

# The Effect of Chilling and Freezing on Some Meat Quality Aspects

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**D**uring the first 24 to 48 hours after an animal is slaughtered, muscle undergoes a bewildering array of bio-chemical and physiological changes in the process of becoming meat. Because during this first 48 hours the carcass is chilled using refrigeration, the chilling process has a profound effect on these changes and, therefore, on the final product.

Four product attributes – tenderness, product yield in relation to weight loss, the ultimate intensity and stability of meat colour and the hardness or “boneability” of fat, particularly where fat cover is heavy – are decided. As a result, although refrigeration of red meat is the most important element in the preservation process, refrigeration must be viewed as more than simply preventing spoilage and ensuring food safety.

### **Post-mortem changes**

To understand the effects of refrigeration on meat, it is necessary to have some understanding of the structure of meat.

Meat is composed of fibres bundled together and held intact by sheaths of connective tissue which consists of the structural protein collagen. The fibres themselves contain proteins, actin and myosin linked together in an ordered, repeating sequence. These “contractile proteins” are responsible for muscle movement.

When a live animal flexes a muscle, the actin and myosin filaments move in relation to each other. The same happens when the muscle is relaxed. This constant contraction and relaxation of the muscle is powered by energy derived from muscle starch, or glycogen, replenished by the animal during periods of rest. (Muscle structure is illustrated in Figure 1.)

During the rigor process, the actin and myosin filaments link by a chemical bond. Once this bond is formed, the filaments can no longer move relative to each other and the muscle becomes inextensible and is said to be “in rigor”.

Once the muscle is in rigor, the relative or “sarcomere” length of the actin-myosin unit is fixed. (Figure 2) This sarcomere length becomes

a prime indicator of the tenderness or toughness of a piece of meat.

For meat to be defined as tender, the bundle of fibres must be easily severed by biting on the meat, without applying too much pressure. The extent to which pressure is necessary to sever the fibres is influenced by the sarcomere length.

When muscle goes into rigor with the filaments in the “at rest” position, the resulting sarcomere length will result in tender meat. Subsequently, there will be no difficulty biting through the fibre bundles.

If there is any contraction of the muscle prior to rigor setting in, the fibres will still bond together in the usual way, but the filaments will be bunched up and the sarcomere length will be shorter and more dense, resulting in tougher meat. (Figure 3)

### **Cold shortening**

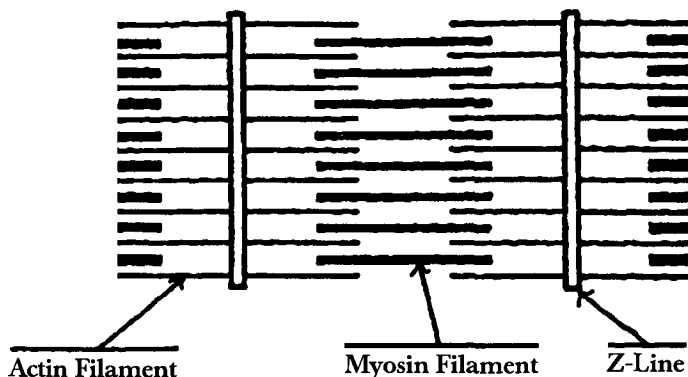
Muscle fibres have a natural tendency to contract if they are subjected to low temperatures before rigor is complete. This phenomenon is known as cold shortening, or cold toughening, and is the most significant cause of toughness in meat from animals less than four years of age at slaughter.

The filaments in a piece of cold-shortened muscle will yield a very dense, tough structure that is difficult to sever. The amount of contraction, and hence the amount of toughening, depends on the extent the muscle is allowed to contract.

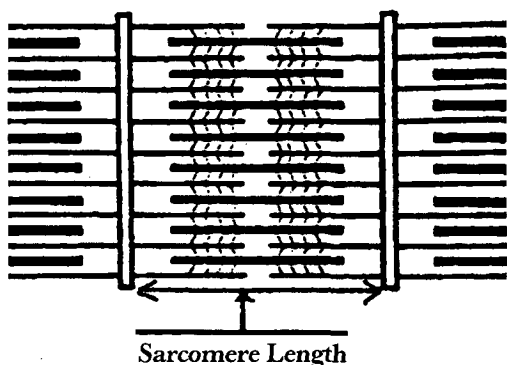
A muscle can be prevented from contracting by one or more means:

- (a) Conditioning, or controlled cooling
- (b) Physical restraint of the muscle
- (c) Electrical stimulation

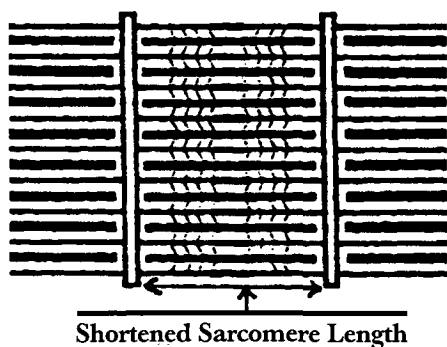
**Figure 1: Muscle structure – actin and myosin filaments**



**Figure 2: Muscle in rigor – sarcomere length**

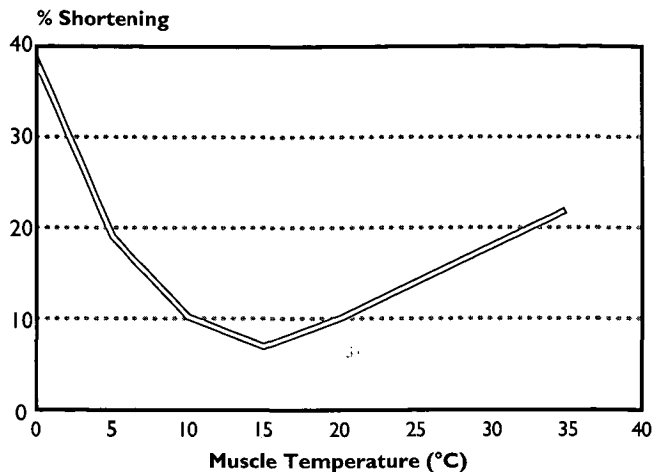


**Figure 3: Cold shortened muscle**



The extent to which the meat is tough will depend on the degree of shortening. Up to 20% shortening will not influence tenderness. Shortening beyond 20%, however, will yield meat of increased toughness. Maximum toughness occurs with muscle shortening of 40%. Beyond this, toughness actually starts to diminish. Muscle which goes into rigor at too high a temperature will also contract to some extent. The degree of contraction, however, is not as severe as that experienced through cold shortening. The optimum temperature for the transition into rigor is 15°C. (Figure 4)

**Figure 4: Effect of pre-rigor temperature on muscle shortening (unrestrained muscle)**



**To avoid cold shortening**

**Conditioning** Cold shortening can be prevented by controlling the way the carcass cools post-slaughter. The lower the temperature of the carcass before it is in rigor, the greater the toughening of the meat. Therefore, effective conditioning regimes prevent any muscle on the carcass from falling below the temperature level at which muscle fibres shorten (12°C) within the first 10 hours of slaughter.

Heavy, well-finished beef carcasses cool more slowly than light carcasses. It cannot be assumed, however, that a slow-cooling, heavy, beef carcass is immune to cold shortening.

For hygiene and weight-loss reasons, rapid chilling is recommended. On the other hand, if chilling is too rapid, both beef and lamb can undergo severe toughening, and electrical stimulation is necessary to give acceptable tenderness.

If the toughening is not too severe, ageing will frequently yield acceptably tender meat.

**Muscle Restraint** Muscle shortening can be prevented by physical restraint. The best way to restrain a muscle is over the skeletal frame of the carcass by hanging the carcass so the muscle is stretched and therefore physically unable to contract.

Muscle restraint is the principle of the “tenderstretch” technique for sustaining meat tenderness. Although still used by a few operations, muscle restraint is not favoured by the industry at large.

### Additional information

CSIRO, Workshop Proceedings, 1993,  
"Chilling of Sides & Carcasses and  
Subsequent Chilled Holding"

Meat Technology Update No. 96/1,  
"Factors Affecting Fat Hardness of Beef  
Carcasses", Australian Meat Technology  
Pty Ltd

Meat Technology Update No. 96/2,  
"Freezer Burn and Weight Loss in Frozen  
Storage", Australian Meat Technology Pty  
Ltd

Meat Technology Update No. 96/4,  
"Tender Beef", Australian Meat  
Technology Pty Ltd

Meat Technology Update No. 96/5,  
"Tender Lamb", Australian Meat  
Technology Pty Ltd

### Additional information

Additional help and advice are available from Food  
Science Australia, Meat Industry Services Section:

	Phone	Fax
Ian Eustace	(07) 3214 2117	(07) 3214 2103
Neil McPhail	(07) 3214 2119	(07) 3214 2103
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Or contact:

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The rate at which these pigments change and the intensity of the end result depends, to a large extent, on temperature. In the case of the oxygenation of myoglobin to oxymyoglobin, low temperatures will slow down the rate of change but will enhance the intensity of the end result.

Fully-bloomed colour, with well-chilled meat at 0°C, takes at least 30 minutes to develop. The oxymyoglobin pigment extends 5mm into meat at this temperature, enhancing the intensity of the bright red colour.

### **Two-toning**

The "redness" of meat colour and its intensity are largely influenced by the condition of meat proteins. If the proteins are denatured to any extent, the reflective capacity of the meat alters and the meat will be a pale colour.

The best illustration of this phenomenon is pale, soft and watery pork (PSE). PSE is the result of a stress-induced problem in pigs causing muscle pH to drop very quickly post-slaughter. A combination of high muscle temperature and low pH causes the meat proteins to denature. In the extreme, this results in a loss of colour and water-holding capacity, hence "pale and watery".

If heavy beef is electrically stimulated but not chilled as rapidly as it should be, the accelerated drop in pH resulting from electrical stimulation, coupled with higher than desired butt temperatures, can cause some degree of protein denaturation. The effect is greater toward the centre or warmer part of the muscle, and the result is a two-toned effect, visible when the meat is sliced.

Two-toning is compounded by an accelerated loss of enzyme-reducing capacity in the meat and, as a result, metmyoglobin browning will occur more quickly in the pale muscle.

### **Hard fat**

The issue of hard fat has been a concern to industry for many years. Workplace safety implications have increased the demands for some permanent solution to the problem arising from the difficulty of cutting through hard fat.

Refrigeration management measures involve monitoring and managing the chilling cycle.

(Recommendations are outlined in a separate brochure.)

### **Freezing**

If hot-boned, non-electrically stimulated meat is frozen pre-rigor, the cold-shortening phenomenon is prevented because muscle is restrained in a frozen state. The rigor process will proceed in frozen meat, albeit very slowly. If the frozen-storage period is long enough – and the temperature high enough, cold shortening and subsequent toughening will be prevented.

If pre-rigor frozen, hot-boned meat is thawed in the short to medium term, the phenomenon of "thaw shortening" will occur. The resulting contraction is more severe than cold shortening and is accompanied by excessive loss of moisture or weep. In this case meat is likely to be extremely tough.