EFFECT OF PACKAGING ON MEAT PRODUCTS

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The title of this session covers a wide spectrum of research activity and it is only possible, given the limitation of time available for presentation, to briefly outline some important aspects of selected areas of research work. The choice of topic will inevitably depend on ones own interest, but it should also take account of new developments in meat products packaging technology, as well as of current research topics, particularly those that have been submitted for consideration by the session rapporteur!

For the purpose of this brief review, 'meat products' will include fresh meat. There are good reasons for doing so based on the criteria mentioned above. Fresh meat is firstly an immediate research interest of the author; secondly, recent technological developments and their application by industry have tended to involve fresh meat; and finally, half the papers in this session are concerned with some aspect of fresh meat research work. At the same time and for similar reasons more established packaging procedures, e.g. canned heat processed meat products, will not be considered.

The development of fresh meat packaging has resulted from the search for new and better systems of meat marketing. At the wholesale level, packaging of primal cuts offers economies in handling, storage and distribution, whilst at the retail level, packaging allows the housewife to see what she is buying by presenting meat in an attractive, hygienic, and convenient form. The development of vacuum packaged primal cuts has gone some way towards improving the efficiency of meat handling and distribution and it is likely that this system will replace the traditional marketing of carcass meat in the future. Shipping and storage costs are becoming simply too expensive to carry the additional cost of low value cuts, excess fat and bone associated with carcasses. Large scale attempts to centrally package retail consumer-size cuts for widespread distribution, however, have been unsuccessful[1]. In spite of the additional advantages which this system offers to the meat packer over vacuum packaging, including greater control of marketing and the opportunity to brand individual retail packs, centralised prepackaging remains an unattained objective of the fresh meat industry.

As a meat exporting country Ireland has a special incentive to develop packaging technology. The increased use of labour inherent in a centralised prepackaging operation and the greater profit margins offered by the manufacture of branded value-added meat products make it important to solve the technological problems associated with these systems and make them technically and economically feasible in the future.

There is an increasing demand in the retail market for a wide range of sophisticated cured and processed meat products. Sliced bacon and cooked ham, salami, luncheon meat etc can all be presented very attractively in convenient consumer-size vacuum packs. Indeed an efficient barrier to oxygen is essential for colour preservation of these products. On the other hand, fresh meat cannot be sold in vacuum packs in the retail market, and attempts to do so in the past have been largely unsuccessful due to consumer resistance to the colour of meat in this form[2]. It would appear necessary to conduct a massive education programme to accompany the introduction of vacuum packaged meat to the retail market-place, in order to make the purple colour of myoglobin, which exists in anoxia, acceptable to the housewife. The meat industry has not shown any serious inclination to carry out such a campaign, nor indeed is there much evidence that it would be successful. In this connection it might be worthwhile to identify the reasons for consumer rejection of vacuum packed retail meat and research in this direction would be useful.

Placing a meat product and especially fresh meat within a film wrapper, with or without air, creates a complex biological system within the enclosed package. Fresh meat continues to respire for a considerable time <u>post mortem</u>, oxygen being converted to carbon dioxide both by the meat enzymes e.g. cytochrome system and by combination with myoglobin pigment. Contaminating organisms also contribute to the respiratory process, the importance of their role in this respect depending on the level of contamination and on the conditions of storage which may provide a favourable environment for growth and multiplication.

The biological activity of cured and processed meats is largely due to bacteriological enzymes. Although oxygen utilisation by the meat tissue still takes place it is at a much reduced level compared with fresh meat. As a result of these processes the composition of the atmosphere within a meat package is continually changing. Actual composition will also depend on physical characteristics of the packaging film, particularly its gas permeability, as well as on solubility of individual gases in meat tissue fluids and on chemical and bacteriological changes taking place within the system.

As far as the meat product is concerned and regarding it from a presentation rather than an eating point-of-view, the basic problems associated with fresh, cured and processed meats are the same and these are: colour, drip and keeping quality. It is on these criteria, as well as on public health considerations, that the principles of meat packaging technology are primarily based.

1. Colour

The colour of fresh meat is due to the relative amounts of the three derivatives of myoglobin, reduced myoglobin, oxymyoglobin and metmyoglobin present at the surface. Reduced myoglobin is the pigment of deep muscle and of the surface of fresh meat under vacuum. On exposure to the air myoglobin rapidly combines with oxygen to form bright red oxymyoglobin, the desired pigment of fresh prepackaged meat. Contact with oxygen, however, eventually leads to oxidation, from the ferrous to ferric state which results in the formation of brown metmyoglobin, the typical pigment of discoloured meat. The oxidation is characterised by being accelerated at low partial pressures of oxygen, the maximum rate occurring at about 1.4 mm Hg. Nitrosylmyoglobin which is the pigment of cured meat, is also subject to oxidation but unlike fresh meat the rate increases with partial pressure of oxygen. Present evidence suggests that the haem pigments of both fresh and cured meats oxidise most readily after dissociation of the relevant ligand, either oxygen or nitric oxide attached to the iron atom of the molecule. Whereas the dissociation of oxymyoglobin increases with decreasing oxygen tension, in the dissociation of nitrosylmyoglobin the tendency to oxidise increases with the oxygen supply[3].

The inter-relationships between myoglobin pigments and partial pressure of oxygen have important consequences in meat packaging technology.

The colour of fresh meat and more particularly its colour stability is perhaps the single most important quality attribute of prepackaged fresh meat, since discolouration normally occurs more rapidly than other deteriorative changes. Rapid discolouration, more than any other factor, has prevented the successful development of centralised prepackaging of fresh meat in retail consumer units. Even where stringent standards of hygiene are applied and where storage conditions are ideal, fresh meat discolours within a few days. If bacteriological contamination is also heavy the colour shelf-life is measured in hours rather than days under normal retail display conditions. The potential of microbiological activity to promote meat discolouration makes it absolutely essential to use only aseptically prepared meat in prepackaging operations.

In the absence of microbial causes of discolouration other factors play an increasingly significant role, the effects of temperature, muscle variation, time post mortem, light and ultra-violet radiation being particularly important in this respect.

Temperature is the most important of these factors. An increase of only a few degrees just above the freezing point of meat causes a greatly accelerated discolouration rate resulting in a reduced shelf-life at the higher temperature. For example, work in the Agricultural Institute has indicated a colour shelf-life for round steak (M. semimembranosus) of over 6 days at 0°C but similar meat is discoloured after 4 days at 5°C and after only 2 days at 7.5°C. Storage at not more than 0°C is absolutely essential for prolonged colour preservation.

Temperature has an indirect as well as a direct effect on colour stability. In addition to the accelerating effect on myoglobin oxidation, higher temperature also promotes bacterial growth, thus further increasing the rate of discolouration which occurs. Next to temperature, and again at low levels of bacterial contamination, the most important rate determining factor in myoglobin oxidation of fresh meat is inter-muscular variability. For example, M. semitendinosus and M. longissimus dorsi generally have very good colour stability whereas M. gluteus medius and M. psoas major tend to form metmyoglobin rather easily even under ideal storage conditions. The intrinsic biochemical causes of differences in oxymyoglobin stability between individual muscles from a single carcase is another topic which requires more detailed study.

Under aerobic packaging conditions where the oxygen concentration at the surface of the meat is high an oxygen concentration gradient is created within the meat tissue and the critical oxygen partial pressure for metmyoglobin formation occurs as a result a few mm below the surface. In this situation a relatively thick oxymyoglobin layer at the surface helps to mask the development of metmyoglobin which forms initially at the interface between the oxymyoglobin layer and the underlying reduced myoglobin pigment in the bulk of the meat. However, in a vacuum pack, in which a residual oxygen content of about 1 per cent may occur in the small volume of package gas,[4] the low partial pressure of oxygen is such that the limit of oxygen penetration is close to the surface. A very thin layer of metmyoglobin is therefore formed at the surface. Fortunately this is normally not thick enough to obscure the underlying purple colour of reduced myoglobin.

Colour stability is nevertheless an important criterion of quality in vacuum packaged fresh and cured meats. It is particularly important in retail packs of cured meats, again because of the value which the consumer puts on red colour and because of the relatively large area of lean meat surface exposed to view. Colour is not just so critical with primal cuts of vacuum packed meat where there is a possibility to trim the surface before preparation of cuts for retail sale and where in any case the surface to volume ratio is relatively small.

The important requirement in both cases is the complete exclusion of oxygen from the system. For long-term storage the limiting factor in colour preservation is probably the small amount of oxygen which gains access to the pack due to the great practical difficulty of making packaging films completely impervious to oxygen. The problems of discolouration caused by exposure of fresh and cured meat to light become increasingly important when they are packaged and exposed to the well lighted retail display conditions of a modern store. Cured meats are more susceptible to light discolouration than fresh because light brings about the dissociation of nitric oxide from nitrosylmyoglobin[3]. Display case lighting can bring about discolouration of cured meat within one hour in the presence of oxygen. Although fluorescent light causes a slight increase in rate of discolouration in fresh prepackaged meat it is of no practical significance. Ultra violet light on the other hand causes a very significant increase in rate of discolouration of fresh meat and must be avoided[5].

2. Drip

Fresh meat has a high water content of approximately 75 per cent and a major problem of meat technology is concerned with preventing loss of fluids from lean meat tissue. The unattractive appearance of blood-like drip in retail consumer packs of fresh meat is a major obstacle to selling prepackaged meat. In vacuum-packaged cuts also the absence of drip is an important criterion of quality. In the latter case 1 - 2 per cent may be commercially acceptable whilst 3 - 4 per cent may be considered excessive[6].

Recent Australian work cites the age of cattle, degree of chilling, cutting style and handling among the important factors which affect the degree of drip in vacuum-packaged meat. To minimize drip older aged cattle, rapid and complete chilling, development of full rigor before cutting (36 h post mortem and deep round temperature of 7°C or below) are recommended. It is also recommended to preserve whole muscles with few cut surfaces as possible and to handle the meat as little and carefully as possible[6].

Cured meat products generally have a lower water content than fresh meat and the presence of salt considerably improves their water-holding capacity. Tumbling procedures, the addition of polyphosphates and emulsification all help to improve water-holding capacity of cured and processed meat products. Drip in the form of visible exudate is not normally a problem with packaged bacon and other cured meats although wetness of these products may be a cause of complaint.

Refrigerated temperature control, avoidence of physical pressures during handling and the packaging of only top quality meat with good water-holding capacity, offer the best means of prevention.

3. Keeping quality

Prepackaging in an air breathing film allows oxygen to pass freely to the surface of the meat and as a result normal meat spoilage organisms, which need oxygen, are able to grow unhindered. The moist atmosphere inside a meat package provides ideal conditions for microbial growth, and spoilage may be more rapid than in meat that is exposed to the air without a packaging film. In the latter case surface drying has a preservative effect which offers some degree of protection against microbial attack.

As well as controlling colour the composition of the gaseous environment within a meat package controls the course which microbiological spoilage will take. For fresh meat the normal spoilage bacterial flora consist of the Pseudomonas/achromobacter group and this is replaced by Microbacterium thermosphactum and other atypical lactic acid bacteria under vacuum[7,8]. The normal putrid type of spoilage which is characteristic of fresh meat stored in air is replaced by a typically sour odour in a vacuum pack.

Although vacuum packaging imparts a distinct advantage to keeping quality, exclusion of oxygen does not prevent spoilage altogether and great care must still be taken to obtain long shelf-life in good condition. Chilled vacuum packaged meat may have very high surface counts (10^8 per cm^2) without showing definite signs of spoilage. Such meat, however, is quite unsuitable for retail cutting and packaging, because of the very rapid discolouration associated with this level of contamination[9].

The accumulation of carbon dioxide is an important factor in the preservative effect exerted by vacuum packaging. Lactobacilli multiply preferentially in the presence of carbon dioxide[10]. In a confined space, such as exists inside a vacuum package, carbon dioxide accumulates rapidly. When its atmospheric concentration rises above about 10 per cent it exerts an inhibitory effect on the microorganisms present, thus prolonging the storage life of the meat. The maximum advantage in terms of high carbon dioxide concentration is achieved when the internal volume is minimal and for this reason a package should fit closely to the surface of the meat.

The preservative effect of vacuum packaging has been responsible for an enormous increase in trade in chilled meat during the 1970's. Vacuum packaging is now extensively used for packaging fresh, cured and processed meats. Boned-out beef cuts are shipped from Australia to Europe and Japan and from the Argentine to European markets. Close control of temperature during transhipment allows meat in this form to be delivered to markets in excellent condition, although it may be already five to six weeks old at the time of delivery.

The presence of curing salts alters the predominant microbiological flora on the meat and helps to prolong shelf life by inhibiting the growth of spoilage organisms. Vacuum packaging also alters the microbial flora from the normal Micrococci associated with aerobic storage to Lactobacilli under vacuum packaging conditions leading again to a souring type of spoilage[7]. Long storage life, in this as in other packaging systems, depends on a high standard of hygiene and the use of low temperature at every stage of preparation, storage and distribution.

With cooked cured meat products there is an additional bacteriological hazard. High cooking temperatures may reduce the normal flora on the meat to a low level, thus giving a clear field of growth to any accidental contamination by pathogenic organisms which can multiply rapidly in the nutrient medium provided by the meat and in the absence of competition from other bacterial types[14].

Quality attribute interactions

An important effect of packaging on colour, drip and keeping quality of meat products is that it accentuates differences between cuts or between individual retail consumer units. Thus differences in colour stability between individual muscles from a single carcase such as between M. gluteus medius and M. longissimus dorsi which would pass unnoticed in a traditional butcher's shop, assume a much greater significance under prepackaging conditions, where a red colour is absolutely essential for retail marketing. The stability of one muscle may serve to accentuate the poor stability of another and exaggerate differences between them.

In a similar way differences in drip loss from cuts of meat are emphasised by prepackaging operations. There is a correspondingly greater need to look at possible ways of eliminating differences in drip between individual pieces of meat. Developments in meat technology thus determine where new research inputs, or increased research emphasis, is required.

Work on water-holding capacity is clearly relevant to packaging technology and recent work has shown that there can be considerable variation in water-holding capacity even within a single muscle such as M. semimembranosus[11]. Variability depends on differences in rates of protein denaturation which in turn are controlled by the rate of chilling at specific depths from the surface and to differing rates of glycolysis at these points. The combined effect of high temperature and high acid condition results in denaturation of sarcoplasmic protein and this effect is most pronounced in deep muscle tissue.

It is worth looking at possible improvements in chilling technique. More uniform water-holding capacity may be achieved by modern rapid chilling procedures, although there is also the possibility that greater chilling efficiency may bring about cold shortening and toughening of the meat. The greater control of chilling offered by carcase hot-boning, in which individual muscles or primal cuts are chilled, may prove to be a significant advantage in this respect.

The interaction between packaging and meat quality is particularly evident where high pH meat is used for this purpose. This applies equally to fresh, cured and processed meats. High pH meat results in a greatly reduced shelf-life of packaged meat. This is a generally accepted principle of packaging technology, although there are few direct references to the absolute effect of pH on keeping quality in the literature. Some cuts of meat e.g. the cuts from the neck tend to have higher pHs and also because of their position in the carcase to be more heavily contaminated during slaughter. Such cuts are particularly susceptible to bacterial spoilage. In addition to finding practical ways to avoid contamination and to reduce the incidence of high pH meat there is need for a more fundamental study of the causes of high pH.

Recent research has been concerned with packaging meat in modified gas atmospheres which offer a number of interesting possibilities in relation to meat packaging technology. There are basically two types of gas packaging system. First the oxygen content of the atmosphere may be enriched to a level of 70 - 80 per cent. This is normally combined with a relatively high concentration of carbon dioxide, (e.g. 20 per cent) which inhibits microbial growth and spoilage, particularly at the high oxygen concentration of the modified atmosphere. Oxygen enriched atmospheres certainly extend the colour shelf-life of fresh meat, particularly meat which is characteristically unstable such as M. psoas major or M. gluteus medius. An atmosphere of 70 per cent oxygen can double the keeping time in air at 0°C.[12]

The second possibility for gas packaging is to replace the normal atmosphere with an inert one. In this case, the pigment is maintained in the reduced myoglobin form and the development of the red oxymyoglobin pigment is delayed until the meat is required for retail sale. This system might be suitable where there is a variation in time between shipment from the meat plant and its arrival at the point of sale.

Inert atmospheres consisting of pure carbon dioxide or pure nitrogen have both been used successfully for this purpose[12]. The myoglobin blooms to a nice red colour when the packs are withdrawn from this atmosphere and exposed to oxygen. Future development of such a system under commercial conditions would probably utilise two packaging films, an inner permeable film in contact with the meat, a number of units packaged in this way and then overwrapped in an impermeable barrier film. A combination of barrier and permeable films has also been used in conjunction with vacuum packaging in which the outer barrier film is removed before retail display.

Another possible way of modifying the atmosphere surrounding the meat in a package is to use solid pellets of carbon dioxide in conjunction with the plastic film wrap. This system has been used commercially and it offers an interesting alternative although doubts have been expressed about its suitability for packaging beef[13]. Essentially the system consists of adding solid carbon dioxide at a level of about 1 per cent to the meat and then wrapping it with a plastic film. The carbon dioxide has a dual function, to reduce the temperature by contact with the surface of the meat and also subsequently to provide an inert atmosphere to inhibit bacterial growth.

A major problem of using inert gas atmospheres to store retail packs of meat is that traces of oxygen may enter the system, either as a result of the packaging operation or through leakages subsequently in the packaging film. Recent work at the Agricultural Institute in Dublin is looking at the possibility of incorporating an oxygen scavenger in order to remove oxygen which might enter. Similar systems are already used for other foodstuffs which are highly susceptible to oxidation, e.g. milk powder.

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