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COLD AND MEAT PRODUCTION

Chilling, freezing and thawing of meat is a problem which has been studied for years, with undiminished interest, by a large number of scientists. This has not been without reason. Complex biochemical changes, occuring in meat continuously, represent a challenge for colleagues being attracted by basic science. The possibility of applying the results of such examinations in practice increases considerably the number of research workers.

In the course of recent years, an exceptionally high number of works from this field has been published in professional literature, in English, Russian, German and French languages. In addition, there were held two international meetings organized by the Meat Research Institute, Lanford, Bristol (Cutting, 1972 and 1974).

The examination results from that field have very often been referred at our meetings (Lacourt and Charpentier, 1971; Voyle, 1971; Judge et al., 1971; Harris and Mac Farlane, 1971; Herlihy et al., 1971; and many others who will be mentioned later on).

In the practice of meat industry, there prevails the tendency to chill meat as soon as possible. The reasons are known. By time, the more intensive was the chilling of meat, the more strongly were expressed some negative consequences of such procedure. At definite conditions of the activity of cold, meat becomes tough. In the light of recent facts and facts having been known for a long time, it is sure that meat toughness caused by cold can be the result of:

- cold shortening, and
- thaw rigor, thaw shortening.

Locker (1960) has established that shortening of sarcomeres causes the toughness of meat. Three years later, Locker and Hagyard (1963) have proved that sarcomeres are very much shortened even when muscles are quickly cooled before the end of rigor mortis. The toughness of meat caused by cold shortening can not be improved by ageing.

For a long time already it has been known (Locker et al., 1972) that if still warm muscle (before the appearance of rigor) is quickly frozen and then quickly thawed, it will be shortened drastically, resulting in a high loss of juice and in tough meat (thaw rigor).

The finding Locker and Hagyard (1963) raised a new problem within the study of the appearance of sarcomere shortening due to cold (cold shortening), and actualized an already known problem - toughness of thawed meat (thaw shortening, thaw rigor).

In the works presented at the Meat Research Institute Symposiums No. 2 and No. 3 (Cutting, 1972; 1974), in the review "The effect of pre-rigor changes on meat tenderness" (Newbold and Harris, 1972), and in the following works: "A new concept of processing beef and lamb" (Locker et al., 1972), "The biochemistry of rigor mortis and cold-contracture" (Bendall, 1973), "La conservation de la viande bovine refrigeree" (Catsaras et al., 1973), new examination results regarding the activity of cold on muscles were summarized:

- Cold shortening was established in beef, mutton, poultry meat and, to a slight extent, in pork;
- The mechanism of cold shortening appearance was explained;

- Shortening of sarcomeres, occuring during the appearance of rigor mortis, was prevented if usual way of hanging sides and carcasses by Achilles'tendon was replaced by some more convenient way (for example, hanging by foramen obturator);
-- In the initial stage of cooling, temperatures (about 16°C) at which sarcomeres are shortened during rigor mortis to the least extent were chosen;
- If during the first 16-20 hours of cooling, before being frozen, meat was cooled at 16°C, it became tender after heat processing;
- Supposing that meat was frozen before the appearance of rigor mortis and before the development of cold shortening (single-phase freezing), thaw shortening will not occur if meat is thawed slowly.

Simultaneously with the above mentioned works on the appearance of cold shortening and its influence on meat quality, and leter on, many other works were also published (Taylor et al., 1972; Bush et al., 1972; Pfeiffer et al., 1972; Hamm, 1973; Bouton et al., 1973; Moerman and te Wechel, 1973; Dawey and Gilbert, 1974; Marsh et al, 1974; Rowe, 1974; Baley, 1974; Bouton et al., 1975; Bartels, 1975).

Although the shortening of sarcomeres undoubtedly causes toughness of meat, all the dilemmas regarding toughness have not been solved by the said works.

In the first period of long-time examinations of meat toughness, it was believed that quantities and kinds of connective tissue determined the degree of toughness. Later on, it was proved that tenderness of meat was influenced by changes taking place in muscle fibers prior to and during the appearance of rigor. Newbold and Harris (1972) described all these chemical and physical changes. During the last fifteen years, starting from the work of Locker (1960), it was proved that the length of sarcomeres was an important element of tenderness. Then follow microstructural changes which also contribute to meat tenderness (Parish et al., 1973, and other authors cited by them). It can be observed that the role of connective tissue (basides the doubtless role of muscle ribers) was neglected in that period. Without denying the exceptionally important role of cooling way in the sarcomere length- consequently in meat tenderness as well, Pfeiffer et al. (1972) point at the importance of changes in connective tissue of muscles being stretched during cooling and egeing at 0°C for 24 hours. The number of covalent transversal connections in stretched muscles was reduced, and this was more important for meat tenderness than the quantity of collagen separated during heat processing of meat. On the basis of histological findings, Rowe (1974) concluded that toughness of meat could not be ascribed only to myofibrillar elements, but also to big changes in connective tissue. Dransfield and Rhodes (1976) also point at interdependance of actomyosin and connective tissue elements.

Cold shortening influences the water binding capacity, too. Muscles with longer sarcomeres show better water binding capacity and during heat processing they are considerably more shortened than muscles with shorter sarcomeres (Bouton et al., 1973c; Bouton et al., 1975c).

Meat will be tenderer if shortening of sarcomeres is prevented, regardless of the reason for their contraction (rigor mortis or cold shortening). The possibilities of applying this knowledge in practice were very intensively examined. The proposed procedures can be divided in three basic groups:

A) Mechanical

- position of carcasses during cooling and influence of gravitation;
- burdening of carcasses;
- compression of muscles during cooling.

B) Conditioning (postponement of intensive cooling).

C) Electrical stimulation.

A. Starting from Herring et al. (1965), a number of investigators has confirmed that the way of carcass hanging influences to a great extent the number of chortened sarcomeres of more important muscle groups. Even after 1972, the interest in this problem has not stopped (Hostetler et al., 1973; Bouton et al., 1973a; Bouton et al., 1974; Joseph, 1974; Hostetler et al., 1975; Bouton et al, 1975b).

According to recent works (Buege et al., 1974; Abban et al., 1975), shortening of myofibrils during cooling is also achieved by burdening, resulting in mechanical stretching of the backbone.

Macfarlan (1973) proved that pressing of muscles, separated from the carcass before the appearance of rigor mortis, favourably influenced the tendernes of meat. This finding was confirmed by Bouton et al. (1975a).

The works devoted to mechanical procedures which prevent the shortening of sarcomeres (hanging of carcasses, stretching by burdening) or disturb the microstructure of tissues (pressing), represent an unquestionable theoretical contribution to the explanation of meat tenderness fenomenn. It seems that the results of these works, at least for the present, have not found much application in the practice.

B. If muscle is cooled below 11°C, it will contract at the moment when pH is over 6.2 (cold shortening). The rate of contraction depends on the pH value. It is more expressive at pH 6.8 than at 6.2 (Bendall, 1972).

Sarcomeres will not shorten too much and meat will not be tough if it is not cooled below 10°C during rigor mortis. Starting from that knowledge, in the course of last 5 to 6 years there were made efforts to find out the regimes which could meet this requirement in the best way. Basides the terms "chilling", "quick chilling", "two-phase chilling", a new term - "conditioning" - was introduced (Locker et al. 1972). The characteristic of this procedure of chilling (and frezing) is as follows: before the beginning of quick chilling, meat is kept for a longer or shorter period of time in departments with higher air temperatures than those used during chilling. Afterwards meat is quickly chilled and, eventually, frozen.

According to current way of work, meat is deboned after cooling of sides or carcasses (generally accepted "classical deboning"). Conditioning (postponement of intensive chilling) brings with fundamental changes in the time of meat deboning as well. According to new proposals, meat should be deboned still warm ("deboning of warm meat") or from partially cooled sides ("deboning of partially cooled meat"). Up to this day, none of the two proposed ways of deboning (warm or partially cooled meat) has been applied in practice. There is still a number of details to be solved. First of all that is the relation between temperature and duration of conditioning of sides (carcasses) prior to deboning, or of meat pieces separated from still warm carcasses. A large number of authors is of opinion that the air temperature at the beginning of conditioning should be about 16°C. According to the recommendation of many investigators (March et al.,

1968; Schmidt and Gilbert, 1970; Smith et al., 1971; Locker et al., 1972; Lacourt, 1972; Bouton et al., 1973b; Smith et al., 1973; Heinz, 1975), the air temperature (16°C) should last considerably: 16 and more hours. In spite of satisfactory quality (tenderness) of meat, there is a danger of the development of food-poisoning bacteria due to keeping of meat at meat at higher temperatures for a longer period of time (Heinz, 1975). Therefore, very rigorous sanitary conditions of production are recommended.

As a result of the wish to produce qualitative meat and to avoid the risk of quick microbial multiplication, McLeod et al. (1973) recommend longer conditioning (24 hours) of lamb meat packed in thermoretractive foils, in departments where the temperature is maintained at about 10°C and not at about 16°C. Valin et al. (1975) kept beef at 10°C for 36 hours. According to Bendall (1974), carcasses should be conditioned at about 10°C for 10-12 hours. Meat Research Institute in Bristol (1976) recommends the same régime of conditioning for meat being deboned from still warm carcasses and immediately after that packed under vacuum.

Starting from 1974, a tendency to fundamental change in the way of meat conditioning has been observed. The temperature of about 16°C at the beginning has remained, but for a considerably shorter period of time. Henrickson et al. (1974) and Falk et al. (1975) kept sides at about 16°C for 3, namely 5 or 7 hours. Afterwards, meat was deboned, packed under vacuum, cooled and stored at 1.1°C. Before deboning, sides should be conditioned for at least 3 hours. Better quality of meat was obtained if it was deboned after 7 hours than after 3, namely 5 hours. Kastner and Russel (1975) and Kastner et al. (1976) are of opinion that conditioning of carcasses at about 16°C for 8 hours gives satisfactory results. According to Smith and Kenan (1974), it is sufficient to keep carcasses (sides) at 7°C for 4 hours prior to deboning and storage of meat during the night at about 1°C. If meat pieces are efterwards packed under vacuum and stored at the same temperature for 7 days more, meat will be of the same tenderness as the corresponding pieces deriving from control sides cooled at about 1°C for 8 days. Similar results were obtained by Heinz (1976).

Grau et al. (1974) and MacLead et al. (1974) examined the ways of conditioning of warmly deboned lamb meat packed in cartons.

C. The investigations carried out in New Zealand are worth of mentioning. By electrical stimulating of carcasses immediately after animal slaughter, pH value of muscles can be reduced below 6,0 within an extraordinery short period of time (about 1 hour). This seems a good reason to believe that a brief stimulation on the bleeding rail could be incorporated in a production line, to give carcasses which by the end of the normal handling period would be ready for chilling of frezing without risk of cold-shortening (Locker et al.1975).

In the USSR, there has been much done regarding the study and introduction of single-phase freezing of meat (Šeffer, 1970; Šeffer, 1972; Šeffer and Musatova, 1974). Thaw rigor does not appear in any kind of meat if sides, quarters or carcasses are thawed before heat processing. Starting from that fact, the All-Union Research Institut of Meat Industry (USSR) prescribed the way of single-phase freezing, storage and thawing of meat. Single-phase freezing of meat in sides has been very quickly spread in the USSR, due to its higher economy in relation to two-phase freezing (the shrink is lower for about 1%, the productivity of work is increased about twice, and the needs in cold space are reduced for about 40%). At the beginning of 1973, 28.2% of meat that had to be frozen in that country was frozen by single-phase procedure. According to the plan, even 75% of the total quantity of meat to be frozen in 1980 will be frozen by single-phase procedure (Šeffer et al., 1974).

According to Behnke et al. (1973), as well as according to Bendall (1974), the consequences of "thaw rigor" of meat pieces frozen by single-phase procedure and heat processed directly, without previous thawing, can be avoided if prior to heat processing meat pieces are kept at about 3-5°C for 1-2 days. During that time, the reserves of ATP will be exhausted.

A large number of works devoted to the study of deboning still warm or partially cooled sides points at the possibility of fundamental changes associated with production and distribution of meat. If this changes are adopted, they will influence the ways of slaughterhouse construction, as well. Cutting rooms would be just behind the kill-floor and not, as it is now, behind the coolers. Only packed deboned meat pieces would be distributed. The followeres of deboning warm or partially cooled meat, their packing under vacuum, and then conditioning or chilling, consider such way of work to have cartain advantages over the packing of alraedy chilled meat:

- the needs in cold space will be decreased since fatty tissue and bones will not be cooled;
- the consumption of energy will be lower: meat will be chilled for a shorter period of time;
- losses of chilling, deboning and storage will be lower;
- expenses of distribution will be reduced;
- meat colour will be steadier;
- the percentage of juice separated inside the package will be lower in relation to vacuum packing of already chilled meat.

It is still uncertain whether deboning of partially cooled or warm carcasses will become a practice in production. All technological and aconomic problems have not been solved up to now. Therefore additional works on deboning and conditioning of meat should be expected.

Changes in the way of packing of "classically deboned meat" (deboning of chilled sides or carcasses) can be observed in the literature to a high extent. Packing of wholesale meat pieces under vacuum was examined in details. The colleagues from the West German Federal Republic paid special attention to this problem. The procedure was favourably evaluated by all investigators. Universality of these investigations can be observed from the following works: Minks and Stringer (1972); Pagliaro et al. (1972); Usborne et al. (1972); Heinz et al. (1973); Tändler (1973); Patterson and Sutherland (1973); Fournand et al. (1973); Kiesow (1974); Böhme (1974); Leistner (1974); Pfeiffer et al. (1974); Heinz (1974); Hodges et al (1974); Smith (1974); Johnson (1974); Shay and Egan (1975).

In contrast to beef and pork, vacuum-packing of mutton is not advised (Jeremich et al.,1972).

Examinations of the possibility and advantages of packing the whole sides, although present in the literature, raised less interest (Braathen, 1972; Smith and Carpenter, 1973; Tändler and Petri, 1974).

Changes in the way of frozen meat storage are also evident. For many yers already, the majority of frozen foods in West Europe has been packed and then stored (Persson, 1970). A new way of the storage of frozen sides and quarters has been introduced in the USSR, according to the technology developed by the All-Union Research Institut of Meat Industry (VNIIMP). They are wrapped in polyethylene sacks and then stored on pallets (Šeffer et al., 1975).

There are many interesting themes from the field of chilling, freezing and thawing, that I did not mention here. Some of them will be discussed today. I tried to cite a large number of works on the problems of utilization of cold, which have been at the very top of the investigators' interest in the course of recent years.

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