Meat Technology Update

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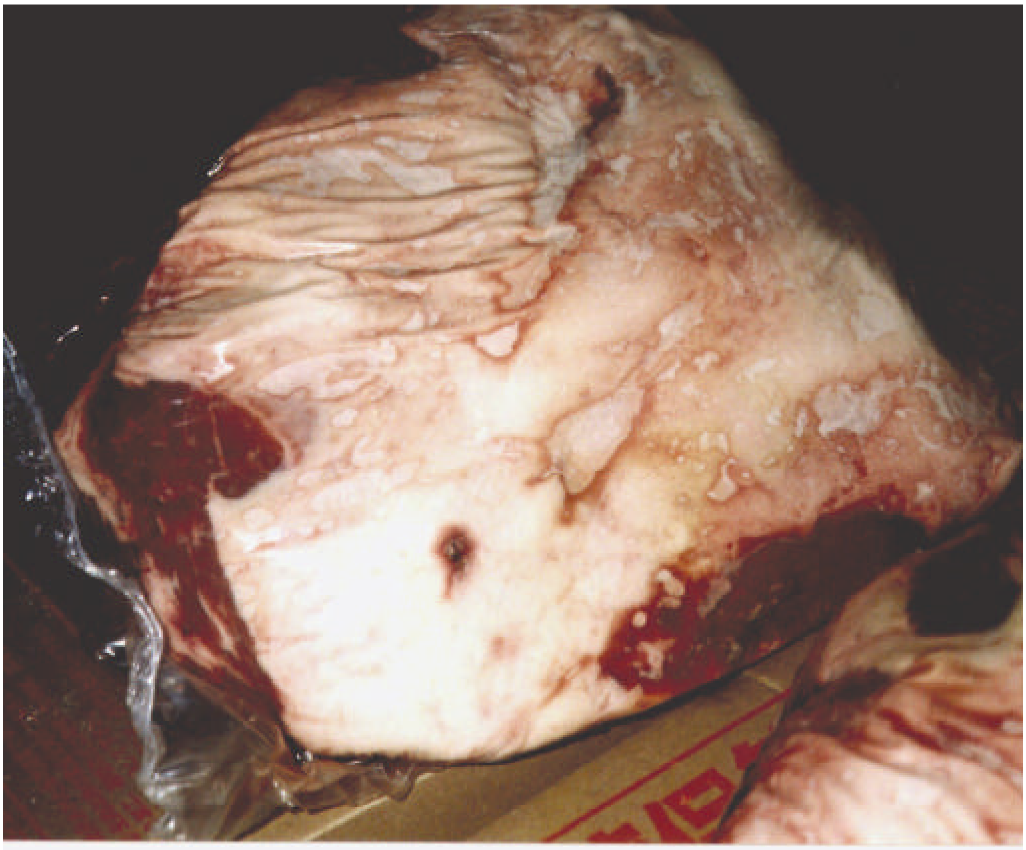
Results for today; Ideas for tomorrow

Gas bubbles in vacuum-packed meat



Sometimes vacuum packs of beef contain small gas bubbles even though the numbers of bacteria are very low. Recent investigations have gone a long way towards explaining why the bubbles occur.

Producers of vacuum-packed meat have known about the phenomenon of gas bubbles in packaged meat for many years. Several packers have reported the appearance of gas bubbles as a quality problem but the cause of the bubbles has been difficult to pin down. Typically, packers have reported that gas bubbles appear within 24 hours of packing and that the bubbles are usually visible over the fat surface of the meat. Reports of bubbles are usually associated with meat from long-term grain-fed cattle.

Food Science Australia staff have investigated the phenomenon of gas bubbles in vacuum-packed meat in a CSIRO Food into Asia project with an industry partner. The investigations have confirmed earlier suspicions that gas bubbles are caused by the release of gas from meat and in particular from the fat portion of meat. The gas bubbles are composed mainly of Nitrogen, and they develop because the solubility of nitrogen in fat decreases as the fat cools down. The bubbles are not related to microbial growth and are not associated with any aspect of the eating quality or shelf life of the meat.

This Meat Technology Update describes some of the recent investigations into gas bubbles and explains the mechanism of how gas bubbles are formed.

Description of the problem

In detailed examinations of packaged meat it was confirmed that gas bubbles almost always form on the fat surface of packaged meat. Furthermore the bubbles invariably form over parts of the fat that are trimmed before packing.

The bubbles appear as a slight separation of the film from the fat surface. The size of the bubbles varies from less than 10 mm to 50 mm in diameter. The bubbles are most extensive on strip loins and rumps. These cuts have the largest area of trimmed subcutaneous fat and are therefore most susceptible to gas bubbles. Gas bubbles

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also affect other cuts such as thick flank, topside, outside and clod. In these cuts only limited areas of the subcutaneous fat are trimmed before packing and these are the areas that are affected by bubbles. Gas bubbles do not affect cuts 2 that have no subcutaneous fat such as cube roll and tenderloin. Cuts with large amounts of internal fat such as chuck roll may develop small gas bubbles in the weep inside packs.

Bubbles are visible the day after packing and grow larger during storage; however, the rate of growth of bubbles is slow. The volume of gas bubbles after six weeks storage is usually only four to five times the volume at 24 hours after packing. In badly affected cuts, the amount of gas in the packs 24 hours after packing is probably less than 1 mL and this may develop to about 5 mL during prolonged storage. Initially there may be many small bubbles in a pack. The small bubbles may grow and coalesce into a fewer number of large bubbles.

Composition of the gas

Although gas bubbles are clearly visible in vacuum packs the day after packing, there is not enough gas in the packs to collect a sample for analysis. It takes about six weeks for the gas volume to increase to a size that can be sampled. The average composition of gas in packs of strip loins, rumps and outsides sampled from six to ten weeks after packing is about 72% nitrogen and 25% carbon dioxide.

To find out which gases are generated in the first few days after packing, some vacuum packs of strip loin were prepared with a small headspace of helium. The headspace was sampled from three hours to seven days after packing. The composition of the headspace changed within three hours of packing with concentrations of both nitrogen and carbon dioxide increasing. At 24 hours the headspace contained about 20% nitrogen and 5% carbon dioxide and this increased to 75% nitrogen and 10% carbon dioxide seven days after packing.

These experiments confirmed that the small gas bubbles that appear soon after packing are likely to be composed mostly of nitrogen with a smaller amount of carbon dioxide.

Where does the gas come from?

It was confirmed that fat is the source of gas bubbles by packing fat and lean separately. Pieces of subcutaneous fat sliced off rumps and strip loins produced gas bubbles in vacuum packs but the denuded cuts did not. In addition, experiments were conducted in which subcutaneous fat was rendered and the resulting tallow vacuum packed. Even vacuum-packed tallow can produce nitrogen gas bubbles a few hours after packing.

One clue to why nitrogen should be released from fat in vacuum packs came from reports about how marine mammals may avoid the bends. One theory is that because nitrogen is five times more soluble in blubber than other tissues, blubber could act as a reservoir for nitrogen when diving mammals ascend from depth.

Another clue is from studies of the solubility of carbon dioxide in fat. In the case of beef fat, there is a small increase in the solubility of carbon dioxide as the temperature increases from –1 to 10 º C. The solubility increases more rapidly above 10 º C and reaches a maximum value at about 22 º C.

The change in solubility of gas in fat appears to be related to the complex phase changes in the different triglyceride mixtures in the fat. When the fat cools from body temperature the solubility of gases should increase in the liquid portion of the fat but as the different triglycerides crystallise the solubility of gases decreases. Fat progressively crystallises as it cools from body temperature and the solubility of gases in subcutaneous fat is low at 0 º C when most of the fat is solid.

Fat in a live animal could be close to being saturated with nitrogen at body temperature. After slaughter, as the fat cools, the solubility of nitrogen in the fat decreases. As the various components of the fat crystallise, nitrogen will be forced out of solution in the fat. Nitrogen that comes out of solution near the surface of the fat can escape from the surface tissue. Nitrogen that comes out of solution in the deeper layers of subcutaneous fat may be trapped in lace by the crystalline structure of the fat in the same way that air bubbles are trapped in ice cubes when water is frozen. When the fat is subsequently trimmed, layers of fat that contain undissolved nitrogen are exposed and nitrogen is released from the freshly exposed surface. If the exposed tissue is enclosed in a vacuum pack, a gas bubble will appear.

The carbon dioxide component

About a quarter of the volume of gas bubbles in vacuum-packed meat is carbon dioxide. While the release of nitrogen from fat, as described above has not been reported previously, there are several reports about the release of carbon dioxide from meat. Some reports indicate that meat produces as much as 0.2 g (i.e. around 100 mL) of carbon dioxide per kg of meat over a five-day period.

It could be expected that gas bubbles in vacuum-packed meat would be formed by carbon dioxide. However the solubility of carbon dioxide in meat is such that if this gas is produced by meat in a tight pack, it will remain dissolved in the meat. If 1 kg of lean meat is sealed in a pack with 960 mL of carbon dioxide, all the gas could be absorbed causing the package to collapse around the meat leaving no remaining pockets of gas. By contrast, nitrogen is sparingly soluble in water and nitrogen coming out of solution in fat is not likely to re-dissolve in lean meat.

Studies on the release of carbon dioxide from meat have been conducted on pieces of meat sealed in atmospheres of inert gas such as nitrogen. In this case, some of the carbon dioxide produced by the meat will be dissolved in the meat but an equilibrium will arise between the carbon dioxide dissolved in meat tissues and carbon dioxide in the surrounding headspace.

This is the situation with gas bubbles in vacuum-packed meat. If there is no headspace in the vacuum pack, carbon dioxide will remain dissolved in the meat. If a headspace is created by release

Table 1: Summary of the different characteristics of gas bubbles and blown packs

Characteristics of gas bubbles	Characteristics of gas production by microbes in blow packs
Gas bubbles are visible between the fat surface and film within 20 hours packing.	No sign of gas until at least 7 days after packing even when conditions to of induce gas production are used.
Gas is predominantly nitrogen with about 25% carbon dioxide.	Gas is predominantly carbon dioxide and also contains about 30% hydrogen.
Gas bubbles are not associated with off-odours or other spoilage.	Gas includes odours compounds such as hydrogen sulphide, short chain fatty acids and amines. Meat is obviously spoiled.
Gas bubbles increase in volume slowly over the storage life of the product.	The gas volume increases rapidly after the first production of gas is noticed.
Gas bubbles can occur on meat with total counts of less than one thousand per cm^2.	Gas production is associated with counts of ten million per cm^2 and higher.
Gas bubbles are usually visible between the fat surface and packaging film.	Gas is visible in the weep and around the meat.

of three undissolved nitrogen from the fat tissue, carbon dioxide dissolved in the lean meat tissue will occupy some of the headspace.

Gas and microbial activity

One of the concerns about gas bubbles in vacuum packs is that the gas could be an indicator of microbial activity. While gas can be produced in vacuum packs by microbial activity, it is clear that the formation of gas bubbles on the fat surface of vacuum-packed meat is not associated with microbial activity. Table 1 summarises the difference between gas bubbles and production of gas by microbes in blown packs.

Avoiding gas bubbles

When pieces of freshly cut subcutaneous fat are vacuum packed, gas bubbles appear in the packs. If pieces of fat are left exposed to air before they are vacuum packed, the number and size of gas bubbles in the packs can be reduced.

If pieces of fat are held chilled for 8 hours before packing there is a considerable reduction in gas bubbles and the bubbles would not be noticed in a commercial situation. If the fat is held for 20 hours before it is packed, gas bubbles can be totally eliminated.

Therefore one solution to the gas-bubble problem appears to be to allow the trimmed surface of fat to de-gas before it is packed. Under normal circumstances, a period of at least 8 hours is necessary to de-gas chilled fat. During de-gassing it seems that nitrogen that has come out of solution in the fat as it cools, escapes from the exposed surface.

Possible solutions

The cause of gas bubbles in vacuum packs is known but it is not easy to suggest commercially practical ways to prevent them.

The key to preventing gas bubbles is to stop the release of nitrogen from the fat surface inside vacuum packs. This can be done by allowing trimmed fat surfaces to de-gas before packing.

Some experiments were conducted on meat that was allowed to de-gas for 24 hours before it was sealed in vacuum packs. Rumps and strip loins were boned and sliced as usual and were placed in vacuum bags but were not sealed in the bags. The open bags were placed in cartons and put in a cartoned meat chiller. They were recovered the next day and the packs were evacuated and sealed.

Gas bubbles were virtually eliminated from the packs that were sealed 24 hours after boning and slicing. Meat from the same production that had been handled conventionally had the usual incidence of obvious gas bubbles.

In most boning rooms it is not practical to hold naked meat or unsealed packs for 24 hours before the meat is sealed in vacuum packs. Such a process could have some disadvantages and requires further investigation. When meat was chilled for 24 hours between boning and sealing the meat in packs, there was a tendency to produce excessive weep in the packs. It is not clear why some of these packs had excessive weep but the quantity of weep would overshadow the improvement in appearance due to the elimination of gas bubbles.

In addition, if cuts are held in unsealed bags in a chiller before they are sealed in the packs, there could be some evaporative weight loss from the meat. In one set of experiments the average weight loss from rumps held for 24 hours before they were sealed in packs was 0.5%.

Microbial counts on some of the meat that was sealed in packs 24 hours after boning were higher than on meat that was packed without delay. However there was no difference in the overall keeping quality of the meat from the two treatments over a ten-week storage period. While it is not expected that a delay between boning and packing will affect the shelf life of the product, this issue needs further investigation.

Trimmed fat surfaces should be exposed for at least eight hours to make a practical improvement in the gas bubble problem but the exposure time can be greatly reduced if the product is held under vacuum. Holding meat at 3 mbar for 1 minute has little effect on gas bubbles but holding meat under vacuum for 5 minutes virtually eliminates gas bubbles when the meat is subsequently vacuum packed (3 mbar is the typical pressure in an evacuated vacuum packing chamber).

Obviously meat cannot be held for 5 minutes under vacuum as part of a normal vacuum packing operation. However it may be possible to hold product in a vacuum chamber separate from the packaging machine for a few minutes before packing. Such a treatment should eliminate gas bubbles. This solution to gas bubbles has not been fully investigated and there could be other unforeseen effects of holding meat under vacuum for an extended period.

Another method of de-gassing fat surfaces before packing is to trim the fat on carcases before boning rather than after boning .If the carcases are trimmed at least eight hours before they are boned, gas bubbles in vacuum packs are greatly reduced or eliminated.

Other solutions

During the course of the experiments, gas bubbles were produced consistently in packs of rumps and strip loins from grain-fed cattle. However other reports have indicated that the appearance of gas bubbles is sporadic. There is a suggestion that the extent of bubbles is lower in winter months than in summer. It is possible that the structure or composition of subcutaneous fat may have an effect on the production of gas bubbles in vacuum packs but such an effect has not been confirmed.

Conclusion

Gas bubbles in vacuum-packed meat are formed by release of nitrogen from freshly trimmed fat surfaces. The nitrogen is usually contained between the fat surface and packing film and gas is not visible in other parts of the pack. There may be cases where nitrogen is released from intermuscular fat and appears as small bubbles in the weep but these cases are uncommon. Once a nitrogen headspace is created, carbon dioxide from the meat tissue will equilibrate in the headspace. Vacuum packs of cuts with a large surface area of trimmed fat such as rumps and strip loins from grain-fed cattle are most likely to exhibit gas bubbles.

Gas bubbles do not affect the shelf life of vacuum-packed meat or any other aspect of meat quality other than appearance in the pack. This type of gas bubble is not related to microbial activity.

De-gassing the trimmed surface of fat at less than 10 ?C before the meat is packed can reduce gas bubbles. Possible methods of de-gassing are:

- holding boned and trimmed cuts in a chiller for at least eight hours before vacuum packing;
- trimming the fat on carcases at least eight hours before boning; and
- holding cuts under vacuum for five minutes before sealing in vacuum packs.

For more information, contact one of the Meat Industry Services staff listed below.

Food Science Australia Meat Industry Services Section

The Meat Industry Services (MIS) Section of Food Science Australia is an initiative supported by Meat and Livestock Australia (MLA) and the Australian Meat Processor Corporation (AMPC) to facilitate market access for, and support world-class practices in, Australia's meat industry.

Need additional information help, information or advice?

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