

# SUPPLEMENTARY MATERIAL

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**Microbiological safety of dry-aged meat:  
a critical review of data gaps and research needs to define process hygiene and safety  
criteria**

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**Supplementary Table 1. Data of total bacteria count, *Enterobacteriaceae* and coliforms including *Escherichia coli* retrieved from the literature and dry-aging duration in days, relative humidity in %, air ventilation in m/sec, meat type, time points, type of sampling, pH, and water activity.**

Ref.	Days	RH (%)	Vent. (m/s)	T (°C)	Meat type	Time-point	Type of sampling	pH	aw	TBC	<i>Enterobacteriaceae</i>	<i>Coliforms/E. coli</i>
Smaldone <i>et al.</i> (2019)	290	68-70	NA	0	Sirloin steak muscle	T0, Tend	Steaks	<b>T0</b> 5.7 ¥ <b>Tend</b> 5.98 ¥	<b>T0</b> 0.965 ¥ <b>Tend</b> 0.955 ¥	<b>T0</b> 6.82 log CFU/g <b>Tend</b> 6.13 log CFU/g	<b>T0</b> 2.58 log CFU/g <b>Tend</b> 2.08 log CFU/g	NA
Lee <i>et al.</i> (2017)	28	85	5+/-3	1+/-1	Sirloin	T0, Tend	T0, Tend	<b>T0</b> 5.48	-	<b>T0:</b> 5.60 log CFU/g <b>Tend:</b> 6.58 CFU/g	-	< 10 CFU/g
Lee <i>et al.</i> (2017)	28	75	-	2+/-1	Sirloin	T0, Tend	T0, Tend	<b>T0</b> 5.48	.	<b>T0:</b> 5.60 log CFU/g <b>Tend:</b> 7.01 CFU/g	-	< 10 CFU/g
Bernardo <i>et al.</i> (2021)	21	65	2.5	2	Loin	T0, Tend	Internal (I)	<b>T0</b> 5.39 <b>Tend</b> 5.51	<b>T0</b> 0.993 <b>Tend</b> I 0.9887 S 0.9730	<b>T0</b> 1.6 log CFU/g <b>Tend</b> 2.65 log CFU/g	<b>T0</b> <1.1 log CFU/g <b>Tend</b> <1 log CFU/g	-
							Surface (S)			<b>T0</b> 1.6 log CFU/g <b>Tend</b> 4.12 log CFU/g	<b>T0</b> <1.1 log CFU/g <b>Tend</b> <1 log CFU/g	-
Bernardo <i>et al.</i> (2021)	21	85	-	-	-	-	I	<b>T0</b> 5.39 <b>Tend</b> 5.51	<b>T0</b> 0.993 <b>Tend</b> I 0.9887 S 0.9730	<b>T0</b> 1.6 log CFU/g <b>Tend</b> 5.26 log CFU/g	<b>T0:</b> <1.1 log CFU/g <b>Tend:</b> 3.42 log CFU/g	-
							S			<b>T0</b> 1.6 log CFU/g <b>Tend</b> 9.47 log CFU/g	<b>T0</b> <1.1 log CFU/g <b>Tend</b> 7.71 log CFU/g	-
Hulánkov á <i>et al.</i> (2018)	12-36	85	0.5+/-0.2	1+/-1	Quarter (loin without bone)	T0, Tend	S	<b>T0</b> 5.68-5.53-5.60-5.67 <b>Tend</b> 5.68-5.60-5.62-5.68	-	<b>T0</b> 2.59 log CFU/cm <sup>2</sup> <b>Tend</b> >5 log CFU/cm <sup>2</sup>	<b>T0</b> < 10 cfu/g <b>Tend</b> < 10 cfu/g	-
							I			<b>T0</b> 2.17 log CFU/g <b>Tend</b> >4 log CFU/g		-
Li <i>et al.</i> (2014)	21	75	NA	5.1	<i>Longissimus thoracis et lumborum</i> section	T1 (8 d) T2 (19 d)	Subcutaneous fat (F) and lean surface (M)	<b>T1</b> 5.58 <b>T2</b> 5.63	-	<b>T1</b> F 5.22 log CFU/cm <sup>2</sup> , M 6.39 log CFU/cm <sup>2</sup> , <b>T2</b> F 6.91 log CFU/cm <sup>2</sup> , M 8.75 log CFU/cm <sup>2</sup>	<b>T1</b> F 0.78 log CFU/cm <sup>2</sup> , M 2.09 log CFU/cm <sup>2</sup> , <b>T2</b> F 2.10 log CFU/cm <sup>2</sup> , M 5.35 log CFU/cm <sup>2</sup>	-

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Di Paolo <i>et al.</i> (2023)	60	78+/-10	0.5	1+/-1	Ribeye steaks	T0, T1 (15 d), T2 (30 d), Tend	Steaks	<b>T0</b> 5.70, <b>T1</b> 5.64, <b>T2</b> 5.66, <b>Tend</b> 5.72	<b>T0</b> 0.982, <b>T1</b> 0.973, <b>T2</b> 0.980, <b>Tend</b> 0.976	<b>T0</b> 4.10 log CFU/g, <b>T1</b> 5.45 log CFU/g, <b>T2</b> 5.31 log CFU/g, <b>Tend</b> 5.38 log CFU/g	<b>T0:</b> 1.78 log CFU/g, <b>T1</b> 2.28 log CFU/g, <b>T2</b> 1.73 log CFU/g, <b>Tend</b> 1.92 log CFU/g	<b>T0</b> 3.08 log CFU/g, <b>T1:</b> 3.52 log CFU/g, <b>T2</b> 1.75 log CFU/g, <b>Tend</b> 3.93 log CFU/g
DeGeer <i>et al.</i> (2009)	21- 28	50	NA	2.2	Loin	T0, Tend	Subcutaneous fat and lean surface	Shell loin (SH) 5.51 Strip loin (ST) 5.49 <b>21d</b> 5.49, <b>28 d</b> 5.49	-	<b>T0</b> SH 2.89 log CFU/cm <sup>2</sup> , SL3.16 log CFU/cm <sup>2</sup> , <b>Tend</b> SH 3.51 log CFU/cm <sup>2</sup> , ST2.89 log CFU/cm <sup>2</sup>	-	<b>T0</b> SH <10 cfu/cm <sup>2</sup> , ST 0.88 log CFU/cm <sup>2</sup> , <b>Tend</b> SH <10 cfu/cm <sup>2</sup> , ST -0.39 log CFU/cm <sup>2</sup>
Ahntstör m <i>et al.</i> (2006)	14-21	87+/-2.6	NA	1.6+/-0.4	Strip loin	T0, Tend	Subcutaneous fat (F) and lean surface (M)	<b>T0</b> 5.4+/-0.1 <b>Tend.</b> 14 d 5.5. 21 d 5.7	-	<b>T0</b> <2.5 log CFU/cm <sup>2</sup> , <b>Tend</b> F 14 d 4.3 log CFU/cm <sup>2</sup> , 21 d 4.7 log CFU/cm <sup>2</sup> , M 14 d 5.1 log CFU/cm <sup>2</sup> , 21 d 4.3 log CFU/cm <sup>2</sup>	-	-
Khazzar <i>et al.</i> (2023)	30	75	0.5	3+/-0.5	Boneless strip loin	T0, T1 (7 d), Tend	Meat	<b>T0</b> 5.63, <b>T1</b> 5.54, <b>Tend</b> 5.60.	<b>T1</b> 0.99. <b>Tend</b> 0.98	<b>T1</b> 2.5 log CFU/g <b>Tend</b> 4.5 log CFU/g	<b>T1</b> 1 log CFU/g <b>Tend</b> 1.9 log CFU/g	-
Mikami <i>et al.</i> (2021)	35	90	1.8-2.5	2.9	Rump	Tend	Crust (C) and inner part (I)	5.62	-	C 4.64 log CFU/cm <sup>2</sup> , I 5.32 log CFU/cm <sup>2</sup>	-	C 3.10 log CFU/cm <sup>2</sup> I 3.64 log CFU/cm <sup>2</sup>
Ryu <i>et al.</i> (2018)	60	80-90	NA	1-4	<i>Longissimus thoracis</i> section <i>Biceps femoris</i> section	T0, T1 (25 d), T2 (40 d), T3 (50 d), Tend	Surface	-	-	<b>T0</b> ~ 2.5 CFU/g ¥ <b>Tend:</b> ~ 5.0 CFU/g ¥	-	< 10 CFU/g
Cambell <i>et al.</i> (2001)	21	75	NA	2	Short loin and strip loin	T0, T1 (7 d), T2 (14 d), Tend	Surface	-	-	<b>T0</b> 1.4 log <sub>10</sub> , <b>T1</b> 3.3 log <sub>10</sub> , <b>T2</b> 3.9 log <sub>10</sub> , <b>Tend</b> 3.3 log <sub>10</sub>	-	-
Gowda <i>et al.</i> (2022)	21-70	40-75	NA	-1 a 3	Bone-in. mainly loins	T0, Tend	Surface and internal	<b>Tend</b> (steaks): 5.73	<b>Tend</b> (steaks): 0.98-0.99	<b>Loin</b> 4.1 log CFU/cm <sup>2</sup> § <b>Steak</b> 3.4 log CFU/cm <sup>2</sup> §	<b>T0</b> < 6.4 log CFU/cm <sup>2</sup> <b>Tend</b> < 7.4 log CFU/cm <sup>2</sup>	-

Lancaster <i>et al.</i> (2022)	45	64.8792.21	0.56-2.03	0.74-5.26	Bone-in strip loin	Tend	Surface (swab)	5.61 to 5.73	0.98 to 0.99	0.18 CFU/cm <sup>2</sup> to 4.00 CFU/cm <sup>2</sup>	-	0.59 to 4 CFU/cm <sup>2</sup>
Van Damme <i>et al.</i> (2022)	42	75 and 85	NA	2-6	Loin	T0, Tend	Superficial adipose tissue (F) and lean meat (M)	<b>T0</b> 5.50 <b>Tend:</b> 5.77	-	<b>T0</b> F 2.9 log CFU/cm <sup>2</sup> , M 2.3 log CFU/cm <sup>2</sup> <b>Tend.</b> F 5.1 log CFU/cm <sup>2</sup> , M 2.5 log CFU/cm <sup>2</sup>	<b>T0</b> F <0 log CFU/cm <sup>2</sup> , M <0 log CFU/cm <sup>2</sup> <b>Tend</b> F 1.6 log CFU/cm <sup>2</sup> , M 0.4 log CFU/cm <sup>2</sup>	-
Berger <i>et al.</i> (2018)	28	78	< 0.2	2	Bone-in loin	T0, T1 (21 d), Tend	Steak (internal)	<b>T0</b> 5.89 <b>Tend</b> 5.79	-	<b>T1</b> 4.046 log CFU/ml	-	-
Shi <i>et al.</i> (2020)	14	85	1.5	2	<i>Longissimus thoracis</i> muscle	T0, T1 (7 d), Tend	Inner part	<b>T0</b> 5.41, <b>T1</b> 5.58, <b>Tend</b> 5.61	-	<b>T0</b> 4.62 log CFU/g, <b>T1</b> 7.21 log CFU/g, <b>Tend</b> 7.53 log CFU/g	-	-

\*before trimming; \*\*after trimming; TBC, total bacterial count; RH, relative humidity; Vent, air ventilation; aw, water activity; ¥, data have been retrieved from the figures; §, data have been retrieved from the supplementary material.

**Supplementary Table 2. Data on psychrotrophic bacteria, lactic acid bacteria, and *Pseudomonas* spp. retrieved from the literature and dry-aging duration in days, relative humidity in %, air ventilation in m/sec, meat type, time points, type of sampling, pH, and water activity.**

Ref.	Days	RH (%)	Vent. (m/s)	T (°C)	Meat type	Time-point	Type of sampling	pH	aw	Psychrotrophic bacteria	Lactic acid bacteria	<i>Pseudomonas</i> spp.
Hulánková <i>et al.</i> (2018)	12-36	85	0.5+/-0.2	1+/-1	Quarter (sample: loin without bone)	T0, Tend	Surface (S) Internal (I)	<b>T0</b> 5.68-5.53-5.60-5.67 <b>Tend</b> 5.68-5.60-5.62-5.68	-	<b>T0</b> 2.47 log CFU/cm <sup>2</sup> ¥ <b>Tend</b> ~5 log CFU/cm <sup>2</sup> ¥ <b>T0</b> 2.13 log CFU/g <b>Tend</b> ~4.5 log CFU/g	<b>T0</b> 1.04 log CFU/cm <sup>2</sup> ¥ <b>Tend</b> ~1.5 log CFU/cm <sup>2</sup> ¥ <b>T0</b> 0.85 log CFU/g <b>Tend</b> ~1.5 log CFU/g	<b>T0:</b> < limit of detection; <b>Tend:</b> < limit of detection
Di Paolo <i>et al.</i> (2023)	60	78+/-10	0.5	1+/-1	Ribeye steaks	T0, T1 (15 d), T2 (30 d), Tend	Steaks	<b>T0</b> 5.70, <b>T1</b> 5.64, <b>T2</b> 5.66, <b>Tend</b> 5.72	<b>T0</b> 0.982 <b>T1</b> 0.973 <b>T2</b> 0.980 <b>Tend</b> 0.976	<b>T0</b> 2.27 log CFU/g, <b>T1</b> 4.33 log CFU/g, <b>T2</b> 3.29 log CFU/g, <b>Tend</b> 3.58 log CFU/g	<b>T0</b> 2.41 log CFU/g, <b>T1</b> 3.00 log CFU/g, <b>T2:</b> 2.94 log CFU/g, <b>Tend:</b> 3.23 log CFU/g	<b>T0</b> 2.06 log CFU/g, <b>T1:</b> 3.89 log CFU/g, <b>T2:</b> 2.65 log CFU/g, <b>Tend:</b> 3.18 log CFU/g
Cambell <i>et al.</i> (2001)	21	75	-	2	Short loin and strip loin	T0, T1 (7d), T2 (14d), Tend	S	-	-	-	<b>T0:</b> 1.4 log <sub>10</sub> ; <b>T1:</b> 1.4 log <sub>10</sub> ; <b>T2:</b> 1.5 log <sub>10</sub> ; <b>Tend:</b> 2.0 log <sub>10</sub>	<b>T0</b> 2.8 log <sub>10</sub> , <b>T1</b> 3.5 log <sub>10</sub> , <b>T2</b> 5.3 log <sub>10</sub> , <b>Tend</b> 3.3 log <sub>10</sub>
Ryu <i>et al.</i> (2018)	60	80-90	-	1-4	<i>Longissimus thoracis</i> section	T0, T1(25d), T2(40 d), T3 (50 d), Tend	S	NA	NA	-	<b>T0</b> ~ 0 CFU/g, <b>Tend</b> ~ 6.0 CFU/g ¥	-
Khazzar <i>et al.</i> (2023)	30	75	0.5	3+/-0.5	Boneless strip loin	T0, T1 (7d), Tend	Meat	<b>T0</b> 5.63, <b>T1</b> 5.54, <b>Tend</b> 5.60	<b>T1</b> 0.99 <b>Tend</b> 0.98	-	<b>T1</b> 0.2 log CFU/g, <b>Tend</b> 0.4 log CFU/g	<b>T1</b> 0.9 log CFU/g, <b>Tend</b> 1.8 log CFU/g
DeGeer <i>et al.</i> (2009)	21-28	50	-	2.2	Loin	T0, Tend	Subcutaneous fat and lean surface	Shell loin (SH) 5.51, strip loin (ST) 5.49, <b>21 and 28 days</b> (mean) 5.49	NA	-	<b>T0</b> SH 0.47 log CFU/cm <sup>2</sup> , ST 0.06 log CFU/cm <sup>2</sup> , <b>Tend</b> SH 1.34 log CFU/cm <sup>2</sup> , ST 1.10 log CFU/cm <sup>2</sup>	-
Li <i>et al.</i> (2013)	14	91	-	2.9	Muscle <i>gluteus medius</i>	T0, T1 (14 d*, Tend (14 d**))	S	<b>T0</b> 5.57 <b>T1</b> 5.62	NA	-	<b>T0</b> 0.01 log CFU/cm <sup>2</sup> , <b>T1</b> 0.4 log CFU/cm <sup>2</sup> , <b>T2</b> 0.3 log CFU/cm <sup>2</sup>	-
Ahntstöröm <i>et al.</i> (2006)	14-21	87+/-2.6	-	2.6+/-0.4	Strip loin	T0, Tend	Subcutaneous fat and lean surface	<b>T0</b> 5.4+/-0.1 <b>Tend</b> 14 d 5.5, 21 d 5.7	NA	-	<b>T0</b> <3 log CFU/cm <sup>2</sup> <b>Tend</b> 14 d 5.5 log CFU/cm <sup>2</sup> 21 d 2.7 log CFU/cm <sup>2</sup>	-
Da Silva Bernardo <i>et al.</i> (2021)	21	65	2.5	2	Loin	T0, Tend	I S	<b>T0</b> 5.39 +/- 0.01 <b>Tend</b> 5.51 +/- 0.01	<b>T0</b> 0.993 <b>Tend</b> I 0.9887, S 0.9730	<b>T0</b> <1 log CFU/g <b>Tend</b> 6.22 log CFU/g <b>T0</b> <1 log CFU/g <b>Tend</b> 2.88 log CFU/g	<b>T0</b> <1 log CFU/g <b>Tend:</b> <1 log CFU/g <b>T0</b> <1 log CFU/g <b>Tend</b> <1 log CFU/g	- -

	21	85	2.5	2	Loin	T0, Tend	I	<b>T0</b> 5.39 +/- 0.01 <b>Tend</b> 5.51 +/- 0.01	<b>T0</b> 0.993 <b>Tend</b> 1 0.9887 S 0.9730	<b>T0</b> <1 log CFU/g <b>Tend</b> 7.21 log CFU/g	<b>T0</b> <1 log CFU/g <b>Tend</b> 5.07 log CFU/g	-
							S			<b>T0</b> <1 log CFU/g <b>Tend</b> 10.55 log CFU/g	<b>T0</b> <1 log CFU/g <b>Tend</b> 8.15 log CFU/g	-
Gowda <i>et al.</i> (2022)	21-70	40-75	NA	-1 + 3	Bone-in. mainly loins	T0, Tend	S and I	<b>T1</b> (steaks) 5.73	<b>T1</b> (steaks): 0.98-0.99	<b>T0</b> 1.6-8.8 log CFU/cm <sup>2</sup> <b>Tend</b> < 1-7.4 log CFU/cm <sup>2</sup>	<b>T0</b> <1-7.3 log CFU/cm <sup>2</sup> <b>Tend</b> < 1-5.0 log CFU/cm <sup>2</sup>	<b>T0</b> < 1-8.8 log CFU/cm <sup>2</sup> <b>Tend</b> < 1-5.0 log CFU/cm <sup>2</sup>
Van Damme <i>et al.</i> (2022)	42	75 85	NA	2 6	Loin	T0, Tend	Superficial adipose tissue (AT) and lean meat (LM)	<b>T0</b> 5.50 <b>Tend</b> 5.77	-	-	<b>T0</b> AT 1.2 log CFU/cm <sup>2</sup> , LM <1 log CFU/cm <sup>2</sup> <b>Tend</b> AT 1.5 log CFU/cm <sup>2</sup> , LM 1.9 log CFU/cm <sup>2</sup>	<b>T0</b> AT 2.1 log CFU/cm <sup>2</sup> ; LM <1 log CFU/cm <sup>2</sup> <b>Tend</b> . AT 4 log CFU/cm <sup>2</sup> . LM <1 log CFU/cm <sup>2</sup>
Berger <i>et al.</i> (2018)	28	78	< 0.2	2	Bone-in loin	T0, T1 (21 d), Tend	Steak (I)	<b>T0</b> 5.89 <b>Tend</b> 5.79	-	-	<b>T1</b> 3.497 log CFU/ml	-
Shi <i>et al.</i> (2020)	14	85	1.5	2	<i>Longissimus thoracis</i> muscle	T0, T1 (7d), Tend	Inner part	<b>T0</b> 5.41 <b>T1</b> 5.58. <b>Tend</b> 5.61	-	-	<b>T0</b> 3.59 log CFU/g, <b>T1</b> 5.73 log CFU/g, <b>Tend</b> 5.29 log CFU/g	-
Mikami <i>et al.</i> (2021)	35	90	1.8-2.5	2.9	Rump	Tend	Crust (C) and inner part (I)	5.62	-	-	<b>C</b> <30 CFU/cm <sup>2</sup> <b>I</b> 2.03 log CFU/cm <sup>2</sup>	-

\*before trimming; \*\* after trimming; RH, relative humidity; Vent, air ventilation; aw, water activity; ¥, data have been retrieved from the figures.