Relationship between Induction Period and Temperature of Fatty Foods

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The oxidative stability of oils and fats is one of their most important properties determining the shelf life of the products in which they are used; indeed for low moisture products such as biscuits and fried snacks, shelf life depends almost entirely on oxidative stability.

Inspite of its importance and much research effort, the oxidation chain remains one of the least understood reactions in food technology and at a recent poll among the Leatherhead Food Research Association (LFRA) Oils and Fats group, more members voted for research on this subject than on any other.

But measuring oxidative stability in a meaningful way has proved to be an extraordinarily difficult task as evidenced by the number of measuring instruments introduced and then abandoned a few years later. A major problem is that oxidation at ambient or refrigerator temperature around which most foods are stored, is a very slow process and in industry, time is the most expensive commodity of all. Industry therefore, has to use accelerated methods which operate at higher temperatures (usually 100°C-120°C) and a further complication is that different companies in the same industry use different test temperatures. In the oil refining industry for example, temperatures of 100°C, 110°C and 120°C are quite common. We mostly need to know two things; can results at one temperature be converted to another temperature and if so what is the mathematical relationship? There is no unanimity on this subject among scientists which prompted us to look into the problem ourselves.

EXPERIMENTAL DATA

For this study, we took the experimental results presented by Poul Eli Frandsen of Danisco Ingredients, Brabrand, Denmark, at the Leatherhead Food RA Oils and Fats panel meeting in London on 5 March 1998. These results were obtained on potato crisps in an Oxipress instrument now marketed by Mikrolab Aarhus*, of Denmark.

This instrument resembles the ASTM Bomb, much used in the petroleum industry. The sample under test, which can be virtually any type of fatty product, is placed in a vessel under oxygen pressure of about five bar and maintained at the desired temperature in an aluminium block, which avoids the messiness associated with the use of heat transfer liquids. The instrument gives a graph of oxygen absorption over time and the end of the induction period is the point of inflection which is quite clear and sharp.

In this case, the sample was potato crisps fried in vegetable oil, tested at 10°C intervals from 80°C to 120°C and the readings obtained were as follows:

Temp (°C)	**Induction Period (Hours)**
80	130.0
90	63.1
100	35.3
110	20.2
120	9.3

RESULTS AND DISCUSSION

It is well known that the rate of most chemical reactions increases strongly with temperature and the fundamental equation which applies in most cases is the Arrhenius one which is of the form:

$$K = Ae^{-E/RT}$$

where K is the specific reaction rate, A is a constant, e is the base of natural logarithms, E is the energy of activation, R is the gas constant and T is the absolute temperature (°Kelvin).

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When the calculated results were tested against the experimental ones, we obtained a highly significant correlation coefficient of $r = 0.9975$ ($n = 5$), ($p < 0.001$), which shows that the Arrhenius equation does indeed explain the results very well. However, this equation giving K or the induction period as an exponential function of the absolute temperature is difficult to calculate and to visualize.

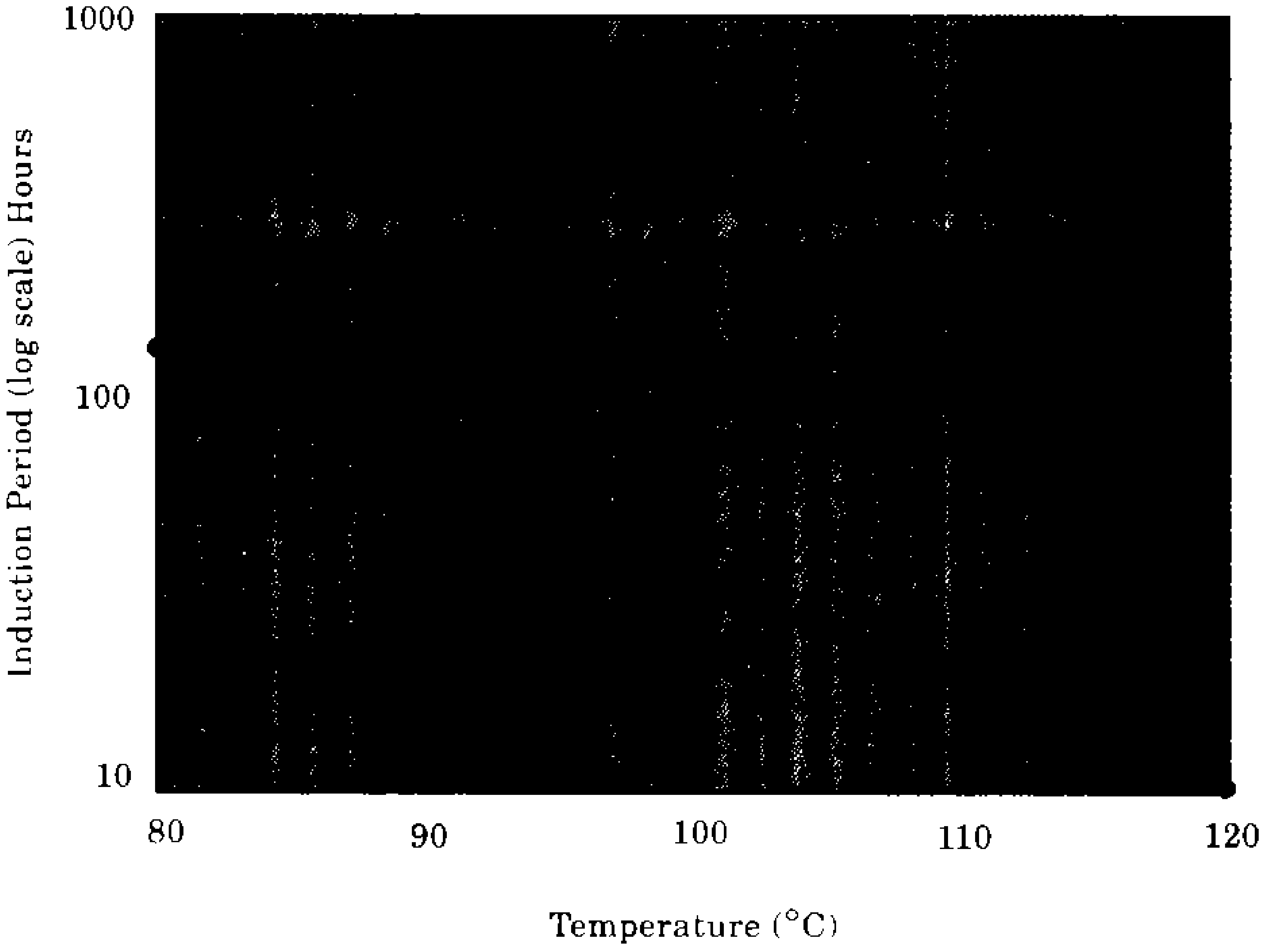
We found that over this range of temperatures (80°C – 120°C) at least, the following empirical equation gave just as good results and is certainly much easier to calculate.

$$\mathrm{Log(IP)} = a - \frac{t}{36} \qquad r = -0.9983\ (n=5) \quad p < 0.001$$

Where (IP) is the induction period (hours),
a is a constant depending on the product
(in this case = 4.333), and
t is the temperature (°C)

Figure 1 shows the agreement between the experimental and the calculated results which is excellent. This equation leads to the result that between 80°C and 120°C, the induction period doubles for every 11°C (more exactly 10.8°C).

One point of caution however; it is unsafe to extrapolate empirical equations much beyond the range of data from which they were derived. A parabola can look like a straight line over a short interval.



$$\mathrm{Log(IP)} = 4.333 - \frac{t}{36} \qquad r = -0.9983\ (n=5) \quad p < 0.001$$

Figure 1. Plot of induction period v. temperature oxipress – potato crisps.