Comparison of Modified Atmosphere Versus Vacuum Packaging to Extend the Shelf Life of Retail Fresh Meat Cuts

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Summary

The use of modified atmosphere and vacuum packaging for retail packaging of fresh meat seems to be becoming of increasing interest throughout the world. In Denmark, centralized packaging of retail fresh meat cuts has been pioneered by several factories over the last 5 to 10 years.

Only packaging in modified atmospheres and vacuum packs has potential for prolonging the shelf life of centralized packaged meat and this paper will, therefore, focus on their advantages and drawbacks when used for retail fresh meat.

The advantages of packaging in modified atmospheres are mainly due to the formation of the stable oxymyoglobin pigment, when the atmosphere used is rich in oxygen. The drawbacks are a short shelf life, a gradual decrease of flavor and aroma and the requirement of more space. Furthermore, the packs are not suitable for freezing.

The advantages of vacuum packaging the fresh meat are, first of all, a long shelf life and a significant reduction in drip loss, compared to packaging in modified atmospheres. The drawback is the purple color, which may be the greatest problem with respect to consumer acceptance.

Introduction

Vacuum packaging of primal cuts of fresh meat is widely used throughout the world and is generally accepted as an effective method:

1) to prolong the keepability of fresh meat

2) to decrease storage and trimming losses

3) to reduce labor costs

Yet at the retail level, the advantages of modern packaging technology are only catching on very slowly, but the use of modified atmosphere and vacuum packs seems to be offering increasing interest.

In Denmark, centralized packaging of retail fresh meat cuts has been pioneered by several factories over the last 5 to 10 years. In the following, some experience and results obtained during this period will be described.

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Methods for Retail Packaging of Fresh Meat

1) Ordinary retail packaging

   The product is packed in a foodtainer and wrapped in a thin film which is permeable to oxygen.

2) Modified Atmosphere packaging

   The product is packed under a modified atmosphere in a sealed "box." In principle, two different types of atmosphere can be used, i.e. oxygen-rich atmospheres (e.g. 80% O_2 + 20% CO_2) and inert atmospheres (e.g. N_2).

3) Vacuum packaging

   The product is sealed in a thick oxygen impermeable film and evacuated.

All three types of packages lower losses due to evaporation and protect the products from outside contamination. However, their appearance and their ability to prolong the shelf life of the meat are extremely different.

Only MA-packages and vacuumpacks have potential for prolonging the shelf life of centralized packaged meat; therefore, this paper will focus on their advantages and disadvantages when used for retail fresh meat.

Production of MA-packed Meat in Denmark

In Denmark, at least three meat packers produce fresh meat packed in modified atmosphere for retail distribution.

Totally, the production is about 70,000 kg weekly, i.e. 200,000 units weekly. About 30% is beef and about 70% pork. Half of the production consists of minced beef and pork, — 25% are packed as pork chops, with and without bones. — while the rest of the production consists of different kinds of meat cuts, such as beef steaks, goulash-type meat, spareribs, slices of pork belly, etc.

The packers produce totally about 45 different types of retail fresh meat cuts, including offals, so the assortment covers almost all the needs for fresh meat cuts in ordinary supermarkets.

In comparison with the total sale of fresh meat, MA packs amount only to about 2%, while as a whole centralized retail packed meat is about 5% to 10%.

Within the next 4 to 5 years, the packers expect the share of MA-packed and otherwise centralized packed meat (including vacuum packed meat) to increase to about 50% of the total production of retail fresh meat cuts.

Most of the meat is distributed by the packers in special containers, where the product temperature can be main-

tained at 0° to 2°C. About 500 retailers are selling the MA-packed meat. Half of these are traditional grocers and half are supermarkets without their own butcher. Especially for the latter type of retailer, it is desirable to get the MA-packed meat, since they can offer a choice of fresh meat in their supermarkets and avoid expenses connected with having their own butcher.

Regulations for Producing MA-packed Meat

The Danish Veterinary Authorities have specified regulations for production and sale of MA-packed meat and other types of centralized packed meat with increased shelf life. To get permission for production, it is necessary to document a strict management of the production hygiene as only products with a very good bacteriological standard are allowed to be sold as MA-packed meat. At the time, it is also necessary to have a very strict temperature control during production and distribution.

The following will give a broad impression of how the production has to be carried out to fulfill the regulations:

1. Raw Materials

a) Only meat from carcasses slaughtered under very hygienic conditions can be used.
b) As soon as possible after dressing, the carcasses have to be chilled at max. 2°C.
c) It is allowed that beef can be chilled at temperatures not exceeding 7°C. After max. 24 hours, the meat has to be placed in a chiller at max. 2°C.
d) Cutting and packaging has to be done as soon as possible and not later than 4 days after slaughter.
e) For cuts of beef which have to be matured (aged) before retail cutting, it is allowed to vacuum pack and store primal cuts at 2°C before retail packaging. The total time from slaughter to retail packaging must not exceed 14 days.

2. Transport of the Raw Materials

a) Special care has to be taken during transport of meat for MA packaging. The meat has to be supplied as whole carcasses or major primal cuts directly from the slaughter plant to the packaging plant. During the transport, the temperature has to be maintained at max. 2°C. If the meat in any case arrives with temperatures exceeding 5°C, it cannot be used for MA meat.
Immediately after arrival, the meat has to be placed in chiller at max. 2°C.
b) The regulations for transport of offals or aged vacuum packed meat are as above.

3. Production

a) Cutting, mincing, packaging, etc., has to be done at max. 5°C in separate rooms where only meat for MA packaging is being handled.
b) During production, the meat temperature must be kept as low as possible. For minced meat, the temperature should not exceed 7°C after the first mincing.
c) Meat which has been aged in vacuum packs has to be controlled by the veterinarians before being used for MA packaging. Trimmings from aged meat must not be used for MA packaging.

4. Retail Packaging

Retail packaging must be done immediately after retail cutting in either modified atmosphere packs or in vacuum packs. The packaging material used must be "impermeable" to gases.

Immediately after packaging, the meat has to be stored in a chiller at max. 2°C, and it must not be distributed before it has been chilled to max. 2°C.

5. Labelling rules

After packaging, the packs must be labelled with the following information:

a) Government control mark or register number
b) The name of the meat packer or "Packed for _____ (name of retailer)."
c) The product specification
d) △L (sign for meat with long shelf life)
e) Date of packaging, estimated shelf life and last day of sale
f) "Must be kept below 2°C at retailer"
g) Information about the shelf life in the home if kept unopened at max. 5°C.

6. Bacteriological control

a) Bacteriological control must be done under supervision of the veterinary inspector.
b) Immediately after packaging, a representative number of samples must be taken for bacteriological examination. For minced meat, at least two samples have to be taken from every batch.
c) A number of samples must be stored at 2°C for the indicated shelf life, so that samples can be taken later for sensory, and, if necessary, bacteriological evaluations.
d) If some of the results indicate an estimated shelf life below 4 days, the meat must not be sold as MA meat.
e) The results from all examinations must be controlled by the Veterinary Authorities, who will decide what is to happen to the products if the standard is too low.

7. Returns

Packers are not allowed to get the retail packed meat back for further processing from the retailer, even if the indicated time for selling is not exceeded. Only if the Veterinary Authorities give their permission, may the retailers return the meat to the packer.

General Factors Influencing the Shelf Life of Retail Fresh Meat

Packaging cannot improve the quality of the product. It can only delay the onset of spoilage by regulating the factors that contribute to it. The product, therefore, is only protected for a limited amount of time, determined by the system that is used.

In principle, a number of parameters influence the shelf life of meat, i.e. the bacteriological standard of the raw materials, the hygiene and temperature during cutting and packaging, and the gas-composition, but the most important parameter is, without doubt, the storage temperature.

The influence of the storage temperature and the initial bacteriological counts on the shelf life of meat packed in

Table 1. The Influence of Storage Temperature and Initial Counts on Shelf Life

Temperature °C	*Shelf Life in days at different initial counts:*		
	0-10²	*10²-10⁴*	*10⁴-10⁶*
0	16	11	6
5	9	6	4
10	5	3	2
15	3	2	1
20	2	1.5	<1

Reference: ICMSF 1980

atmospheric air and 100% relative humidity is illustrated in Table 1.

From Table 1, it is quite obvious that the influence of the storage temperature on the shelf life is very important. In the lower temperature range, changes will have a more pronounced effect than in the higher temperature range. At the same time, it is also obvious that the lowest initial counts, especially at lower temperatures, gives the longest shelf life.

The figures shown are, of course, quite general. Many other factors influence the shelf life too, i.e. pH-value, relative humidity and composition of the microflora.

As already pointed out, packaging of fresh meat in modified atmosphere or vacuum must be done under extremely good hygienic conditions and under the best possible temperature control.

Modified Atmosphere

Packaging of fresh meat in modified atmosphere is mainly done in thermoformed trays, where a gas-mixture is backflushed into the package after vacuumizing. For most products, the head-space is approx. three times the volume of the meat. The gas-mixture, usually 20% carbon dioxide and 80% oxygen, helps to extend the product's shelf life, mainly by maintaining the meat color. Carbon dioxide is primarily added to the gas-mixture in gas-packed meat because it has a restraining effect on the bacterial growth when the initial counts are low. Oxygen is a reactive gas which influences the flavor as well as the color of the meat.

Another commonly used gas is nitrogen. In retail packaging of meat, nitrogen is considered a neutral filler as it influences neither the color of the meat nor its keeping quality. In Denmark, it is almost entirely used for packaging cured meat products.

The influence of the gases on the growth of microorganisms is important. The presence of oxygen makes the meat spoil as rapidly as in the ordinary retail pack, while carbon dioxide can suppress the growth of several common aerobic spoilage organisms.

More than 100 years ago, Pasteur demonstrated the effect of carbon dioxide on microorganisms, but most of the work of practical value for the meat industry has been done within the last few decades.

Some of the fundamental work was done by the Canadian workers Clark and Lentz (1969, 1972, 1973), who pointed out three most important facts:

1) The optimum concentration of carbon dioxide is 15% to 20%.

2) There is an interaction of temperature and carbon dioxide. The most pronounced effect is at 0°C, while at temperatures exceeding 5°C the carbon dioxide has a very limited effect.

3) The bacteriological counts and especially the physiological conditions of the bacteria are important. If the bacteria have started the growth phase, carbon dioxide has nearly no effect at all.

The longer shelf life obtained by packaging in an atmosphere of 20% carbon dioxide and 80% oxygen might to some degree be due to a change in the microflora, in the direction of bacteria which, due to the influence of carbon dioxide, metabolize in such a way that spoilage odor will not occur.

Thus, it seems reasonable to say that the longer shelf life is a combination of many factors, such as a delay of the bacterial lag phase, a longer generation time and a change in composition of the microflora. It is important to point out that carbon dioxide only has a very limited effect on shelf life if the temperature is high or if the bacteria are in the growth phase at the moment of packaging.

These facts underline the importance of having a very good hygiene during the integrated production, as well as keeping very low temperatures during packaging and storage.

It seems realistic to say that if packaging under MA conditions increases the shelf life of the meat from 2 to 8 days, 3 of the days are due to a good hygiene, 2 days are due to low temperatures and only one day is due to the carbon dioxide.

This statement is only valid for the bacteriological shelf life, while the shelf life with respect to color stability is quite different. To understand the importance of color changes, it is necessary to summarize a few possibly well-known facts.

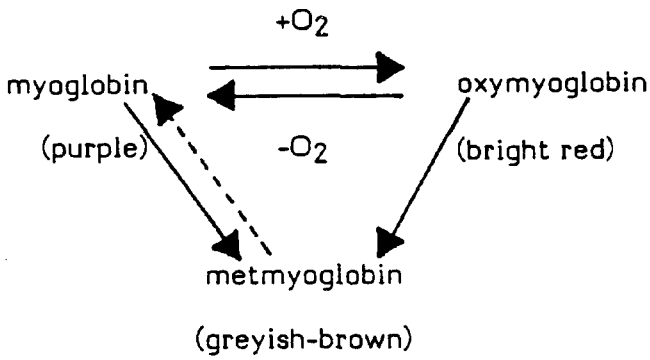
The color of meat is mainly due to the content of myoglobin pigment. Depending on the species, the type of muscle, the age of the animal, etc., the color might vary from light pink to dark red. In freshly cut meat, the shade of the color is bluish as long as the pigment is in its anaerobic form. As soon as the freshly cut surface is exposed to oxygen from the air or from a modified atmosphere, the color will change to a brighter red shade, which is typical for oxygenated myoglobin, also called oxymyoglobin. The oxygenation of myoglobin can be reversed as long as the meat is fresh. Thus, if the oxygenated ("bloomed") meat is placed in a vacuum bag or covered with a glass plate in such a way that the exposure to oxygen is discontinued, the meat turns purple again. The meat consumes the oxygen which is linked to myoglobin, transforming the oxymyoglobin to myoglobin again.

The capability of meat to attract and consume oxygen is most pronounced in the first 2 days after slaughtering, then it declines during the next 2 weeks. If the meat surface is constantly exposed to oxygen, the oxymyoglobin will gradually be transformed into metmyoglobin, which has a greyish brown color, due to a chemical oxidation. The formation of

metmyoglobin will accelerate if the proteins on the meat surface are decomposed by bacteria, dry out, are heated or the like. Only in rare cases, can metmyoglobin be reduced back to myoglobin.

The changes are illustrated in Figure 1.

Figure 1



The most pronounced formation of metmyoglobin will occur about 2 mm below the oxymyoglobin zone, where the partial oxygen pressure is about 6 mm Hg. In the case of packaging with high concentrations of oxygen (about 80%), the zone of oxymyoglobin will increase to about 10 to 12 mm, and the metmyoglobin will no longer shine through to the surface (MacDougall et al., 1975).

The presence of oxygen also causes other changes in the meat than the ones already mentioned. Oxygen provides good growth conditions for spoilage bacteria and simultaneously reacts with a great number of the chemical components of the meat and the fat in such a way that the flavor changes gradually.

To summarize the role of the composition of the gas-mixture, the use of about 20% carbon dioxide and about 80% oxygen seems to be a very good combination with respect to obtaining an attractive meat color and to restrict the bacterial growth in such a way that a reasonable shelf life of the meat can be obtained.

Vacuum Packaging

Vacuum packaging at its simplest is defined as the evacuation of air from a package which then is sealed to maintain an anaerobic environment. Under such circumstances, the essential conditions for bacteria life are changing dramatically, due to a different composition of the residual air.

The vacuum process does not remove enough oxygen to completely restrict the growth of spoilage bacteria, such as *Pseudomonas*. The inhibitory effect of oxygen to spoilage bacteria is not obtained before the concentration of oxygen is very low. This condition will occur within a few days after packaging, due to the respiration of lean tissues and microbial activity. This activity results in conversion of oxygen to carbon dioxide, which can reach a level of 30% to 50%. The gaseous environment is responsible for suppression of common aerobic spoilage bacteria and the development of facultative anaerobes such as Lactic Acid bacteria.

A complete dominance of Lactic Acid bacteria is desirable, as most of these bacteria are harmless in respect to spoilage of the meat. Composition of the initial count is also important, as other bacteria such as *Brochotrix thermosphacta* and *enterobacteria* are able to grow anaerobically.

Table 2. Generation Time in Hours at Anaerobic Growth

Temperature °C	*Lactic Acid bacteria*	*Enterobacteria*	*B. Thermosphacta*
15	3.8	5.4	6.8
10	4.6	8.5	9.7
5	6.5	23.2	20.1
2	8.4	55.7	32.8

In Table 2, the generation time of these bacterial groups is shown.

From Table 2, it can be seen that low temperature favors the Lactic Acid bacteria. If there is just a small amount of oxygen in the packs, also the aerobically *Pseudomonas* will also show a certain growth. It is, therefore, very important to use packaging material with a very high degree of impermeability to oxygen. At the same time, it is also very important to obtain as high a degree of vacuum as possible.

As with packaging in a modified atmosphere, the shelf life of vacuum packed meat depends to a very great extent on the bacteriological status of the meat at the time of packaging. Another important factor to be mentioned is the pH-value, because vacuum packed meat with a high pH-value spoils very rapidly, due to the growth of hydrogen sulfide-producing bacteria such as *Alteromonas putrefaciens* (Newton and Gill, 1980-81). The process of vacuum packaging of meat should therefore include pH control.

The color of vacuum packed meat is, because of the lack of oxygen, purple myoglobin. During storage, the color may change slowly to the greyish-brown metmyoglobin due to chemical oxidation, e.g. caused by "aging," decomposition of the pigment by microorganisms. Also, the oxidation of myoglobin may be accelerated, perhaps due to high concentrations of carbon dioxide.

A real sign of spoilage, such as metmyoglobin formation, etc., only occurs on rare occasions. Therefore, the most reliable indication of the state of freshness of vacuum packed meat is the odor of the meat when the pack is opened.

To create a system for vacuum packaging of fresh meat, it is necessary to provide not just a packaging system but a complete process, which is made up of good food manufacturing, packaging materials, packaging machinery, etc. Many such systems have already been created, and the most promising ones are perhaps the systems including thermoformed and thermal packs, shrinking bags and vacuum skin packaging.

Advantages and Drawbacks of Packaging in Modified Atmosphere and in Vacuum

Packaging in modified atmospheres or in vacuum packs may in principle be done in the same type of packaging material. The most commonly used materials are laminates of plastic films with a very low permeability to oxygen and carbon dioxide. In the case of MA packs, the low permeability is needed to keep the gases within the packages, while the

opposite is the case in vacuum packaging.

Despite the use of the same material and principle, the two packaging systems are quite different in respect to appearance and shelf life.

Appearance of the Meat

As already pointed out, the appearance of MA-packed meat is very attractive to the consumer, because a bright red color seems to be synonymous with freshness. This might very well be the reason for the increasing interest in acceptability of retail fresh meat packed in modified atmosphere.

The color of the meat packed in vacuum packs is purple because of the lack of oxygen. This presumably presents the greatest drawback when selling vacuum packed meat. This is especially the case for beef, while consumers might be more likely to accept vacuum packed pork and veal.

Aroma and Flavor

Using gas mixtures rich in oxygen may provide good growth conditions for spoilage bacteria; they may simultaneously react with a great number of chemical components of the meat and the fat in such a way that the flavor deteriorates gradually. In the case of vacuum packaging, the meat will retain its aroma and flavor for a longer period mainly because the microflora within the packs consist of harmless Lactic Acid bacteria. The activities of these bacteria simultaneously result in development of a sour odor.

Shelf Life

The shelf life of MA-packed meat is limited by the high content of oxygen and by the activity of spoilage bacteria. MA-packed meat is usually labelled to be sold within 4 to 7 days after packaging, but a shelf life of 9 to 12 days at 2°C may very well be obtained at retail (Buchter, 1980).

The work done at DMRI on vacuum packaging of fresh cuts of beef and pork indicates a considerably longer shelf life compared to MA packaging. Using a high degree of vacuumizing and cling sealing, a shelf life of 1 to 3 weeks at 2° to 4°C can easily be obtained (unpublished data).

Final Remarks

Modified atmosphere has only a few advantages, compared to vacuum packaging, e.g. the color, packaging of bone-in cuts, while the drawbacks are many. Packaging in MA packs gives the meat a shorter shelf life, it requires more space during distribution and storage, and it is not suitable for freezing.

The advantages of vacuum packaging are, first of all, the longer shelf life and a significant reduction in drip loss. The packs are very suitable for keeping in the consumer's freezer. Vacuum packed meat requires only little space during distribution and storage. Another advantage is that leakers are very easy to identify. The greatest drawbacks are the purple color, which may be a problem with respect to consumer acceptance. Also, the problems concerning packaging of bone-in cuts and the difficulties in recognizing the exact shape and quality of the cuts in vacuum bags are real obstacles to the introduction of the system.

A summary of the comparison of the two packaging systems as presented in this paper is shown in Table 3.

Table 3. Characteristics of Packaging in MA Packs and in Vacuum Packs

Packaging Systems	*Meat Color*	*Shelf Life*	*Shelf Life Limited by*
MA packs with 80% oxygen + 20% carbon dioxide	Bright red	4-6 days	Oxygen + bacteria
MA packs with nitrogen	Purple	1-3 wks.	Bacteria
Vacuum packs	Purple	1-3 wks.	Bacteria

References

Buchter, L. 1980. Hot-boned and traditional-chilled beef as raw material for the production of controlled atmosphere retail packs — comparison of sensory and microbiological properties. 26th European Meeting at Meat Research Workers, Colorado Springs, USA, August 31st-September 5th.

Clark, D.S.; Lentz, C.P. 1969. The effect of carbon dioxide on the growth of slime producing bacteria on fresh beef. Can. Inst. Food Technol. J. 2, 72-75.

Clark, D.S.; Lentz, C.P. 1972. Use of carbon dioxide for extending shelf life of prepackaged beef. Can. Inst. Food Technol. J. 5, 175-178.

Clark, D.S.; Lentz, C.P. 1973. Use of mixtures of carbon dioxide and oxygen for extending shelf life of prepackaged fresh beef. Can. Inst. Food Technol. J. 6, 194-196.

JCMSF. 1980. International Commission on microbiological specifications for Foods. Microorganisms in Food III.

MacDougall, D.B.; Taylor, A.A. 1975. Color retention in fresh meat stored in oxygen — a commercial scale trial. J. Food Technol. 10, 338-347.

Newton, K.G.; Gill, C.O. 1978. Storage quality of dark, firm, dry meat. Applied and Envir. Microbiol. 7, 375-376.

Newton, K.G.; Gill, C.O. 1980-81. The microbiology of DFD fresh Meats. Meat Science 5, 223-232.