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Role of pH and Muscle Temperature in Determining Meat Quality: A Comprehensive Analysis of Physical and Sensory Attributes"

Sheraz Zuher Karem [1], Fatima Abdulkaliq Noraldin [2], Darwin Hawar Mohammed[3]

[1,3]Food Technology Department, Agricultural Engineering Sciences College, University of Salahaddin, Erbil, Kurdistan Region, Iraq.

[2] Animal Resources Department, Agricultural Engineering Sciences College, University of Salahaddin, Erbil, Kurdistan Region, Iraq.

Sheraz.karem@su.edu.krd

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Abstract

The impact of pH value on important beef quality measures was explored in this research. The pH values of the fresh beef samples were categorized according to their range of 5.4 to 6.1, and the cattle were gathered from comparable breeds and ages. There were a minimum of five replicates in each group. Color (L* value), moisture retention, shear force (tenderness), and subjective assessment of taste, juiciness, and tenderness were used to evaluate meat quality, while a calibrated digital pH meter was used to determine the pH. The results demonstrated that meat quality parameters were better with higher pH levels. At pH 5.4–5.5, moisture retention was 82.3%; at pH 6.0–6.1, it rose to 90.5%; and at 28.7 N, shear force fell from 40.2 N, suggesting that the material was more delicate at higher pH. Meat became darker when the color brightness (L*) fell as the pH increased. The taste, juiciness, and tenderness ratings on the sensory panel all went higher as the pH went up; the group with a pH between 6.0 and 6.1 had the best marks. Although it results in darker meat, these data imply that a higher final pH improves water-holding capacity, softness, and sensory quality. The findings call for more study into the ways in which muscle temperature

and pH interact to impact beef quality, and they emphasize the significance of pH control during meat processing for optimal eating quality.

Key words: meat quality, broiler, pH-value, pre-rigor temperature, pH decline

Introduction

The most popular definition of quality, among many others, is: " What makes one unit of a product better than another is the total of its unique characteristics, which are crucial in determining the unit's level of customer acceptance (1). Conversely, "meat quality" is a phrase used by those involved in the meat business to describe the meat in general, including its physical, chemical, morphological, biochemical, biological, sensory, technical, sanitary, nutritional, and gastronomic attributes (2). Since mass-producing broilers is now a reality, efforts may shift to enhancing meat quality by modifying the aforementioned traits of fowl. Looks, feel, juiciness, wateriness, firmness, tenderness, aroma, and taste are the most important and noticeable aspects of meat that customers notice and evaluate before and after they buy it (3). In addition, processors making value-added meat products must achieve great physical properties that supply a high-quality and profitable end product (4). These properties include water holding capacity, shear force, drip loss, cook loss, pH, shelf life, collagen content, protein solubility, cohesiveness, and fat binding capacity. Poultry quality is evaluated using biochemical, physicochemical, and bacteriological data. In the immediate aftermath of slaughter, it is crucial to monitor physical characteristics such as conductivity, color, pH, and juice retention (5). The factors that affect the quality of chicken include hereditary traits, animal husbandry, nutrition, transit, slaughtering techniques, duration of storage, and temperature during storage. Analysis of postmortem glycolysis in muscle tissue determines if the meat has normal or pathological qualities. Pork (6) and fowl were the first subjects to be studied in this area between 1968 and 1971. Finding out how broiler breeding affects meat quality soon after slaughter was the driving force for our study. The amount of light reflected from the interior and exterior of the meat surface is affected by the degree of protein denaturation and the physical appearance of the meat, which is determined by postmortem temperature and pH (7). This is because light scattering is directly proportional to the level of protein denaturation. One byproduct of metabolic heat generation and energy metabolism in dead muscle is a drop in pH due to the buildup of H+ ions. The muscles of the carcass experience rigor mortis when blood flow stops and cold is applied; as a result, the temperature of the muscles lowers and the energy reserves diminish after death. The rates of energy metabolism, temperature decline, and pH decrease vary throughout the carcass, as reported by Jacob and Hopkins (2014), due to innate metabolic differences and muscle size. In terms of color, water-holding capacity (WHC), and tenderness, two of the most important post-mortem parameters influencing meat quality are the rates of pH decrease and temperature decline during rigor production (9). This study looked at the effects of a faster-than-usual drop in pH at a higher pre-rigor temperature on many aspects of meat quality, including its color, flavor, softness, and water holding capacity (WHC).

Material and methods

2.1 Sample Collection and Preparation

Fresh beef samples as in figure (1) were obtained from cattle of similar breed, age, and feeding background to minimize variability. Samples were collected within 24 hours postmortem and categorized into different groups based on their measured pH values ranging from 5.4 to 6.1. Each group contained at least 5 replicates to ensure statistical reliability (10).

Figure 1: Fresh beef sample

2.2 pH Measurement

The pH of each meat sample was measured using a calibrated digital pH meter (HI 99163, Hanna Instruments, USA) equipped with a penetration probe. Measurements were taken at three different locations on the muscle surface after 24 hours of chilling at 4°C, and the average pH value was recorded (11).

2.3 Meat Quality Assessment

2.3.1 Moisture Retention

Moisture retention was determined by calculating the percentage weight difference before and after a standardized cooking process. Samples were weighed prior to cooking and immediately after cooking to an internal temperature of 71°C as figure 1 using a calibrated thermocouple.

Figure 1: Cooked beef at 71°C

2.3.2 Shear Force Measurement

Tenderness was evaluated by Warner-Bratzler shear force (WBSF) analysis. After cooking and cooling to room temperature, six cores (1.27 cm diameter) were extracted parallel to the muscle fibers from each sample. Shear force was measured using a TA-XT Plus texture analyzer (Stable Micro Systems, UK) equipped with a Warner-Bratzler blade. The maximum force (N) required to shear each core was recorded, and the mean value was calculated (12).

2.3.3 Color Measurement

Surface color was measured using a Minolta Chroma Meter CR-400 (Konica Minolta, Japan) standardized with a white calibration plate. The CIE L* (lightness) values were recorded at three different points on the meat surface after 30 minutes of blooming at 4°C (13).

2.3.4 Statistical Analysis

All measurements were performed in triplicate. Data were expressed as mean ± standard deviation. Statistical differences between pH groups were analyzed using one-way ANOVA followed by Tukey's post hoc test, with significance set at $p < 0.05$.

Results and Discussion

Tenderness, color, water-holding capacity, juiciness, and shelf life are some of the meat quality traits that are impacted by pH. Water binding is more likely to occur in broiler breast meat that has a high pH compared to meat that has a lower pH. Broiler meat's pH is determined by the muscle's glycogen content before slaughter and the pace at which glycogen is converted into lactic acid after slaughter. Just by looking at the color of the meat, you can tell what the pH is. When the flesh is really black, its pH is high, and when it's extremely light, its pH is low (13). There is a correlation between the pH of the meat and its color, namely the breast fillets. Breast meat color differences, mostly due to pH effects, impact several things, including freshness, flavor, marination moisture pick-up, drip loss, water holding capacity, and cooking loss (14).

2.2 Impacts of rapid pH decline at a high muscle temperature on tenderness

Extensive research has been conducted on the molecular, structural, and physiological mechanisms that contribute to tenderness, a crucial quality attribute in meat (15; 16; 17). Tenderness in meat is affected by many parameters, including the quantity and solubility of connective tissue, the shortening of sarcomeres during rigor development, and the proteolysis of myofibrillar and myofibrillar-associated proteins after death (18). Following this, we will go on to talk about how postmortem metabolic activities impact collagen properties and how much postmortem sarcomere shortening and proteolysis there is. The impact of a quick decrease in pH at a higher-than-average temperature on soreness in muscles has been studied and documented: Table 1 shows that, similar to the shear force findings, tenderness ratings improved as pH increased, rising from 6.5 ± 0.4 to 8.6 ± 0.3 throughout the pH range. A considerable drop in shear force values (from 40.2 ± 3.0 N at pH 5.4-5.5 to 28.7 ± 2.0 N at pH 6.0-6.1) was seen as the pH increased, suggesting that the tenderness was enhanced at higher pH levels. Meat with a higher pH had better moisture retention and was judged as being more succulent, leading to a rise in juiciness ratings from 7.0 ± 0.5 to 8.7 ± 0.4. Consistent with earlier research showing that higher final pH values enhance meat softness by improving water-holding capacity and lowering protein denaturation (19), we find that shear force decreases as pH increases. Similarly, sensory juiciness ratings are positively correlated with pH (20), as a higher pH helps to conserve intracellular water. On the other hand, there are studies that suggest that meat cooked in an intermediate pH range (~6.0-6.1) could be harder because of changes in muscle protein breakdown and sarcomere shortening (21). Meat with a higher pH is often more juicy and soft, which improves the eating quality, however the link between pH and tenderness is complicated (22)

Table1 : Effect of pH Value on Meat Quality Parameters

pH Range	Moisture Retention (%)	Shear Force (N)	Color (L*)	Flavor Score (1–10)	Juiciness Score (1–10)	Tenderness Score (1–10)
5.4–5.5	**82.3 ± 1.5**	**40.2 ± 3.0**	**42.1 ± 1.2**	**6.8 ± 0.4**	**7.0 ± 0.5**	**6.5 ± 0.4**
5.6–5.7	**85.7 ± 1.2**	**35.4 ± 2.7**	**39.5 ± 1.0**	**7.5 ± 0.3**	**7.8 ± 0.4**	**7.4 ± 0.3**
5.8–5.9	**88.1 ± 1.0**	**32.0 ± 2.5**	**37.8 ± 1.1**	**8.2 ± 0.2**	**8.3 ± 0.3**	**8.1 ± 0.2**
6.0–6.1	**90.5 ± 1.3**	**28.7 ± 2.0**	**36.4 ± 1.2**	**8.7 ± 0.3**	**8.7 ± 0.4**	**8.6 ± 0.3**

Values are mean ± standard deviation; flavor, juiciness, and tenderness scores are based on sensory panel evaluation.

2.3 Impacts of rapid pH decline at a high muscle temperature on meat colour

Color is one of the most important features of meat. Buyers mostly use it to assess cured and fresh meats before making a purchase. Meat that is reddish-pink or light cherry red is preferred because it indicates to the customer that the meat is intact and suitable for consumption (23). Meat looked darker at higher pH levels (42.1 ± 1.2 at pH 5.4-5.5 vs 36.4 ± 1.2 at pH 6.0-6.1), as seen in Table 1, which shows that Color lightness (L*) values declined as pH climbed. The standard method for determining meat color is during grading; after around 24 hours, it is available for purchase in supermarkets. When stores start to lower prices or remove goods from shelves, the color starts to fade, thus the amount of deterioration on such shelves is an important consideration. The chemical state of myoglobin, the amount of flight scattering, and pigment concentrations (mostly myoglobin) are the determinants of muscle color (24).

2.4 Impacts of rapid pH decline at a high muscle temperature on flavour

Factors influencing the acceptability of meat flavors include the shape, amount, and equilibrium of taste molecules. When food is uncooked, it lacks taste. Once cooked, it takes on its full flavor. The non-volatile components of lean and fat tissue undergo a complicated sequence of thermally induced reactions when cooking, leading to the creation of several compounds (25). In Table 1, we can see that as the pH ranged from the lowest to the highest, the sensory assessment ratings for taste increased, going from 6.8 ± 0.4 at the lowest pH range to 8.7 ± 0.3 at the maximum variety. Furthermore, (Bennett et al. 1973; Goransson et al. 1992; Flores et al. 1999). Regular (low rigor temperature) beef muscles are more widely enjoyed by consumers, but high temperature (PSE-like) beef strip loin and rump are less well-received by the market (26).

2.5 Impacts of fast pH fall at a high muscle temperature on water-holding capacity and juiciness

How much water fresh meat can hold onto is defined by its water-holding capacity (WHC). A significant amount of weight loss from carcasses and cuts may be caused by poor WHC, which in turn reduces the production and quality of meat products due to drip and purge loss (27). Consequently, table 1 shows that the amount of moisture retained increased gradually as the pH rose, going from 82.3 ± 1.5% at pH 5.4-5.5 to 90.5 ± 1.3% at pH 6.0-6.1. It was traditionally believed that fast pH fall at high muscle temperature did not pose a significant concern in beef, but there are few research on ruminant meat and a large body of literature on the impact of this phenomenon on WHC in pig (for reviews, see 28; 29).

Conclusion

In conclusion, this study demonstrates that higher pH values in beef are strongly associated with improved meat quality, including increased moisture retention, greater tenderness, and enhanced sensory attributes such as flavor and juiciness. However, higher pH also results in darker meat color, which may influence consumer perception. The findings underscore the significance of controlling pH during meat processing to achieve optimal eating quality. While rapid pH decline at high muscle temperatures can negatively affect water-holding capacity and color stability, careful management of chilling and processing conditions can help maximize tenderness and overall acceptability. Further research is recommended to clarify the biochemical mechanisms underlying these effects and to develop strategies for consistently producing high-quality beef.

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