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Effect of "dry aging" or "wet aging" of beef on eating quality*

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This study evaluates the influence of different aging methods on eating quality of beef cuts according to Meat Standards Australia (MSA) methodology using two methods: 'wet aging' and 'dry aging'. Paired samples were taken from the same position from muscles from each carcase side with treatment alternated across sides and allowed to age for 7, 21 or 35 days under each aging method. The muscles used were obtained from the anterior, central and posterior parts of the carcass (*M.triceps brachii* – TB, *M. infraspinatus* – INF, *M. longissimus thoracis et lumborum* – LTL and *M. biceps femoris* – BF). Eating quality was evaluated by 360 consumers utilising MSA protocols to evaluate 132 samples from 6 carcasses. Eating quality expressed as an MQ4 score, a weighted average of tenderness, juiciness, flavour and overall liking scores showed significant differences between the two aging methods. There is evidence to suggest that consumers tend to rate dry aged product more highly than wet aging across the tenderness, flavour and overall liking.

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This study evaluated the influence of different aging methods on eating quality of beef cuts according to Meat Standards Australia (MSA) consumer testing methodology using 'wet aging' and 'dry aging' in paired samples across a range of aging durations and muscles. It was possible to utilise MSA consumer test methodology because Polish consumers readily identified beef of varying quality and consistently allocate samples to four alternative quality levels [Pogorzelski *et al*. 2019]. We found that consumers preferred dry aged beef over wet aged beef and this was most significant in consumers' evaluation of the flavour and overall liking sensory traits.

The aging of meat post slaughter may contribute to its tenderness and juiciness [Perry 2012], as well as to improvement of flavour [Gorraiz *et al*. 2002, Jeremiah and Gibson 2003]. The tenderness improvement of beef during the aging process does not depend on the degradation of the individual muscle proteins [Hopkins and Thompson 2002] or from the activity of one specific enzyme, but is associated with many biochemical and structural changes of proteins [Huff-Lonergan *et al.* 1995, Huff-Lonergan and Lonergan 2005]. Therefore, understanding the mechanisms responsible for the beef aging process is important for researchers and the meat industry. It is equally important to understand the consumer perception throughout the aging process, as this gives rise to the possibility of predicting and standardizing the quality of beef enabling the industry to generate beef of repeatable high quality, as desired by consumers [Caballero *et al*. 2007, Brewer and Novakofski 2008].

There are two main methods of beef aging. The most commonly used is the "wet aging method". It is characterized by the storage of vacuum-packed primal cuts at low temperature (but above the freezing point). Another much older method is "dry aging". Dry aging is based on the storage of meat (carcasses, sides, primal cuts, muscles) without packaging in a controlled environment [Campbell *et al*. 2001]. The traditional use of "dry aging" began to decline in the 1960's due to development of vacuum packing, which took place first in the United States. Adoption of vacuum packaging of beef grew rapidly to the extent that by the 1980s more than 90% of the beef sold by beef packers in the United States was packed in this way. The benefits of vacuum packaging were presented by Minks and Stringer [1972] and Hodges *et al.* [1974]. They showed a positive effect of this type of packing on weight loss of stored meat and its microbiological safety. They did not observe any adverse changes to the flavour in the tested meat after vacuum packing.

However, there are many other factors affecting the final quality of beef subjected to aging processes. For instance, Franco *et al*. [2009] found that properly chosen conditions such as time and temperature contribute to the final eating quality of beef. It has also been found that conditions post-mortem affect the aging process with consequent influence on tenderness, flavour and the final quality and consumer acceptance [Monsón *et al*. 2005, Stetzer *et al*. 2006]. Aging effects may also differ across muscles with Novakofski and Brewer [2006] reporting that cuts characterized

by initial high tenderness values exhibit an insignificant improvement in tenderness or even a deterioration after an extended aging period.

A further characteristic difference between wet and dry aging is that whereas most vacuum packaged cuts are boneless, dry aged product is often aged "on the bone". Aging on the bone relative to boneless may also interact with flavour or other ageing mechanisms.

A unique feature of the process of dry aging beef is the formation of characteristic flavour attributes [Jiang *et al*. 2010]. While some studies show that the flavour profile from dry aging is no different to that obtained from wet aging [Sitz *et al*. 2006], other studies suggest that dry aging leads to the production of a more attractive flavour profile [Campbell *et al*. 2001, Huerta-Leidenz *et al*. 2004].

Given sufficient understanding of aging processes these might be controlled to increase consumer satisfaction by developing desired flavour and tenderness outcomes. The key is to obtain desired quality parameters in the most economical manner. [Vieira *et al*. 2006]. A prolonged aging process increases costs for the supply chain which need to be compensated by a higher price. It is known that consumers are willing to pay more for a product of high and consistent quality [Polkinghorne and Thompson 2010]. Determination of the optimal conditions for the aging process, enables processors to minimise production costs and maximize process efficiency. The aim of the study was to compare the eating quality of beef aged using the wet and dry method. The study hypothesized that dry-aged beef produces a product of higher eating quality desired by consumers.

Material and methods

Experimental design and slaughter details

The experimental design dictated strict paired within animal and muscle position comparisons of dry and wet aging treatments to maximise the statistical power within a small number of animals. Selected beef primal cuts were collected from both sides of 6 young bulls at a commercial Polish slaughterhouse (the animals were slaughtered in accordance with the European Union Council Regulations (EC) No 1099/2009 for the protection of animals at the time of slaughter) during deboning. The carcasses were characterized by the EUROP muscle scores from R+ to O+, EUROP fatness scores from 2 to 2+, ultimate loin pH from 5.50 to 5.92, marbling (by USDA) from 100 to 350 and ossification (USDA) from 140 to 170. The carcasses taken for testing came from crossbreeds of Holstein-Friesian X Simental. Each cut was identified by a colour coded and uniquely numbered laminated ticket. The colour coding and number allocated a cut from one side to the dry aged treatment and that from the second side to the wet aged treatment. The treatment sides were rotated to ensure an equal number of left and right-side allocations. The sides were quartered at the 12/13 rib junction for boning. Within each muscle, position was further defined for allocation to ageing treatments with identical position for each aging period allocated across the dry and wet aged sides. Position was balanced within each muscle for 7-, 21- and 35-day aging periods.

Sample collection and preparation

The collected primals were specified according to the UNECE Bovine Language [Anon 2004], also consistent with the Handbook of Australian Meat [Anon 1998]. Cuts collected at the abattoir and their UNECE/HAM codes were: short loin (1552), ribs prepared (1602), oyster blade (2303) and bolar blade (2302). Following Polish boning practice the *M.biceps femoris* muscle was removed as a single piece combining the UNECE/HAM outside flat (2050) and rump cap (2091) cut codes. The collected primals were vacuum packed with their identifying labels and transported chilled to the Warsaw University of Life Science for storage at 2°C.

Each cut was removed from chilled storage for further fabrication at the University 3 days post slaughter. The bone in portions allocated to dry ageing were minimally trimmed, leaving the spinalis and other rib muscles on the rib, and then a coloured laminated label was pinned to the allocated position for each ageing period with each ageing period carrying a different colour to aid in clarity. The boneless cuts allocated to dry ageing were similarly labelled and also aged as full primals.

The entire cuts were placed within a Maturmeat ™ 150 dry aging cabinet with dimensions of 73x78x211cm and designed to hold 100 kg of meat on five stainless steel shelves. The cabin enabled control of the temperature, humidity and air flow rate. Environmental conditions applied in this study were: temperature 2±1°C, humidity 77±2%, and air flow rate 0.2m/s.

The paired primals allocated to wet ageing were fully processed to consumer samples following MSA grill protocols 3 days post slaughter. Each primal was firstly reduced to component muscles and each muscle denuded with silverskin removed. The denuded muscles were then fabricated using a cutting jig to obtain 25mm slices cutting across the grain. The slices from each allocated position were further fabricated to produce 5 individual steaks approximately 38 x 50 x 25 mm thick. Each steak was wrapped in freezer wrap and the 5, comprising a sensory sample, vacuum packed in a single bag with a pre-allocated unique identification label affixed. In addition to unique identification each label included a freeze down date corresponding to the allocated 7-, 21- or 35-day aging period.

Ageing periods were rotated across position in each muscle. The trial design documentation, including a visual "map" was consulted during fabrication to determine the ageing period allocated to each position. This differed by primal and precisely replicated the dry aged allocation. To allow for expected shrinkage and required surface trimming of the dry aged muscles an additional 25 mm portion was allocated between each of the aging positions in the wet aged muscles.

The packed samples were placed in the same chiller and stored at an ambient temperature of 2°C. Throughout the whole storage period, temperature in the chiller was monitored and did not exceed 2±1°C.

Three samples, allocated to 7-, 21- and 35-days aging, were prepared from the *M. longissimus thoracis et lumborum* (LTL) muscle, with one from the rib (thoracis) portion and one from each of the anterior end and centre (lumbar) sections of the short loin.

Four samples were fabricated from the *M.Biceps femoris* (BF) and allocated to the three aging periods. A single sample was prepared from the muscle head overlaying the rump (UNECE/HAM 2091). Aging periods of 7, 21 and 35 days were rotated across this position and aligned with the adjacent portion in the remaining larger muscle portion (UNECE/HAM 2050) to provide a comparison of the two positions. Three samples, designated H1, adjacent to the UNECE 2091, progressing to H2 and T3 were prepared from the UNECE/HAM 2050 and rotated for aging days.

The Mm. Triceps brachii (TB) and *Infraspinatus* (INF) muscles were utilised from the blade. These muscles were fabricated from the primal cuts, fully denuded and samples prepared from a designated head and tail position.

On each ageing date the dry aged cuts were removed from the dry ageing cabinet and the designated portions for that aging date removed with the remainder returned to the cabinet. The portion removed was then deboned as required and the individual muscle portions denuded and fabricated into 5 small steaks as for the wet aged pairs. Both the dry and wet aged samples' vacuum packs were then frozen and stored in the same -18±1°C freezer until selected for sensory evaluation.

Consumer assessment of eating quality

Sensory analysis was conducted using the MSA sensory protocols for grilled steaks described by Watson *et al.* [2008].

Consumer recruitment. Recruitment of consumers was done online via a website. Consumers who wished to participate completed a questionnaire on the website. The first steps concerned questions about PESEL number (individual number of the citizen, it allowed to verify the age of the respondent) and frequency of eating beef. Up to 22 people were registered to ensure the required 20 people per test session. Before starting the test each consumers personal data were verified based on the ID card with the data given by the consumer during registration.

Consumer demographics. The study involved 360 consumers. The participation of women and men was reasonably balanced, with women accounted for 47.2% of the respondents. The largest group were those aged 20-25 years (42.2%), with the lowest in the 50+ age group (7.2%). People aged 31-39 years accounted for 16.9% of respondents, 40-50 years 11.9%, 11.2% in the 26–30-year age range and 10.6% under 20 years old.

The most common occupations performed by consumers were: office worker (21%), student (21%) and other (16%). From 7 to 12% of the respondents were engaged in occupations such as teacher (7%), technical staff (8%), physical worker (8%), seller/service (12%). Traders and the unemployed accounted for 3%, while housewives were less than 1%. More than ninety percent of respondents claimed to have had secondary education (54%) or higher (39%). More than half of respondents (52%) declared incomes below 550€/month, while 15% of respondents declared incomes above 950€/month.

Roughly half of the consumers declared that they eat beef at least once a week (once a week 30%; more than once a week 18%). A further 23% of consumers reported eating beef once every two weeks, while 26% ate beef once a month. While recruitment specified a preference for medium cooked steaks 32% of actual participants recorded preferred medium and 46% medium well-done beef. Rare and medium-rare were preferred by 11% of total respondents and 12% well done

Sensory design and sample presentation. In accordance with MSA grill protocols testing was planned around "picks" which controlled the serving of 42 samples, arranged within 7 products comprising 6 samples each, to 60 consumers served in three sessions of 20. Each consumer was served seven samples, the first a common mid quality sample with subsequent rounds used to evaluate the trial product. The 6 test products reflected expected eating quality from poor to excellent to ensure a wide sensory spectrum. Each consumer was served one sample from each product as dictated by software with the serving order controlled by a 6 x 6 Latin square to ensure balanced presentation order and serving before and after each other product. Each sample was evaluated by 10 consumers.

The 5 individual steaks within each sample were dispersed across the 60 consumers with one served within each subset of 12 consumers and served in 5 different presentational order positions. This outcome was facilitated by software and by a "posting" procedure which physically transferred each of the 5 frozen steaks within a sample to a predetermined position on 5 different round sheets, each containing 10 steaks from 10 different samples drawn from the 6 test products. The round sheets were vacuum packed to hold the steaks in position until cooking. The round sheets corresponded to cooking order for rounds 1 to 7 within each of the 3 groups of 20 consumers. The round sheets were placed in a refrigerator to thaw at 4°C for 24 hours prior to cooking. Each sheet was then placed on a tray, opened and placed adjacent to the grill in serving order. The strict 3 – 4 – 3 steak orientation of each round sheet was transferred to the grill placement for cooking and again for removal and resting. At the nominated resting time each steak was halved and transferred to paper plates carrying the unique reference ID displayed on the sample bag, round sheet position and consumer questionnaire.

Cooking procedure. Samples were cooked to a medium degree of doneness using a double-sided clam shell Silex™ S-Tronic S165 with cast iron plates, the top grooved and bottom flat grill. The top plate was set to 190°C and the base plate to 210°C. Cooking time was precisely controlled utilising a timing chart that dictated sample loading, top plate closing, cooked steak removal and serving times, The grill was switched on one hour prior to the first step on the timing chart which commenced a session at 0:00 by placing 10 meat scrap pieces of similar mass to the samples on the grill. These were cooked for the designated time to equilibrate the grill temperature and ensure even heat recovery over the subsequent 7 rounds. The scraps were discarded after a visual check of doneness. All samples were grilled for 5 min with 3 min resting time before serving. Seven cooking rounds of 10 steaks were conducted

within each test session of 20 consumers. Each of the 10 steaks per round were halved post cooking and served to two consumers. An ID cross check was made between the round sheet and plate labels to ensure accurate transfer.

Questionnaire, sample scoring and data management. The questionnaire consisted of three main parts. The first part (two pages) contained ten questions characterizing consumers and their preferences for beef consumption. The second part consisted of seven identical pages for evaluating the samples. Each of them had four-line scales (line length 100 mm), to describe the four sensory quality features: tenderness (anchored by Not Tender and Very Tender), juiciness (anchored by Not Juicy and Very Juicy), with flavour and overall liking (anchored by Dislike Extremely and Like Extremely). Consumers evaluated samples by putting vertical line on a linear scale in the place that in their opinion described the quality of the consumed sample most accurately. After marking the line scales for a sample, the consumer was asked to assign the sample to one of four quality levels (satisfaction): unsatisfactory quality, good everyday quality, better than everyday quality or premium quality. The third part of the questionnaire consisted of four questions, at first consumers were asked to determine the price they would be willing to pay for each of the four meat quality descriptions by marking a line scale for each marked from 0 zł to 110 zł per kg in 10 zł increments. Answers to the following three questions provided further information on how often consumers bought beef, how much money they spent, and what cuts were most often bought. The Polish version of the questionnaire was based on that published by Watson *et al*. [2008]. Consumers were instructed on how to complete the questionnaire prior to serving of the first sample. Between the evaluation of one sample and the next consumers were asked to eat a piece of bread and drink a 15% solution of apple juice in order to clean the palate.

All data was independently entered into the spreadsheet by two people and scores compared. Any line scale reading that differed by greater than 1mm was checked to confirm the score. An MQ4 score was calculated using standard weightings (tenderness x 0.3 + juiciness x 0.1 + flavour x 0.3 + overall satisfaction x 0.3). The mean MQ4 and individual trait values and a clipped mean created by removing the two highest and two lowest scores were then compiled for analysis. The completed sensory data was then combined with animal, slaughter, grading, muscle and treatment information for statistical analysis.

Statistical analysis. The analysis used a linear mixed model fit by the R package nlme (Linear and Nonlinear Mixed Effects Models) using REML (a method for estimating variance components in models with random effects) [Pinheiro *et al*. 2018, R Core Team 2018] to test for effects relating to treatment (dry aging vs wet aging), muscle (BF, INF, LTL, TB), days aged (7, 21 and 35 days) on the 5 different sensory scores (tenderness, juiciness, like flavour, overall satisfaction and MQ4 scores). First order interactions were tested, however none were significant at the 5% level of significance across any of the sensory scores and hence were not included in the final models. A random term for carcass number was also included in the models.

Results and discussion

Aging method effect

Eating quality expressed as a MQ4 score showed a significant difference between dry aging and wet aging (Tab. 1).

Table 1. Estimated mean differences (coefficients) relative to baseline category standard errors are shown in parentheses)

Item	Dependent variable				
	MQ4	Tenderness	Juiciness	Flavour	Overall liking
Days aged (relative to 7 days aged)					
21	2.571	4.204*	1.501	0.704	2.423
	(1.683)	(2.379)	(1.978)	(1.480)	(1.726)
35	0.443	3.201	-0.560	-1.434	-0.370
	(1.675)	(2.367)	(1.967)	(1.473)	(1.718)
Muscle (relative to BF)					
INF	11.777***	19.177***	13.389***	7.965***	10.309***
	(1.961)	(2.771)	(2.303)	(1.725)	(2.011)
LTL	17.147***	22.328***	13.931***	14.708***	17.508***
	(1.729)	(2.444)	(2.031)	(1.521)	(1.773)
TB	4.345**	3.927	1.049	4.931***	5.740***
	(1.961)	(2.771)	(2.303)	(1.725)	(2.011)
Treatment (relative to wet aging)					
Dry aged	3.054**	3.111	1.682	3.124**	3.020**
	(1.365)	(1.929)	(1.604)	(1.201)	(1.400)

BF – *M. biceps femoris*; INF – *M. infraspinatus*; LTL – *M. longissimus thoracis et lumborum*; TB – *M. triceps brachii*.
One, two and three stars indicate statistical significance at the 10, 5 and 1% levels, respectively.

The changes in meat quality that occurred after dry aging were better perceived by consumers than those after wet aging by around 3 points. The difference in MQ4 score arose primarily though the flavour and overall liking. On average, consumers scored dry aged product 3 points higher on both flavour and overall liking than wet aged product.

The significant improvement in flavour and overall liking is consistent with results found by Warren and Kastner [1992] who noted that dry aging had positive influence on flavour. However, other studies have found that wet aged beef loins had significantly higher eating quality attributes, such as flavour, and overall palatability, compared to beef obtained from dry aged carcasses [Jeremiah and Gibson 2003, Sitz *et al.* 2006].

While not statistically significant, the effect size for tenderness was comparable to that of juiciness, a 3.1-point improvement in tenderness for dry aged product relative to wet aged product. There is no consensus in the literature around whether dry or wet aging produces the best tenderness outcome. Stenström *et al*. [2014] studying dry aged beef versus wet aged found similar phenomenon. They noticed that meat subjected to

dry aging was perceived by 71% of the consumers as more tender. However, wet aging was found to result in a more tender product by Sitz *et al*. [2006], who studied a consumer panel, and Parrish *et al*. [1991] , who tested both untrained consumers and a professional panel. Furthermore, Warren and Kastner [1992] and Troy [1999] found no differences between dry aged and wet aged beef, while Richardson *et al*. [2008] found that wet aged beef was less tender than dry aged.

Consumers were not able to detect any significant difference in the juiciness of beef subjected to the aging methods (Tab. 1). This is consistent with Stenström *et al.* [2014] who found that the aging method did not affect juiciness. However, previous studies Richardson *et al*. [2008] have found that dry aged carcasses resulted in better juiciness compared to the wet aged beef samples from the same carcasses. Significant improvement in juiciness of dry aged meat has been also reported by Campbell *et al.* [2001] and Kim *et al*. [2016].

Aging period and muscle effects

Interestingly, the number of days aged did not yield statistically significant results and the effect sizes were mostly quite small (Tab. 1 and Fig. 1). Tenderness was the only trait that had consistent results, with both 21- and 35-day aged product resulting in more tender product than 7 days aged, however this was not statistically significant at the 5% level of significance. However, Brewer and Novakofski [2008] noted that consumers perceived the majority of change in tenderness occurred during the first 7 d of aging. Aging had no effect (P>0.05) on juiciness and flavor. As mentioned previously, there was also no significant interaction found between aging period and aging method, however, further investigation of this should be conducted with larger sample sizes.

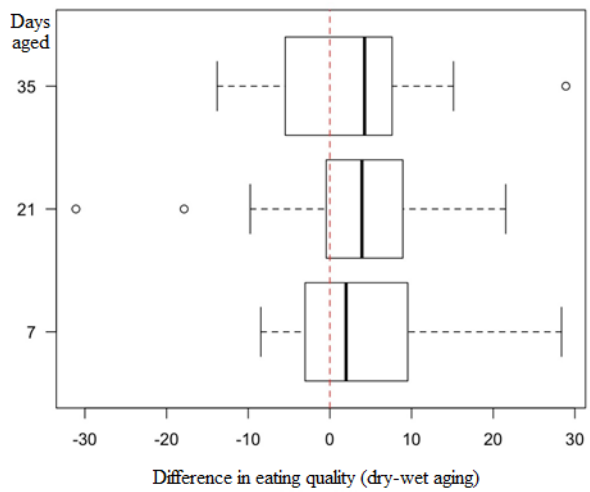

Fig. 1. Difference in eating quality in terms of aging period.

While no significant interaction between muscle and aging method was found, as expected, there were significant differences in eating quality between each of the muscles tested. Table 2 shows the estimated marginal means for each of the four muscles consumed, averaging over the levels of aging and aging method. The LTL muscle had the highest scores across all traits followed by INF, TB and BF. Figure 2 and Table 3 shows difference in eating quality in terms of muscle and aging method. We found a pattern of consumer scores inclining towards dry aging in all groups of muscles. Also, there were significant differences in MQ4 score for *M. triceps brachii* (average difference 6,8) and *M. longissimus thoracis et lumborum* (average difference 4,8), however there was no significant differences for *M. infraspinatus* and *M. biceps femoris*.

Table 2. Estimated marginal means and corresponding 95% confidence intervals for each of the muscles averaging over the levels of aging and treatment

Muscle	Dependent variable				
	MQ4	Tenderness	Juiciness	Flavour	Overall liking
BF	44.60 (39.89, 49.31)	36.79 (30.36, 43.21)	46.53 (40.93, 52.13)	49.24 (45.65, 52.82)	46.83 (42.41, 51.25)
INF	56.37 (50.84, 61.91)	55.97 (48.34, 63.59)	59.92 (53.36, 66.48)	57.20 (52.8, 61.6)	57.14 (51.8, 62.47)
LTL	61.74 (56.75, 66.74)	59.12 (52.27, 65.96)	60.46 (54.52, 66.4)	63.94 (60.07, 67.82)	64.34 (59.59, 69.08)
TB	48.94 (43.41, 54.47)	40.72 (33.09, 48.34)	47.58 (41.01, 54.14)	54.17 (49.76, 58.57)	52.57 (47.24, 57.9)

BF – *M. biceps femoris*; INF – *M. infraspinatus*; LTL – *M. longissimus thoracis et lumborum*; TB – *M. triceps brachii*.

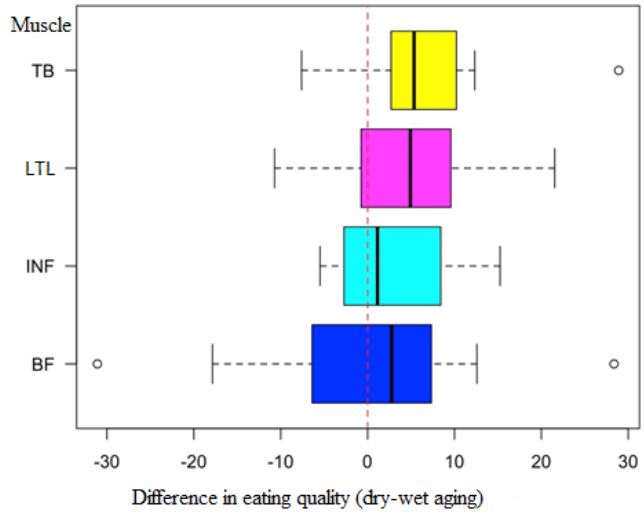

Fig. 2. Difference in eating quality in terms of muscle and aging method.

Conclusions

Eating quality expressed as a MQ4 score showed significant difference between two aging methods. The changes that occurred during dry aging were better perceived by consumers than wet aged. We found that flavour and overall liking were the most significant driver of difference between dry and wet aging, though the effect size for tenderness was similarly large. From the muscle point of view dry aging had a positive influence on *M.triceps brachii* and *M.longissimus* thoracis et lumborum. Also, it is possible to observe a pattern for the positive effect of dry aging method on eating quality for *M. biceps femoris* and *M. infraspinatus*. Consumers did not appear to be able to discern any significant difference in juiciness between the two aging methods.

The authors have no conflict of interests.

Table 3. Average difference (dry aged – wet aged) with one sided p-values from paired t-test

Muscle	n	MQ4		Tenderness		Juiciness		Flavour		O.All.like.	
		average	p-value	average	p-value	average	p-value	average	p-value	average	p-value
TB	18	6.8	0.011	4.1	0.181	4.0	0.093	7.9	0.007	8.7	0.004
LTL	18	4.8	0.012	9.3	0.001	4.0	0.076	1.4	0.194	2.5	0.114
INF	18	2.6	0.101	2.1	0.137	-1.6	0.282	3.4	0.105	3.4	0.133
BF	24	0.1	0.491	-1.5	0.282	0.4	0.443	1.9	0.190	0.4	0.448

BF – *M. biceps femoris*; INF – *M. infraspinatus*; LTL – *M. longissimus thoracis et lumborum*; TB – *M. triceps brachii*.

REFERENCES

1. ANON., 1998 – Handbook of Australian Meat, 7th edition, AUSMEAT, Brisbane, Australia.
2. ANON., 2004 – UNECE standards Bovine Meat, Carcasses and Cuts.
3. BREWER S., NOVAKOFSKI J., 2008 – Consumer Sensory Evaluations of Aging Effects on Beef. ***Journal of Food Science*** 73, 78-82.
4. CABALLERO B., SIERRA V., OLIVÁN M., VEGA-NARED I., TOMAÁS-ZAPICO C., ALVAREZ-GARCÍA O., TOLIVIA D., HARDELAND R., RODRÍGUEZ-COLUNGA M.J., COTO-MONTES A., 2007 – Activity of cathepsins during beef aging related to mutations in the myostatin gene. ***Journal of the Science of Food and Agriculture*** 7, 192-199.
5. CAMPBELL R.E., HUNT M.C., LEVIS P., CHAMBERS E., 2001 – Dry-Aging Effects on Palatability of Beef Longissimus Muscle. ***Journal of Food Science*** 66, 196-199.
6. FRANCO D., BISPO E., GONZÁLEZ E., VÁZQUEZ J.A., MORENO T., 2009 – Effect of finishing and ageing time on quality attributes of loin from the meat of Holstein-Fresian cull cows. ***Meat Science*** 83, 484-491.
7. GORRAIZ C., BERIAIN M.J., CHASCO J., INSAUSTI K., 2002 – Effect of aging time on volatile compounds, odor, and flavour of cooked beef from Pirenaica and Friesian bulls and heifers. ***Journal of Food Science*** 67, 916-922.
8. HODGES J. H., CAHILL V. R., OCKERMAN H.W., 1974 – Effect of vacuum packaging on weight loss, microbial growth and palatability of fresh beef wholesale cuts. ***Journal of Food Science*** 39(1), 143-146.

9. HOPKINS D.L., THOMPSON J.M., 2002 – Factors contributing to proteolysis and disruption of myofibrillar proteins and the impact on tenderisation in beef and sheep meat. ***Australian Journal of Agricultural Research*** 53, 149-166.
10. HUERTA-LEIDENZ N.O., RODAS-GONZÁLEZ A.R., SMITH G.C., 2004 – Effect of vacuum aging and influence of sire on palatability of beef longissimus from grass-fed F1 Senepol x Zebu bulls. ***Revista Científica*** 14, 263-269.
11. HUFF-LONERGAN E., LONERGAN S.M., 2005 – Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. ***Meat Science*** 71, 194-204.
12. HUFF-LONERGAN E., PARRISH F.C., ROBSON R.M., 1995 – Effects of postmortem aging time, animal age, and sex on degradation of titin and nebulin in bovine longissimus muscle. ***Journal of Animal Science*** 73, 1064-1073.
13. JEREMIAH L.E., GIBSON L.L., 2003 – The effects of postmortem product handling and aging time on beef palatability. ***Food Research International*** 36, 929-941.
14. JIANG T., BUSBOOM J.R., NELSON M.L., O'FALLON J., RINGKOB T.P., ROGERS-KLETTE K.R., JOOS D., PIPER K., 2010 – The influence of forage diets and aging on beef palatability. ***Meat Science*** 86, 642-650.
15. KIM Y.H.B., KEMP R., SAMUELSSON L.M., 2016 – Effects of dry-aging on meat quality attributes and metabolite profiles of beef loins. ***Meat Science*** 111, 168-176.
16. MINKS D., STRINGER W.C., 1972 – The influence of aging beef in vacuum. ***Journal of Food Science*** 37(5), 736-738.
17. MONSÓN F., SAÑUDO C., SIERRA I., 2005 – Influence of cattle breed and ageing time on sensory meat quality and consumer acceptability in intensively reared beef. ***Meat Science*** 71, 471-479.
18. NOVAKOFSKI J., BREWER S., 2006 – The Paradox of Toughening During the Aging of Tender Steaks. ***Journal of Food Science*** 71, 473-479.
19. PARRISH F.C., BOLES J.A., RUST R.E., OLSON D.G., 1991 – Dry and Wet Aging Effects on Palatability Attributes of Beef Loin and Rib Steaks from Three Quality Grades. ***Journal of Food Science*** 56(3), 601-603.
20. PERRY N., 2012 – Dry aging beef. ***International Journal of Gastronomy and Food Science*** 1, 78-80.
21. PINHEIRO J., BATES D., DEBROY S., SARKAR D., R CORE TEAM., 2018 – *nlme: Linear and Nonlinear Mixed Effects Models*. R package version 3.1-137, URL: https://CRAN.R-project.org/package=nlme.
22. POGORZELSKI G., WOŹNIAK K., POLKINGHORNE R., WIERZBICKA A., PÓŁTORAK A., 2019 – Polish consumer categorisation of grilled beef at 6mm and 25mm thickness into quality grades, based on Meat Standards Australia methodology. ***Meat Science*** 161, 1-7.
23. POLKINGHORNE R.J., THOMPSON J.M., 2010 – Meat standards and grading: a world view. ***Meat Science*** 86, 227-235.
24. R CORE TEAM 2018 – *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
25. RICHARDSON R.I., NUTE G.R., WOOD J.D., 2008 – Effect of wet vs dry ageing on eating quality of beef from traditional breeds. Presented at the 54th International Conference of Meat Science and Technology CapeTown, South Africa.
26. SITZ B.M., CALKINS C.R., FEUZ D.M., UMBERGER W.J., ESKRIDGE K.M., 2006 – Consumer sensory acceptance and value of wet-aged and dry-aged beef steaks. ***Journal of Animal Science*** 84, 1221-1226.
27. STENSTRÖM H., LI X., HUNT M.C., LUNDSTRÖMA K., 2014 – Consumer preference and effect of correct or misleading information after ageing beef longissimus muscle using vacuum, dry ageing, or a dry ageing bag. ***Meat Science*** 96, 661-666

28. STETZER A., TUCKER E., MCKEITH F., BREWER S., 2006 – Quality changes in various beef muscles enhanced prior to aging. II. Complexus, Serratus ventralis, Vastus lateralis, Vastus medialis and Longissimus dorsi muscles. ***Journal of Food Science*** 73, 6-10.
29. TROY D.J., 1999 – Enhancing the tenderness of beef. Final report. Project Armis No. 3916. The National Food Centre. Research and training for the food industry. Research Report no 11.
30. VIEIRA C., GARCÍA-CACHÁN M.D., RECIO M.D., DOMÍNGUEZ M., SAÑUDO C., 2006 – Effect of ageing time on beef quality of rustic type and rustic x Charolais crossbreed cattle slaughtered at the same finishing grade. ***Spanish Journal of Agricultural Research*** 4, 225-234.
31. WARREN K.E., KASTNER C.L., 1992 – A comparison of dry-aged and vacuum-aged beef strip loins. ***Journal of Muscle Foods*** 3(2), 151-157.
32. WATSON R., GEE A., POLKINGHORNE R., PORTER M., 2008 – Consumer assessment of eating quality – Development of protocols for MSA testing. ***Australian Journal of Experimental Agriculture*** 48, 1360-1367.