OPTIMUM PROCESS CONDITIONS FOR SINGLE-SIDED PAN-FRYING OF HAMBURGERS FOR SAFETY

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Background

Hamburger (meat patty) is one of the most popular foods in North America and also spread all over the world. However, such a simple food has ever led to numerous foodborne diseases. Hamburger disease is caused by *E. coli* O157:H7. FDA has recommended a minimum target cooking temperature of 68.3ºC with 16 s holding, for foodservice operations to enhance food safety (FDA 1999). However, it is difficult to implement these standards in a restaurant or at home due to the complexities and accuracy in measuring the internal temperatures, and the non-homogenous composition of the patties.

Objectives

To improve the quality of cooked patties while ensuring food safety, it is necessary to systematically study the influences of different cooking conditions, and optimize the single-sided pan-frying with turnings for frozen and unfrozen patties.

Modelling

During recent years, several models of patty cooking have been proposed (Ikediala *et al*. 1996; Chen *et al*., 1999; Zorrilla and Singh 2003; Pan *et al*. 2000). To develop the models, for pan-frying, heat was considered to be transferred to the patty surface by convection and conduction from the hot plate, and through the patty by conduction. Moisture and fat transfers were assumed to be due to the capillary flow due to patty shrinkage and pressure increase at increased temperature. The predicted temperature at each node in the patty was used to calculate the destruction or survival rate of microorganisms. The destruction rate of microorganism was represented by first-order kinetics and the decimal reduction time differential equation model. The simulation program was written in MATLAB-simulink and executed on a PC.

Materials and methods

The patties were bought as a batch. The frozen patties were individually packed in plastic bags to prevent moisture loss, and stored in a freezer at -8°C. To obtain unfrozen patties, the stored patties were thawed at a 4°C overnight. Patties were pan-fried using a combo health grill. A proportional controller through a solid state relay controlled frying temperature. Frying time was up to 10 min depending on patty initial temperature and pan temperature. For unfrozen patty, the first flipping (turning) was after 120 s, the second at 240 s and the third at 360 s with total time of 480 s. For frozen patty, these times were 240 s, 360 s, 480 s and 600 s, respectively. Water content was measured using AOAC (1984) method #24.002 with four replications. Fat content was measured using AOAC (1984) method #24.005, i.e. Soxhlet method. The temperature histories at the pan surface, and geometric centre and top and bottom layers of the selected patties were measured using high temperature rated copper-constantan thermocouple probes with diameter of 0.25 mm.

Results and discussion

<u>Experimental validations:</u> Predicted and experimental beef patty temperatures at 3 locations in a patty were compared (Fig. 1) and agreement is good. The temperature of the patty bottom rises quickly at early stage. The prediction errors for the bottom, centre, and top temperatures range from 2.33ºC to 5.28ºC. The errors for centre temperature predictions are smaller than those for bottom and top temperature predictions. Good

fit between the measured and predicted moisture contents (r^2 = 0.986, slope = 0.915, and intercept = 0.026 for the linear trendline) was observed. The root mean squared errors (*RMSE*) between experimental and predicted data were calculated. The prediction errors of average moisture contents for frozen and unfrozen patties were 0.1032 d.b. and 0.1695 d.b respectively. Good fit between the measured and predicted fat contents (r^2 = 0.989, slope = 1.023, and intercept = -0.029 for the linear trendline) was also observed. The fat content had a tendency to converge at equilibrium fat content gradually when increasing the cooking time or heating temperature. *RMSE* of fat contents for two cookings were 0.0778 and 0.0638 d.b.

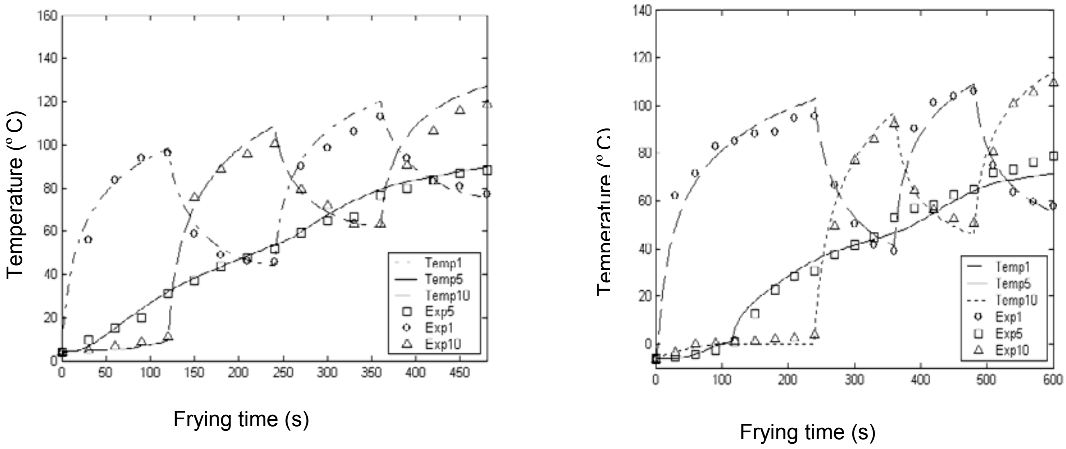


Fig. 1 Temperatures for unfrozen (left) and frozen (right) patties with overturned 3 times at 160°C pan temperature (Temp1, 5 and 10 are predicted temperatures of node1, 5 and 10, respectively. Exp1, 5 and 10 are measured temperatures of these nodes)

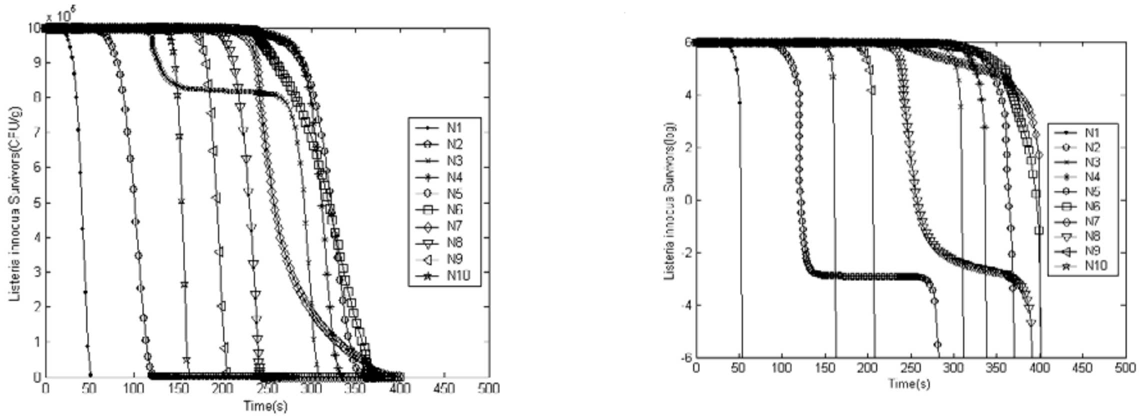
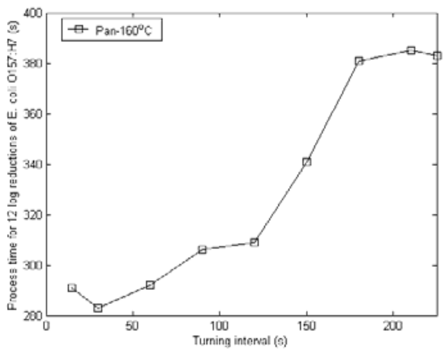


Fig. 2 Predicted *Listeria innocua* inactivation at different locations during pan-frying for frozen (left) and unfrozen (right) patties

<u>Effect of different turning intervals:</u> The results show significant differences from 0.25 min to 3.75 min of turning intervals (Fig. 3). The maximum difference of process time was up to 102 s. When increasing the length of each interval, the time showed an ascending tendency and leveled off at about 3.5 min. The minimum time was 283 s at a turning interval of 0.5 min. Compared to the time at 1 min intervals, the difference was just 9 s. If the turning interval is too large, it could result in quality deterioration of the patty. Thus, for unfrozen patties, 1 min turning interval may be more practical.

<u>Effect of initial temperatures (Tpi) of the patty:</u> With increasing Tpi, the process time is reduced at a constant heating temperature (Fig. 4). When frying frozen patties, process time decreased slowly with the increase in Tpi at 160°C and 180°C pan temperatures. At 140°C pan temperature, the process time reduced faster. When the patties were thawed before frying (Tpi = 0 to 20°C), the time reduced gradually with the increase in Tpi. The process time for the unfrozen patty is considerably less than that for the frozen. At Tpi -20°C, the process time for 140°C pan temperature was almost twice as long than that for 180°C pan temperature.

<u>Effect of patty thickness (Xpi):</u> More time is needed to complete 12 log reductions of *E. coli* O157:H7 when increasing the Xpi. With decrease in the Xpi from 11 mm to 8 mm, the process time reduced considerably. At pan temperature of 140°C, the process time for an 11 mm thick patty was >3 times longer than that for 8 mm Xpi. A higher turn-over frequency is a means to reduce the process time for thicker patties. At 140°C and 160°C pan temperatures, increasing the number of overturns from 3 to 5 reduced the required process time by 1102 s and 200 s, respectively. At 180°C pan temperature, basically there was no difference between the process times for 3 and 5 overturns. This suggests that for low pan temperatures, increasing overturns effectively reduces the process time.



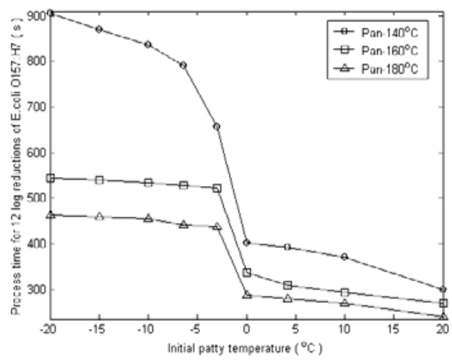
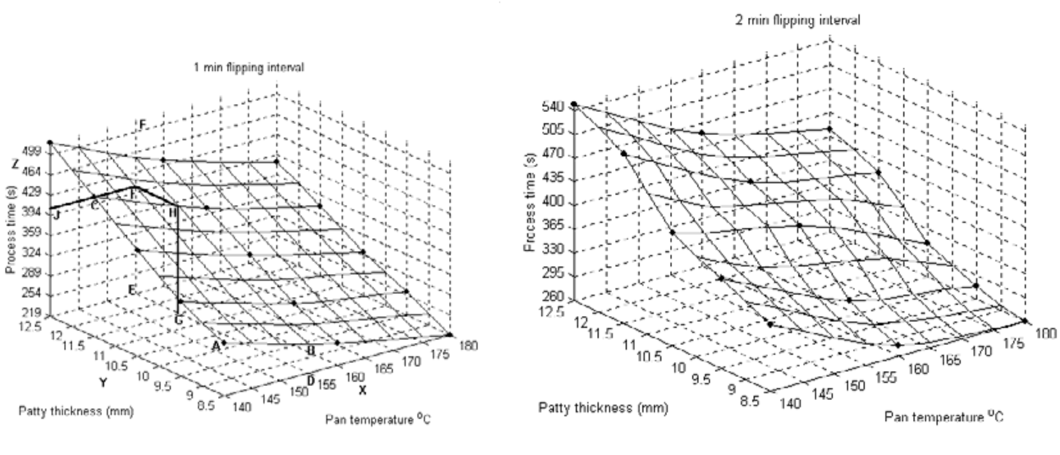


Fig. 3 Effect of different turning intervals on process time for 12 log inactivations of *E. coli* O157:H7 at 160°C pan temperature for (Tpi = 4.2°C) single-sided pan-frying

Fig. 4 (right) Process time at various initial patty temperatures and pan temperatures for with 3 overturns (Tpi < 0°C)

<u>Effect of Various D Values of *E. coli* O157:H7:</u> The heat resistance for each bacterium is affected by intrinsic and extrinsic factors, such as meat species, muscle types, product formulations, and other factors (Murphy *et al*., 2002). Increasing the fat content of hamburger increased the D values of microorganisms. More time was needed when increasing the D value of *E. coli* O157:H7. At 160°C and 180°C pan temperatures, the process time increased very slowly with increase in D. When comparing the results at 140°C pan temperature, the difference of the process time was considerable (182 s) with D value from 4840 s to 6280 s. Thus, a small variation of D value of *E. coli* O157:H7 has less effect on the process time at higher heating temperatures.

<u>Three-dimensional plots for the process time:</u> The three-dimensional plots present the relationship of pan temperature, patty size (thickness), and the process time for 12 log reductions of *E. coli* O157:H7 (Fig. 5).



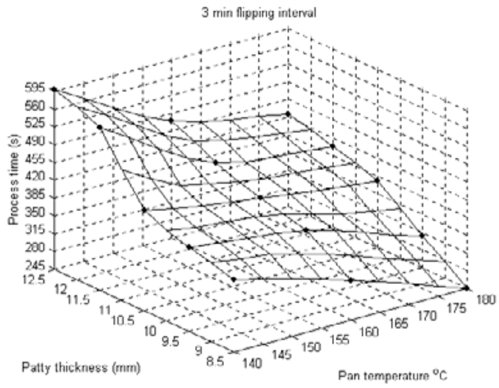


Fig. 5 Three-dimensional plots for single-sided pan-frying to determine process time

Conclusions

Good agreements were obtained between observed and simulated temperature profiles, and moisture and fat losses. The increase in heating temperature and initial patty temperature resulted in an increased patty centre temperature and higher rates of moisture and fat losses, but decreased the process time for 12 log reductions of *E. coli* O157:H7. The optimal turning interval of 1 min at 160ºC pan temperature was obtained. The process time for the unfrozen patty is considerably lower than that for the frozen to overcome the latent heat of fusion. With decrease in the patty thickness or increasing the number of overturns, the process time decreased considerably. A small variation of D value had less effect on process time at higher heating temperatures, but had significant difference for lower heating temperatures.

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