JOURNAL OF VETERINARY MEDICAL RESEARCH 2019, 25 (x): xx-xx

Journal homepage:
http://www.bsu.edu.eg/bsujournals/JVMR.aspx

Online ISSN: 2357-0520 Print ISSN: 2357-0512

Original Research Article

The influence of meat storage atmosphere on the quality parameters

Fathy A. Khalafalla [a], Abdel-Rahim H.A. Hassan [a]* and Rabab A-H. Ali [b]

a Food Hygiene and Control Department, Faculty of Veterinary Medicine, Beni-Suef University, Beni-Suef, Egypt.

b Veterinary Medicine Directorate, Beni-Suef, Egypt.

ABSTRACT

This study was carried out to assess the effect of storage conditions on the sensory, quality parameters and microbiological status of beef from the muscle "Semitendinosus". The experiment was design into 4 groups of beef samples, the first was control and the others were unpacked, aerobic packed and vacuum packed chilled meat. The obtained results showed that the mean values of mesophilic counts were $6\times10^7\pm5\times10^6$, $3\times10^7\pm3\times10^6$, $3\times10^7\pm2\times10^6$ and $5\times10^7\pm5\times10^6$ CFU/g, while those of psychrophilic count were $5\times10^7\pm5\times10^6$, $3\times10^6\pm3\times10^5$, $4\times10^6\pm3\times10^5$ and $7\times10^6\pm7\times10^5$ CFU/g, whereas the mean values of coliforms MPN were $10^5\pm10^4$, $10^5\pm10^4$, $2\times10^4\pm10^3$ and $4\times10^7\pm2\times10^6$ MPN/g, the mean values of fecal coliforms MPN were $2\times10^3\pm2\times10^2$, $4\times10^4\pm3\times10^3$, $2\times10^3\pm10^2$ and $10^7\pm10^6$ MPN/g, the mean values of *E.* coli MPN were $9\times10^2\pm9\times10$, $6\times10\pm6\times10^2$, $6\times10^3\pm10^2$ and $2\times10^3\pm10^2$ MPN/g and the mean values of Staphylococcus count were ($9\times10^5\pm9\times10^4$, $10^6\pm10^5$, $2\times10^6\pm10^5$ and $2\times10^6\pm2\times10^5$ CFU/g) for control, unpacked, aerobic packed and vacuum packed chilled stored beef, respectively. The unpacked meat showed increase in shelf life time till four days as the sensory evaluation become excellent till four days also, increased pH, drip, water holding capacity (WHC) and cooking loss at four days. Staphylococcus reach to unsatisfactory level. Area packed meat increase in shelf life time till six days showing excellent sensory evalution at six day, decreasd drip, water holding capacity and cooking loss and slowly increased in bacterial count. Anaerobic meat have the longest shelf life time till 10 days as vacuum packing reduce drip, WHC and cooking loss. Also decrease mesophilic, fecal coliform growth. The quality assurance of cold storage was discussed as well as the vacuum packaged chilled beef has long shelf –life time than aerobic packed and fresh meat. This attributed to that package and cold storage reduce microbiological and physio-chemical alterations in meat. The recommendations to extension of shelf life time were discussed.

ARTICLE INFO

Article history:

Received 9/2017

Accepted 12/2017

Online 3/2019

Keywords:

meat, chilling, quality parameters, pH, meat drip, water holding capacity.

***Corresponding author**. *Department of* Food Hygiene and Control Department, Faculty of Veterinary Medicine, Beni-Suef University, Beni-Suef, Egypt.**Email:** abdelrahim@vet.bsu.edu.eg

1. Introduction

The development of quality assurance a program for chilled meat in different processing condition affected on the keeping quality of the final product of meat This is a complex task because chilled meat quality is determined by a number of parameters. Other parameters including drip in vacuum packs. Pack tightness and self-life are less well defined. The package of fresh meat as well as exposed for sell under the different condition may be affected chill life time (Hassona, 2001; Gill and Landers, 2004 and Hernandez-Macedo et al., 2010). The quality parameter including water holding capacity, pH, cooking loss and drip were affected by chilling storage as well as in either packed or unpacked meat (Honikel, 1985). This study was designed in order to assess the effect of different of storage condition on the sensory, quality parameters and microbiological status of beef stored under chilling temperature either packed or un packed. The economic importance of packing of beef to extend shelf life time was discussed.

2. Material and methods:

2.1. Collection of samples

A total of 10 Kg of beef from semitendinosus muscle (complete intact muscles with their fascia) were collected from beef carcasses marketed in butcher`s shops in Beni-Suef city, Egypt. The collected samples were directly transferred in an insulated ice box to the laboratory with minimum of delay for further preparation and treatment.

2.2. Design of the experiment:

At the laboratory, the collected samples were divided into 4 groups as following:

Fresh meat to be stored at room temperature (25 °C).

Chilled meat to be stored unpacked at ≤ 2 °C.

Chilled meat to be stored aerobically packed at ≤ 2 °C.

Chilled meat to be stored vacuum packed at ≤ 2 °C

And every group was packed in triplicates each piece of about 250 g. The stored samples were periodically examined according to the following scheme: zero day (within 6 hours of animal slaughtering), 2nd day, 4th day, 6th day and soon until the time of apparent decomposition.

2.3. Evaluation techniques:

2.3.1. Sensory evaluation:

Sensory evaluation of beef including color was evaluated according method recommended by (Gracey, 1986 and Hunt et al., 1991), odor and texture were evaluated according method recommended by (Gracey, 1986 and Miller et al., 1994).

2.3.2. Physical parameters:

2.3.2.1. pH measurement:

The technique recommended by Santos et al. (2002) was done. Briefly, ten grams of meat was homogenized for about 2 minutes with an equal mass of distilled water in a food blender (Arnica Quick, China). The electrode was introduced into the test portion and the temperature correction system was set to the temperature of the test portion. The pH was directly read from the scale on the instrument of the nearest 0.05 pH unit when constant value has been reached.

2.3.2.2. Determination of water holding capacity:

The filter paper press method has been a useful relative indication of WHC. The filter paper method of Kauffman et al. (1986). Samples, 2.5 cm in diameter and 1.0 cm in thickness, were collected and weighed. A sample was placed on

humid filter paper between to plexiglass plates and subjected to a specified pressure for a time.

2.3.2.3. Determination of drip:

Technique recommended by Kauffman et al. (1986) was done. Measuring of drip involves the weight loss from meat during defined period. The meat was weighed before being placed in the bag then patted dry with filter paper and weighed again after 24h at refrigerator and calculates difference between two weight.

2.3.2.4. Determination of cooking loss:

The method reported by Honikel (1987) was done. Cut samples 5 × 3 × 2 cm cubes devoid of fat and connective tissue. Each cube, which was weighed (W1) and individually placed inside polyethylene bags, was cooked in a water bath at 80 °C until an internal temperature of 70 °C was reached. During cooking, the internal temperature was tracked by the portable needle-tipped thermometer. The cooked samples were then cooled at 4 °C for 16 h, removed from the bags, patted dry with filter paper, and reweighed (W2). The cooking loss was calculated according to the following equation:

$$\text{Cooking loss} = \frac{(W1 - W2)}{W1} \times 100\%$$

2.3. Bacteriological techniques:

2.3.1 Sample preparation for bacteriological examination:

Preparation of the collected samples will be done according to the technique recommended by AOAC (1990) as follows; ten grams of samples will be transmitted to a sterile homogenizer flask containing 90 ml of 0.1% sterile peptone water (DM185D, MAST, UK). The contents were homogenized at 2000 r.p.m. for 2.5 minutes using a sterile homogenizer (MPW 302, Universal Laboratory Aid, made in Poland). The homogenate was allowed to stand for about 15 minutes at room temperature. The contents of the flask represented the dilution 10-1 were thoroughly mixed by shaking, one ml was aseptically transferred using a sterile pipette into a sterile test tube containing 9 ml of 0.1 % sterile peptone water to be diluted in a sequential manner by tenfold serial dilution up to 10-6.

2.3.2. Determination of mesophilic counts

The pouring technique recommended by (AOAC, 1990) was applied. In brief, one ml from each dilution was separately pipetted into a double set of sterile Petri dishes. Fifteen ml melted standard plate count agar (6G2307, Biolife, Italy) tempered at 45 °C were poured into each Petri dish, then thoroughly mixed and left to solidify. The inoculated plates were incubated in inverted position at 35 °C for 48 h.

Mesophilic count /g = Average No. of colonies × dilution factor

2.3.3. Determination of psychrophilic counts:

The pouring plate technique recommended by (AOAC, 1990) was applied as previous in mesophilic count, while the inoculated plates were incubated in inverted position at 7 ºC for 10 days.

2.3.4. Most probable number of coliforms:

The three tubes method (MPN) recommended by (AOAC, 1990) was applied. Briefly, one ml from each dilution using sterile separate pipette was separately transferred into each of the three replicate Lauryl Sulphate Tryptose broth tubes (M080-5006, HIMEDIA, India). All inoculated tubes were incubated at 35 ºC for 48 hours. Positive

results showing gas production in the inverted Durham's tubes were recorded. After that, a loopful from each positive tube of LST was confirmed by tubes containing Brilliant Green Bile Lactose broth (Oxoid; CM 31). Inoculated tubes were incubated at 35 ºC for 24 to 48 h. Positive tubes showing gas production were recorded. The most probable number (MPN) of coliforms per gram was estimated and recorded according to the table recommended by (AOAC, 1990) using the following equation:

MPN/g = No. from the table × middle dilution factor/100

2.3.5. Most probable number of faecal coliforms:

A loopful from each positive Brilliant Green Bile Lactose broth tubes was transferred into sterile test tubes containing E.C. broth (6L3202, Biolife, Italy) preheated at 44 ± 0.5 ºC with inverted Durham's tubes. The inoculated tubes were incubated at 44 ± 0.5 ºC in a thermostatically controlled water bath (WB-28, China) for 48 hours. Positive tubes showing gas production were recorded and MPN of faecal coliform was estimated per gram according to the table recommended by AOAC (1990) using the following equation:

MPN/g = No. from the table × middle dilution factor/100.

2.3.6. Most Probable Number of E. coli:

The technique recommended by AOAC (1990) was used as follows; a loopful from each positive E.C. broth tube was streaked onto the surface of Eosin Methylene Blue agar (EMB; 6L0601, Biolife, Italy). The inoculated plates were left to dry before inversion and incubation at 35 ºC for 24 hours. Plates showing typical colonies (greenish metallic nucleated with dark purple center with or without sheen) were recorded and MPN of E. coli was estimated per gram according to the table recommended by AOAC (1990) using the following equation:

MPN/g = No. from the table × middle dilution factor/100

2.3.7. Enumeration of Staphylococcus aureus:

The prepared samples were examined according to the technique recommended by AOAC (1990). A tenth ml of each decimal dilution (10-1 dilution) was transferred to every of two Baird Parker agar (LABM, lab085, UK) plates. The inoculum was carefully spread over the dried surface of the agar plate as quickly as possible by using sterile glass spreader. The inoculated plates were then inverted and incubated at 35 °C or 37 °C for 24 h ± 2h. All plates were incubated at 35 °C or 37 °C for a further 24 h ± 2 h. Typical colonies are black or grey, shin and convex (1 – 1.5 mm in diameter after incubation for 24 h, and 1.5 – 2.5 mm in diameter after incubation for 48 h) and surrounded by a clear zone which may be partially opaque. After incubation for at least 24 h, an opalescent ring immediately in contact with the colonies may appear in this clear zone.

3. Results:

Table (1) The overall acceptability of different beef groups

Groups	Zero day		2nd day		4th day		6th day		8th day		10th day	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Control	4	100	4	100	1	25	spoilage	spoilage	spoilage	spoilage	spoilage	spoilage
Unpacked meat	4	100	4	100	4	100	1	25	spoilage	spoilage	spoilage	spoilage
Aerobic packed meat	4	100	4	100	4	100	2	50	spoilage	spoilage	spoilage	spoilage
Anaerobic packed meat	4	100	4	100	4	100	4	100	2	50	spoilage	spoilage

Table (2) The quality parameters of different beef groups

Time	**Meat groups**	**pH**	**Drip (%)**	**Water holding capacity (%)**	**Cooking loss (%)**
Zero day	Control	5.5	3.5	1.2	32
	Unpacked	5.5	1.8	0.9	25
	Aerobic packed	5.5	2.1	1.6	38
	Anaerobic packed	5.5	0.9	0.8	21
2nd day	Control	5.8	2.4	1.1	24
	Unpacked	5.8	0.9	0.5	23
	Aerobic packed	5.7	1.9	1.3	30
	Anaerobic packed	5.7	0.8	0.7	18
4th day	Control	6	2	1	10
	Unpacked	6	0.8	0.3	19
	Aerobic packed	6.3	1.7	1	25
	Anaerobic packed	6.5	0.6	0.5	17
6th day	Control	6.3	1.5	0.2	8

	Unpacked	6.3	0.7	0.2	15
	Aerobic packed	6.4	1.5	0.9	22
	Anaerobic packed	6.5	0.5	0.4	13
8^{th} day	Control	-	-	-	-
	Unpacked	6.4	0.5	0.1	14
	Aerobic packed	6.9	0.9	0.6	20
	Anaerobic packed	6.8	0.4	0.3	12
10^{th} day	Control	-	-	-	-
	Unpacked	6.9	0.3	0.1	12
	Aerobic packed	7.1	0.7	0.3	12
	Anaerobic packed	6.9	0.3	0.2	9

Table (3) Microbial examination of examined samples

Items	**Type of meat**	**APC**		**MPN**			**Staphylococcus**
		Mesophilic	**Psychrophilic**	**coliform**	**Fecal coliform**	**E. coli**	
Zero day	Control	$2\times10^5 \pm10^5$	$10^5 \pm10^4$	$4\times10^3\pm10^2$	$10^3\pm10^2$	$6\times10^2\pm6\times10$	$4\times10^4\pm4\times10^3$
	Unpacked	$2\times10^5 \pm10^5$	$10^5 \pm10^4$	$9\times10^2\pm5\times10$	$7\times10^2\pm4\times10$	$3\times10\pm10$	$2\times10^4\pm10^3$
	Aerobic	$3\times10^5 \pm10^5$	$4\times10^5 \pm10^4$	$2\times10^3\pm10^2$	$2\times10^2\pm10$	$3\times10\pm2\times10$	$10^5 \pm10^4$
	Anaerobic	$2\times10^5 \pm10^5$	$10^5 \pm10^4$	$10^3\pm10^2$	$10^3\pm10^2$	$2\times10^2\pm2\times10$	$8\times10^5 \pm8\times10^4$
2^{nd} day	Control	$3\times10^6 \pm2\times10^5$	$2\times10^6 \pm2\times10^5$	$10^4\pm10^3$	$10^3\pm10^2$	$7\times10^2\pm7\times10$	$5\times10^5 \pm5\times10^4$
	Unpacked	$2\times10^6 \pm2\times10^5$	$2\times10^5 \pm2\times10^4$	$10^3\pm10^2$	$2\times10^2\pm10$	$10^2\pm10$	$10^5 \pm10^4$
	Aerobic	$10^6 \pm10^5$		$2\times10^3\pm10^2$	$10^3\pm10^2$	$7\times10^2\pm5\times10$	$2\times10^5 \pm10^4$
	Anaerobic	$5\times10^6 \pm5\times10^5$	$4\times10^5 \pm2\times10^4$	$10^4\pm10^3$	$10^4\pm10^3$	$10^2\pm10$	$8\times10^5 \pm8\times10^4$
			$8\times10^5 \pm8\times10^4$				

4th day	Control	$5\times10^7 \pm4\times10^6$	$3\times10^6 \pm3\times10^5$ $2\times10^6 \pm2\times10^5$	$10^4\pm10^3$	$10^3\pm10^2$	$9\times10^2\pm8\times10$	$7\times10^5 \pm7\times10^4$
	Unpacked	$5\times10^6 \pm5\times10^5$		$10^3\pm10^2$	$3\times10^2\pm10$	$2\times10^2\pm2\times10$	$2\times10^5 \pm10^4$
	Aerobic	$2\times10^6 \pm10^5$	$8\times10^5 \pm4\times10^4$	$5\times10^3\pm4\times10^2$	$10^3\pm10^2$	$9\times10^2\pm6\times10$	$6\times10^5 \pm10^4$
	Anaerobic	$6\times10^6 \pm6\times10^5$	$6\times10^6 \pm6\times10^5$	$6\times10^5 \pm10^4$	$2\times10^5 \pm2\times10^4$	$10^2\pm10$	$10^6 \pm10^5$
6th day	Control	$6\times10^7 \pm5\times10^6$	$5\times10^7 \pm5\times10^6$	$10^5 \pm10^4$	$2\times10^3\pm2\times10^2$	$9\times10^2\pm9\times10$	$9\times10^5 \pm9\times10^4$
	Unpacked	$6\times10^6 \pm6\times10^5$	$5\times10^6 \pm5\times10^5$	$10^4\pm10^3$	$2\times10^3\pm10^2$	$9\times10^2\pm3\times10$	$5\times10^5 \pm10^4$
	Aerobic	$3\times10^6 \pm10^5$		$10^5 \pm10^4$	$10^3\pm10^2$	$9\times10^2\pm7\times10$	$8\times10^5 \pm10^4$
	Anaerobic	$7\times10^6 \pm8\times10^5$	$2\times10^6 \pm10^5$	$2\times10^6 \pm10^5$	$2\times10^6 \pm2\times10^5$	$7\times10^2\pm7\times10$	$10^5 \pm10^4$
			$10^6 \pm7\times10^5$				
8th day	Control	_	_	_	-	-	-
	Unpacked	$3\times10^6 \pm3\times10^5$	$2\times10^6 \pm2\times10^5$	$2\times10^4\pm10^3$	$2\times10^4\pm10^3$	$9\times10^2\pm6\times10$	$10^6 \pm10^5$
	Aerobic	$4\times10^6 \pm2\times10^5$		$7\times10^3\pm2\times10^2$	$7\times10^3\pm5\times10^2$	$10^3\pm10^2$	$10^6 \pm10^5$
	Anaerobic	$8\times10^6 \pm8\times10^5$	$3\times10^6 \pm3\times10^5$	$7\times10^6 \pm10^5$	$3\times10^7 \pm3\times10^6$	$9\times10^2\pm10$	$2\times10^6 \pm2\times10^5$
			$2\times10^6 \pm2\times10^5$				
10th day	Control	_	_	_	-	-	-
	Unpacked	$3\times10^7 \pm3\times10^6$	$3\times10^6 \pm3\times10^5$	$10^5 \pm10^4$	$4\times10^4\pm3\times10^3$	$6\times10\pm6\times10^2$	$10^6 \pm10^5$
	Aerobic	$3\times10^7 \pm2\times10^6$		$2\times10^4\pm10^3$	$2\times10^3\pm10^2$	$6\times10^3\pm10^2$	$2\times10^6 \pm10^5$
	Anaerobic	$5\times10^7 \pm5\times10^6$	$4\times10^6 \pm3\times10^5$	$4\times10^7 \pm2\times10^6$	$10^7 \pm10^6$	$2\times10^3\pm10^2$	$2\times10^6 \pm2\times10^5$
			$7\times10^6 \pm7\times10^5$				

4. Discussion:

According the data in table (1) the degree of acceptability of the examined fresh and chilled anaerobic packed meat were excellent till 2nd day and 6th day respectability while unpacked and aerobic packed chilled meat were excellent till 4th day. It indicated that good anaerobic package for meat keep it good quality for long time. Data of table (2) showed that the quality parameter of examined fresh sample as pH, drip, water holding capacity and cooking loss were 6.3, 1.5, 0.2 and 8 respectively after 6 days after that it spoilage while in unpacked chilled meat were 6.9, 0.3, 0.1 and 12 after 10days but in case of chilled aerobic packed samples were7.1, 0.7, 0.3and 12 in 10th day and in chilled anaerobic packed were 6.9, 0.3, 0.2 and 9 at 10th day. The present data in table (3) showed that the mesophilic count ,psychrophilic count, most probable number

of coliforms, , most probable number of fecal coliforms, E-coli and staphylococcus were $2\times10^5 \pm10^5$,$10^5 \pm10^4$, $4\times10^3\pm10^2$, $10^3\pm10^2$, $6\times10^2\pm6\times10$, $4\times10^4 \pm\times10^3$ organisms/g in fresh meat at zero time. While they are reached to $6\times10^7 \pm5\times10^6$, $5\times10^7 \pm5\times10^6$, $10^5 \pm10^4$, $2\times10^3\pm2\times10^2$, $9\times10^2\pm9\times10$ and $9\times10^5 \pm9\times10^4$ after 6 days storage at room temperature. The presence of these organisms on meat parts could be attributed to the fact that meat contains an abundance of all nutrient required for the growth of bacteria in adequate quantity. This held the view that reported by (Okonkwo et al., 2011). The mesophilic count and psychrophilic count were $2\times10^5 \pm10^5$, $10^5 \pm10^4$ m.o/g at zero time while most probable number of coliforms , most probable number of fecal coliforms and E.coli each constituted that $9\times10^2\pm5\times10$, $7\times10^2\pm4\times10$ and $3\times10\pm10$. Finally, staphylococcus was $2\times10^4 \pm10^3$ such counts increased after ten days to reached $3\times10^7 \pm3\times10^6$, 3×10^6 , $\pm3\times10^5$, $10^5 \pm10^4$, $4\times10^4 \pm3\times10^3$, $6\times10\pm6\times10^2$ and $10^6 \pm10^5$ m.o/g for each respectively in chilled unpacked meat. The aerobic plate count was excessed the (EOS, 2005) in examined sample after 6 days constituting $6^6 \times10^6 \pm6\times10^5$ in unpacked meat.

The aerobic plate count of aerobic packed chilled beef the mesophilic count was $3\times10^5 \pm10^5$ while psychrophilic count was $4\times10^5 \pm10^4$ m.o/g at zero time.

Concerning the most probable number of coliforms, fecal coliforms and E-coli constituting $2\times10^3\pm10^2$, $2\times10^2\pm10$, $3\times10\pm2\times10$ m.o /g. at aerobic packed meat.

The staphylococcus was $10^5 \pm10^4$ m.o/g. such count was increased to reach mesophilic count $3\times10^7 \pm2\times10^6$, psychrophilic $4\times10^6 \pm3\times10^5$, coliform $2\times10^4 \pm10^3$, Fecal coliform $2\times10^3\pm10^2$, E.coli $6\times10^3\pm10^2$, Staphylococcus $2\times10^6 \pm10^5$ m.o/gm after respectively at anaerobic packed chilled meat.

Such count after ten days reached to $5\times10^7 \pm5\times10^6$, $7\times10^6 \pm7\times10^5$ for mesophilic and psychrophilic count while most probable number of coliforms, Fecal coliform and E.coli that $4\times10^7 \pm2\times10^6$ $10^7 \pm10^6$ and $2\times10^3\pm10^2$ as well as staphylococcus was $2\times10^6 \pm2\times10^5$ m.o/g at anaerobic packed chilled meat.

It is well known that packaging makes food more convenient and gives the food greater safety assurance from microorganisms, biological and chemical changes so that the packaged foods may have longer shelf life (Skandamis and ychas, 2002). Vacuum packaging and modified atmosphere packaging are effective means of prolonging the storage life of perishable foods (Calleja et al., 2010).

Vacuum packages for meat increase the shelf life and thus improve the distribution efficiency and marketing of the product so it used to improve the microbiological quality of meat.

6. References

AOAC (1999). Association Official Methods of Analysis .By Authority of the Code of Federal Regulations: 9 CFR 318.19

Brightwell, G.; Clemens, R.; Urlich, S. and Boerema, J. (2007). Possible involvement of psychrotolerant Enterobacteriaceae in blown pack spoilage of vacuum-packaged raw meat. Int J Food Microbiol. 119 (3): 334-339.

Broda, D.M.; Musgrave, D.R. and Bell, R.G. (2003). Molecular differentiation of clostridia associated with "blown pack" spoilage of vacuum-packed meats using internal transcribed spacer polymorphism analysis.Int. J. Food Microbiol. 84(1): 71-77.

Calleja J. M.; Santos , J. A. Otero A. and . García-López M.-L(2010). Effect of vacuum and modified atmosphere packaging on the shelf life of rabbit meat. Journal CyTA – J. of Food 8(2):23-36

EOS. (1688/2005) for beef burger. EOS.No. (1971/2005) for canned sausage.EOS.No.(1973/2005)for kofta. Egyptian Standard Specification or Egyptian Organization for Standardization and Quality Control for meat products.

Okonkwo, J.C; Okonkwo, I.F and Ebyh, GU (2011). Effect of breed, sex and source within breed on the haematological parameters of the Nigerian goats. Online J. Anim. Feed Res. 1(1): 8-13.

Holzapfel, W. H. (1998). The gram-positive bacteria associated with meat and meat products. In A. Davies and R. Board (ed.), The microbiology of meat and poultry. p. 35-74.

Honikel, K.O. and Kim, C.J. (1985): Uber die Ursachen der Entstehung von PSE-Schweinefleisch. Fleischwirtschaft 65, 1125-1131.

Skandamis, N. and Nychas E. (2002). Preservation of fresh meat with active and modified atmosphere packaging conditions. International Journal of Food Microbiology 79 35– 45.