KINETICS OF COLOR FORMATION DURING COOKING OF FINE EMULSION SAUSAGE

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INTRODUCTION

In order to predict the effects of sterilization on food chemical and sensory attributes, earlier investigators [3, 4] introduced a cook value *(C)*, similar in nature to the pasteurization value *(P)* used in thermobacteriology. The cook value was successfully used to describe, among other changes, the degradation of thiamine in buffer [5] and the loss of visual appeal in fish pudding [6], at sterilization temperatures (105-130°C; read the review by Holdsworth [1] for more applications). Calculation of *C* values for a given quality attibute required prior knowledge of the attribute sensitivity to time and temperature and was only possible if the degree of change could be linearly related to temperature increase. In that case, sensitivity to temperature was represented by the *z* value (1/slope of the regression line).

Little information is available on the use of the *C*-value concept in the cooking of meat products and only in a few cases were *z* values for sensory quality actually determined in the range of temperatures used in cooking [7-9]. In particular, although the influence of heating on the color of cooked sausages has been described in two studies [2, 9], attempts to precisely relate cooking cycles and sausage color were unsuccessful. A study was therefore undertaken to follow the actual color formation during the course of cooking and to investigate possible strategies to use the collected data for prediction purposes.

MATERIALS AND METHODS

An industrial high-speed bowl cutter (Kilia 40, 6 blades, 25 kg maximum capacity) was used to prepare a finely comminuted sausage emulsion consisting of pork trimmings (85% lean, 69% of green weight [gw]), pork back fat (13% gw), water (15% gw), NaCl (2.1% gw), Na-nitrite (200 ppm), and Na-erythorbate (500 ppm). The prepared emulsion was introduced into flat (3 mm thick) cylindrical (4 cm diameter) plastic sample dishes, which were hermetically closed and stored in the dark, at 12°C for 2 h. The samples were subsequently immersed into water baths adjusted to constant temperatures of 60°C, 66°C, 72°C, 78°C, and 84°C, then randomly collected at regular times (5 to 300 min), cooled in iced water, stored at 2°C, in the dark, for 20 ± 4 h, and evaluated for L*a*b* color coordinates, using a Minolta Chroma-Meter II chromameter. All sausages were prepared from the same meat block, which had been previously homogenized, then frozen in batch-size portions.

A separate experiment was later conducted to evaluate color formation at lower temperatures (20°C, 30°C, 40°C, 50°C, and 60°C). New homogeneous blocks of 85% lean pork trimmings and of pork back fat were prepared and used in the manufacture of finely comminuted sausages, following the same recipe as in experiment #1. The Kilia cutter being no longer available, emulsion was prepared in a 8 kg capacity Stephan VCM-12 vacuum-cutter instead.

RESULTS AND DISCUSSION

The increase in time of sausage cured color (followed by the a* value) in the 60-84°C range was well described ($R^2 = 0.9632\text{-}0.9892$) by an exponential rise to a maximum, $a^* = a^*_i + \Delta a^* \, [1 - exp(-bt)]$ (equation 1), in which a^*_i is the initial a* value, Δa^* is the amplitude of a* increase ($\Delta a^* = a^*_{max} - a^*_i$), b is the rate constant, and *t* is the heating time (Figure 1, experiment #1). The rate of color development increased with increasing heating temperature (b= 0.0326, 0.0538, 0.0724, 0.1341, and 0.1490 for 60°C, 66°C, 72°C, 78°C, and 84°C, respectively) but the final color reached was not substantially affected by temperature (60°C, 12.8 ± 0.2; 66°C, 13.3 ± 0.1; 72°C, 13.4 ± 0.1; 78°C, 13.0 ± 0.2; 84°C, 13.4 ± 0.1).

Color changes with time at temperatures of 40-60°C were also well described ($R^2 = 0.9713\text{-}0.9901$) by an exponential rise to a maximum (Figure 1, experiment #2) but the final color reached was considerably lower than in experiment #1. No attempt was made to determine why, since the study was designed to understand the pattern, rather than to determine the extent, of color formation, but differences in pigment concentration between the two meat lots were most likely involved. As seen at higher temperatures, the rate of color formation decreased with decreasing temperatures and there was no color formation at 20°C.

Equation 1 can be rearranged as: $\log_{10} [(a^*_{max} - a^*)/\Delta a^*] = - bt.\log_{10} (e) = - 0.43429 \, bt = (1/D_t).t$, in which D_t is the time in minute required to decrease by a factor of 10 the fraction of color which remains to be formed. The temperature dependence of color formation can then be evaluated by plotting $\log_{10} |D_t|$ as a function of temperature (Figure 2). Temperature dependence is clearly linear in the 60-84°C range and is represented by a *z* value of 35.0°C (1/slope of the regression line). Linearity of the temperature dependence at lower temperatures (experiment #2) is not as strong and will have to be confirmed in additional experiments. The fact that different *z* values were obtained in the two temperature ranges likely reflects that two different phenomena were in fact observed. Color formation at temperatures above 60°C is due to the accumulation of dinitrosohemochrome which forms as a result of nitrosomyoglobin denaturation by heat, while little is known on the causes of color changes in the 20-60°C temperature range.

The data from experiment #2 were subsequently used to calculate the predicetd a* values in fine emulsion sausages during smokehouse cooking. The calculation was applied to two different cooking cycles, corresponding to the cooking of identical sausages (12.5 cm flat diameter), introduced into the smokehouse at different times (Figure 3, temperature). Results indicated that, in both cycles, color developed rapidly (cycle A, 40 min; cycle B, 30 min) at the product surface to reach its maximum value before color started to form in the center (Figure 3, a* value). Color formation in the product core took much longer (cycle A, 120 min; cycle B, 80 min). In both cycles, core color had peaked to its maximum value before the legal end-point temperature of 69°C was reached. At these times, pasteurization values were 19.8 min (cycle A) and 44.6 min (Cycle B).

CONCLUSIONS

The results of this preliminary study indicate that it is possible to describe color formation during heating of fine emulsion sausage by mathematical equations that can later be used to predict the evolution of color during cooking. The results also suggest that completion of a regular cooking cycle with an end-point temperature of 69°C guarantees that color is fully developed, both at the product surface and in its centre. Additional work is required to refine our knowledge of the kinetics of color formation and to determine whether a comprehensive model can be developed, to predict the extent of color formation, as well as its rate.

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Figure 1: Kinetics of colour formation (a* value) during heating of sausage slabs at constant temperatures (20-84°C)

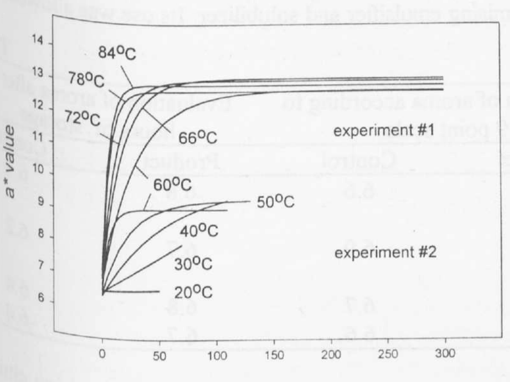

Figure 2: Determination of the temperature dependence (z value) of colour changes during cooking of sausage slabs

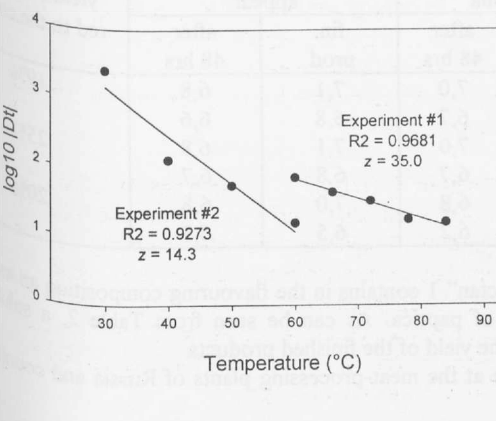

Figure 3: Evolution of product temperature and predicted colour during cooking of fine emulsion sausage (plain line: surface; dotted line: core)