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Parallel session 8: Microbial and chemical spoilage

PS8.01 Requirements to shelf-life of fresh meat and meat products 448.00

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***Abstract* - Shelf-life is an important issue for producers of fresh meat and meat products. Supermarkets and consumers ask for long shelf-life as well as good quality throughout the entire shelf-life period. The predominant reason for meat spoilage is microbial activity. But even fresh sterile vacuum-packed meat has limited shelf-life, which might be caused by the activity of intrinsic enzymes as the meat becomes very bitter in taste. Several research groups have worked on the development of mathematic models describing the growth of specific micro-organisms and other groups have worked on modelling the sensory shelf-life of fresh meat and cured meat products. Studies of shelf-life of fresh meat show that "general" spoilage of vacuum-packed meat is not visible to the consumer and there is no correlation between the visual appearance of the vacuum-packed meat and the flavour or microbial count in the meat. In ready-to-eat meat products the sensory shelf-life depends on the microbial competition in the products. When the same product was sliced at different plants it was found that the total count and number of lactic acid bacteria did not differ in the samples, but the taste "old and sour" only increased in samples from one plant. To optimize shelf-life of ready-to-eat meat products the most efficient parameter is slicing hygiene and storage temperature. Furthermore, addition of preservatives like NaCl and lactate are good alternatives to increase shelf-life as they both inhibit the growth of pathogens like *L. monocytogenes* and the growth of different spoilers.**

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***Index Terms* - challenges to the industry, fresh meat, important factors determining shelf-life, processed meat.**

I. INTRODUCTION

Shelf-life is an important issue for producers of fresh meat and meat products. Supermarkets and consumers ask for long shelf-life as well as good quality throughout the entire shelf-life period. This is a challenge to the meat industry as they have to optimize the most beneficial processes in order to achieve the best shelf-life.

Shelf-life can be defined as the period of time a product can be stored without being sensory unacceptable or becoming a health risk. In this definition we include deterioration due to both chemical and microbial changes in the product. Depending on the specific product, the processing and storage conditions will be the dominating parameters in determining the shelf-life of the particular product. It has to be noted that a product can be classified as sensory acceptable but contain an unacceptable number of pathogens which makes the product unacceptable for human consumption and the shelf-life is exceeded. Therefore, there is not always a clear correlation between sensorial acceptability and bacterial count.

The predominant reason for meat spoilage is microbial activity. The micro-organisms can cause discoloration, off-odours, off-flavours, gas formation, slime formation and/or changes in texture. In some cases the spoilage is caused by one specific spoilage organism [10, 12] and in other cases the spoilage seems to be caused by the growth of a more heterogeneous micro-flora.

Several parameters affect the shelf-life of fresh meat and processed meat. The first step in the production line is the living animal. The quality of the meat can be affected by factors such as health, age, sex, feeding and enzyme activity. The next steps are slaughtering, deboning and cutting during which time, temperature, hygiene and packing are important parameters affecting the shelf-life of fresh meat for industrial use or retail. For processed meat, the shelf-life is further affected by processing like curing, fermentation, heat treatment, slicing, packing, hygiene and temperature.

In the literature, several research groups have worked on the development of mathematic models describing the growth of specific microorganisms like *Brochotrix thermospacta* [1,5] and *Pseudomonas* spp. [4] or pathogens like *Listeria monocytogenes, Salmonella or E. coli* [8,9]. These models are excellent tools to gain knowledge on the growth of specific organisms but they do not provide the meat industry with an estimate of the most probable shelf-life of their products. Other groups have worked on modelling the shelf-life of fresh meat [13,15] and cured meat products [14]. The benefit of these models is the description of the sensory shelf-life of the product and not the growth of specific micro-organisms. However, these models are results of the specific combination of micro-organisms growing in the product and this combination of micro-organisms is not necessarily the ones contaminating products produced at different meat companies.

The objective of the work done at the Danish Meat Research Institute was to investigate whether the shelf-life of fresh beef and pork could be predicted based on the number of psychrotrophic colony count at the time of packing in combination with different packing methods and storage temperatures [15] and to study the effect of the slicing plant and storage on the microbial growth, aroma composition and sensory profile in MA-packed saveloy [11].

II. WHY SHELF- LIFE IS IMPORTANT

Throughout the supply chain for fresh meat and meat products, shelf-life is a crucial issue for all involved partners. Apart from the technical aspects, shelf-life is also an important economic factor and has strong commercial impact. On the Business-to-Business market, economics concern the meat industry as well as retailers and the food service sector. They all need an efficient system for logistics throughout the supply chain in order to minimize losses and damage to the product that might lead to lack of supply, recalls of products and other inconveniences with great economic consequences.

Shelf-life for fresh meat and meat products could be extended by lowering the temperature to between 0 °C and -2 °C during distribution to the retail business. This approach called deep chilling or super chilling needs special cooling units during transport. If the supplier is able to demonstrate a longer shelf-life with super chilling, it is possible to increase the business opportunities and the competitive advantage. As a meat packer it is thus possible to cover a larger area and to supply more costumers either retailers or industry. One example is case-ready products which are a growing category of products in retail, as the discounters are gaining market shares in many countries and are demanding more fresh products to strengthen their profile. The advantage for the retailer is the possibility of having more flexibility with longer shelf-life, and the end users will have increased opportunities to choose fresh products instead of the alternative of frozen products.

From an industrial point of view, super chilling is a way to reduce shelf-life limitations in terms of shipping cuts for further processing for a longer distance. The technological challenge is, however, to ensure a steady low temperature close to -2 °C throughout the entire transport. Another aspect is the possible saving of energy to freeze cuts for buffer storage, as super chilling can be usable in buffer storage. So there seems to be an incentive to develop technical solutions ranging from the actual cooling units to identifying the advantages of different types of packing combined with super chilling.

III. SHELF-LIFE OF FRESH MEAT

The consumer has an obvious interest in purchasing meat that shows no signs of spoilage. Packers have an interest in increasing the shelf-life as much as possible allowing them to market a product with a high quality and reducing costs for logistic. Authorities demand that the packers' document that the shelf-life stated on the pack reflects the true shelf-life and not the wishes of the sales department.

The work of Meinert et al. (2009) [15] has made it possible to draw some general conclusions regarding shelf-life of fresh meat (beef and pork). From the consumer point of view, it is important that the determining factor for shelf-life of vacuum-packed meat is raw meat odour. This leaves the consumer unable to secure the quality of the purchase without opening the pack. The result may be lack of confidence in the stated shelf-life and a demand for newly packed fresh meat. One of the results from the experimental work was that the shelf-life of single packs, in a batch of fresh meat produced under as similar circumstances as possible, differs considerably. In a study using vacuum-packed cuts of beef stored at 2.1 °C for 85 days, the first spoiled pack was observed after 38 days and the last acceptable pack was observed after 71 days [15]. This leaves the producer in a dilemma - if the chance of a consumer buying a pack of fresh meat with notes of spoilage has to be very small, then the shelf-life stated on the pack must be short compared to the time where 50 % of the packs can be expected to be acceptable respectively unacceptable. On the other hand, if the producer is willing to take the chance, that at the end of the stated shelf-life only a few packs left have the characters of fresh meat, then the shelf-life stated on the pack can be long compared to the "average" shelf-life. For the producers, the model described [15] can be used to evaluate how a given shelf-life can be achieved. It is interesting that the effect of temperature is much larger than the effect of psychrotrophic count at the time of packing. An example is shown in Figure 1, where the average shelf-life of vacuum-packed pork (days until the average character of raw meat odour is 5) with a normal (2 log cfu/cm^2), low (0.5 log cfu/cm^2) and high (3.5 log cfu/cm^2) psychrotrophic count at the time of packing is shown at three different temperatures (0, 2 and 5 °C).

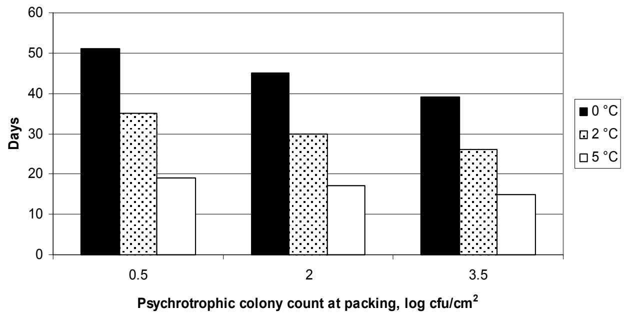

Figure 1. Average shelf-life of vacuum packed pork (the day where only 50% of the packages is acceptable) stored at 0°C, 2°C and 5°C. Products produced with a normal (2 log cfu/cm^2), low (0.5 log cfu/cm^2) and high (3.5 log cfu/cm^2) psychrotrophic count at the time of packaging.

Furthermore, the experimental work [15] has shown that fresh sterile vacuum-packed meat has a limited shelf-life. This must be caused by the activity of intrinsic enzymes as the meat became very bitter in taste. This shows that temperature in combination with bacteriological load at the time of packing will determine the kind of spoilage predominate in fresh vacuum-packed meat.

Another interesting observation during the studies of shelf-life is that "general" spoilage in vacuum-packed meat is not visible to the consumer. There is absolutely no correlation between the visual appearance of the vacuum-packed meat and the flavour or microbial count in the meat. This show that the consumer or retailer has no chance of condemning the meat before the pack has been opened.

It should be noted that the remarks above only refers to the "ordinary" kind of spoilage. Interesting kinds of spoilage still occur, and they are not described by the model. For instance one kind of spoilage is related to the growth of *Pseudomonas* spp. like *P. libanensis* which produce a blue colour during growth on the surface of meat [7]. On the surface of ham visible blue colouring can be detected only 5 days after slaughtering and on a "pig-fat-medium" visible growth was detected after 3 days of incubation at either 5°C or 20°C. The shelf-life predicted for pork stored aerobic at 5°C is 6 days (90% of the packs are acceptable) or 8 days if only 50% of the packs have to be acceptable.

Another kind of spoilage is "blown packs" found in vacuum-packed beef. When this kind of spoilage occurs it can be detected within approx. 2-3 weeks of storage at 5°C. In inoculated samples, gas production was observed in a few samples after only 8 days and all packs were more or less blown after 19 days of storage at 5°C. All packs were sensory unacceptable in less than 2 weeks. If the samples were stored at 0°C, gas production was observed in a few samples after 15 days and all packs were more or less blown after 35-40 days. All packs were sensory unacceptable in less than 3 weeks. But the model for vacuum-packed beef predicts a shelf-life of 40 days at 2°C and 22 days at 5°C (90% of the packs are acceptable) or 58 days at 2°C and 32 days at 5°C if only 50% of the packs have to be acceptable.

"An eternal life does not exist for fresh meat."

IV. SHELF-LIFE OF PROCESSED MEAT

Ready-to-eat meat products are often post-contaminated because of a slicing and packing step after heat treatment. The number of bacteria and the identity of the contaminants affect the shelf-life as well as the storage temperature and the amount of preservatives added to the recipe.

Cooked, sliced meat products packed in vacuum or modified atmosphere normally maintain a good sensory quality for at least 4 weeks at 5°C. The dominating bacteria in such products are lactic acid bacteria. In some cases, high numbers of lactic acid bacteria do not spoil the products [6] and in other cases the lactic acid bacteria present are spoilers [2]. Some of the dominating strains causing spoilage belong to the species: *Leuconostoc carnosum, Carnobacterium divergens, Enterococcus faecalis* and *Brochotrix thermospacta* [2, 3, 16].

In the work described by Holm et al (2009) [11] a cooked saveloy was sliced and MA-packed (30/70 CO_2/N_2) at three different plants. Holm et al. (2009) [11] describes the changes in aroma composition during storage. During storage for 6 weeks at 5°C these packs were also examined for microbial growth and sensory evaluations were performed. The sensory evaluation showed that all products were acceptable after four weeks of storage. But in all products the smell and taste of "fresh meat" and "spices" decreased during storage. In products sliced in one of the three production plants (B) we also found an increase in the smell and taste called "old and sour". However, the total count and number of lactic acid bacteria did not differ in products from plant B and C. But in the microbial analysis we also measured the number of *B. thermospacta* (STTA-agar)*, Enterobacteriaceae* (RVG-g agar)*,* Pseudomonades (CFC-agar) and Yeast (MYGP agar). The results showed an increase in *B. thermospacta* to 6 log cfu/g in four weeks, *Pseudomonades* increased to more than 5 log cfu/g in 6 weeks and yeast increased to 5 log cfu/g in 6 weeks. In the products from slicing plant A and C no increase in these counts was observed even though *Brochotrix* was detected in samples from all 3 slicing plants at day 1, and *Pseudomonades* were below the detection level in samples from all slicing plants. These data might illustrate the fact that complicated microbial interactions occur in MA-packed meat products. In some products, a natural occurring lactic acid bacteria flora is able to be the dominating flora whereas in other cases the lactic acid bacteria are not able to outflank spoilers like *Pseudomonades* and *Brochotrix*. Furthermore, the results show that strains among *Pseudomonades* are able to grow in MA-packed meat products with 30% CO_2. This shows that we do need methods or indicators which can be used as an early warning of spoilage as the number of bacteria is not good enough and also gives the warning far too late.

To optimize shelf-life of ready-to-eat meat products the most efficient parameters are slicing hygiene and storage temperature. Then addition of preservatives like NaCl and lactate are good alternatives to increase shelf-life as they both inhibit the growth of pathogens like *L. monocytogenes* and the growth of different spoilers.

V. CONCLUSION

Temperature, packing and hygiene are the most effective parameters to optimize when shelf-life of fresh meat and processed meat has to be increased.

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