5:5 **The validity of the TTT-concept on the shelf lives of chilled, cured meat products.**

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Introduction

Sliced vacuumpacked cured meat products are sold in large quantities in Denmark, mainly for use in open sandwiches. The main part is distributed in the chilled state, at a temperature which should not exceed 5°C.

At the Danish Meat Products Laboratory we have over the past years studied the microbiology and storage life of such products, and found that Brochothrix thermosphacta is an important spoilage organism in perishable vacuum-packaged cured meat products (Qvist and Mukherji, 1981).

In 1983, a quality control on special labelled products with the commercial name "Bandolé Products" was established. The laboratory controls that the ingredients are in accordance with the labelling. Further, it has set up production standards, and checks that the labelled "Best before" date is appropriate. The laboratory has prepared guidelines for the shelf life of different products, and if a company claims that their products have longer shelf lives, this has to be verified.

It is a general desire in the trade to achieve longer shelf lives for products. If this is accomplished, it could lead to an increased export of these products in the unfrozen state.

One way to achieve longer shelf lives would be to use lower temperatures, i.e. temperatures around or a little below the freezing point of these cured meat products, which is about -3.5°C. The effect of using deep-chilling or super-chilling is the object of this experiment.

Another aspect is to test the validity of the TTT-theory on chilled products. For most frozen foods, the TTT-theory has been found valid, but regarding chilled foods comparatively few experiments have been carried out. The TTT-theory may be expressed in the following statement: Under ordinary conditions, the time/temperature influences are cumulative over the entire storage life of the product and their sequence is without influence on the accumulated total shelf life loss.

Materials and methods

Three types of cured meat products were used, all samples taken from a commercial production line.

Product A, a luncheon meat product (Bologna type sausage). The forcemeat is filled into casings, and cooked in steam cabinets at 75°C to an internal temperature of 70°C. The product was sliced at a temperature of 2°C, and vacuumpacked.

Product B, smoked and cooked pork loin. Pork loin is cured, max. water uptake is 8%. It is filled into a casing, and cooked and smoked. It was sliced at a temperature of -0.5°C, and vacuumpacked.

Product C, unsmoked pork filet. Pork filet is cured and slightly dried. It has a max. water uptake of 2%. It was sliced at -4°C, and vacuumpacked.

Packaging

All packages contained 6 slices, the weight was about 60 grams. The packaging material was a laminate of polyamide and polyethylene (PA/PE-laminate).

Storage

All three types were divided into 5 groups:

I
II Constant temperature, -3.5°C
III Constant temperature, +2°C
IV Constant temperature, +4°C
V 1. week -3.5°C, 2. week +4°C, 3. week -3.5°C, ...
1. week +4°C, 2. week -3.5°C, 3. week +4°C, ...

Chemical analysis

Samples from each product were analysed for fat, water, and salt (NaCl). The routine methods at the laboratory were used.

Microbiological analysis

According to the routine control of these products

- SPC (standard plate count) was enumerated on plate count agar (PCA)
- Lactic acid bacteria were enumerated on MRS-agar
- Brochothrix thermosphacta was enumerated on STAA-agar.

Organoleptic evaluation

The routine organoleptic evaluation is carried out by four staff members (food technologists, food microbiologists or veterinarians). The scores are given in a scale from 1 to 3. 3: normal and satisfactory; 2: acceptable; 1: unacceptable (it is possible to use scores of 2.5 and 1.5). The properties evaluated are appearance, odour and taste.

A trained, external taste panel (10 persons) was used on two occasions:

- the first time, after 8 weeks of storage, where the panel evaluated, in a forced choice comparison test, group II, IV and V of each of the three products.
- the second time, after 9 weeks, where the panel compared samples from group I, and samples from group I which had been removed to 4°C 10 days earlier. On this occasion a forced choice comparison test was also used.

Results

Chemical analyses

The results are shown in table 1.

Product	% fat	% salt	% water	100 x salt/water
A. Luncheon meat	25.1	2.8	54.8	5.1
B. Cooked pork loin	2.8	3.3	73.2	4.4
C. Unsmoked pork filet	3.8	3.5	72.1	4.8

Table 1. Chemical analysis of the products. Each figure is the average of three results, and each result from a mixture of three samples.

Microbiological analyses

The results for SPC (standard plate count), lactic acid bacteria, and Brochothrix thermosphacta are shown in tables 2, 3 and 4 for product A, B, and C, respectively.

Organoleptic analyses

The results for all three products are given in table 5. Only the figures for taste are given, as the figures for appearance did not change very much, while the figures for odour generally were a little higher than the scores for taste.

Remarks

During the two first weeks, no remarks were given. During further storage, but before the products were found unacceptable, typical remarks were:

Product A: burnt taste (and odour); bitter; off-taste; unfresh;
Product B: slightly wet; wet; unfresh; acid taste;
Product C: slightly wet; wet surface; unfresh; acid.

When the products were found unacceptable, the remarks given were: sour; slimy; (tainted).

Taste panel

The forced choice comparison test after 8 weeks revealed no differences at all, between group IV (-3.5°C/4°C) and group V (4°C/-3.5°C). Also, no difference was found between group II (constant temperature of 2°C) and group IV or V. The results were identical for all three products.

After 65 days, the forced choice comparison between samples from group I (-3.5°C) and samples which had spend 56 days at -3.5°C and then were removed to +4°C, resulted in no statistically significant differences.

Discussion

Products A and B are cooked, and the initial count is a little higher than what the laboratory recommends. The number of Brochothrix thermosphacta right after packaging was so that a short storage life of these products could be expected. Table 2 and 3 show, however, that during storage B. thermocphacta was found in few samples only, the dominating flora being lactic acid bacteria.

In product A, stored at 4°C, the bacterial number increased during 4 weeks to about 5.5 (log); the organoleptic quality was acceptable in 7 weeks.

In product B, stored at 4°C, the bacterial number rose to 1 million after 3 weeks, and reached a plateau of several millions after 4 weeks; the organoleptic quality was acceptable in about 6 weeks.

Product C was uncooked, and the initial count was high, about 400,000. A practically pure culture of lactic acid bacteria was found during the whole experiment. The count rised to about 10 millions in 8 days, and to about 100 millions in 14 days at 4°C or at 2°C, and also at -3.5°C counts above 20 millions were found throughout. However, the organoleptic quality was acceptable in 4-6 weeks at 2°C or at 4°C, and in more than 8 weeks at -3.5°C.

These findings support Qvist and Mukherji (1981) who emphasize the importance of bacterial competition and composition, and conclude that imposing legal bacteriological standards in this type of product is of no benefit.

For all three products, the shelf life at -3.5°C is at least 9 weeks, i.e. significantly longer than at 4°C. Earlier experiments (Boegh-Soerensen, 1976) on chicken, stored at -2°C, also have shown the beneficial effect of using deep-chilling (super chilling) in the chilled chain (producers storage rooms, at wholesalers, during transport) up till the retailers cabinets. However, to be able to recommend such changed temperatures it is necessary to study the economical aspects, e.g. increased energy consumption (which may be of minor importance), the need of establishing special storage rooms for different types of chilled foods (e.g. -2°C for poultry, -3.5°C for cured meats, etc.).

Besides, it is necessary to study further the shelf life of cured meat products in such a cold chain. This experiment has shown no difference between storage at alternating temperatures (groups IV and group V). This could mean that the TTT-theory could be applied for chilled cured meat products.

In practice the first 1-2-3 weeks could then be storage at deep-chill temperatures, followed by some time in retail cabinets, at warm and fluctuating temperatures, cf. Boegh-Soerensen (1980). Also, a certain time in the consumers' refrigerator (often 8-10°C) should be included in studies on the validity of the TTT-theory for chilled meat products.

References

Boegh-Soerensen, L. (1976) Superkøling af fjerkræ. Livsmedelsteknik, 18, No. 6, p.267-269.

Boegh-Soerensen, L. (1980) Product temperatures in chilled cabinets. Proceedings from 26. EMMRW, Colorado Springs.

Qvist, S. and Mukherji, S. (1981) Brochothrix thermosphacta. In: Psychrotrophic Microorganisms in Spoilage and Pathogenicity. Edited by: T.A. Roberts, G. Hobbs, J.H.B. Christian, N. Skovgaard. Academic Press.

Storage at	Test	Storage time (days) 1	8	10	14	17	21	29	35	38	42	49	56
-3.5°C	SPC		2.00	-	-	2.75	3.04	2.04	1.60	2.38	3.64	2.30	5.00
I	Lacto.		<2	-	-	<2	<2	<2	<2	<2	3.41	<2	<2
	B.therm.		<2	-	-	3.04	<2	<2	<2	<2	3.20	2.00	3.77
+2°C	SPC		2.20	-	-	4.04	-	6.60	-	6.90	-	-	-
II	Lacto.		<2	-	-	2.70	-	6.30	-	6.68	-	-	-
	B.therm.		<2	-	-	4.81	-	<2	-	<2	-	-	-
+4°C	SPC	3.90	2.54	3.04	4.72	2.04	5.90	6.60	6.15	7.51	7.72*	6.81*	7.60*
III	Lacto.	3.15	<2	2.60	4.56	2.00	4.30	5.90	5.85	7.75	7.08	5.77	5.80
	B.therm.	3.83	<2	<2	3.89	<2	<2	<2	<2	<2	5.08	4.90	4.11
-3.5°C/	SPC		-	2.85	2.60	2.61	3.20	4.70	6.00	-	6.86	-	-
+4°C	Lacto.		-	<2	<2	<2	<2	4.73	5.60	-	6.89	-	-
IV	B.therm.		-	<2	<2	<2	<2	<2	5.08	-	2.30	-	-
+4°C/	SPC		-	-	2.40	5.15	2.60	4.66	3.11	6.41	7.15	-	-
-3.5°C	Lacto.		-	-	<2	4.52	<2	3.46	3.48	5.00	6.30	-	-
V	B.therm.		-	-	<2	4.26	<2	<2	2.30	<2	5.34	-	-

<: means less than 2 per gram.
*: means that this sample is found organoleptically unacceptable.

Table 3. Microbiological results (log_{10} counts per gram) for product B, smoked and cooked pork loin.

Storage at	Test	Storage time (days) 1	8	10	14	17	21	29	35	38	42	49	56
-3.5°C	SPC		2.18	-	-	1.60	2.60	2.95	2.30	2.60	2.43	2.30	3.26
I	Lacto.		<2	-	-	<2	2.30	<2	<2	<2	2.85	<2	<2
	B.therm.		<2	-	-	<2	<2	<2	<2	<2	2.30	2.00	<2
+2°C	SPC		2.64	-	-	4.64	-	5.48	-	6.18	-	-	-
II	Lacto.		<2	-	-	<2	-	5.15	-	<2	-	-	-
	B.therm.		<2	-	-	<2	-	<2	-	3.85	-	-	-
+4°C	SPC	3.70	3.04	3.38	3.67	2.34	2.95	5.72	5.00	6.04	4.85	4.34	5.64
III	Lacto.	3.90	<2	<2	<2	<2	<2	<2	<2	<2	2.30	2.30	4.90*
	B.therm.	3.38	<2	<2	2.30	<2	<2	5.60	<2	5.23	<2	<2	4.90
-3.5°C/	SPC		-	3.08	3.58	3.34	2.30	3.20	4.64	2.70	4.04	3.90	4.90
+4°C	Lacto.		-	<2	<2	<2	<2	<2	3.08	4.08	4.23	<2	<2
IV	B.therm.		-	2.48	<2	<2	<2	<2	4.64	<2	<2	<2	3.04
+4°C/	SPC		-	-	3.38	1.78	2.48	3.95	2.23	3.34	5.60	-	-
-3.5°C	Lacto.		-	-	<2	<2	<2	<2	<2	<2	5.77	-	-
V	B.therm.		-	-	<2	<2	<2	<2	<2	<2	5.47	-	-

<: means less than 2 per gram.
*: means that this sample is found organoleptically unacceptable.

Table 2. Microbiological results (log_{10} counts per gram) for product A, sliced luncheon meat (Bologna type sausage).

	Storage	Score after days 2	7	14	21	29	35	42	49	56
Product A:	I: -3.5°C		-	-	2.25	2.5	2.38	2.0	2.25	2.25
Luncheon	II: +2°C		-	-	-	2.0	-	-	-	-
meat	III: +4°C	3.0	2.88	2.25	2.38	2.5	2.50	2.50	1.75	1.13*
(Bologna type	IV: -3.5°C/+4°C		-	2.38	2.5	2.5	2.63	2.5	2.38	2.38
sausage)	V: +4°C/-3.5°C		-	2.5	2.5	2.0	3.0	2.5	-	-
Product B:	I: -3.5°C		-	-	2.38	2.5	2.63	2.0	2.25	1.75
Cooked	II: +2°C		-	-	-	1.5	-	-	-	-
pork loin	III: +4°C	3.0	2.75	3.0	2.50	1.5	2.63	1.13*	1.0*	1.13*
	IV: -3.5°C/+4°C		-	3.0	3.0	2.5	2.63	2.13	-	-
	V: +4°C/-3.5°C		-	3.0	3.0	2.0	2.0	1.63	-	-
Product C:	I: -3.5°C		-	-	2.25	2.5	2.13	1.75	2.13	1.83
Pork filet	II: +2°C		-	-	-	1.0*	-	-	-	-
	III: +4°C	3.0	3.0	2.75	1.88	1.0*	2.38	1.13*	-	-
	IV: -3.5°C/+4°C		-	3.0	2.88	1.5	2.63	1.13*	-	-
	V: +4°C/-3.5°C		-	3.0	2.38	1.5	2.50	1.13*	-	-

Table 5. Average scores for taste during storage. 3: normal and satisfactory; 2: acceptable; 1: unacceptable.
*means unacceptable.

Storage at	Test	Storage time (days) 1	8	10	14	17	21	29	35	38	42	49	56
-3.5°C	SPC		7	-	-	7.54	7.36	7.60	7.48	6.97	7.53	6.77	7.20
I	Lacto.		7	-	-	7.45	7.26	6.92	7.18	7.00	7.32	6.30	6.57
	B.therm.		<2	-	-	2.78	<2	<2	<2	<2	<2	2.00	<2
+2°C	SPC		7	-	-	7.60	-	7.86*	-	7.70	-	-	-
II	Lacto.		7	-	-	7.74	-	7.61	-	7.04	-	-	-
	B.therm.		<2	-	-	2.60	-	<2	-	<2	-	-	-
+4°C	SPC	5.60	6.96	7.60	8.00	7.89	7.43	8.53*	6.18	7.45	7.79*	-	-
III	Lacto.	5.30	7	5.78	7.51	7.76	7.23	7.99	7.43	6.90	7.58	-	-
	B.therm.	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	-	-
-3.5°C/	SPC		-	6.62	7.90	6.90	7.08	7.73	7.66	-	7.91*	-	-
+4°C	Lacto.		-	5.51	7.15	7.20	6.95	7.41	7.78	-	7.68	-	-
IV	B.therm.		-	<2	<2	<2	<2	<2	<2	-	<2	-	-
+4°C/	SPC		-	-	7.59	7.18	7.15	8.46	7.58	7.48	7.87*	-	-
-3.5°C	Lacto.		-	-	7.60	7.18	7.00	7.92	7.60	7.45	7.73	-	-
V	B.therm.		-	-	<2	<2	<2	<2	<2	<2	<2	-	-

<: means less than 2 per gram.
*: means that this sample is found organoleptically unacceptable.

Table 4. Microbiological results (log_{10} counts per gram) for product C, unsmoked pork filet.