Colour Kinetics during Cooking of Pork and Beef Muscle.

T.K.C. Hay[1], M.C. Lanari[1], N. Amos[2], B. D'Arcy[3] and D. Gutzke[1]

[1]Food Science Australia, Brisbane Laboratory, Qld., 4173. [2]Food Science Australia, Sydney Laboratory, NSW, 2113.

[3]School of Land and Food, University of Queensland, Gatton College, Gatton, Qld., 4345.

BACKGROUND

The internal colour of cooked meat is used as an indicator of degree of doneness and wholesomeness. Internal temperature affects tenderness, juiciness and flavour as well as colour. Therefore, factors like pH, myoglobin concentration and muscle type, which affect the relationship between colour and internal temperature, will influence the sensory characteristics of the final product. Different muscle types (predominantly red or white fibred) can unsuspectingly be over- or under-cooked, leading to palatability and food safety problems, respectively. To ensure that meat is cooked to the consumer's expectations, a means for predicting internal colour and the factors that affect it needs to be developed.

OBJECTIVE

To develop a kinetic model which describes the variations of internal colour during cooking of different pork and beef muscles.

METHODS

Ten longissimus lumborum (LL) (pH 5.6±0.1) from 5 grass fed yearling bovine carcasses and ten LL (pH 5.5±0.2) and 20 knuckles (K) (vastus lateralis and rectus femoris) (pH 6.0 ± 0.4) from 10 young porcine carcasses were obtained from a local abattoir.

Muscles were cored (3.5 cm diameter and 2.5 cm thick); samples were placed into plastic bags and cooked at 65 °C for different time periods. Internal temperature was recorded with copper/constantan thermocouples inserted into the geometric centre of the core. Following cooking, samples were cut through the center parallel to the flat surface. After 1 minute, the internal colour (CIE L*a*b*) was determined with a Minolta CR-200 chromameter. Meat colour was expressed by its redness (a*) and hue angle (HA), HA = arctan (b*/a*). An increase in HA indicates a loss of redness.

The reflectance spectra of the samples were recorded (450-750 nm) using a Cary 3E UV/visible spectrophotometer.

RESULTS AND DISCUSSION

Figures 1 and 2 show the variations in a* and HA during cooking, for the different muscles and species studied. Variations of a* with cooking time presented a well defined maximum at $t = t_s$, followed by a slow decline. This could be attributed to variations in the balance between the red and brown pigments of cooked meat. When cooked meat is cut and exposed to air, the purple deoxymyoglobin (deoxyMb) will oxygenate and form the bright red oxymyoglobin (oxyMb) in a fast reaction known as 'blooming'. For times $< t_s$, the concentration of red oxyMb will be higher than that of the brown pigment, resulting in an increase in redness (higher a*). At times $> t_s$, the level of the brown pigment will be higher than that of oxyMb, and a* will decline.

Oxygenation of deoxyMb was confirmed by analysing the reflectance spectra (450-750 nm) of meat samples cooked for time periods between 0 and 35 min. The reflectance spectra of beef LL for various cooking periods (Figure 3) clearly shows the loss of the reflectance band at 555 nm and the appearance of two new bands at 542 nm and 578 nm, due to the conversion of deoxyMb to oxyMb (Swatland 1989). Similar bands were present in the spectra of pork muscles (data not shown). Beef LL and pork K presented a larger increment in a* during blooming than pork LL. This may be due to the difference in pigment concentration. Myoglobin contents of the muscles were 5.61, 4.10 and 1.50 mg/g myoglobin for beef LL, pork K and pork LL respectively. The low myoglobin content of pork LL compared to K and beef LL, may hinder oxyMb detection. Miller (1994) reported that the formation of oxyMb in pork LL was much slower and less extensive than in beef LL.

The oxygenation of deoxyMb follows a first order kinetics (Lanari and Zaritzky 1988). Ateba and Mittal (1994) demonstrated that the changes in surface colour of meatballs during frying followed a similar pattern. Considering this, the following segmented model was developed to describe this system:

for $t < t_s$ $\delta C/\delta t = k * e^{(-\Delta H/RgT)} * C$ (1)

for $t > t_s$ $\delta C/\delta t = k' * e^{(-\Delta H'/RgT)} * C$ (2)

where t = time and t_s = time where a* is maximum and equation (1) = equation (2); C = a* or b*, k and k' = frequency factor (sec^{-1}), ΔH and $\Delta H'$ = activation energy (kJ mol^{-1}), T = absolute temperature (K) and R_g = universal gas constant (kJ K^{-1} mol^{-1}).

Numerical methods were used to solve equations (1) and (2); calculated values for t_s, $\Delta H'$ and k' and are shown in Table 1. From the predicted a* and b*, HA values were calculated (Figure 2). The segmented model satisfactorily fit the experimental data. The correlation coefficients (R^2) between predicted and observed a*, b* and HA values ranged from 0.97 to 0.99 for beef LL, 0.90 to 0.98 for pork K and 0.97 for pork LL .

Calculated activation energies ($\Delta H'$) of pork muscles were higher than those of beef, which suggests that the formation of cooked colour in pork muscles is more sensitive to temperature.

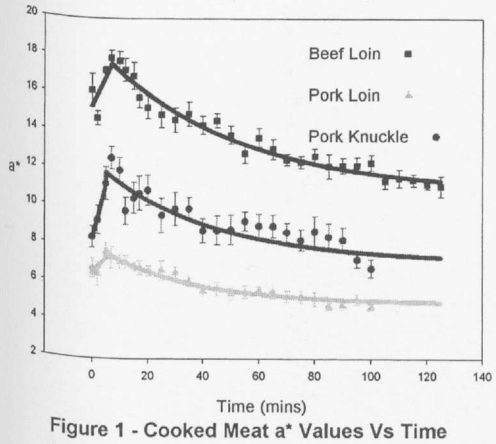

Figure 1 - Cooked Meat a* Values Vs Time

(solid lines represent a* values predicted by the model)

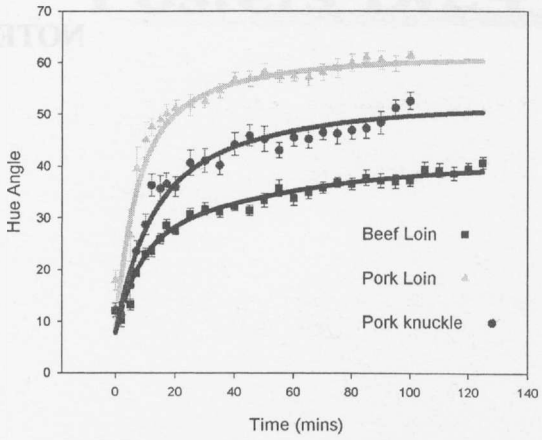

Figure 2 - Cooked Meat Hue Angle Vs Time

(solid lines represent hue angle (HA) values predicted by the model)

Table 1 – Summary of muscle colour kinetics during cooking.

Muscle		*t_s (mins)*	*R^2*	*Activation energy $\Delta H'$ ($kJ\ mol^{-1}$)*	*Frequency factor $k' \times 10^{-4}$ (sec^{-1})*
Beef LL	a*	7.00	0.98	128.14	3.60
	b*		0.97	144.73	21.00
Pork K	a*	5.78	0.90	149.65	4.30
	b*		0.97	149.44	15.64
Pork LL	a*	5.00	0.97	157.30	5.35
	b*		0.97	155.83	19.50

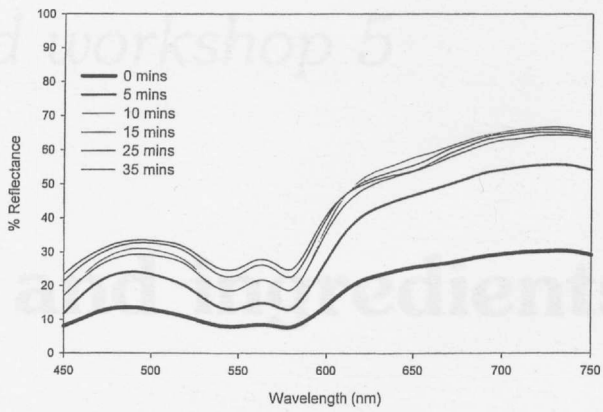

Figure 3 - Beef Loin Reflectance Spectra during Cooking

CONCLUSIONS

The variations of internal colour during cooking were successfully described using first order kinetic equations. Comparison between predicted and observed data showed good agreement.

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NOTES