MEAT QUALITY: UNDERSTANDING OF MEAT TENDERNESS AND INFLUENCE OF FAT CONTENT ON MEAT FLAVOR

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ABSTRACT: This literature review focuses on meat tenderness and flavor, which are most important in determining meat quality, but difficultly predictable and maintained. Meat tenderness primarily relates to muscle tissues while meat flavor is mostly resulted from fatty tissues. Many studies have indicated that not only protein composition of muscle fibers but also handling and slaughtering conditions, genetic traits, and growth progress could affect meat tenderness. Surprisingly, there is somewhat connection between tenderness and flavor through marbling of meat cuts. The more marbling the meat cut has, the more flavorful and tender it is. Some clear understandings of those quality traits of meat are important to improve quality of meat and processed meat products.

Key words: meat quality, meat tenderness, meat flavor, marbling, postmortem, connective tissues, fatty tissues

1. INTRODUCTION

Sales of meat are influenced by the appeal of meat to consumers, that is described as "quality". Many factors determine the quality in meat. It includes requirements of food safety and animal welfare. It also includes the sensory appeal of meat such as palatability and perceived healthiness, especially in relation to the amount and type of fat and other fatty components. Meat quality describes how much meat is attractive to consumers. Meat must look good to consumers before satisfying their palate when they decide to buy it. Once the meat is bought, cooked, and served, the aroma, tenderness, juiciness, and flavor must meet the expectations (Aberle et al., 2001). The aroma and juiciness can be improved using spices and cooking method. However, the tenderness and flavor depend on textural characteristics, composition of meat, and many other factors.

2. MEAT TENDERNESS

2.1. Meat Protein and Muscle Fibers

Meat tenderness is the most difficultly predicted trait, but it is very important to meat quality and consumer acceptance. Tenderness is based on ease of chewing that is contributed by many factors. Among them, the fibrous nature of muscle contributes to chewing resistance (Gerrard and Grant, 2003). The fact that many myofibrils are arranged in register across the muscle fibers leads to more strength for muscle and decreases muscle tenderness. The unit of skeletal muscle is the muscle fiber. Among many components of muscle fiber, protein is the most important one. Muscle proteins are categorized as sarcoplasmic, myofibrillar, and stromal proteins based on their solubility. Sarcoplasmic proteins are extracted in aqueous solution with low ionic strength (0.15 or less). Myofibrillar proteins are extracted by salt solutions and require higher ionic strength, called salt-soluble proteins. Stromal proteins include proteins of connective tissues, which are very fibrous and insoluble (Aberle et al., 2001). Of insoluble proteins, collagen is composed about 0.5 proportions, elastin is about 0.03, and the remaining 0.47 is a mixture of various proteins such as reticulin. Both type and amount of connective tissues affect meat tenderness.

The connective tissues, which are present in all muscles in the epimysial, perimysial, and endomysial components surrounding the muscle fibers, lead to strength of muscle but now make it tough. The strength of connective tissues is derived from its collagen fibers. Hence, meat tenderness is obviously influenced by collagens of the muscle. The resilience depends on the elastic fibers in the intercellular matrix. The collagen fibers are straight, inextensible, non-branching, white in color, and different in diameter, from 16 nm in fetal tissues to about 250 nm in some tendons from adult animals. The connective tissues can be divided into two main categories: loose and dense (regular or irregular) connective tissues based on density and organization of fiber bundles. The dense connective tissues that are very common in tendons are much tougher than the loose ones. Additionally, the five types of collagen in different tissues are categorized by their elemental polypeptide chains (Lawrence and Fowler, 2002). Although the high ratio of type III collagen may result in an increase in toughness, the extent and type of cross-linking between different types of collagen are of greater importance. The increase in cross-linking associated an expansion of dense connective tissues and the insolubility of collagen increase with age; therefore affect muscle tenderness. Thus, when considering collagen content, its types, and cross-linking, younger animals will produce more tender meats than will older animals (Gerrard and Grant, 2003).

Another considerable muscular factor is muscle types. The ratio of slow-twitch oxidative (type I) and fast-twitch glycolytic (type II) muscle fibers also evidently influence meat tenderness. The ratio varies among individual animals of the same breed, breeds, and crosses. Beef tenderness is positively related to type I muscle and negatively related to the others. These differences are linked to higher ratio of protein turnover in tender muscle and higher level of calpain (Lawrence and Fowler, 2002), which plays an important role in protein degradation, so in the meat tenderness.

2.2. Postmortem Conditions

The contractile system of muscles is another factor that contributes to meat tenderness. The contraction makes the Z discs closer to each other and increases density of filaments, therefore reduces chewing ability. After slaughter, but before the rigor mortis, it is still able for filaments to slide over each other. However, after rigor mortis, the two types of filaments become fixed. Because of some reason by which the rigor mortis comes right at the time of contractile state, the meat will be very tough. It results from not enough ATP to operate the calcium pump, so the calcium concentration in sarcoplasm begins to rise, and muscle relaxation fails to start. Additionally, the stored oxygen supply is reduced, and the anaerobic metabolism starts to maintain the homeostasis. This process needs energy from ATP. All of those start the major energy reserve through glycogen catabolism because the reaction using creatine phosphate in postmortem muscle lasts shortly. Glycogen must first be degraded by glycogen phosphorylase to form glucose-1 phosphate. The whole process produces three ATP with glycogen as starting material. Due to lack of oxygen, enzyme lactate dehydrogenase catalyzes the reduction of pyruvate to lactic acid by NADH (Scanes, 2003).

This process also regenerates NAD+ for glycolysis step in ATP formation. However, the built-up lactic acid inactivates the enzymes relating to glycolysis and slows down the process of ATP regeneration. That is why there is still not enough ATP for muscle relaxation, and rigor mortis is maintained. On the other hand, lactic acid makes the pH gradually fall and the rigor mortis is rapidly developed (Aberle et al., 2001), which decreases meat tenderness. The proteolysis is also one of factors affecting meat tenderness. Meat cuts from carcasses at 24 h postmortem are less tender than cuts taken for several days although they were the same sub-primal cuts taken from the same carcasses. The reason for this phenomenon is the action of various enzymes that are active postmortem and start to hydrolyze contractile proteins. Resulted from this destruction, meats become more tender. Of the protease system, calpain,

which organizes the protein turnover in living muscle tissues, attacks proteins that hold myofibrils together or locate in Z-lines. Hence, meat is tender when cooked.

2.3.Genetic and Growth Effects

Meat tenderness depend on breeds within a species, types within a breed, and gender. Within a breed, the low proportion of collagen and high solubility of collagen per se with small degree of polymerization of constitute chains is probably the reason why some muscles are more tender than the others. There is a special case of callipyge gene in sheep that biochemically produces large buttocks consisting of muscle with very little fat and high proportion of type IIB muscle fibers (Scanes, 2003). This gene is expressed only if it is on chromosome 18 inherited from the father and is not on the chromosome from the mother, which causes lower tenderness. This fact may be also caused by an increase in calpastatin activity, which decreases protein degradation postmortem (Lawrence and Fowler, 2002), because calpastatin is a specific endogenous inhibitor of calpain.

Back to postmortem contraction of muscle, regardless of stress caused by transportation, handling, etc., pigs genetically predisposed to stress usually carry at least one of the following genes: halothane (stress) gene or Rn (Napole) gene. Halothane gene causes a rapid decline in pH, whereas Rn gene causes low ultimate pH. Elimination of these two genes from the swine population should reduce the frequency of PSE pork. However, these stress-related genes are prevalent in swine because both are linked to improvement of carcass leanness. The other important factor affecting meat tenderness is muscle growth performance of animals. The bulls achieving high growth rates produced lean meat with significantly lower shear force value for *m. biceps femoris* muscle (Sinclair et al., 1998). There is an evidence that speed of growth in the later stages of the production cycle before slaughter can essentially affect quality attributes (e.g. drip loss) as well as tenderness (Lawrence and Fowler, 2002). The bull produced more tender muscle after a compensatory growth (Hornick et al., 1998). Compensatory growth also improves meat tenderness in pigs (Kristense et al., 2004; Blanchard et al., 1999a). Reasons for that effect were related to the fast growth rate inducing the deposition of "younger" muscle in which the connective tissues are less structured. Moreover, the length of compensatory growth influenced level of in vivo protein turnover and postmortem proteolysis (Therkildsen et al. 2002). In addition to compensatory growth, double muscling is another growth phenomenon on cattle that can make the muscle more tendered with less total collagen (up to 40% or less on dry matter). The majority of difference in collagen content is in perimysial connective tissue. The alterations in the collagen maturation may also change toughness. The concentration of a collagen cross-link, histidinohydroxymero-desmosine, is lower in *semitendinosus* muscle of double muscling cattle, compared to normal animals (Ngapo et al., 2004). Because of differences in muscle fiber types, connective tissues, etc., muscles that are located in various locations are also different in toughness. These differences were also indicated in a study on Warner–Bratzler shear-force evaluations of forty bovine muscles (Belew et al., 2003).

3. FAT CONTENT AND MEAT FLAVOR

3.1. Fat and Meat Flavor

Flavor is the most important factor in our food choices (Pearson and Gillett, 1999). "Fat is the source of flavor in meat and is particularly important to characteristics of species flavor variations". The different flavors among beef, pork, chicken, turkey, and lamb come from fatty components. Fatty tissues give them specific flavor profiles. Fat acts as one of precursors of flavor by combining with amino acids from proteins and other components when heated. When fat melts, it releases flavors and gives sudden burst of these flavors. Fat consists of a glycerol molecule linked by ester bonds to three fatty acids and is termed as triacylglycerol or triglyceride. The main component, which is responsible for properties and functions of fats, is

fatty acid. Fatty acids differ from each other in length of their hydrocarbon chains and presence or absence of double bonds. Fatty acids that lack double bonds are described as saturated and those having double bonds are unsaturated. Nutritional treatments can be used to manipulate the fatty acid content of muscle to improve nutritional balance, such as an increase in the ratio between polyunsaturated fatty acid (PUFA) and saturated fatty acid. Increasing PUFA levels may also change flavor because of their greater susceptibility to oxidative breakdown and the generation of abnormal volatile compounds during cooking. To increase PUFA is to supplement vegetable oil to animal diet. There is much research on supplementation of vegetable oils to obtain the same type of fatty acids in animal fat (Fiego et al., 2005; Eder et al., 2004). The results showed that animals would get what they ate, especially for monogastric animals. Ruminants are different due to biohydrogenation of fatty acids after their breakdown in the rumen. The biohydrogenation is caused by ruminal microbial population, which probably plays the most important role in ruminant digestion.

3.2. Importance of Marbling

Lipid content of muscle varies from 1.5% to 13%. Although most of lipids are present in adipose tissues, some called marbling and found intracellularly in muscle fibers has the most important roles in meat quality. Marbling is intramuscular fat that is deposited within muscle in loose network of perimysial connective tissues, between the muscle bundles. Marbling has much stronger and more predictable effects on juiciness and flavor than tenderness. This intramuscular fat was thought to accumulate in the finishing phase of growth, but recent research has suggested that marbling increases linearly overtime.

Moderately Abundant   Moderate   Slight
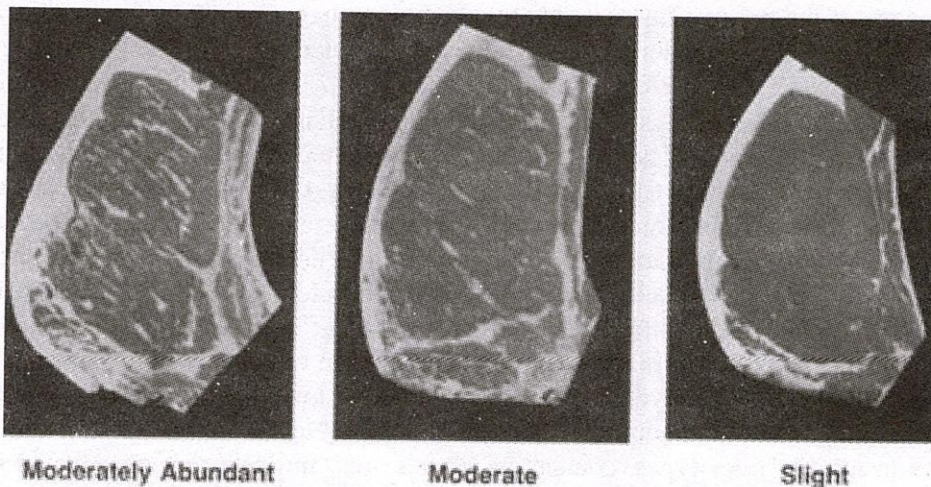
Differences in marbling content of Roseda Black Angus rib steak

Marbling cells develop within muscles that help the animal stand, the so called postural muscles. This muscle is destined to become strip loin cuts of meat. Fat is a lately developing tissue in cattle because fat growth accelerates as animals approach maturity after formation of muscle and bone. While muscle growth slows down and bone growth ceases as an animal ages, fat growth continues in a well-fed animal. However, some marbling is also present even in the unborn calf. The total amount of marbling in a muscle results from increase in number of marbling cells as well as size of cells. Cells are distributed among several groups of fat cells. When several of these groups merge, it looks like a seam. That is why marbling sometimes is called seam fat. Number of cells in any particular group determines appearance of marbling and increases with animal age. Most marbling leaves meat during cooking process because of melting. However, some is certainly left behind, tends to lubricate meat, contributes to mouth feeling, and does have positive addition to the whole flavor of meat. Practically, marbling

score has great effect on meat tenderness and cooking quality. Because marbling melts over meat surface, moisture of meat, and therefore meat juiciness, is maintained during cooking. Moreover, melting marbling leaves a porous structure in meat and helps improve chewing ability. In beef, marbling mostly determines total beef quality. Marbling is usually considered as "cooking insurance" of meat.

3.3. Genetic Effects

Genetic make-up of animals is one of the most important factors in determining marbling (Scanes, 2003). Breeds like Angus are well known for their marbling potential. Genetic traits may also determine how marbling is distributed though it is very difficult to be controlled. The good plan of nutrition during finishing stage contributes to higher marbling scores, certainly, in animals genetically able to marble. Having more cells rather than bigger cells in early stages of life is almost the key effect on the potential to deposit fat later, therefore, the accumulation of marbling fat.

3.4. Fatty Tissues

The lipid of fatty tissues is important to the development of flavor in meat, which undergoes cooking process and releases flavoring volatiles. These volatiles increase with age in all animals (Lawrence and Fowler, 2002). Therefore, the older animal will produces greater flavor. High concentration of linoleic acid in the lipid of fatty tissues can have a definite effect on flavor. If level of linoleic acid in lipid of sheep and cattle adipose tissues is high, it will produce oily, sweet or bland tastes during cooking. Conversely, high concentration of oleic acid in lipid will improve the flavor. Additionally, temperature control in storing and in packing pork is also important if high concentration of linoleic acid is present in the lipids. This is because linoleic acid is much unsaturated and easily combines with atmospheric oxygen to give rise to oxidative rancidity and makes the products unpalatable. Moreover, the fatty tissues are also relating to level of abnormal odor of animal. Two compounds that are responsible for increase of boar odor are skatole and androstenone. Both of them are found in fatty tissues.

4. CONCLUSION

Among sensory traits of meat, tenderness and flavor are very important ones that determine quality of meat cuts. While tenderness is essentially affected by composition, texture of muscle, and some biochemical processes happening in slaughtering, fabricating, and storing carcasses, the flavor, which is influenced by fat content, can be manipulated by genetic methods, growth performance control and dietary supplementation. Collagen in muscle composition and marbling in fat content are two principal components that are responsible for meat tenderness and flavor respectively. Not only collagen content but also its type and organization have effects on tenderizing meat muscle. Hence, any method used to make meat muscle more tender should consider collagen in connective tissues as undesirable component. In addition to processing methods, some other technologies can be used to improve meat tenderness and flavor, such as aging, which can let rigor mortis be over and lead to protein degradation, electrical stimulation, calcium injection, and vitamin D supplementation. Vitamin D can increase meat tenderness up to 26% for strip loin, 18% for top sirloin, and 19% for inside round based on Warner-Bratzler shear ratios. Finally, although having major impact on meat flavor, marbling was suggested to enhance meat tenderness despite the fact that there is not many strongly conclusive studies on this issue.

CHẤT LƯỢNG THỊT: ĐỘ MỀM VÀ NHỮNG ẢNH HƯỞNG CỦA HÀM LƯỢNG MỠ LÊN HƯƠNG VỊ THỊT

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TÓM TẮT: Bài báo chủ yếu bàn về khía cạnh độ mềm và hương vị của thịt, những yếu tố quan trọng nhất trong việc quyết định chất lượng thịt, nhưng rất khó dự đoán và duy trì trong ngành công nghiệp thịt. Độ mềm của thịt chủ yếu liên quan đến các mô cơ, trong khi đó, hương vị của thịt lại được quyết định bởi mô mỡ. Rất nhiều nghiên cứu chỉ ra rằng không chỉ thành phần protein của hệ thống sợi cơ mà ngay cả những yếu tố như điều kiện vận chuyển và giết mổ, di truyền, và quá trình tăng trưởng của động vật cũng ảnh hưởng nhiều đến độ mềm của thịt. Điều ngạc nhiên là có một mối liên hệ nào đó giữa độ mềm và hương vị thông qua cái gọi là "marbling" (intramuscular fat – một loại mỡ nằm len giữa các mô cơ và các tế bào của thịt). Thịt có càng nhiều marbling chừng nào thì càng mềm và càng nhiều hương vị chừng đó. Do vậy, những hiểu biết căn bản và cặn kẽ về những tính chất này của thịt sẽ rất quan trọng để có thể cải thiện chất lượng của thịt và các sản phẩm thịt được chế biến.

Từ khóa: chất lượng thịt, độ mềm của thịt, hương vị của thịt, marbling, postmortem, mô liên kết, mô mỡ.

REFERENCES

[1]. Aberle, E. D., J. C. Forrest, D. E. Gerrard, E. W. Mills., *Principles of meat science.* Kendal/Hunt Publishing, (2001).

[2]. Belew, J. B., J. C. Brooks, D. R. McKenna, and J. W. Savell, *Warner–Bratzler shear evaluations of 40 bovine muscles*, Meat Sci. 64:507-512., (2003).

[3]. Eder, K., G. Müller, H. Kluge, F. Hirche, and C. Brandsch, *Concentrations of oxysterols in meat and meat products from pigs fed diets differing in the type of fat (palm oil or soybean)*, (2005).

[4]. Gerrard, D. E., A. L. Grant., *Principles of animal growth and development*, Kendall/Hunt Publishing, (2003).

[5]. Karp, G., *Cell and Molecular Biology: Concepts and Experiments*, 4th ed. John Wiley & Sons, (2005).

[6]. Kristensen, L., M. Therkildsen, M. D. Aaslyng, N. Oksbjerg, and P. Ertbjerg., *Compensatory growth improves meat tenderness in gilts but not in barrows*, J.Anim. Sci.82:3617-3624, (2004)

[7]. Lawrence, T. L. J., V. R. Fowler, *Growth of farm animals.* CABI Publishing, (2002).

[8]. Lo Fiego, D. P., P. Macchioni, P. Santoro, G. Pastorelli, and C. Corino, *Effect of dietary conjugated linoleic acid (CLA) supplementation on CLA isomers content and fatty acid composition of dry-cured Parma ham.* Meat Sci. 70:285-291, (2005).

[9]. Pearson, M., T. A. Gillett, *Processed meat.* Aspen Publisher Inc, (1999).

[10]. Scanes, C. G., *Biology of growth of domestic animals*, Iowa State Press.Blackwell Publishing, (2003).

[11]. Wood, J. D., M. Enser, A. V. Fisher, G. R. Nute, R. I. Richardson, and P.R.Sheard, *Manipulating meat quality and composition*, Proc. Nutr. Soc. 58(2): 363-370, (1999).