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Predicting the pH of acid marinated meat.

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Background

pH has a great influence on the properties of meat. Among other things, it influences the water holding capacity, tenderness, juiciness and colour (Hamm, 1972; Offer and Knight, 1988; Gault, 1991). One way of changing the properties of meat is lowereing the pH by means of acid marination. The actual pH after marination may be of crucial importance. For instance, if the pH is lowered insufficiently, the result may be a less tender meat with a decreased water holding capacity. On the other hand too large a decrease in pH may cause unpleasant taste characteristics. Thus, it is important to understand the principles that govern the pH of acid marinated meat.

Objectives

To predict the pH of meat marinated using various amounts and concentrations of acids. The predicted numbers are compared with experimental results for marination using acetic acid.

Method

Slices 5 mm thick of beef *semitendinosus* were marinated in acetic acid. Two concentrations of acetic acid were investigated, 0.017 M (0.1 %) and 0.042 M (0.25 %). The weight of the marinade divided by the weight of the meat was taken as 1, 3, 10 and 30 respectively. After 24 hours of marination, the pH of the marinade was constant. The pH of the thin meat slices was then considered to be the same as that of the marinade.

Theory

We have previously derived an equation that predicts the pH-decrease in muscle homogenate upon titration using an acid (Svensson & Tornberg, 1998). For the present purpose, we rewrite the equation to obtain the pH of the meat and marinade at equilibrium as

$$C\,R \approx (1+10^{pKa-pH})\,\rho\,N_b(pH) \qquad (1)$$

where C is the molar concentration of the acid, R is the weight of the marinade divided by the weight of the meat, K_a is the acid constant and ρ is the density of the marinade, which as a good approximation may be taken to be that of water. The function $N_b(pH)$ times the weight of the meat equals the molar amount of protons bound by the meat as the pH is lowered from that of the unmarinated reference. N_b may be obtained by titratiting meat homogenate using a strong acid like HCl, see Figure 1 (Svensson & Tornberg, 1998).

It is worthwhile to consider the predictions of equation (1) in some detail. For a given acid, roughly the same pH is obtained as long as the product of C and R is constant. Another important situation is when the acid may be considered to be fully deprotonated at the equilibrium pH, that is when $10^{pKa-pH} << 1$. In this particular case, the pH becomes independent of the acid constant.

Results and Discussion

The predicted pH obtained by marinating beef *semitendinosus* using various amounts and concentrations of acetic acid (pKa = 4.76), lactic acid (pKa = 3.86) and phosphorous acid (pKa = 2.12) is shown in Figure 2. Note the logarithmic scale on the abscissa. The predicted pH at small C*R is similar for the three acids. The differences in pH obtained using the different acids increase with C*R. The result of a strong acid would, in Figure 2, overlap the results for phosphorous acid.

Table 1 shows the predicted and experimental results for marination using different concentrations and amounts of acetic acid. Agreement between theory and experiment is striking. Although the present study is limited, it indicates that the approximations behind equation (1) are reasonable. A few additional points deserve to be mentioned. The experimental results are only preliminary. Any error in the experimentally determined function N_b will influence the predicted numbers. Both the titration and the marination experiments have to be repeated in order to determine the statistical significance of the results. The function N_b, will to some extent, vary between different muscles (Gault, 1991). In addition different muscles will have different ultimate pH. Nevertheless, Figure 2, is still expected to be useful as a rough prediction of the acid marination of different muscles.

The present study is based on thin slices of meat. This minimizes diffusion barriers which markedly slow down the equilibration of protons. For thick pieces of meat, appreciable proton gradients may remain after marination (Seuss & Martin,1993). In such cases, equation (1) is of limited value.

Conclusions

We have shown an equation that predicts the decrease in the pH of meat induced by acid marination. The predicted pH after acid marination is dependent on the product of the molar concentration of the acid and the ratio between the weight of the marinade and the weight of the meat, the acid constant and the buffering capacity of the meat. The predicted pH compares well with experimental results for marination using acetic acid.

References

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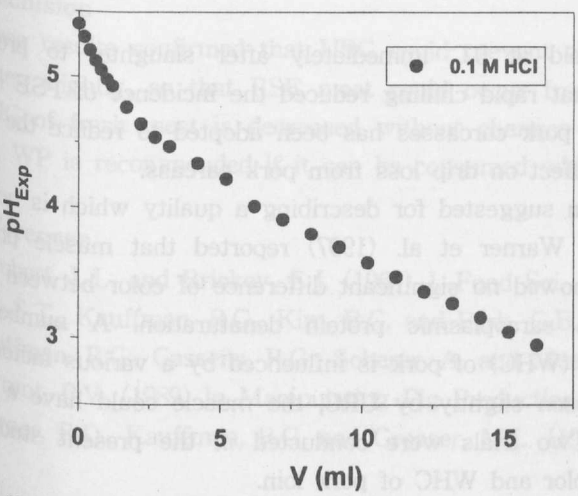

Figure 1. Titration of 5 g of meat homogenate using 0.1 M HCl (Svensson and Tornberg, 1998)

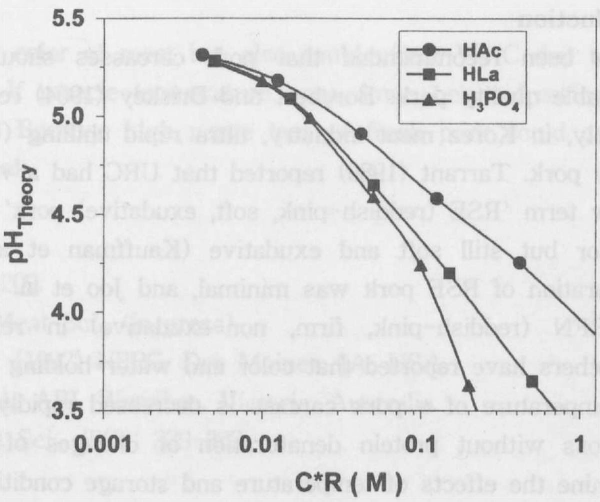

Figure 2. The predicted pH after marinating meat using various acids as a function of C*R.

Table 1. Theoretically predicted and experimentally observed pH after marinating 5 mm thick slices of meat with acetic acid at various concentrations, C, and ratios between weight of marinade and weight of meat, R.

C_{HAc} (M)	R	pH_{Theory}	pH_{Exp}	C_{HAc} (M)	R	pH_{Theory}	pH_{Exp}
0.017	1	5.22	5.13	0.042	1	4.99	4.91
0.017	3	4.89	4.87	0.042	3	4.60	4.58
0.017	10	4.47	4.49	0.042	10	4.17	4.25
0.017	30	4.11	4.21	0.042	30	3.81	3.88