DMRI PREDICT, A TOOL TO DETERMINE SHELF LIFE OF FRESH MEAT

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Reliable prediction of shelf life for fresh meat is of the utmost importance to ensure good eating quality at the use-by date and to ensure optimal and flexible retail distribution. It is the responsibility of the meat producer to determine the use-by date. Therefore, the Nordic meat industry's demand for a tool to declare an optimal use-by date for various pork cuts initiated the development of mathematical models for prediction of shelf life. Three individual models for fresh pork were developed, one for each of the packaging methods: vacuum, aerobic (e.g. thin wrap or open meat boxes) and modified atmosphere (high oxygen). These models can be combined and the use-by date can be predicted based on a sequence of storage conditions. The models for fresh pork cuts, as well as the models for beef and chicken, contain the inevitable natural variation and therefore reflect real life. All models can be reached on the homepage http://dmripredict.dk.

I. INTRODUCTION

The meat producers are responsible for fulfilling the documentation requirements for determining the use-by date for chill-stored fresh meat. Predicting a reliable shelf life of chill-stored fresh meat is important in order to ensure good eating quality at the use-by date and to ensure optimal and flexible retail distribution. Initiated by the Danish, Norwegian and Swedish meat industries, DMRI has worked for several years to develop mathematical models for the prediction of shelf life of fresh meat concerning both pork, beef and chicken. The models are based on data from large storage experiments with meat collected at several commercial production sites. In this way, the models reflect the real life situation for the meat producers by including the natural variation in shelf life that are present at all times. In the early work-stages it was shown that shelf life of fresh meat could be predicted based on the colony count of psychrotrophic bacteria at the time of packaging in combination with the selected packaging method and storage temperature. Furthermore, that raw meat odour was proven to be a valid predictor of shelf life (1). The models for beef, pork and chicken, respectively, are gathered on the homepage: http://dmripredict.dk with free access.

The aim of the presented work was to develop a mathematically based model for the prediction of shelf life of fresh pork under different storage conditions with the possibility of combining different storage conditions in the same shelf life prediction.

II. MATERIALS AND METHODS

Meat. The meat cuts were collected at different commercial slaughterhouses in Denmark, Germany, Sweden and Norway. Preferably, the meat was packed at the production site. The cuts used included loins (with and without rind), collar, top round, spareribs, belly, and tender loin.

Transport. The packed meat was transported from the production site to DMRI in a cooling van with controlled temperature conditions.

Temperature logging. The temperature was logged from the time of departure at the production site and all the way through the storage experiment.

Storage. For each storage experiment, approx. 70-90 individual packs of meat were included, the lower the temperature, the longer the shelf life and the more packs were needed. The temperature range of the experiments was from -1 °C to +7 °C.

Storage conditions. In some of the storage experiments, the storage conditions were changed during the experiment, e.g. a subgroup of meat samples was moved to another temperature or the packed meat was opened and repacked (Figure 1).

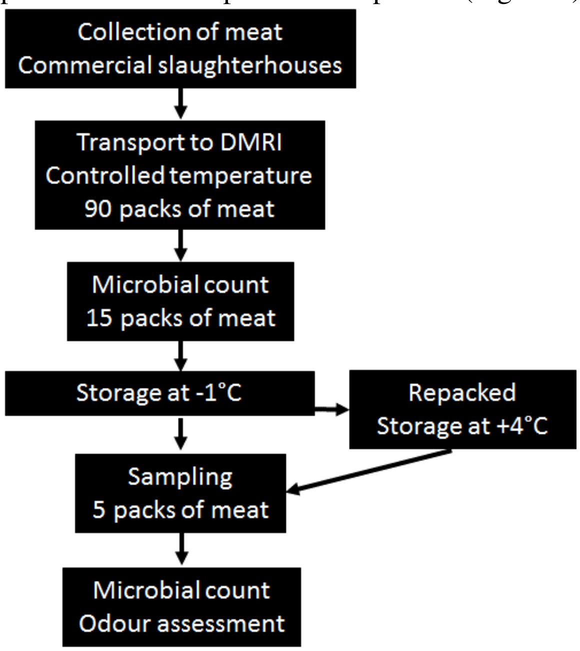

Figure 1. Flow diagram of the overall design for the series of storage experiments during which a subgroup of samples were placed under new storage conditions. The storage experiment was not stopped until the meat was rotten. See Table 1 for all storage combinations with repack.

Storage experiments. A large number of individual storage experiments was conducted; these are outlined in Table 1 and 2. The model "back bone" are the 20 experiments shown in Table 2.

Table 1. The ten storage experiments for the repack study. VAK = vacuum and MAP = high oxygen modified atmosphere (70% O_2 + 30% CO_2), see also Figure 1.

Experiment	**Pork cut & Packaging Storage at -1°C**	**Repack Storage at +4°C**
1	Belly, aerobic	No repack
2	Belly, vacuum	No repack
3	Loin, aerobic	No repack
4	Loin, vacuum	No repack
5	Belly, aerobic	MAP
6	Belly, vacuum	VAK
7	Belly, vacuum	MAP
8	Loin, aerobic	VAK
9	Loin, vacuum	MAP
10	Loin, vacuum	VAK

Table 2. The conditions used for the twenty storage experiments conducted for model development. The collars used in experiment 15-18 were without rind. "High and low count" refers to the level of bacteria on the meat at the time of packaging.

Experiment	Pork cut	Packaging	Storage
1	Loin	VAK	+7°C
2	Loin	Aerobic	+7°C
3	Collar	MAP	+2°C
4	Collar	MAP	+7°C
5	Tender loin	MAP	0°C
6	Tender loin	MAP	+4°C
7	Spareribs	VAK	-1°C
8	Tender loin	VAK	-1°C
9	Collar + rind	Aerobic	0°C
10	Collar + rind	Aerobic	+3°C
11	Collar + rind	Aerobic	+7°C
12	Collar - rind	Aerobic	0°C
13	Collar - rind	Aerobic	+3°C
14	Collar - rind	Aerobic	+7°C
15	Collar, high count	VAK	+4°C
16	Collar, low count	VAK	+4°C
17	Collar, high count	Aerobic	+4°C
18	Collar, low count	Aerobic	+4°C
19	Top round	Skin pack	+5°C
20	Top round	Skin pack	+5°C

As can be seen from Table 2, skin packed pork was also tested; it showed the same shelf life as for vacuum packed pork. The significance of initial bacterial counts was also tested. Collar was a frequently used pork cut as it consists of several minor muscles and some fat. Collar is considered more prone to oxidation than e.g. loin.

Furthermore, shelf life investigations were included in other projects as well. Some of these data have also been included in the model, but are not shown in Table 1 and 2, as these studies ended earlier in the shelf life period (before the meat was rotten) than the original shelf life studies.

Microbiological and odour analyses. Uniquely, the microbiological and sensory analyses were conducted on the same individual sample and could thus be directly linked to the development of spoilage. The order of analyses was 1. psychrotrophic colony count (2) and 2. raw meat odour and general appearance.

Raw meat odour was evaluated by at least three experienced assessors from DMRI. The odour was characterized using the following scale: 2: fresh; 4: slightly diverging but acceptable; 6: diverging to an unacceptable degree; 8: putrid/rotten.

Gas composition. When modified atmosphere was used for packaging, the gas composition was measured with a Dansensor (PBI-Dansensor, Ringsted, Denmark) for control; data was not included in the model.

Data analysis. Fitting of both the microbiological growth curves and the sensory evaluation of the raw meat odour was performed using nonlinear regression (proc Nlin) (3) with the Baranyi and Roberts growth model (Figure 2).

$$\ln(N) = \ln(N_\infty) - \ln\left(\left(\frac{N_\infty - N_0}{N_0}\right)e^{-\mu_{\max}\cdot A(t)}\right)$$

$$A(t) = t + \frac{1}{\mu_{\max}}\ln\left(e^{-h_0} + \left(1 - e^{-h_0}\right)e^{-\mu_{\max}\cdot t}\right)$$

Figure 2. The Baranyi and Roberts model (4)

The parameter h_0, which corresponds to the lag phase, was independent of temperature and packaging method, but the lag phase for development of odour showed dependency on the initial psychrotrophic colony count. Growth curves from different studies were compared using the MicroFit v1.0 software developed by the Institute of Food Research.

III. RESULTS AND DISCUSSION

This work was initiated by the Nordic meat industry's demand for a tool declaring an optimal use-by date for various cuts, packed aerobically (including a thin wrap), in vacuum or in high-oxygen modified atmosphere (MAP) and stored at different temperatures within the cooling range. The models are based on data from controlled and systematically executed storage experiments using cuts randomly collected over time at commercial plants in four countries. The inclusion of natural variation seen in "real life" is essential for the robustness and applicability of the models.

Each model is based on data from approx. five individual storage experiments. A model is in this context defined as one packaging method (vacuum, wrap or MAP) within the temperature range of -1 °C to +7 °C. Each model applies for all pork cuts (+/- rind, +/- fat, +/- bones). However, a separate model was developed for minced pork, and this was merely due to the fact that MAP was the only investigated packaging method.

Most often, the meat is stored under different conditions, from the production site until it reaches the consumer. In order to be able to predict a total shelf life based on different sequences in the cooling chain, it was the idea to combine the three models (vacuum, aerobic and MAP).

Therefore, a number of experiments were conducted, during which the storage conditions were changed for a subgroup of samples (Figure 1). It was important to investigate and validate the actual response to changes especially regarding bacteria growth; would the growth slow down or would it boost? Neither was seen! In fact, the growth continued by following the established curve for the new storage condition, Figure 3.

The corresponding development in odour is shown in Figure 4.

As can be seen from both Figure 3 and 4, the observed values in the actual experiment follow the average model rather well. However, at the end of the shelf life it can be seen that observed shelf life, based on odour, was over estimated.

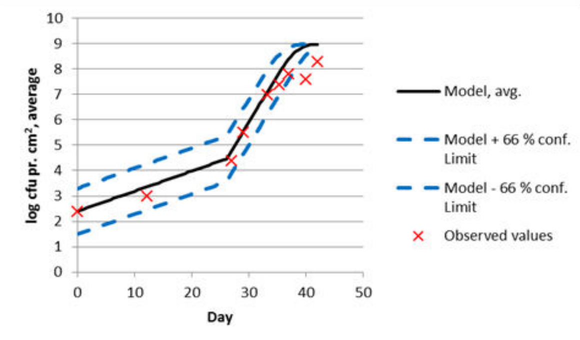

Figure 3. Psychrotrophic count on loins stored in vacuum pack for 26 days at -1 °C, and repacked in modified atmosphere (70 % O_2 + 30 % CO_2) and stored at +4 °C. Predicted development in psychrotrophic count (model, avg.) shown together with 66 % upper and lower confidence limits and observed values.

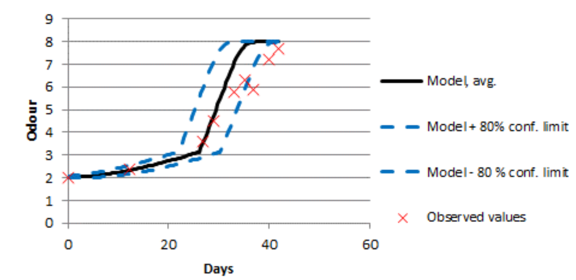

Figure 4. Odour development for loins stored in vacuum pack for 26 days at -1 °C, and repacked in modified atmosphere (70 % O_2 + 30 % CO_2) and stored at +4 °C. Predicted development in odour (model, avg.) shown together with 80 % upper and lower confidence limits and observed values.

The large number of data from the individual storage experiments performed over a period of approximately 8 years has ensured that the model is accurate, as the model contains most of the natural variation seen in "real life". The uncertainty of the models, including cut-to-cut variation, is shown using confidential limits.

The minimum period of time the model can handle is one day. Solely based on natural variations between single cuts, modelling growth/shelf life for periods less than one day does not make sense. This prediction based on combinations also opens up for flow optimization within the production plant. It may become apparent, if too much of the shelf life is used at the plant leading to fewer days at the retail and finally at the consumer.

IV. CONCLUSION

Validated models for fresh pork cuts packed in vacuum, aerobic or high-oxygen modified atmosphere were developed. The models can be combined and the use-by date can be predicted based on a sequence of storage conditions. The models for fresh pork cuts, as well as the models for beef and chicken, contain the inevitable natural variation, and the models are therefore robust as they reflect real life.

ACKNOWLEDGEMENTS

The Danish Pig Levy Fund, Nortura, Norway and HKScan, Sweden funded this work. The authors thank Kim Keller Rasmussen, Dezone for excellent technical assistance with the models.

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