How pH Affects Processed Meats

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Introduction

1. How does the pH of meat ingredients impact water-holding capacity in processed meats?
2. How does the pH of meat affect myoglobin and lipid oxidation in processed meat products?

pH and Water-Holding Capacity

The overall negative charge of myofibrillar proteins (myosin & actin = 45 % by weight) within the sarcomere is positively correlated with water-holding capacity, product yields, and meat quality. Since the overall negative charge increases as pH increases, the pH at 24 h postmortem (pHu) is an indicator for water-holding capacity and yields. This is assuming that there was a normal rate of pH decline as muscle was converted to meat (i.e. no pale, soft, and exudative meat or dark, firm, and dry meat). The overall negative charge causes protein repulsion, which provides more space for water to reside as well as increased ionic bonding between amino acid side chains and water.

Sarcomeres from pork meat are presented in Figure 1. The top sarcomere (Fig. 1a) represents a pH of approximately 5.3, which is just above the isoelectric point of actin and myosin (approximately 5.0). Therefore, the overall charge on the myofibrillar proteins is slightly negative but close to neutral. The isoelectric point for a protein is the pH in which 50 % of the charges are positive and 50 % are negative. It is the point with the lowest water-holding capacity since there is the least amount of space in the sarcomere, and the overall charge is neutral. The second sarcomere (Fig. 1b) is indicative of a pH of 5.8. The overall charge is negative, there is more space in the sarcomere, and the water-holding capacity is greater than the pork with a pH of 5.3. The third sarcomere (Fig. 1c) represents a pH of 6.3, which has a greater overall negative charge than pH levels of 5.3 and 5.8. This leads to increased water-holding capacity due to increased space in the sarcomere and increased ionic interactions. When making fresh sausage, a pH of 6.1 to 6.4 is recommended to improve water-holding capacity and maintain a longer lasting red color in the meat case. For processed meat products, such as deli ham and bologna, a pH of 6.1 to 6.4 is also optimal because it leads to increased yields and a firmer texture due to increased protein bind. Salt and phosphate function well in processed meat products, partially due to increased ionic strength, as both phosphate and the chlorine atoms in salt are negatively charged.

pH and Water-Holding Capacity

As pH drops from 7.0 to 5.0, there is a nearly linear increase in the rate of myoglobin oxidation across species such as bovine, sperm whale, and yellow-fin tuna (Brown and Mebine, 1969; Gotoh and Shikama, 1974, Figure 2). At higher pH levels, such as the 7.3 to 7.4 found in living muscle, myoglobin remains relatively stable. However, at lower pH levels, myoglobin becomes far more susceptible to oxidation. There are a few key mechanisms behind this phenomenon (Bekhit et al., 2018).

- Globin Protein Denaturation: Low pH denatures the globin portion of myoglobin, which usually protects the heme groups, leading to the dissociation of oxygen from the heme and the subsequent oxidation of the iron molecule.

- Oxymyoglobin Instability: The pigment responsible for meat's bright red color, oxymyoglobin, is less stable at low pH. For instance, its half-life at 25°C is 60 times shorter at pH 5.0 when compared to pH 9.0. In addition, metmyoglobin reductase is much more active at a pH between 6.0 to 6.4 than between 5.6 to 6.0, which maintains the oxymyoglobin state for a longer period of time.

- Protonation and ROS Formation: As pH decreases, bound oxygen is protonated more rapidly, generating reactive oxygen species (ROS) that accelerate the oxidation process.

- Iron-Catalyzed Oxidation: The oxidation process catalyzed by iron is highly pH-sensitive, with the greatest activity observed under acidic conditions.

pH and Lipid Oxidation

Lipid oxidation in muscle tissue is highly pH-dependent. Research indicates that the extent of lipid oxidation, as measured by the thiobarbituric acid reactive substances (TBARS) test, decreases as pH rises from 3.0 to 7.0 across various meats, including fish, turkey, chicken, pork, beef, and lamb (Tichivangana and Morrissey, 1985). This pH effect is largely due to its impact on the activity of pro-oxidants like Fe^{2+}, Cu^{2+}, Co^{2+}, and metmyoglobin.

Mitigating Oxidation in Sausages

In summary, increasing pH can improve the storage stability of comminuted and restructured meat products, such as sausages and deli meat. A higher pH results in reduced protein and lipid oxidation, leading to a fresher appearance, better flavor, and less rancidity. Phosphates and polyphosphates are often added to sausages to raise pH and inhibit lipid oxidation by chelating metal catalysts. Additionally, using pre-rigor meat (pH > 6.0) in sausage production is a viable option (Aberle et al., 2012), as it increases yields, meat quality, and extends shelf life.

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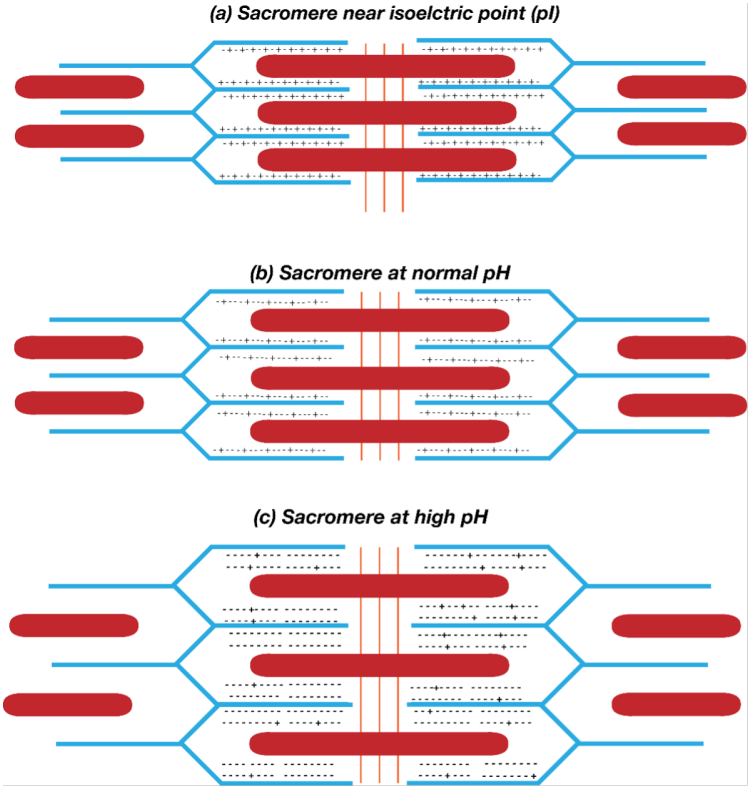

Fig. 1 The effect of pH on the electrostatic interaction between parallel actin and myosin filaments (Locker, 1959).

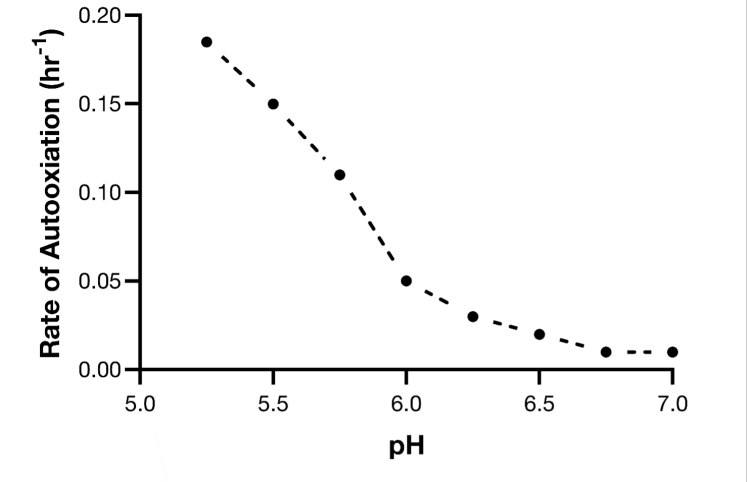

Fig. 2 The effect of pH on the autoxidation of bovine myoglobin (From Brown and Mebine, 1969).

References

Aberle, E.D., Forrest, J.C., Gerrard, D.E., Mills, E.W., 2012. Principles of Meat Science (5th Edition). Kendall Hunt, pp.124.

Bekhit, A.E.D.A., Morton, J.D., Bhat, Z.F. and Kong, L., 2019. Encyclopedia of Food Chemistry, 2, pp.202-210.

Brown, W.D. and Mebine, L.B., 1969. Journal of Biological Chemistry, 244(24), pp.6696-6701.

Gotoh, T. and Shikama, K., 1974. Archives of Biochemistry and Biophysics, 163(2), pp.476-481.

Locker, R. H. (1959). Journal of Biophysical and Biochemical Cytology, 6, 419–422.

Tichivangana, J.Z. and Morrissey, P.A., 1985. Irish Journal of Food Science and Technology, pp.99-106.

