

RECOMMENDATIONS FOR MICROBIOLOGICALLY SAFE COOKING OF MEAT AT TEMPERATURES BELOW 75°C

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Abstract - This study was performed to make recommendations for safe cooking of meat at temperatures below 75°C, based on safety experiments of meat. The advantages of cooking meat at temperatures below 75°C are increased juiciness of the meat and less weight loss during cooking. However, it is important that the heat treatment ensures inactivation of pathogens. Six different meat cuts were inoculated with a 5-strain cocktail of *L. monocytogenes* in the core of meat that was subsequently heated at 58, 60, 63, 65 and 70°C. Samples from the core were analysed three to four times during heat treatment. The results show that a holding time is necessary to include after reaching the set temperature, when cooking to core temperatures at 58 and 60°C to ensure a 4 log reduction of *L. monocytogenes*. Furthermore, the D-value increases 2.5 times during heating at 58°C. Consequently, these recommendations for safe cooking are based on the entire 4 log reduction being obtained during the holding time, hereby including a safety margin. The holding times are 1, 6, 12, 35 and 72 minutes at 70, 65, 63, 60 and 58°C, respectively. All the heating times ensure the same safety as cooking to 75°C for 9 seconds.

Key Words – Low temperature cooking, roasts, safety.

I. INTRODUCTION

In Denmark, the application of sous vide cooking and cooking at low temperatures (below 75°C) has increased during the past 10 years in the catering sector. The advantages of these cooking methods are increased juiciness of the meat and a low cooking loss.

The safety aspect of heating meat at low temperatures is important because pathogenic bacteria, such as *L. monocytogenes*, are able to survive gentle heat treatment and multiply at low temperatures [1]. Using the log D/z concept, the mean log D_{70°C} (min) for *E. coli* (n=383), *Salmonella* (n=1141) and *L. monocytogenes*

(n=940) [2] were recalculated to the mean D_{60°C} values of 1.88 min, 1.86 min and 2.33 min, respectively. The D_{60°C} values indicate that *L. monocytogenes* is generally more heat resistant in the low temperature range than *E. coli* and *Salmonella* and is therefore an appropriate test organism in heat treatment experiments at temperatures below 60°C.

The prevalence of *L. monocytogenes* in fresh meat is expected to be low. Rhoades [3] reported that, in a FSIS survey, 52 *L. monocytogenes* positive samples were found in 100 samples of minced beef. The positive samples contained 2.9 MPN/g. Nørrung [4] detected *L. monocytogenes* at a level of 10-100 cfu/g in 12 of 343 samples of fresh meat. The highest contents were found in minced beef. Gunvig [5] showed that *L. monocytogenes* increases by 2 log in pork roasts stored at 5°C for 19 days. Therefore, it is assumed that, in the worst case, fresh meat can contain 4 log of *L. monocytogenes*/g, and a low temperature heat treatment that ensures a 4 log reduction of *L. monocytogenes* must be regarded as safe.

Danish legislation requires that food products are heated treated to a minimum of 75°C in the core, or it can be demonstrated that another heat treatment is equivalent to heating to 75°C in the core [8]. The USDA has introduced new recommendations that allow pork, beef and lamb roasts, chops and steaks to be cooked to a core temperature of 62.8°C followed by a 3-minute holding time [9]. The Danish catering sector requires a generic documentation for safe heat treatment at temperatures below 75°C to comply with the Danish legislation.

In the present study, the reduction of *L. monocytogenes* was determined during heat treatment of six meat cuts at 58, 60 and 63°C, and the results are converted to a generic recommendation for cooking meat at low temperatures.

II. MATERIALS AND METHODS

Selected strains

L. monocytogenes DMRICC 3012 (from the meat environment), DMRICC 4106 (human outbreak), DMRICC 4124 (meat), DMRICC 4127 (sausage) and DMRICC 4140 (bacon) with $D_{60^{\circ}\text{C}}$ values in the range of 0.55-1.77 minutes [6].

Meat cuts

Six different meat cuts were applied: beef patties (140 gram, height = 1.5 cm), pork patties (140 gram, height = 1.5 cm), trimmed pork loins (height = 5.5 cm) and eye round (height = 3 cm), pork hearts (height = 3.5 cm) and loin ribs (height = 2 cm).

Safety experiment

Each strain was grown for 24 h at 37°C, and then all five strains were mixed with brain heart infusion (BHI, Oxoid) and then mixed with green fruit colouring (Dr. Oetker) in a ratio of 2:1. The meat cuts were inoculated in the geometric core by injecting 1 ml of the coloured cocktail. The patties were inoculated by placing 2 g minced meat mixed with 0.1 ml of the coloured cocktail between two meat patties each weighing 70 g, resulting in a meat patty weighing 140 g. All products were vacuum-packed in boilable pouches (CN300 CRYOVAC®). The vacuum-packed samples were placed in a 40 litre water bath or an industrial sous vide equipment (Classic Gastro, 40 kg) at 58, 60 or 63°C. After the core-temperature (T_c) was reached, and during the holding time, three samples from each heat treatment were analysed three to four times. The coloured area in the geometric core was aseptically transferred to BHI. Serial dilutions in physiological saline with 0.1% Bacto-peptone were made, and samples were spread onto the surface of Oxford agar (Oxoid, CM0856) and incubated at 37°C for 48 h.

Theoretical calculations of inactivation

The inactivation effect of the heat treatments was calculated by using the log D/z concept and the $D_{60^{\circ}\text{C}} = 8.7$ minutes and $z = 6.3^{\circ}\text{C}$ for *L. monocytogenes* [7]. This D-value was selected because it was determined in meat and represent a worst-case scenario. The mean $D_{60^{\circ}\text{C}}$ value for *L.*

monocytogenes is 2.3 minutes (n=940) [2]. Furthermore, the holding time until the total process obtained a 4 log reduction of *L. monocytogenes* and the $F_{60^{\circ}\text{C}}$ value for the heating and the entire process were calculated.

III. RESULTS AND DISCUSSION

Safety experiment

The heat inactivation of *L. monocytogenes* was measured in six different meat cuts at 58°C. Table 1 shows that *L. monocytogenes* is reduced by approx. 0.5 log cfu/g to more than 6 log cfu/g during heating to a temperature of 58°C in the core. The highest log reductions are measured in cuts with high $F_{60^{\circ}\text{C}}$ values.

In the water bath experiments at 58°C including beef patties, loins (height = 5.5 cm) and eye round (height = 3 cm), *L. monocytogenes* is reduced by more than 6 log cfu/g after 30 and 360 minutes' holding times, respectively.

The highest $D_{58^{\circ}\text{C}}$ value in the inoculation cocktail is 3.9 minutes [6]. In three tests with the industrial sous vide equipment, the $D_{58^{\circ}\text{C}}$ value was measured to approx. 10.5 minutes, which is 2.5 times higher than the value for the inoculation cocktail. This indicates that *L. monocytogenes* is adapted to heat during the heat treatment, and this circumstance must be included in the recommendations for heat treatment holding times. Heat treatment of beef patties at 60°C ensured more than a 2 log reduction during the heating to 60°C in the core, and more than a 6 log reduction of *L. monocytogenes* is obtained after 20 minutes' holding time.

Heat treatment of pork loin and pork and beef patties at 63°C ensured more than a 4 log reduction during heating to 63°C in the core independent of the height of the meat (Table 1).

Table 1. Log reduction of *L. monocytogenes* or measured D-values during heat treatments at 58, 60 and 63°C.

	Temperature (T _c) °C	Time to T _c ¹ °C	F _{60°C} ⁴ for heating minutes	Reduction at T _c minutes	Holding time ² log cfu/g	Total reduction ³ minutes	D-value log cfu/g
Pork patties (sous vide)	58	37	3.9	0.5	-	-	10.45
Loin ribs (sous vide)	58	36	3.3	0.2	-	-	10.63
Pork hearts (sous vide)	58	100	10	1.1	-	-	10.55
Loin (sous vide)	58	155	16.4	>6	-	-	m
Loin (water bath)	58	180	m	>4	360	>6	m
Eye round (water bath)	58	120	m	>4	360	>6	m
Beef patties (water bath)	58	23	2.3	1.1	30	>6.7	m
Beef patties (water bath)	60	24	5.2	2.7	20	>6.7	m
Pork patties (sous vide)	63	50	27	>6	-	-	m
Loin (sous vide)	63	179	113.7	>6	-	-	m
Beef patties (water bath)	63	28	19.3	4.6	3	>6.7	m

- 1) Time to T_c = Time until the heat treatment temperature is reached in the core
 - 2) Holding time = Time at the specific temperature, theoretically calculated
 - 3) Total reduction includes the reduction during heating to T_c and during the holding time at T_c
 - 4) F_{60°C} is a measure for the effect of the pasteurisation
- m= not calculated due to less than three measurement points

The results show that it is necessary to include a holding time for heat treatments at 58 and 60°C to ensure a 4 log reduction of *L. monocytogenes*. Furthermore, the recommendation of heating times must include a safety margin for heat adaption for *L. monocytogenes*.

Theoretical calculation of inactivation

Time and temperature profiles were measured in nine out of the eleven experiments.

High F_{60°C} values for the heating process indicate long heating times due to cuts with a high height of the product (Table 2).

Table 2 shows that heating to a core temperature of 58°C requires holding times in the range of 39 to 64 minutes to obtain a 4 log reduction (D_{60°C, z=6.3°C} = 8.7 minutes) if the reduction during heating is included. The measured D_{58°C} value of 10.5 minutes in the safety experiment is equal to a holding time of 42 minutes to obtain 4 log reduction of *L. monocytogenes* at 58°C. The calculated holding times are in some cases longer than 42 minutes, thus the authors suggest that the recommendations should be based on a 4 log reduction during the holding time by using the D_{60°C, z=6.3°C} = 8.7 minutes. Hereby a safety margin is included for e.g. heat adaptation and different F_{60°C} values during heating.

The F_{60°C} value is calculated for each product, and Table 2 shows that eight out of nine heat treatments result in F_{60°C} values of 35 minutes, meaning that the heat treatment ensures the same level of safety. The heating of pork loin in sous vide has a higher F_{60°C} value due the long heating time (179 minutes). Heat treatment at 75°C for 9 seconds is an equivalent heat treatment to the eight treatments with F_{60°C} = 35 minutes in Table 2.

Table 2. Theoretical calculation of reduction of *L. monocytogenes* during heating at 58, 60 and 63°C

Product	Temperature (T _c) °C	F _{60°C} ⁴ for heating minutes	Time to T _c ¹ minutes	Reduction at T _c log cfu/g	Holding time ² minutes	Total reduction ³ log cfu/g	F _{60°C} -value minutes
Pork patties (sous vide)	58	3.9	37	0.4	64	4	34.7
Loin ribs (sous vide)	58	3.3	36	0.4	65	4	34.6
Loin (sous vide)	58	16.4	155	1.9	39	4	35.2
Pork hearts (sous vide)	58	10	100	1.1	52	4	34.5
Beef patties (water bath)	58	2.3	23	0.3	67	4	34.48
Beef patties (water bath)	60	5.2	24	0.6	30	4	35.15
Pork patties (sous vide)	63	27	50	3.1	3	4.1	35.99
Beef patties (water bath)	63	19.3	28	2.2	5	4	34.25
Loin (sous vide)	63	113.7	179	13.1	0	13.1	113.7

- 1) Time to T_c = Time until the heat treatment temperature is reached in the core
- 2) Holding time = Time at the specific temperature
- 3) Total reduction includes the reduction during heating to T_c and during the holding time at T_c
- 4) F_{60°C} is a measure for the effect of the pasteurisation

Generic recommendations for cooking meat at temperatures below 75°C

The recommendations are separated into two groups:

- 1) Whole roasts, chops and steaks (raw and semi processed) where the bacteria are on the surface. The bacteria on the surface are inactivated during heat treatment in an oven or on a pan, due to high temperatures on the surface, even though the core temperature is below 75°C.
- 2) Minced, enhanced and mechanically tenderized meat for which the bacteria are distributed evenly in the meat.

Based on results from the safety experiment and the theoretical calculations, the recommendations are as follows:

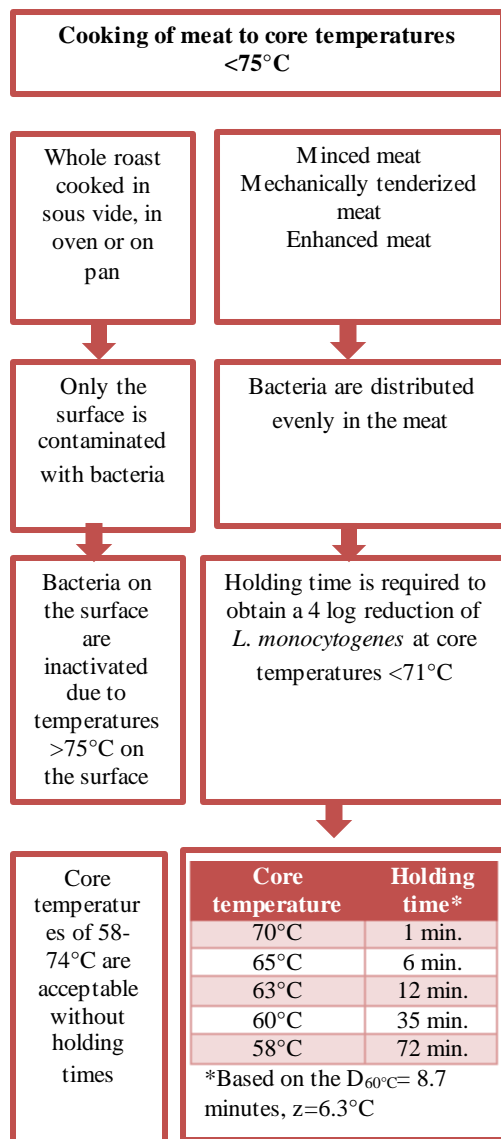


Figure 1. Generic recommendations for safe cooking

IV. CONCLUSION

Inactivation of *L. monocytogenes* in six different meat cuts shows that a holding time is required for heating at 58 and 60°C. An increase in D-value is measured during heating at 58°C, probably due to heat adaptation. Based on this knowledge, a safety margin is included in the final generic recommendations, which ensures a 4 log reduction of *L. monocytogenes* during the holding time. Recommendations for holding times are 1, 6, 12, 35 and 72 minutes at 70, 65, 63, 60 and 58°C, respectively.

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