Prediction of acid induced pH-decrease in meat.

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Background

The pH is of fundamental importance for the properties of meat. It affects, among other things, meat tenderness, juiciness, water holding capacity and the interaction of meat with salt (Hamm, 1972; Offer & Knight, 1988). Meat has a large buffering capacity, i.e. in order to lower the pH of meat it is necessary to supply a large number of protons (Bendall, 1979; Rao & Gault 1989). The majority of the added protons bind to various meat components, e.g. proteins, and consequently reduces the obtained pH decrease. It has been demonstrated that acids differ markedly in their ability to lower the pH of meat (Gault, 1991). As far as we are aware, no attempt has been made to quantitatively predict the experimental observations. Presumably this is due to the chemical complexity of meat.

Objectives

To theoretically predict the acid induced pH decrease in meat.

Method

To minimise diffusion barriers, homogenised meat were used in a titration experiment. 30 grams of deionized water was added to 5 grams of finely comminuted meat from beef *M. semitendinosus*. The pH of the solution was recorded as a function of the added acid. Only one titration experiment was done for each acid.

Theory

We consider the dissociation of an acid HA with the acid constant K_a

$$HA \iff H^+ + A^-, \qquad K_a = [H^+][A^-]/[HA]. \tag{1}$$

As already mentioned, some of the protons released by the acid bind to the meat components. We therefore introduce the notations free and bound protons, H^+_F and H^+_B, respectively. As only acidic solutions are considered, the anion concentration is approximated as

$$[A^-] = [H^+_F] + [H^+_B]. \tag{2}$$

The total acid concentration, C_{HA}, is then given by

$$C_{HA} = [HA] + [A^-]. \tag{3}$$

Using (2) and (3), the acid constant may be written as

$$K_a = [H^+_F]\,([H^+_F] + [H^+_B])\,/\,(C_{HA} - [H^+_F] - [H^+_B]). \tag{4}$$

The concentration of bound protons is determined by titrating the meat homogenate with hydrochloric acid, which is fully dissociated, and using the relation

$$[H^+_B] = C_{HCl} - [H^+_F] = C_{HCl} + {}^{10}\log[H^+_F]. \tag{5}$$

For practical reasons we introduce the notations C^{add}_{HA}, n_B, V_o och V_{add} to denote the molar concentration of the added acid, the molar amount of protons bound to the meat, the total sample volume at the beginning of the titration and the volume of acid added to the sample respectively. Thus,

$$C_{HA} = C^{add}_{HA}\,V_{add}\,/\,(V_o + V_{add}) \tag{6}$$

and

$$n_B = [H_B]\,(V_o + V_{add}). \tag{7}$$

Equation (4) may now be rewritten as

$$K_a = 10^{-pH}\,(10^{-pH} + n_B/(V_o + V_{add}))\,/\,(C^{add}_{HA}V_{add}/(V_o + V_{add}) - 10^{-pH} - n_B/(V_o + V_{add})). \tag{8}$$

By rearranging the last equation, the volume of a given acid necessary to achieve a particular pH in the meat is obtained as

$$V_{add} = (n_B + 10^{-pH}\,V_o)\,(1 + 10^{pKa-pH})\,/\,(C_{HA} - 10^{-pH}(1 + 10^{pKa-pH})) \approx n_B\,(1 + 10^{pKa-pH})\,/\,C^{add}_{HA}, \tag{9}$$

where in the last step advantage has been taken of the fact that, in practice, the amount of bound protons will be much larger than the amount of free protons. In order to compare the predictions of equation (9) with experiments, meat was titrated with three acids, phosphoric acid (pK_a=2.12), lactic acid (pK_a = 3.86) and acetic acid (pK_a = 4.76).

Results and discussions
The titration with 0.1 M hydrochloric acid, which gives the amount of protons bound by the meat as a function of pH, is given in figure 1. Theoretical predictions and experimental results for the titration with 0.1 M phosphoric acid, 0.2 M lactic acid and 0.2 M acetic acid is shown in figures 2, 3 and 4 respectively. In all cases equation (9) surprisingly well predicts the acid induced pH-decrease. There is a strong similarity between the titration results obtained with hydrochloric acid and phosphoric acid. This is a consequence of the phosphoric acid being almost completely dissociated over the measured pH range. About twice as much of the more concentrated but weaker lactic acid is needed in order to obtain a pH around 3. Thus, the lactic acid is only partially dissociated. On the contrary, at the beginning of the titration, where the lactic acid is fully dissociated, about half as much of the lactic acid as of the hydrochloric acid solution is needed to obtain a given pH-decrease. The case is even more pronounced for titration with 0.2 M acetic acid, which is partially dissociated already at the beginning of the titration. About ten times more of the acetic acid than of the hydrochloric acid solution is necessary to obtain a pH around 3.5. The present results shows that equation (9) surprisingly well predicts the acid induced pH-decrease in meat. We emphasise that the theoretically predicted numbers are based on the amount of bound protons. An error in the hydrochloride acid titration therefore effects all the theoretical results. We also point out that further work is necessary in order to determine the reproducibility of the experimental results.

Conclusions
We have presented an equation that predicts the pH- decrease in meat as a function of the added amount of acid. The predicted pH-decrease depends on the buffering capacity of the meat, the amount of added acid and the acid constant. In spite of the chemical complexity of meat, a remarkable agreement with experiments is found.

References

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Hamm, R. (1972) *Kolloidchemie des Fleishes*, Verlag Paul Parey.
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Rao, M. V. & Gault, N. F. S. (1989) *Meat Science*, **26**, 5.

Figure 1. Titration of meat homogenate with 0.1 M hydrochloric acid.

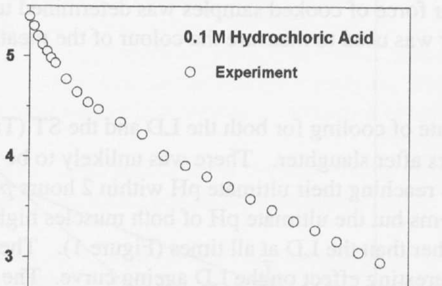

Figure 2. Titration of meat homogenate with 0.1 M phosphoric aicd. (o) Experiment and (•) Theory.

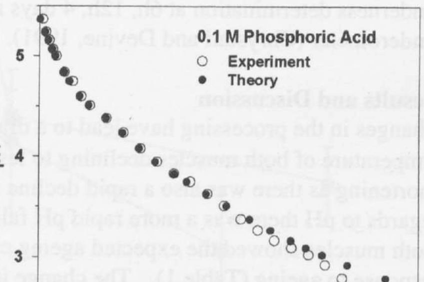

Figure 3. Titration of meat homogenate with 0.2 M lactic acid: (o) Experiment and (•) Theory.

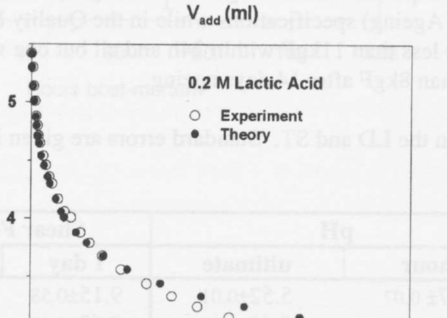

Figure 4. Titration of meat homogenate with 0.2 M acetic acid. (o) Experiment and (•) Theory.