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Meat quality, microbiological status and consumer preference of beef *gluteus medius* aged in a dry ageing bag or vacuum

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ABSTRACT

This study investigated meat quality and consumer preference after ageing beef *gluteus medius* in a water vapour-permeable dry-ageing bag or in vacuum for 14 days. Higher ageing and trim losses but lower thawing loss, cooking loss and water content were found in samples aged in dry ageing bags compared to those aged in vacuum. Samples aged in dry ageing bags had higher total bacteria and yeast counts but lower lactic acid bacteria counts than those aged in vacuum, both before and after trimming. Meat aged in dry ageing bag was more tender and juicier and overall preferred by consumers compared with samples aged in vacuum. Female participants outperformed the males in detecting differences in palatability. No differences were found in pH, smell, shear force, colour, *Enterobacteriaceae*, and mould counts. Thus, by using a dry ageing bag, it is possible to produce dry-aged meat in a more controlled condition without negative effects on sensory or other quality attributes.

1. Introduction

Dry ageing is one of the main types of ageing process in which meat is unpacked and exposed directly to environmental conditions. Dry-aged beef is characterised by its high, unique flavour and product quality (DeGeer et al., 2009). However, the dry ageing process is costly because of high ageing shrinkage, trim loss, risk of contamination, and requirements of ageing conditions and space (Parrish, Boles, Rust, & Olson, 1991). In contrast, wet ageing, also called vacuum ageing, is widely used in the meat industry due to its high production yield and convenience in storage and transport (Warren & Kastner, 1992). Results from sensory analysis of wet-aged versus dry-aged meat flavour have been inconsistent, which indicates that many consumers are more familiar with wet-aged flavour. Consumers are, however, willing to pay more for dry-aged products and may also prefer the dry-aged flavour when they have become familiar with this type of meat (DeGeer et al., 2009).

Recently, a new dry ageing process using a highly water vapour-permeable bag (dry ageing bag) was introduced to the market to improve the traditional unpackaged dry ageing process. Meat aged in a dry ageing bag was expected to have the same sensory quality as traditional unpackaged dry aged meat but with less ageing and trim losses, lower risk of contamination and fewer requirements on environmental control (Ahnström, Seyfert, Hunt, & Johnson, 2006; DeGeer et al., 2009). Ahnström et al. (2006) compared dry ageing of beef strip loins in dry ageing bags for 14 or 21 days with the traditional dry ageing process. Meat aged in dry ageing bags for 21 days had a lower ageing loss, trim loss and yeast counts on lean tissue, but increased lactic acid bacteria counts on adipose and lean tissues, compared with traditional dry aged meat. No difference was observed in pH, moisture, fat, cook loss, shear force, total plate counts or any measured sensory traits. DeGeer et al. (2009) investigated the combined effects of dry ageing methods (traditional unpackaged versus dry ageing bag), meat cut styles (bone-in shell loins versus boneless strip loins), and ageing time (21 versus 28 days) on meat quality of dry-aged beef. There was no difference in sensory traits, *E. coli*/coliforms and lactic acid bacteria counts between the two ageing methods. Meat aged in dry ageing bags had lower weight loss compared with traditional dry-aged meat.

However, there has, to our knowledge, been no study comparing meat quality of beef aged in dry ageing bags with beef aged in vacuum. It is of interest to know if consumers would prefer meat aged in dry ageing bags when comparing it with vacuum-aged meat that they are more familiar with. Moreover, the muscle *gluteus medius* has seldom been used for dry ageing compared with *longissimus* muscle. The objective of this study was to investigate meat quality, microbiological status and consumer preference after ageing beef *gluteus medius* in dry ageing bags compared with in vacuum.

2. Materials and methods

2.1. Animals and treatments

Eight heifers of the Hereford breed were used in this study. All animals were 22–24 months old and slaughtered on the same day

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at a commercial slaughter plant according to their standard routines. The average carcass weight was 240 kg (standard deviation 32). Conformation and fatness were graded according to the EUROP schemes modified to the Swedish system, in which 15 classes are used (for conformation score, E^+ = best, P^- = poorest; for fatness score, 5^+ = fattest, 1^- = leanest) (Commission of the European Communities, 2005; Swedish Board of Agriculture, 1998). The conformation scale was P^- and the fatness scale was 5^+ for all heifers.

On day 6 *post mortem*, the muscle *gluteus medius* (GM) was cut out from both sides of each carcass and vacuum packed. On day 7 *post mortem*, muscle pH was measured at the anterior side of GM using a portable pH meter (Knick Portamess® 913, Berlin, Germany) equipped with a combination pH gel electrode (SE 104, Knick, Berlin, Germany). For each pair of GM muscles from the same animal, a small piece of meat from the anterior side was cut off for microbiological and water content analysis (Fig. 1); the remaining parts of the muscle were used for additional ageing. The left and right side muscles from the same animal were assigned to either of two ageing methods according to a randomised order on the first animal.

2.2. Ageing, trimming and sampling

Two ageing methods were used in this study. (1) Dry ageing bag (Bag). Samples were packed in dry ageing bags (Tublin® 10, TUB-EX ApS, Denmark) using vacuum to seal the bags to get contact between the bag and the meat. The bags were made of a polyamide mix and were 50 μm thick with water vapour transmission rate 5000 g/50 μ/m^2/24 h at 38 °C and 50% relative humidity. (2) Vacuum ageing (Vacuum). Samples were packed in vacuum. The vacuum bags (Cryovac® BB6050, Sealed Air Corporation, USA) were 68 μm thick, the permeability of O_2 was 20 cm^3/m^2, 24 h, bar at 23 °C, 0% relative humidity and the maximum permeability of CO_2 was 100 cm^3/m^2, 24 h, bar at 23 °C, 0% relative humidity.

All samples were kept on stainless steel gratings and aged in darkness for 14 days, i.e. in total 21 days *post mortem*. The cooling room used for the ageing process had an average temperature of 2.9 °C and an average humidity of 91%. The air was not filtered and no UV light was used. Samples were turned over and rotated among shelf positions every day to minimise location effects.

After the ageing process, samples were taken out and a smell score was decided by three trained individuals together after opening the package using a score from 1 (normal smell) to 5 (bad smell). Samples aged in dry ageing bags were trimmed to remove the dry layer on the surface and pH was measured at the anterior side of each GM muscle. Samples from each piece of muscle were then taken for the different analyses as shown in Fig. 1. Samples for water content, shear force and consumer test were stored at −20 °C in vacuum until analysis.

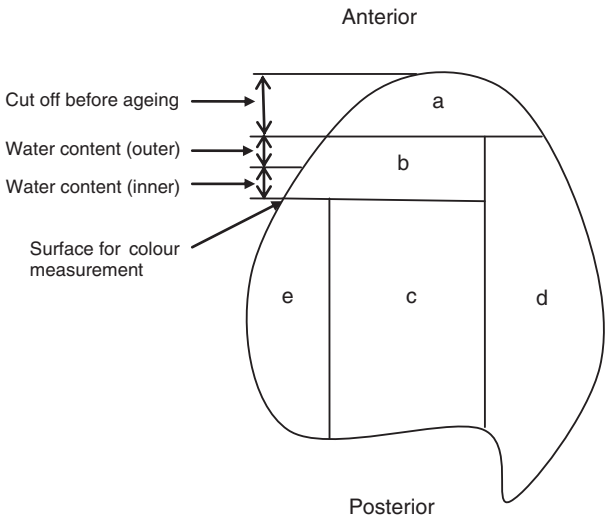

Fig. 1. Sample location for the different analyses before and after ageing process. a) Cut off before ageing and used for water content and microbiological analysis as control; b) colour measurements and then water content analysis (4 cm); c) shear force analysis; d) consumer test; e) alternative piece for consumer test.

The weight losses were calculated as follows: ageing loss (%) = weight loss during ageing/weight before ageing × 100%; trim loss (%) = weight loss during trimming/weight before trimming × 100%; total ageing and trim loss (%) = (sample weight before ageing − sample weight after trimming)/sample weight before ageing × 100%.

2.3. Water content

Water content of the 2 cm outer layer and the next 2 cm inner layer (Fig. 1) were analysed separately. Duplicate samples of 3 g meat were chopped into small pieces and then put into aluminium tins that had been dried in oven at 105 °C for 16 h and cooled in desiccator for 1 h. The aluminium tins with the sample were kept in oven at 105 °C for 16 h and then cooled in desiccator for 1 h. The water content was calculated as weight loss during drying in the oven in percent of sample weight before drying.

2.4. Colour

The meat colour was measured using a Minolta CM-600d spectrophotometer (Konica Minolta Sensing Inc., Osaka, Japan) with 8 mm diameter measuring aperture, illuminant D65, 10° standard observer and CIE L*, a*, b* colour scale. The measuring aperture was covered with a glass plate and the instrument was calibrated against a white plate ($L^* = 97.62 \pm 0.01$, $a^* = -0.16 \pm 0.01$, $b^* = 0.00 \pm 0.01$). The colour was measured through oxygen-permeable PVC film (NORM PACK 115 45–1, Tempac AB, Tyresö, Sweden) after blooming for 1.5 h in darkness (Fig. 1). The average of four measurements on the meat surface was used. The chroma value was calculated as $(a^{*2} + b^{*2})^{1/2}$ and hue angle as arctan b*/a*. The Minolta instrument recorded reflectance values in the range of 360 nm to 740 nm with 10 nm intervals. Reflectance values that were not directly given by the colour instrument at specific wavelengths (474, 525 and 572 nm) were calculated according to linear interpolation. Then, the Kubelka–Munk K/S values were calculated. The relative content of deoxymyoglobin (DeoxyMb) was calculated as (K/S474)/(K/S525), the relative content of oxymyoglobin (OxyMb) as (K/S610)/(K/S525) and the relative content of metmyoglobin (MetMb) as (K/S572)/(K/S525) (AMSA, 2012). Because the K/S ratio decreases when the relative content of the corresponding myoglobin form increases, the K/S ratios were transformed to make the changes in the myoglobin species easier to interpret. The K/S ratio of DeoxyMb was transformed to [1.5 − (K/S474)/(K/S525)], the K/S ratio of OxyMb was transformed to [1 − (K/S610)/(K/S525)] and the K/S ratio of MetMb was transformed to [2 − (K/S572)/(K/S525)].

2.5. Microbiological analysis

Four 2-mm-thick samples with a 2.5-cm diameter were aseptically taken from the surface of each piece of GM muscle before ageing (control), after ageing but before trimming, and after trimming. The samples were put into a blender bag (Grade Packaging, VWR), mixed with 100 ml of buffered peptone water and stomached in a blender (easyMIX®, AES Laboratoire, France) for 2 min. Appropriate serial decimal dilutions of the homogenate were made in peptone saline (0.1% peptone in 0.85% NaCl) and 0.1 ml of each dilution was plated on the following agars: PCA (Plate Count Agar, Oxoid) incubated at 30 °C for 72 h for determination of Total Bacteria Counts (TBC); VRBGA (Violet Red Bile Glucose Agar, Difco) incubated at 37 °C for 24 h for determination of *Enterobacteriaceae* (EB) counts; MRS agar (de Man, Rogosa and Sharpe, Oxiod) incubated at 25 °C for 5 days for

determination of lactic acid bacteria (LAB) counts; and SAB (Sabouraud Dextrose Agar with Chloramphenicol, Acumedia) incubated at 25 °C for 7 days for determination of yeast and mould counts. All incubations, except for LAB, were performed under aerobic conditions. LAB counts were incubated in an anaerobic jar with a disposable anaerobic conditions generator (AnaeroGen, Oxoid). To confirm that colonies growing on VRBGA were EB, the oxidase test (Becton, Dickinson & Co.) was performed.

2.6. Water-holding capacity and shear force analyses

The frozen samples for shear force measurement were thawed at 4 °C overnight and then kept in a room temperature water bath for 30 min to equalize temperature. The samples were weighed and heated in vacuum package in a 72 °C water bath until a core temperature of 70 °C. The samples were then cooled in running cold tap water for 30 min, stored at 4 °C overnight and weighed the next day. Water-holding capacity was calculated as percentage of meat weight loss during thawing and cooking. Thawing loss (%) = (sample weight before freezing − sample weight after thawing)/sample weight before freezing × 100%. Cooking loss (%) = (sample weight before cooking − sample weight after cooking)/weight before cooking × 100%. Total loss at thawing and cooking (%) = (sample weight before freezing − sample weight after cooking)/sample weight before freezing × 100%. Furthermore, total loss at ageing, thawing and cooking (%) = total ageing and trim loss (%) + total loss at thawing and cooking (%).

Warner–Bratzler shear force was measured using the method as described by Honikel (1998). For each cooked sample, twelve strips were cut out being at least 30 mm long and with a 100-mm^2 (10 × 10 mm) cross-sectional area. The direction of muscle fibres was parallel to the longitudinal direction of the strip. The strips were tested on a Stable Micro System Texture Analyser HD 100 (Godalming, UK) that had a 1-mm-thick cutting blade with a rectangular shaped cutting area (11 mm × 15 mm) and a speed of 0.83 mm/s when cutting through the strips. Shear force was recorded as peak force (N) and total energy (area under the curve, Nmm).

2.7. Consumer test

The frozen samples were thawed in refrigerator for 48 h. The samples were cooked in oven at 150 °C until the central temperature reached 65 °C, resulting in a final temperature of 68 °C. Samples were cooled in refrigerator overnight and then cut into 3-mm-thick slices with all edges trimmed off to get a uniform appearance.

The consumer test was carried out at a supermarket on one afternoon between 3 and 6 pm. The cooked beef samples from the same animal and anatomical location were put on a paper plate and labelled by three digit numbers. To minimise the effects of tasting order, equal number of plates with opposite sample order was prepared. The consumers participating in the test (n = 105) were asked to taste the two samples starting from the left side of the plate. After tasting, they had to answer the following questions on the questionnaire: (1) Which sample do you think tastes better? (2) Which sample do you think is more tender? (3) Which sample do you think is juicier? Each person made 1 or 2 independent tastings, with a different sample order if two tastings were made. The participants also answered general questions about gender, age and frequency of beef consumption. In addition, 24 students also tested the meat at our university campus using the same procedure as described above.

2.8. Statistical analysis

The statistical analysis was carried out using Statistical Analysis System (Version 9.2, SAS Institute, Cary, NC, USA). The MIXED procedure was used with treatment (vacuum and dry ageing bag) as fixed factor and animal as random factor. The model used for water content analysis also included sample layer and interaction of treatment and layer as fixed factors. The option PDIFF was used for calculating significant differences between least squares means. The consumer test was analysed using Chi-square test.

3. Results

3.1. pH, smell, weight loss, water-holding capacity and shear force

There was a significant effect of ageing treatment on weight losses during ageing (Table 1). The ageing loss, trim loss, and total ageing and trim loss were higher in samples aged in dry ageing bags than in vacuum. For water-holding capacity parameters, the thawing loss, cooking loss, and total loss at thawing and cooking were significantly lower in samples aged in dry ageing bags than those in vacuum, i.e. water-holding capacity was after ageing higher in samples aged in dry ageing bags (Table 1). In general, the total loss at ageing, thawing and cooking was higher in samples aged in dry ageing bags than those aged in vacuum. There was no effect of ageing method on pH value, smell, and instrumental shear force including peak force and total energy (Table 1).

3.2. Water content

The water content was affected by ageing treatment, sample layer and their interaction (Table 2). The water content of samples aged in dry ageing bags was lower than in those aged in vacuum and control (before ageing), whereas there was no difference between meat aged in vacuum and control. The water content in the outer layer of samples aged in dry ageing bag was lower than in the inner layer whereas a corresponding difference between layers in samples aged in vacuum was not detected.

3.3. Colour

There was no difference in meat colour between samples aged in vacuum and in dry ageing bags for 14 days (Table 3), except for a tendency to higher content of MetMb after ageing in the dry ageing bag than in vacuum ($P = 0.058$).

Table 1
Effects (least squares means) on pH, smell, weight loss, water holding capacity and shear force in beef of ageing in dry ageing bag or in vacuum for 14 days.

Trait	Control[a]	After ageing		SE	*P*-value
		Bag	Vacuum		
pH	5.57	5.62	5.58	0.03	0.273
Smell[b]		1.1	1.1	0.10	0.668
Weight loss					
Ageing loss (%)		15.2	2.4	0.53	<0.001
Trim loss (%)		7.3	2.1	1.07	0.011
Total ageing and trim loss (%)		21.3	4.4	1.34	<0.001
Water holding capacity					
Thawing loss (%)		1.2	3.1	0.25	<0.001
Cooking loss (%)		13.1	18.2	0.45	<0.001
Total loss at thawing and cooking (%)		14.2	20.7	0.37	<0.001
Total loss at ageing, thawing and cooking (%)[c]		35.8	25.1	1.35	0.002
Shear force					
Peak force (N)		39.9	39.9	2.72	0.994
Total energy (Nmm)		241.1	245.2	11.36	0.710

SE: standard error.
[a] Measured before ageing.
[b] Smell scale was from 1 (normal smell) to 5 (bad smell).
[c] Total loss at ageing, thawing and cooking = total ageing and trim loss + total loss at thawing and cooking.

Table 2
Water content (%) in beef before (control, day 0) and after ageing in dry ageing bag or in vacuum for 14 days, least squares means.

Control	Bag		Vacuum		SE	*P*-value[e]		
	Outer	Inner[d]	Outer	Inner[d]		Treatment	Layer	Treatment × Layer
74.6[A]	70.9[Bc]	73.3[b]	74.4[Aa]	75.1[a]	0.39	<0.001	<0.001	0.020

[abc] Means with different superscript lowercase letter indicate significant differences between treatments and layers after ageing for 14 days ($P < 0.05$).
[e] *P*-value after ageing in dry ageing bag or in vacuum for 14 days.
[AB] Means with different superscript capital letter indicate significant differences between control (day 0) and outer layer of treatments after ageing for 14 days ($P < 0.05$; overall *P*-value: <0.001; SE: 0.35).
SE: standard error.
[d] The 2-cm layer next to the 2-cm outer layer.

3.4. Microbiological analysis

There were significant effects of ageing treatment on TBC, LAB and yeast counts, both before and after trimming (Table 4). TBC increased after the ageing process before trimming, irrespective of ageing treatment, and the samples aged in dry ageing bags had higher TBC than those aged in vacuum. The LAB counts were higher in samples aged in vacuum than in dry ageing bags, and they were also higher than in control samples. The yeast counts were significantly increased in samples aged in dry ageing bags compared with control and they were also higher than those aged in vacuum. After trimming, the TBC and yeast counts were higher in samples aged in dry ageing bag than those in vacuum; however, the LAB counts were higher in samples aged in vacuum than those aged in dry ageing bags. There was no effect of ageing method on EB and mould counts.

3.5. Consumer test

In total 129 participants took part in the consumer test and made 1 or 2 independent tastings and the total number of answers was 169. Participants included 56.6% females and 43.4% males and most of them (42.6%) were between 41 and 65 years old. Most of the participants (42.6%) said they consumed beef at least once a month (Table 5).

Consumers who found no difference between the two ageing treatments were excluded from the statistical analysis. Results from pooling the genders differed from those obtained for each gender separately (Table 6). For all participants, significantly higher number of consumers (58.0%) preferred meat aged in dry ageing bags, and there were tendencies that they considered meat aged in the dry ageing bag to be more tender ($P = 0.065$) and juicier ($P = 0.082$) than vacuum-aged meat. Females preferred meat aged in the dry ageing bag, and also found it was more tender and juicier than meat aged in vacuum. For the males, there was no difference in overall preference, tenderness and juiciness between samples from the two ageing treatments.

Table 3
Colour in beef after ageing in dry ageing bag or in vacuum for 14 days, least squares means.

Trait	Bag	Vacuum	SE	*P*-value
L*	29.6	30.3	0.79	0.340
a*	17.9	18.8	0.65	0.134
b*	13.8	15.0	0.66	0.115
Chroma	22.6	24.1	0.90	0.120
Hue	37.5	38.6	0.56	0.105
DeoxyMb[a]	0.57	0.57	0.01	0.789
OxyMb[a]	0.73	0.75	0.01	0.116
MetMb[a]	0.55	0.52	0.02	0.058

SE: standard error.
[a] Deoxymyoglobin (DeoxyMb) is shown as (1.5 − K/S ratio), oxymyoglobin (OxyMb) as (1 − K/S ratio) and metmyoglobin (MetMb) as (2 − K/S ratio).

4. Discussion

The higher ageing loss, trim loss, and total ageing and trim loss of meat aged in dry ageing bags compared to that aged in vacuum were expected because there was a higher moisture loss when using the dry ageing bag compared to vacuum ageing. This was confirmed by the result on water content because even the water content of the 2 cm inner layer of meat aged in the dry ageing bag was lower than that of vacuum aged meat. Moreover, Warren and Kastner (1992) reported higher ageing loss from dry-aged beef strip loins compared to vacuum-aged. In the study by Sitz, Calkins, Feuz, Umberger, and Eskridge (2006), they found that dry-aged steaks had lower moisture content than wet-aged steaks.

In the present study the water-holding capacity was higher in meat aged in dry ageing bags than in vacuum, which was in agreement with Laster et al. (2008) who found that the cook yield was higher for dry-aged top loin and top sirloin steaks than wet-aged steaks. Although the study by Warren and Kastner (1992) did not find a significant difference in cooking loss between dry-aged and vacuum-aged strip loins, the mean values for dry-aged meat were lower than vacuum-aged counterparts. However, our study showed that the total loss at ageing, thawing and cooking was still higher in meat aged in dry ageing bag than in vacuum, which means that the higher water-holding capacity in meat aged in dry ageing bags cannot compensate for the weight loss during ageing and trimming. Lower product yield in dry-aged meat exists also after using dry ageing bags, compared with the vacuum ageing process. In the studies by Laster et al. (2008) and Smith et al. (2008), lower total saleable yield was observed for dry-aged steaks compared to wet-aged steaks.

Table 4
Total bacteria counts (TBC), *Enterobacteriaceae* (EB), lactic acid bacteria (LAB), yeast and mould on beef before (control, day 0) and after ageing in dry ageing bag or in vacuum for 14 days, least squares means.

Trait[d]	Control	After ageing		SE	*P*-value
		Bag	Vacuum		
Before trimming					
TBC	1.2[c]	5.2[a]	2.4[b]	0.42	< 0.001
EB	0.4	0.4	0.4	0.31	0.979
LAB	0.01[b]	0.4[b]	1.7[a]	0.41	0.030
Yeast	0.01[b]	3.0[a]	0.01[b]	0.10	< 0.001
Mould[e]	0.01	0.01	0.01	–	–
After trimming					
TBC	–	5.2	3.9	0.37	0.006
EB	–	0.5	0.8	0.32	0.515
LAB	–	0.3	2.3	0.30	0.002
Yeast	–	1.9	0.1	0.38	0.014
Mould[e]	–	0.01	0.01	-	-

[abc] Means with different superscript letter indicate significant differences between treatments before trimming ($P < 0.05$).
SE: standard error.
[d] Unit: log cfu/cm^2. Data of < log 1.0 was adjusted to 0.01.
[e] No variation was found for mould.

Table 5
Statistics regarding the participants in the consumer study (n = 129).

Information	% (number)
Sex	
Female	56.6 (73)
Male	43.4 (56)
Age (year)	
<19	3.9 (5)
19–25	15.5 (20)
26–40	22.5 (29)
41–65	42.6 (55)
>65	15.5 (20)
Beef consumption[a]	
>1/week	21.7 (28)
1/week	31.0 (40)
1/month	42.6 (55)
More seldom/never	4.7 (6)

[a] Question asked: how often do you eat a whole piece of beef (e.g. steak, beef, roast beef)?

Our study did not find differences in meat colour and shear force between samples aged in vacuum or dry ageing bags. The meat colour after different ageing processes was not measured in earlier studies; results from the present study indicate that ageing meat in dry ageing bags had no negative effects on meat colour. For shear force, our result was in accordance with Sitz et al. (2006) and Smith et al. (2008), with no differences in shear force between dry-aged and wet-aged steaks. However, Laster et al. (2008) found that dry-aged top sirloin steaks had a lower shear force than wet-aged steaks, whereas the opposite was shown for ribeye steaks.

Water, air and oxygen can pass through the dry ageing bag, but not microorganisms including virus. These characteristics of dry ageing bags can thus protect the meat from being contaminated, and also modify the growth of microorganisms already present in meat. We found that the mould and EB counts from samples aged in dry ageing bags were similar to those from vacuum-aged and control samples, suggesting that no extra growth as a result of treatment had occurred. LAB counts were lower in dry ageing bags than those in vacuum-aged samples. Similar results were also reported by Parrish et al. (1991) and were most likely due to the anaerobic conditions in vacuum packaging that result in the dominance of this type of bacteria, in contrast to meat exposed to aerobic conditions (Ahnström et al., 2006). On the other hand, the TBC and yeast counts were higher in samples aged in dry ageing bags, both before and after trimming. This was possibly a consequence of the transmission of oxygen through the dry ageing bag, and for the yeast, also because they can tolerate the low water activity. Ahnström et al. (2006) found that dry ageing in a bag decreased the yeast count on lean tissue in comparison with traditional unpackaged dry ageing. This means there are advantages of using the dry ageing bag, e.g. to decrease the risk of microbiological contamination compared with traditional unpacked dry ageing. Our study showed that some of the microbiological parameters, most importantly the TBC counts, were higher in samples aged in dry ageing bags than in vacuum. However, judging from both the smell test results and the moderate levels of the microbiological growth, all the samples were acceptable with regard to food safety.

Enhanced flavour was considered as a typical improved sensory characteristic from dry-aged meat compared with vacuum-aged meat. Results from former sensory studies that compared vacuum ageing with the traditional dry ageing process were inconsistent. In the study by Parrish et al. (1991) and Sitz et al. (2006), wet-aged steaks were rated higher in overall palatability/acceptability than those aged by traditional dry ageing process. Smith et al. (2008) and Laster et al. (2008) found no difference in overall likeness between ageing treatments. Our results, when including all participants, indicated that meat aged in dry ageing bags was preferred by consumers. Campbell, Hunt, Levis, and Chambers (2001) showed that the sensory panelists considered dry-aged meat more tender and juicier compared with vacuum-aged meat, whereas in our study, consumers tended to consider the samples aged in dry ageing bags more tender and juicier. In studies by Smith et al. (2008) and Laster et al. (2008), the sensory test results showed no differences in tenderness and juiciness between wet-aged and dry-aged meat. In the present study, the consumer test results differed between females and males, which supports the theory that females have a more highly developed sense of smell and taste and can identify more subtle differences in sensory characteristics, compared with males (Cain, 1982; Doty, Applebaum, Zusho, & Settle, 1985).

Table 6
Consumer preference test on beef aged in dry ageing bag or in vacuum for 14 days, % (number).

Traits[a]	Bag	Vacuum	No difference	*P*-value[b]
All (n = 169)				
Overall like	58.0 (98)	37.3 (63)	4.7 (8)	0.006
Tenderness	52.7 (89)	39.1 (66)	8.3 (14)	0.065
Juiciness	53.9 (91)	40.8 (69)	5.3 (9)	0.082
Females (n = 100)				
Overall like	66.0 (66)	32.0 (32)	2.0 (2)	0.001
Tenderness	59.0 (59)	37.0 (37)	4.0 (4)	0.025
Juiciness	63.0 (63)	33.0 (33)	4.0 (4)	0.002
Males (n = 69)				
Overall like	46.4 (32)	44.9 (31)	8.7 (6)	0.900
Tenderness	43.5 (30)	42.0 (29)	14.5 (10)	0.896
Juiciness	40.6 (28)	52.2 (36)	7.2 (5)	0.317

[a] Questions asked: (1) Which sample do you think tastes better? (2) Which sample do you think is more tender? (3) Which sample do you think is juicier?
[b] Consumers who found no difference between the two ageing treatments were excluded in the statistical analysis.

5. Conclusions

Dry ageing bag, compared with vacuum ageing, could produce meat with enhanced tenderness and juiciness, characteristics that are valued by consumers. The total weight loss was higher in meat aged in dry ageing bags, despite lower weight loss during thawing and cooking. Thus, the total product yield was lower after ageing meat in dry ageing bags than in vacuum. However, by using dry ageing bags it is possible to produce dry-aged meat under more controlled conditions without negative effects on sensory or other quality attributes.

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