REFRIGERATION, FREEZING AND THAWING

SESSION P: QUALITY OF CHILLED AND FROZEN MEAT

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The chilling of meat is an integral part of the processing whereby meat animals are converted into a commodity that can be transported to feed populations far away from where the animals were raised. Meat is chilled primarily to lessen the chances of bacterial spoilage, for example, on the surface and near the bone. As refrigeration engineering has progressed it has become possible to chill very large numbers of carcasses very rapidly and since it has been found that evaporative weight losses are reduced by rapid chilling there has been a strong inducement to meat factories to chill as fast as possible. A rapid throughput of carcasses is economically advantageous.

However, very fast chilling may cause contraction and therefore toughening in the muscle. This is particularly important in high price cuts such as those from the longissimus dorsi which are grilled or roasted. So a balance must be struck between the need to inhibit bacterial growth, reduce carcass weight loss and obtain high throughput, and the need to minimise cold-shortening and the high costs incurred by installing and running very fast refrigeration plant. It is comparatively straightforward to determine the financial savings obtained by reducing evaporative weight loss and increasing throughput. It is easy to calculate the cost of running refrigeration plant at increased

rates of heat extraction. It is much more difficult to quantify the cash return due to better hygiene, or the sales lost due to increased toughness[1, 2].

It is only in recent years that meat quality research has been able to provide even simple rules for processing in factories, and practice is still largely governed by considerations of engineering efficiency rather than quality control[3]. However, the application of basic scientific knowledge to research and development will increasingly help to define the financial advantages of *inter alia* tenderness[4], good colour, low drip, and long shelf life. These parameters are critical for the consumer and are all influenced very greatly by chilling and freezing conditions[5, 6]. Precise quality control oriented to the consumer product rather than the intermediate commodity will allow and encourage the development of the meat factory into a food factory.

There is a growing realisation that the procure, kill and ship operation which puts carcasses onto the meat commodity markets of the world is not enough to guarantee to the producing country stable outlets, continuing employment and reasonable profits. There is already a trend to concentrate more processing near the point of origin, in the factory itself. The product of the factory then will not be carcasses but primal cuts, vacuum packs and consumer packs of many types including frozen meats ready to go onto the shelves of the supermarkets and stores.

The implications of this for quality control are profound. Factories will have the opportunity to influence to a much greater extent the quality of the goods they produce and will be able to build brand loyalties among their customers, provided

that their goods are of consistent high quality. To effect this will require a managerial revolution in the factory and every stage of meat production will have to be understood in much more precise scientific terms than now and will have to be monitored and controlled effectively.

All the papers in this section contribute to various aspects of understanding the basis of quality in chilled and frozen meat and they are of interest at various stages of animal production and meat processing. There are two papers on production techniques and their effectiveness as assessed on the post-mortem chilled meat. There is a paper on the ProTen system, which is a method of tenderising using pre-mortem injection of proteolytic enzyme. There are two papers on possible modifications of factory technique post slaughter. One, explores the possibility of varying chilling rate, suspension method, and post-mortem aging and assesses the effectiveness of these procedures in improving meat quality. The other paper deals with hot-boning on the line to produce primal cuts ready for marketing. There is an important contribution to the theoretical basis of tenderness testing. Three papers deal with the further preservation of meat through freezing and freeze drying. There is a paper on chemical changes during frozen storage of meat and a paper on an aspect of frozen meat quality that has been neglected for too long, namely the effects of frozen storage on the vitamin content of the meat and its implications for nutritional value. A final paper deals with the effect of microwave pre-heating and freeze-drying on pork quality.

The first paper by S. Cepin of Yugoslavia, is entitled 'The Influence of Feeding Intensity on Carcass Quality and Other

Properties of Meat'. Cepin makes the point that the taste for fat meat is now declining in America and has not been important for many years in Europe. Overfeeding nowadays to produce unwanted fat is very expensive yet since there is a possibility that fat meat is more tender, juicy and flavourful it is necessary to find out whether a high level of feeding will produce high quality meat whose enhanced sale price will pay for the extra food consumed.

Yugoslavian brown bulls were fed with maize silage and concentrates for 1 year to a slaughter weight of approximately 474 kg. Four planes of nutrition were used and the intake of starch units was 3 292, 3 510, 3 909, and 4 016 for the four groups I II III & IV; these values differed at the 0.1% level. The actual daily gains however were 1.070, 1.076, 1.131 and 1.094 kg and these did not differ significantly from one group to another. The starch units consumed per kg of daily gain were ($X\ 10^3$) 3.1, 3.3, 3.5 and 3.7 (rounded figures). These differed at 1% significance. The percentage lean in the carcasses was 73.2, 71.9, 70.4 and 69.8 while fat was 11.0, 12.0, 13.1 and 14.6%. Both these parameters differed from group to group at the 0.1% level. The carcass weights were about 270 kg and did not differ significantly.

So the outcome of the high level feeding was to produce more fat and less lean not only relatively but also absolutely. Was this compensated by meat which was more tender, juicy and flavourful from the overfat carcasses? The taste panels could not find significant differences between the four treatments. In short, Cepin's results are another link in the chain of evidence that indicate that 'fattening' for quality is an

expensive and wasteful exercise[8].

The second paper is by B. Dzinleski and his colleagues from Skopje, Yogoslavia. It is 'The Influence of the Way of Breeding Fattened Lambs on Yield and Meat Quality'. I think that a fairer translation of the original title would be "The Influence of Pattern of Nutrition on the Meat Yield and Quality of Fat Lambs". In this paper the authors took three groups of meliorated Ovcepolska lambs, 74 in all, weaned at 21 days. Approximately equal numbers of males and females were included in each group. Group I were fed from 21 to 56 days with 'mixture' with dried skim milk, Group II were fed with 'mixture' with fish meal. From 56 days to slaughter at 112 days Groups I and II were fed with 'mixture' without the animal proteins. Group III the control suckled their mothers and were fed ad libitum with 'mixture' to the slaughter date.

In all groups male lambs' live weight was significantly greater. The live weights in Groups I and II were significantly less than Group III. The % carcass yield of Groups I and II were higher.

Carcass analysis on the loins showed that a higher % yield of lean was obtained from Groups I and II. However the loins were heavier from the control Group III and the mean absolute yield of lean in g. from the loin was

I ♂	♀	II ♂	♀	III ♂	♀	
385.7	353.63	377.94	350.97	402	362.09	g.
739.33		728.91		764.09		

The maternal milk fed lambs in Group III actually produced more lean meat in absolute yield in the loin. The authors conclude

however that since the percentage yield is better, the artificial diet - they use the word applied in the English translation -, of Group I and II is to be preferred.

The second important point of this paper is that the different sources of animal protein i.e. dried skim milk in Group I and fish meal in Group II were not found to influence either the yield or the chemical composition of the meat.

Taste panel tests showed that all the meat was acceptable but that within the Groups the meat of male lambs was more juicy than that of female lambs.

The next paper is by H.F. Bernholdt & Eric Pritchard of Swifts. This is essentially a review of the famous ProTen process for tenderising meat. The authors state that the most important quality attribute in meat is tenderness and that most customers when disappointed with their purchases gave toughness as the reason.

The process is approved by the USDA and the FDA and has been tested to ensure that there are no side effects either on the live animal or the consumer. Papain is injected between 2 and 30 min before slaughter and the animal killed and dressed in the normal way. The amount injected is governed by the weight and the grade, that is, the degree of fatness. For example, a 1000 lb steer, graded US choice, receives 80 millitres and this results in a level of 5 to 10 parts per million in the meat tissue. The steers liveweight is 455 kg and 80 g of liquid would give an overall concentration of 176 parts per million not 5 to 10. So I conclude that the authors are referring to probably grams of papain when they quote concentrations of 5 to 10 ppm*.

Even this is not fully informative since the activity of the papain is what will actually determine its effectiveness, not the weight of it. Since activities of papain samples vary from batch to batch and according to the degree of purification one cannot assess on the data here how much proteolytic activity is actually in the tissue. Nor do the authors tell us whether they are still using the exceptionally ingenious technique of oxidising the papain before use so that it will be inactive until a reducing atmosphere develops in the muscle post-mortem. This always seemed to me to be the really clever thing about the ProTen process and it is a pity that they do not mention it+.

The enzyme is clearly very effective in tenderising. 40% of Swift's meat, about 2.5% of the US total, is now treated. The process is in use in the UK, Australia and Japan. Some of our plants here in Ireland use it under contract to Swift's from time to time. The enzyme makes cuts which normally require long slow wet cooking, that is, braising or stewing, amenable to roasting or even grilling. A new system of cutting has been devised which is not described here for lack of space and the results of taste panel tests show great improvements in tenderness. In tests in Eastern Europe some very impressive results were obtained with 'silverside' that is roughly the outside round, MM biceps femoris and semitendinosus, and with the brisket. After ProTen treatment these became as tender as grilling meat. (Table 1)

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* Dr Bernholdt replied that these concentrations were residual, in the dressed meat, determined using a radioisotopic method.

+ Dr Bernholdt confirmed that oxidised papain is used.

Table 1: The Effect of ProTen on Brisket

	Score	
Animal	Control	ProTen
Heifer	2.0	5.0
One Calf Cow	2.4	4.8
Old Cow	1.9	4.7
Cows 3 - 4 yrs	2.3	4.8
Cows over 4 yrs	1.8	4.6

(5 point scale, 5 = very tender)

One would like some standard errors perhaps to estimate the significance of the results. I think we can conclude that the ProTen process is on the evidence in this paper on effective and useful addition to the armoury of devices for tenderising.

The next paper is from Oklahoma and is by Henrickson, Falk & Morrison. The title is 'Beef Quality resulting from Muscle Boning the Unchilled Carcass'. It deals with the hot-boning of beef. This is one of the most important developments yet made in the meat industry. It will enable the industry to put a carcass straight through from slaughter to chill to shipping in vacuum packs on a conveyor belt system. Hot meat can be more easily removed from the bone and will shape into attractive primal cuts more readily as New Zealand workers have shown[9, 10]. Chilling the boned-out meat can be effected in a quarter of the space required for an equivalent carcass.

The disadvantages are of course bacterial attack on the cut surfaces and cold-shortening and toughening. Commercial steers were used and one side of each carcass was chilled normally, at 1.1°C for 48h. The other side was assigned to either 3 or 5 or 7h conditioning at 16°C, then the muscles were excised,

packed in Cryovac and chilled at 1.1°C for the remainder of the 48h.

Table 2: The Effects of Hot Boning on long. dorsi

	Hot boned Groups (conditioning time hrs)			Corresponding Control Cold boned Groups		
	3	5	7	3	5	7
Shear values (lbs)	16.44	15.25	14.60	15.14	13.47	14.33
Difference (from control)	NS	*	NS			
Sarcomere lengths (μM)	2.45	2.40	2.57	2.58	2.48	2.70
Difference	NS	NS	NS			
Panel	4.14	4.42	4.47	4.42	4.68	4.41
Difference	*	NS	NS			

It may be seen from the table that the hot-boned meat differed only slightly from the normal cold-boned controls.

Bacterial counts were low. They were estimated on the ground trimmings from each control and treatment side. Psychrophiles ranged from 10^2 - 10^3 organisms per gram and mesophiles from 10^3 to 10^4 org. per gram in both control and hot-boned sides. Other parameters of acceptability such as colour, cooking losses, press fluid loss were not significantly different between the treatments. All this data indicates that one can excise l. dorsi from the carcass 3h post-mortem without a discernable loss in quality. Hot boning is obviously an option that should be investigated by meat companies. It offers great possibilities for savings and better managerial control.

The key to the success of hot boning is hygiene and slow cooling, so that the meat temperature does not fall below 16°C where the contraction of muscle is least. If muscle is chilled below this, contraction becomes increasingly severe and meat becomes tougher. There is evidence that this happens and meat becomes tougher. There is evidence that this happens on the bone as well as off it, since a muscle which is slack on the carcass can be induced to contract and toughen if it is stimulated by cold[11, 12].

The next paper is 'The Effects of Chilling Rate, Suspension and Aging on Beef Quality' by myself. We have found that simply delaying conventional chilling has a significant effect on the toughness of the long dorsi. The toughening that is caused by chilling is not wholly removed by 14 days aging. From this we argue that the whole system of rapid chilling of carcasses in the factories ought to be reappraised.

The results were obtained on 18 two-tooth Hereford heifers. One side of each animal was suspended normally and the other was suspended by the pelvic girdle so that the hind leg stuck out at right angles and the muscles round the outside of the hip and along the back were stretched as they went into rigor. Subsequent examination at 2, 7 and 14 days showed that the meat of the long. dorsi was very tough if rapidly chilled and normally suspended and that this toughness was reduced by aging or tenderstretch suspension or slow chilling.

Table 3: The Effect of Chilling, Tenderstretching and Aging in L. dorsi Panel Scores

		Suspension	
		Normal	Tenderstretch
slow	2 days aged	4.07	4.80
chilled	7 " "	4.60	5.20
(~23° at 10h) post-mortem	14 " "	4.91	5.67
medium	2 days aged	4.80	4.73
chilled	7 " "	5.18	5.78
(~21° at 10h) post-mortem	14 " "	5.16	5.53
fast	2 days aged	2.24	3.53
chilled	7 " "	4.09	5.22
(~10° at 10h) post-mortem	14 " "	4.56	5.56
Suspension Method differences		* *	
Chilling Rate differences		NS	
Aging		* *	

(9 point scale, 0 = extremely tough, 8 = extremely tender)

The effect of chilling overall is non-significant. The very low score at "fast, 2 day aged, normal suspension" shows however the effect of cold shortening in the long. dorsi while still on the bone. This may be responsible for some complaints of tough sirloin steaks! Slow chilling prevents this toughening while tenderstretching and aging can reduce it.

The semimembranosus was improved by tenderstretching and aging but not affected by chilling rate. The psoas was very slightly toughened by tenderstretching (as expected) but otherwise unaffected. The glutaeus medius was slightly tenderised by aging and tenderising while the biceps femoris and

semitendinosus were not affected by any treatment. The objective test for shear force correlated quite well with the taste panel verdicts. The semimembranosus was very much improved in tenderness by tenderstretching.

We found that sarcomeres were lengthened in all muscles by tenderstretching, except in the psoas major where of course they were shortened. In the long. dorsi although fast chilling increased toughness we detected no significant sarcomere shortening. Other parameters of quality like drip in vacuum packs, cooking loss and colour were not affected by different treatments. Bacterial counts did not exceed 4×10^5 organisms cm^2. Evaporative weight loss was 1.2% in fast chilling, 1.6% in medium chilling and 1.5% in slow chilling. We conclude that all three methods of tenderising, aging, tenderstretching and slow chilling have potential for use in an advanced meat factory. But the extra profitability conferred by guaranteeing tenderness should be quantified in some way by research, in order to determine the commercial value of the three methods.

The next paper by Nickolayev, Baranov and Zayas, is entitled 'A Study into Elasto-Resilient and Strength Characteristics of Beef Meat with reference to its Tenderness'. The authors point out that meat is frequently sheared so fast that many of its elasto-resilient and plastic features do not have time to develop and therefore useful data which could help in understanding the sensory subjective features of meat is lost. It would be better to stretch the meat instead at a slow rate of strain.

Three relationships were studied. The first is the P/E relation obtained under a slow constant rate of deformation of 0.06 mm per second. The second is the E/T relation obtained under

a constant stress of sample deformation of 40 - 50% applied for 2 minutes. The third is the shear stress, i.e. maximum load/sample area at a shear speed of 0.25 mm sec^{-1}. Considering the first relation, where P is the stretching force and E is the resulting deformation or strain, two moduli /E/ and /b/ can be found. /E/ is the resilient modulus (modulus of elasticity) of the meat in the initial part of the resilient field, that is where the relation between force and length is still linear, up to the proportional limit. /b/ is the modulus of breaking stress. Equations for finding these from the stress strain curves and other data in the test are given and the dimensions of the meat samples are given.

Taste panel tests on the meat show that the highest value of correlation coefficients are found between tenderness and breaking stress /b/ in raw meat. The three muscles examined, long dorsi, semitendinosus and trapezius present parallel curves when breaking stress for various samples is plotted against taste panel score. When the muscles are cooked the curves coalesce into a single line. The authors attribute the coalescence to the hydrothermal destruction of connective tissue in the muscles and the removal of differences between their structure. All muscles were cooked in the same manner, heating in water to an internal temperature of 80°C.

The authors do not accept that cooked meat in general may be satisfactorily evaluated by the breaking stress of raw muscle, as has been suggested elewhere. (The reference seems to have been ommited in the list of references). Only certain muscles or their groups can be so evaluated.

The next paper which is by Hofmann, Bluchell and Baudisch from Kulmbach is called 'Investigation of Chemical Changes during Storage of Frozen Meat'. It is clearly of importance to build up a corpus of knowledge about what changes do occur in meat over a period of frozen storage particularly now when it looks as though it may be necessary to store meat for many months and even years to smooth out the troughs and peaks of the production cycle[13].

The authors report that SH groups can be valuable as an indicator for changes in quality of frozen meat though the literature is contradictory since some authors say SH decrease while others say they increase. The present authors used long. dorsi from beef and pork. One part was frozen in vacuum sealed bags, the other was frozen in air at -19°C. The samples were tested at 2, 4, 16 and 24 months for protein nitrogen, non-protein nitrogen, total SH, non-protein SH, iodine number, drip loss on thawing loss of weight, taste, juiciness; and tenderness. The chemical changes were quite small. The ratio non-protein SH to non-protein nitrogen decreased slightly on storing but the changes were not large enough to establish a loss of quality. The nutritional value and the quality did not change very much though a slight decrease in tenderness was noticed after two years. Snow formed on the inside of the air space in the bags which were not vacuum sealed. The authors in their discussion draw attention to the need to specify non-protein SH groups and to avoid the imprecise and ambiguous term 'free SH groups'.

The next paper is from Bulgaria, from Nestorov and Kozhuharova. Their title is 'Studies on the Changes in Thiamin and Retinol Content in Pig Liver and Muscles after Sharp Freezing and Long Cold Storage'.

Retinol is Vitamin A and thiamin is vitamin B_1. The authors report that there is insufficient data on thiamin and retinol losses in pig muscle and liver in frozen storage and in view of the importance of these vitamins it is clearly necessary to establish whether they are reduced in cold-storage. Samples were quick-frozen at -38°C and stored at -20°C for up to 3 months. During all this time there was a progressive fall in the amount of the two vitamins. Retinol which began at 27 336 international units post slaughter in the liver fell to about 93% of this value after 3 months, in long. dorsi muscle it began at 825.5 i.u. that is about 1/30th the amount in liver and fell also by about 7 to 8 percent. (The summary gives these figures but the paper on p 3 gives different ones). Thiamin losses are of the same order. The starting level in liver is 0.54 mg percent, which is about 5.4 parts per million by weight. In long. dorsi muscle it is 0.76 mg %. After three months these are respectively 0.49 and 0.70, losses of 9% for liver and 7 - 8% for muscle. These figures compare well with losses from liver or muscle which is slowly frozen and stored at higher temperatures. For example liver stored for 20 days at -4° loses 29% of its retinol and stored at -15° it loses 23%. Over 40 days the losses are doubled approximately to 62 and 61% respectively. The authors point out that the maintenance of the vitamin content of meat at near in vivo levels requires low temperature storage and probably quick freezing as well. This paper and the preceeding one are important in that they mark a new awareness among us in our studies of quality. Hitherto many of us have made the assumption that meat is intrinsically so nutritious that the question of vitamin content can be largely ignored. I think

that these papers show that a high degree of technology may in fact be necessary to protect the nutritional properties of meat[14].

The final paper in this session is from the Soviet Union and is by Zayas, Izotova and Zhouravskaya. The title is 'A Study into the Effects of microwave pre-heating and of freeze drying on Pork Quality'. The meat from pork long. dorsi is cooked by microwaves to a done appearance and an internal temperature of 80 - 85°C. It is frozen at -35°C for 2 hours and then freeze dried. It was found that the final temperature of the product could be allowed to rise to 80°C. This did not affect the quality of product but speeded up the drying process. A number of indices of quality were then tested, including solubility of proteins, water holding capacity, histological structure and microbial lead. Microwave heating cooks the meat in 4 - 5 min whereas conventional cooking in an open kettle took 40 min. It was found that the proteins of the microwave cooked meat were subjected to less deep post-denaturation changes due to the much shorter processing time. This was reflected in the higher solubility of the proteins and by higher levels of free sulfhydryl. There was less moisture loss from the microwave cooked meat and less loss of extractives. These advantages are lost if cured meat is to be cooked and freeze dried and the authors recommend that the freeze dried product be reconstituted with a 1% sodium chloride solution. Organoleptic tests showed that the microwave cooked meat had higher scores for taste and consistency as compared to controls following freeze drying and reconstitution in 1% sodium chloride. The authors conclude on the basis of their data that the production of freeze dried ready-to-serve dishes should include cooking by microwave in the

interests of producing better quality.

References

N.B. Many references are to be found in the Symposium "The Why and How of Meat Chilling", A.R.C. Langford, Bristol, ed. C.L. Cutting, 1972. This will be abbreviated as 'Why and How of Chilling 1972'. Similarly the Why and How of Meat Freezing 1973'.

1. Ingram, M. in Why and How of Chilling 1972, p 1.1.
2. Anon. A New Concept of Processing Beef and Lamb. FAO/WHO Food Standards Programme Supporting Document CX/MH 72/9 1972.
3. Murray, K. Meat Cooling in Theory and Practice in Proc. Inst. Fd Sci and Technol. (UK), 4, 130, 1971.
4. Rhodes, D.N. in Why and How of Chilling 1972, p 4.1.
5. Hood, D.E. and Riordan, E.B. J. Fd. Technol. 8, 333, 1973.
6. Hood, D.E. Proc. 17th Mtg Europ Meat Res Skrs Bristol 1973, p 677.
7. Carroll, M.A. Processing Irish Beef for Export in Beef for the Seventies. An Foras Taluntais, Dublin 1971.
8. Blumer, T.N. J. Anim Sci 22, 771 (1963).
9. McLeod, K. et al J. Fd. Technol 8, 71, (1973).
10. Schmidt, G.R. and Gilbert, K.V. J. Fd Technol, 5, 331, (1970)
11. Herring, H.K. Cassens, R.G. and Briskey, E.J. J. Fd. Sci. 30, 1049 (1965).
12. Marsh, B.B. Woodhams, P.R. and Leet, N.G. J. Fd. Sci. 31, 262, (1966).
13. Harrington, G. in 'Why and How of Freezing' 1973.
14. Cutting, C.L. and Hollingsworth, D. in 'Why and How of Freezing' 1973.