Measuring changes in internal meat colour, colour lightness and colour opacity as predictors of cooking time

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Abstract: **Consumers and cooks often assess the degree of doneness of roasted beef by the internal meat colour. The aim of this experiment is therefore to develop real-time colour measurement of the cooking process in order to determine the degree of doneness, and thus the end of the cooking process, by the change in internal meat colour. The experiments were conducted with pieces of *bovine longissimus dorsi.* The meat was cooked in dry heat in an oven used in private households. Oven temperature and internal meat temperature were measured by thermocouples. The design of experiments (DoE) method 'Box Behnken' was used to determine various oven temperatures (100 °C, 140 °C, 180°C) and end temperatures (55 °C, 65 °C, 75 °C) and to ensure the reproducibility of the experiments. The change in internal meat colour was measured with a true colour sensor. The colour values (*X, Y, Z*) provided by the true colour sensor show significant variation within initial values and end values. Change in colour lightness caused by the increase of meat colour opacity is dominant. Calculating the first deviation of the *Y* values (*dY/dt*) indicates that most rapid changes in lightness occur within a temperature range of 42 °C and 56 °C. The results show that changes in colour lightness can be used to predict the remaining cooking time when beef is roasted to different end temperatures.**

Keywords: **meat colour, real-time measurement, household technology**

I. INTRODUCTION

Whole pieces of roast beef are traditionally served at different degrees of doneness depending on consumers' preference.

As the meat colour change caused by heat treatment is easily visible to the human eye, consumers tend to assess the degree of doneness by the colour of the meat [1]. This method might be considered to be unsafe in terms of food safety because meat colour is affected by several factors other than temperature [2]. However as the bacterial contamination of whole pieces of red meat, e.g. steaks or chops, is restricted to the external surfaces, steaks roasted to a rare or medium degree of doneness can be eaten with safety [3].

There are several methods of measuring meat colour, e.g. computer vision [4], or reflection based fibre measurement [5]. While the real-time measurement of internal meat temperature by thermocouples was successfully developed many years ago and has been state-of-the-art ever since, the real-time measurement of internal meat colour is still in the early stages of development.

The aim of this experiment is therefore to develop real-time colour measurement of the cooking process in order to determine the degree of doneness, and thus the end of the cooking process, by the change of the internal meat colour [6].

II. MATERIALS AND METHODS

The experiments were conducted with pieces of *bovine longissimus dorsi*. The meat was roasted in dry air in an oven commonly used in private households. The change of the internal meat colour was measured with a true colour sensor. The *X* (red), *Y* (green, lightness) and *Z* (blue) colour values provided by the true colour sensor were converted to the $L^*a^*b^*$ colour space. In order to reduce the number of experiments while maximising the information obtained, the design of experiments (DoE) method was used. The Box-Behnken design - considering 3 factors on 3 levels (meat weight: 750 g, 1000 g, 1250 g; oven temperature: 100 °C, 140 °C, 180 °C; meat centre point temperature: 55 °C, 65 °C, 75 °C) - was chosen and the reproducibility of the experiments was ensured by nine centre point experiments with roasts of 1000 g each, 65 °C meat centre point temperature and 140 °C oven temperature.

III. RESULTS

The result shown in the presentation focuses on the real-time measurement of the meat colour. The absolute colour values (*X*, *Y*, *Z*) provided by the true colour sensor show significant variation within initial values and end values and could thus not be used for determination of the degree of doneness. Converting the *XYZ* values to $L^*a^*b^*$ values shows that change in lightness L^* is dominant. Calculating the first deviation of the *Y* values (*dY/dt)* indicates that most rapid changes in lightness are within a temperature range of 42 °C and 56 °C. At this temperature, the degree of meat doneness is still assumed to be rare, but the prediction of how long it will last from this point until the desired end temperature is reached delivers promising results.

IV. CONCLUSION

The aim of the experiments described above was to predict the degree of doneness of roasted beef by looking at the change in internal meat colour. Although the measurement of the true meat colour failed, it can be said that changes in meat colour lightness are useful for determining the remaining cooking time when beef is roasted to different end temperatures by using different oven temperatures.

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