasing Temperature Method

The LITM consists of a single experiment in which the temperature of the stirred batch reactor is raised at a predetermined rate, and samples are withdrawn at intervals and analyzed in the usual way. This procedure provides the data required to calculate all the kinetic parameters with only one run of experiment. The analysis of the kinetic data obtained by the LITM is based on three eqns.: the rate eqn. \((-dC/dt = k C^n)\), Arrhenius eqn. \((k = k_0 \exp (-Ea/RT))\), and the time-temperature relationship \((T = T_0 + at)\). Combining these three eqns. yields:

\[
\ln \left( -\frac{a dC}{C^n dT} \right) = \ln (k_0) - \frac{Ea}{RT}
\]  

(1)