MARINATION OF RAW PORCINE LONGISSIMUS MUSCLE - INFLUENCE ON MUSCLE FIBRE AREA AND WATER-HOLDING CAPACITY

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SUMMARY

It is well known that the pH of meat affects quality traits such as water-holding capacity, texture and tenderness. This knowledge is applied in sour marination, for example. One reason for marinating meat is to improve its tenderness and juiciness. Consequently tough meat of poor quality can be upgraded. The purpose of the present study was to ascertain how incubation buffers ranging from extremely low to high pH values affect the muscle fibre cross-sectional area and water-holding capacity of raw pork of normal quality, and also of meat cooked after marination. The results of this study clearly illustrate the importance of pH-value for swelling capacity and hence the water-holding capacity (WHC) of normal raw meat and of meat cooked after marination. In addition an increase in the mean fibre cross-sectional area was found in both raw and cooked meat, even though the effect of pH on cross-sectional area was less than on swelling, probably because in swelling, both longitudinal and radial changes in the fibre are included, whereas when measuring fibre cross-sectional area, only the radial change is taken into account.

Introduction

The pH of meat is of considerable consequence for meat quality traits such as water-holding capacity (WHC), texture and tenderness (Dutson, 1983). This knowledge is of practical use in marination. The term marinade means any liquid used to soften and flavour meats, and sour marination with organic acids such as acetic acid and lactic acid is common practice. In such marinades, water is absorbed and the cooked meat becomes more tender, especially meat containing large amounts of connective tissue (Wenham and Locker, 1976; Gault, 1984; Gault, 1985).

In Chinese cookery, the procedure of alkaline marination of meat is sometimes used to tenderize tough meat. The meat is marinated in a $NaHCO_3$ solution (Hsieh et al., 1980; Skurray et al., 1986). Hsieh et al., (1980) noted that in beef muscle marinated in 8% $NaHCO_3$, the myofibrils were obviously swollen, and no space was visivle between the myofibrils. The Chinese method can be compared to the traditional Swedish alkaline treatment of dry fish ('lutfisk') for which $Ca(OH)_2$ and Na_2CO_3 are used. The objective of the alkaline marination of meat and fish is to improve their tenderness and juiciness, thus allowing tough meat and poor quality meat and fish to be upgraded. It has been found in beef that both low and high muscle pH after marinating improved the texture, increased the WHC and moisture content, and reduced cooking losses (Oreskovich et al., 1992).

The aim of the present study was to investigate how incubation buffers, with pH values ranging from extremely low to high, affect muscle fibre cross-sectional area and water-holding capacity of raw pork of normal quality and also cooked meat after marination.

Material and Methods

Muscle samples: Muscle samples from the posterior part of porcine M. longissimus dorsi (LD), from 3 animals of normal slaughter weight, and normal ultimate pH (pH ≈ 5.5), were taken 2 days after slaughter. From each animal, seven 10 mm thick slices were then cut across the muscle fibre direction. From each slice, two discs 26 mm in diameter were prepared, using a punch. Incubation: The incubation buffers were made by mixing 66.7 mM KH_2PO_4 and 66.7 mM K_2HPO_4 in different proportions and adjusted with NaOH and HCl to cover the range pH 3 to pH 13. For each pH treatment two discs were weighed and placed in sealed plastic

cups to which 50 ml of incubation buffer was added. The cups were subjected to continuous swirling at 4 °C for 48 h. Control discs were incubated in buffers with the ultimate pH. Water-holding capacity and pH measurements: After incubation the discs were reweighed. To determine the pH in meat 2 g from each muscle disc was homogenized in 10 ml 0.15 M KCl. One disc from each pH treatment was individually cooked in a sealed plastic bag in a water bath at 80 °C for 20 min and immediately chilled in an ice-water bath. The discs were then reweighed. As a measure of WHC in the muscles, swelling ratios were calculated according to Gault (1985) as Raw Meat Swelling ratio (RMS) and Cooked Meat Swelling ratio (CMS), both divided by the corresponding raw weight before incubation. Histochemical stainings: From each pH incubation both the raw and cooked samples were used for histochemical staining. From the centre of each disc, three pieces (2x3x5 mm) were cut perpendicular to the muscle fibre orientation. These pieces were fixed over-night (50% 150 mM saline, mM), 15% phosphate buffer with the same pH as during incubation, 10% glutaraldehyde and 25% water), and then rinsed in incubation buffer. Dehydration and infiltration with a resin (Historesin Basic Resin, LKB, Sweden) was done according to Ridderstråle et al. (1976). Transverse sections (3 μm) were stained for reticular fibres (Gridley's ammoniacal silver nitrate method, Sorvall microtomes, 1979), and mounted with Eukitt. Measurements of the mean muscle fibre cross-sectional areas on photographs were performed on 25 fibres per pH treatment (MOP-Digiplan, Konstron Messgeräte Gmbh, Germany). Statistical analyses: Linear correlation coefficients were calculated with the CORR procedure (SAS Institute Inc., 1989). Principal component analysis (PCA) was performed using the SIRIUS 3.0 package (Pattern Recognition System A/S, N-5015 Bergen, Norway, 1991) after the variables had been standardized to mean=0 and σ^2=1.

Results and Discussion

The effects of marination with different pH-values on the swelling ratios (raw and cooked) are shown in Fig. 1. These results clearly illustrate the importance of pH for the swelling capacity and hence the WHC of meat on both sides of the isoelectric point of the myofibrillar proteins. This is consistent with results from a study with freshly excised muscles from frog treated with HCl or NaOH. A maximum swelling of about 3.5-fold at pH 2.6 and about threefold at a pH of 11.8 was seen (Jordan-Lloyd, 1916, 1932, cited by Offer and Knight, 1988). The non-linear relationships has also been found in beef muscle (Oreskovich et al.; 1992). Gault (1985) studied the relationship between WHC and cooked meat tenderness in post-rigor beef muscles below their normal ultimate pH. He found that a gradual decrease in muscle pH below the isoelectric point of the myofibrillar proteins, caused a gradual increase in the WHC of the meat by water absorption. The pH values ranging from 3.0 to 5.5 affected the extent of water absorption by cooked meat and also its tenderness. In the present study an increase in muscle fibre cross-sectional area was also observed in both raw and cooked muscle (Fig. 2). This is in agreement with other findings where swelling associated with both increasing and decreasing pH has been reported as a result of swelling of the myofibrils (Penny et al., 1963; Offer & Trinick, 1983). It was also suggested, by Gault (1985), that although the swelling observed in meat at these lower pH values was due primarily to myofibrillar swelling across the muscle fibre axis, the contribution of collagen swelling and myofibrillar swelling along the muscle fibre axis might also account for the anisotropic swelling which was observed with decreasing pH. This tallies with the present findings, where the effect of the pH was greater on the swelling than on the fibre cross-sectional area (Table 2).

A deviation between pH in the incubation buffers and pH of the meat following incubation is evident in Fig. 3, thus revealing the buffer capacity of the muscle. This high buffering capacity of porcine longissimus dorsi muscle, a muscle with a large proportion of glycolytic IIB fibres (Karlsson et al., 1993), is in agreement with Rao and Gault (1989) who compared buffering capacity and fibre type proportions in twelve bovine muscles. They concluded that there exists a positive relationship between the buffering capacity of a muscle and the proportion of IIB fibres. One reason for this high buffering capacity of glycolytic muscles is the dipeptides anserine and carnosine.

The use of the multivariate technique principal component analysis (PCA) is one way to simultaneously study a correlation structure of meat quality traits (Karlsson, 1992). The variable loadings on the first PC can be interpreted as a measure of the relationships between the variables, and can thus be seen as non-linear correlations (Tables 2, 3). The lower loadings for the raw and cooked fibre cross-sectional areas compared with the swelling ratios show that the marination effect of the pH has a greater influence on the swelling, which includes both longitudinal and radial changes in the fibre, whereas the measure of the fibre cross-sectional area only includes the radial change in the fibre.

Whether or not a muscle with deviating meat quality, such as PSE (pale, soft, exudative) when the muscle proteins are partially denatured, is also able to swell when treated in marinades of low and high pH as meat of normal quality does, remains to be studied.

Conclusion

The results from this study clearly illustrate the importance of the pH-value for the swelling capacity and hence the WHC of raw meat of normal quality and in meat cooked after marination. In addition, an increase in the mean fibre cross-sectional area was found in both raw and cooked meat.

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