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Effects of pelvic suspension of beef carcasses and wet aging time of cuts on eating quality and sensory scores of 14 muscles

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To evaluate the effect of carcass hanging method and aging period on beef eating quality young cross-breed bulls were slaughtered in a slaughterhouse in south-eastern Poland. After the slaughter operations were completed, one carcass side was hung by the Achilles tendon and the other by the hip bone. Suspension methods depending on the carcass sides were used in rotation. Consumer samples were prepared from 14 muscles collected from each of the 50 sides. The use of different hanging methods showed their varied impact on tenderness, juiciness, flavour overall liking and eating quality of beef cuts. A positive effect of tenderstretch on eating quality was observed for six of the muscles (*longissimus thoracis, spinalis dorsi, longissimus lumborum, vastus lateralis, gluteus profundus* and *semimembranosus*), no effect was observed for seven, and a negative effect of suspending carcass by hip bone was noted for just one muscle.

KEY WORDS: beef / eating quality / suspension method / beef aging

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The abbreviations contained in the text.

CUB045 - *Longissimus thoracis*
TDR062 - *Psoas major*
CUB081 - *Spinalis dorsi*
TOP001 - *Adductor femoris*
EYE075 - *Semitendinosus*
TOP073 - *Semimembranosus*
KNU066 - *Rectus femoris*
TOP033 - *Gracilis*
KNU099 - *Vastus lateralis*
EUROP - EU Beef Carcass Classification Scheme
OUT005 - *Biceps femoris*
USDA - United States Department of Agriculture
RMP005 - *Biceps femoris tail*
UNECE - United Nations Economic Commission for Europe
RMP087 - *Tensor fasciae latae*
MSA - Meat Standards Australia
RMP231 - *Gluteus profundus*
MQ4 - Meat Quality, 4 variables
STR045 - *Longissimus lumborum*
PESEL - Universal Electronic System for Registration of the Population

Consumers define the quality of beef in different ways. At the purchase stage, if we do not take into account the trust in the brand or quality system, the only thing that can allow the consumer to determine the quality is the name of the cut and the appearance. On the other hand, the quality after consumption is influenced by the individual feelings that the consumer had while eating (eating quality) - Torrico *et al*. [2018]. The main factors contributing to eating quality are: flavour, tenderness, juiciness, and overall liking. These sensory characteristics are affected by a number of production and processing procedures, such as choice of breed, feeding system, farming system, handling, the entire slaughter and post-slaughter process [Horbańczuk *et al.* 1998]. Among the post-slaughter procedures, the hanging method and maturation are very important due to their impact on various sensory characteristics [Gebeyshu *et al.* 2013, Pogorzelski *et al.* 2022].

In Poland, as well as in other European countries, the most common method of suspending beef carcasses is suspending them by the Achilles tendon (AT)

[Pogorzelski *et al.* 2022]. This method involves suspending the carcass by the hind leg by placing the hook under the Achilles tendon. The weight of the carcass and gravity forces a different position of the carcass than the natural standing position, the hind leg is extended backwards in relation to the standing position and the spine is bent towards the abdominal cavity [Hostetler *et al.* 1970]. Suspension by the Achilles tendon causes the myofibrils of a large number of muscles to contract during rigor mortis, resulting in shortened muscles. Meat obtained using this method is generally tougher [Ahnström *et al.* 2012]. Although beef carcasses are most often hung with this method because they are much easier to handle in transport and storage and they take up less space, which allows better use of the chillers capacity, as well as it is believed that by using aging it will be possible to obtain the tenderness that the meat potentially has [Pogorzelski *et al*. 2022].

Another relatively new method of suspending carcasses, developed several decades ago, is tenderstretch (TX), also known as aitchbone hanging, pelvic suspension or hip suspension. This method involves suspending the carcass by the pelvic bone or ligament prior to rigor mortis. In this method, the position of the carcass is different than in AT, the hind leg drops to a position almost perpendicular to the spine, and the spine is straight without forced bends. This carcass position causes stretching of most of the hindquarters muscles, which causes a decrease in their toughness by therefore reduces myofibril shortening [Hostetler *et al*. 1972]. Many authors point to the positive effects of using tenderstretch. Bayraktaroglu and Kahraman [2011], showed an increase in the length of sarcomeres in the *biceps femoris* muscle from tenderstetched carcasses compared to those suspended by achilles tendon. Studies have shown that suspension by the hip bone can cause a significant increase in tenderness, up to 40% [Liu *et al.* 2016, Niana *et al*. 2018, Park *et al.* 2008]. In addition, it was noticed that tenderstetch also has a slight effect on such sensory attributes as juiciness, flavour [Ahnström et al. 2012] and overall liking [Moran *et al.* 2020]. On the other hand, Ahnström *et al*. [2012] in their research showed that the use of tenderstretch can shorten the period of aging.

Very important factor affecting the eating quality of beef is aging. There are two main aging methods, wet aging and dry aging. Wet aging consists in storing meat in vacuum packaging in refrigeration conditions, while dry aging is carried out by storing meat in refrigeration conditions without packaging with a certain humidity and air flow [Pogorzelski *et al.* 2021]. Without any doubt, both of these methods affect the eating quality of beef. Marino *et al.* [2013] noted ageing as a well-known method for increasing beef tenderness as a result of biological changes that disintegrate myofibrillar and cytoskeletal proteins. Beef maturation also improves juiciness [Irurueta *et al.* 2008], palatability [Campbell *et al.* 2001] and overall liking [Cho *et al.* 2016].

The aim of this study was to evaluate the effect of hanging method of beef carcasses and the aging time on the eating quality (MQ4) of various cuts and its sensory attributes.

Material and methods

Experiment design

Young cross-breed bulls were slaughtered in a slaughterhouse in south-eastern Poland. The maternal component was Holstein Frisian cattle, while the paternal component was Limousine or Simmental. The bulls came from two suppliers located similar distances from the meat plant. All animals arrived at the slaughterhouse at a similar time and spent a similar period in lairage. The slaughter process was carried out in accordance with the standards applicable in the European Union. After the slaughter operations were completed, one carcass side was hung by the Achilles tendon and the other by the hip bone. Suspension methods depending on the sides were used in rotation. After appropriate suspension, the research material was directed to the chiller.

Meat sample preparation

Consumer samples were prepared from fourteen cuts specified according to the UNECE Bovine Language [Anon 2004] and the Handbook of Australian Meat [Anon 1998], (14 muscles), CUB045 *longissimus thoracis*, CUB081 *spinalis dorsi*, STR045 *longissimus lumborum,* EYE075 *semitendinosus*, KNU066 *rectus femoris*, KNU099 *vastus lateralis*, OUT005 *biceps femoris*, RMP005 *biceps femoris*, RMP087 *tensor fasciae latae*, RMP231 *gluteus profundus*, TDR062 *psoas major*, TOP001 *adductor femoris*, TOP033 *gracilis*, TOP073 *semimembranosus*. The *biceps femoris* muscle, which is normally found in two cuts after boning (the tail as the rump and the rest as the outside), was analyzed as two separate samples. These were collected from each of the 50 chilled sides. Carcasses were characterized by relatively low variability in terms of parameters such as EUROP fatness score from 2 to 2+, EUROP muscle score from U to O, carcass weight from 290.6 to 439.7 ossification (by USDA) from 130 to 190, marbling (USDA) from 100 to 390, ultimate loin pH in the range 5.47-5.82.

Whole cuts were collected and labeled during deboning, then the muscles were separated and divided into consumer samples. one consumer sample consisted of 5 individual steaks with a thickness of 25 mm, each was wrapped in plastic cling film, the whole was vacuum packed and labeled. Samples prepared in this way were divided into groups depending on the maturation period and placed in a cold store (2 ±1°C) for aging. The studied periods of maturation were 7, 14 and 21 days. After the maturation period, the samples were blast frozen.

Cooking protocols

To conduct consumer tests, frozen samples were placed in the refrigerator 24 hours before testing to thaw. One hour before the start of the study, the samples were removed from the refrigerator and left at room temperature to raise their temperature to approximately 20°C. The heat treatment used in this experiment was grilling. It was carried out using a dual contact grill with cast iron plates Silex S-Tronic S165. An hour before start of grilling, the machine was started to warm up properly. Also to ensure

constant processing conditions each time, meat scraps not taking part in the research were placed on the grill as the first to standardize temperature. The entire process of heat treatment of the seventy steaks in seven rounds (10 steaks per round) followed a strict time regime that defined the time of grilling the samples, resting (3 min), cleaning the plates, applying new samples to the plate, cutting and serving to consumers.

As detailed in the MSA protocol to maintain ID, samples were placed on the grill in order specified in test design, the transfer of samples from heating plate to cutting board took place in the same order. To ensure correct layout of the samples, transfer was monitored by a second independent observer. Samples intended for serving were placed on plates with their code, which was checked for compliance with the code found in the consumer questionnaire.

The samples were served as a single grilled piece of meat without the addition of any spices that would affect their aroma or taste.

Sample allocation

Consumer tests were carried out in central Poland in a city with about 2 million inhabitants. The MSA protocols described by Watson, Gee, et al. [2008a] were used to design, prepare and conduct consumer tests. One test was performed in three sessions of twenty people each. One session consisted of seven rounds, in each round the consumer was given one piece of meat which was half of the sample cut in half, which means that in the round two consumers were evaluating the same sample. In the first round, the consumer was given a medium-quality steak called 'link', after which the consumer was given 6 samples from different muscles constituting the research material. One test evaluated the quality of 42 samples of which 6 were 'links' and 36 samples of varying quality from different muscles. The placement of the samples was designed using software utilizing Latin square (6×6) which ensured an even distribution of the samples across the entire test. Which means that 5 individual steaks from each sample were placed in 5 different representative positions and served to consumers dispersed across test sessions.

Consumer recruitment

Due to the need to involve a large number of consumers in the research, the online method was chosen for the recruitment. Two people were responsible for building and operating the website allowing to register for the research. The website informed consumers about the subject of the research, ensured communication with respondents and made possible to choose a convenient date from the set test dates. During the registration, respondents were asked about their preferences regarding the methods of beef preparation, degree of doneness, frequency of consumption and to fill in the PESEL number. This number allowed to determine the age of the respondent and to identify the consumer during the tests. 20 respondents per session were required to conduct the test, while the website allowed 22 people to register. This procedure was used to ensure that the required 20 people showed up for the study.

Questionnaire and score sheet

The response form used in this experiment was created from a questionnaire published by Watson *et al*. [2008a]. The questionnaire in the first part contained questions about the demographic data of an individual respondent. The second part consisted of seven pages for sample evaluation, with four 100 m linear scales on each sample page and four sample quality evaluation boxes. The lines were designed to assess the tenderness, juiciness, flavour and overall liking, while the boxes corresponded to quality levels such as: unsatisfactory quality, good everyday quality, better than everyday quality or premium quality. Lines for individual sensory attributes were described at both ends, I dislike at the left end and like at the right end. The consumer assessed the sample by putting a vertical line on the scale in the place that properly describes his impressions for the relevant sensory attribute.

Statistical analysis

Material subjected to sensorial analysis was obtained from 25 animals. From each animal 14 culinar elements were cut out from every single carcass. Afterwards, sensorial analysis was performed by 10 consumers for each sample in every treatment variant (in total 1331 analysed samples). Statistical analysis of obtained data was conducted using Statistica software version 13.3 (StatSoft, Tulsa, OK, USA). The Shapiro–Wilk test was used for testing the normality of data distribution . One-way ANOVA followed by the Tukey test was applied for analysis of sensorial analysis of samples to distinct probes subjected to certain aging time periods (7,14 or 21 days) and hanging method **(**achilles tendon and tenderstretch). The level of significance was set at $\alpha \leq 0.05$.

Results and discussion

Tenderness

The use of different hanging methods showed (Tab. 1) their varied impact on tenderness of beef cuts, Thompson [2002] noted similarly when describing managing meat tenderness. A positive effect of tenderstretch on tenderness was observed for most of the cuts, no effect was observed for a few, and a negative effect of suspending carcass by hip bone was noted for just one cut.

Table 1 shows that two cuts from loin responded positively to the tenderstretch, but no significant differences were noted for the another two muscles. This is due to the difference in the position of the cuts in the carcass, the *longissimus lumborum* and *longissimus thoracis* muscles are located on the outer side of the spine (back), therefore the suspension by the hip bone straightened the spine and stretched these two muscles, which contributed to the increase in Tenderness [Clinquart *et al.* 2022]. On the other hand, the *psoas major* muscle is located on the side of the abdominal cavity and straightening the spine caused its contraction [Warner *et al.* 2010], but due to the generally high tenderness of this muscle, consumers did not notice a significant difference. Also, the tenderness of the *spinalis dorsi* muscle was not affected by the

Table 1. Effect of suspension method and aging period on the mean sensory scores for the sensory attributes and eating quality (MQ4)

Aging Cut	SM	Tenderness			Juiciness			Flavour			Overall liking			MQ4		
		7	14	21	7	14	21	7	14	21	7	14	21	7	14	21
CUB045	AT	42.59±11.44^{a}	45.18±13.11^{a}	46.58±14.16^{a}	60.31±7.89	59.64±8.85	59.6±10.1	51.41±8.61^{a}	57.14±6.89	56.1±7.53^{a}	49.27±11^{a}	57.05±9.2	54.3±10.2^{a}	48.5±8.48^{a}	53.95±8.35^{a}	53.29±9.47^{a}
	TX	58.46±11.43^{b}	60.08±9.68^{b}	59.63±12.05^{b}	64.6±8.79	64.06±6.99	62.14±7.03	60.96±8.65^{b}	61.14±5.09	61.67±5.73^{b}	60.62±9.2^{b}	62.65±7.24	63.35±8.3^{b}	60.07±8.72^{b}	60.81±6.94^{b}	61.13±7.32^{b}
CUB081	AT	70.92±8.14	71.73±1.7	75.44±4.81	68.69±6.07^{A}	69.75±4.08^{ABa}	74.96±3.96^{B}	62.42±10.1	63.12±4.59^{a}	62.83±2.67	63.46±10.9	64.33±7.32^{a}	65.54±4.61	64.8±9.25	66.29±3.54^{a}	67.95±2.65
	TX	75.4±6.42	75.38±5.59	74.98±9.26	74.19±7.56	75.35±5.18^{b}	72.71±9.74	64.79±13.4	69.6±6.24^{b}	65.06±12.6	67.04±11.1	71.79±6.5^{b}	67.46±13.8	69.57±9.1	72.37±5.34^{b}	69.21±10.8
EYE075	AT	38.19±11.73	39.15±10.34	39.58±10.28	55.69±8.83	56.3±5.76	53.25±7.9	54.29±6.2^{a}	55.19±7	54.57±4.58	51.82±6.99	52.07±6.57	53.94±4.76	49.12±7.08	49.1±5.59	49.93±4.97
	TX	39.42±9.03	43.51 ±10.85	41.47±10.4	55.22±7.41	55.57±6.96	52.82±6.77	50.31±6.7^{b}	52.81±8.92	52.85±6.72	48.29±6.31	50.06±8.79	52.69±6.05	47.08±5.47	49.69±8.16	49.25±6.56
KNU066	AT	46.9±10.74	48.76 ±10.76	46.19±10.2^{a}	54.43±7.94	53.64±9.45	58.65±9.62	54.5±7.08	54.13±6.49	56.36±8.77	54.86±8.04	54.67±6.75	55.07±8.01	51.97±7.29	52.23±6.59	52.63±8.31
	TX	50.99±11.06	54.21±9.11	55.8±8.7^{b}	50.64±9.71^{A}	57.2±8.93^{AB}	60.74±7.33^{B}	55.86±7.83	58.03±7.89	58.82±8.8	55.77±9.93	58.58 ±8.15	59.57±7.26	53.9±8.75	56.84±7.28	57.87±7.43
KNU099	AT	28.47 ±9.7^{a}	30.31±10^{a}	29.39±7.7^{a}	46.37±10.25	46.84±8.47	47.24±8.54	48.91±7.61	45.01±8.6^{a}	47.93±6.22	44.05±8.06	44.2±8.4^{a}	44.61±7.7a	41.33±7.4^{a}	40.65±7.98^{a}	41.61±6.0^{a}
	TX	36.66±8.48^{b}	40.16 ±10.9^{b}	40.75±11.6^{b}	51.29±11.31	50.94±10.5	50.21±9.19	50.31±5.98	55.56±9.1b	51.19±8.21	48.17±7.29	53.92±10.6^{b}	50.75±9.9b	45.77±6.2b	49.83±9.1^{b}	48.1±9.1^{b}
OUT005	AT	32.39±11.37^{a}	35.09 ±10.23	35.7±11.67	55.69±9.15	52.19±7.74	51.64±8.0^{a}	51.48±8.72	49.2±6.54	51.23±6.65	47.01±8.7a	47.22±8.16	47.92±6.87	44.93±8.68	45.01±7.03	45.71±7.27
	TX	41.84±13.1^{b}	36.32 ±10.92	41.96±9.88	58.33±11.56	55.87±9.45	56.87±6.0^{b}	54.18±8.7	51.83±8.7	52.35±5.05	52.46±9.2b	48.36±10.1	50.86±7.53	49.87±9.49	47.12±8.26	49.13±5.83
RMP005	AT	49.53±11.06	51.41 ±13.65	57.23±6.3	61.27±10.4	63.48±5.99	67.21±6.63	53.86±11.6	54.25±10.3	59.02±6.94	55.23±11.8	53.9±13.2	59.02±10.1	53.33±10	52.61±11.4	58.76±5.57
	TX	52.34±12.6	52.11 ±10.12	59.2±7.98	67±5.53	62.14±4.82	68.15±4.07	57.2±7.18	55.34±6.03	59.16±6.61	57.04±7.16	54.99±7.39	61.4±3.88	55.73±7.57	54.5±6.42	59.63±4.03
RMP087	AT	49.87±7.38^{a}	52.1 ±8.96^{a}	52.56±7.6^{a}	60.13±7.23^{a}	62.5±7.74	60.19±6.68	55.79±6.83	57.85±6.9^{a}	56.93±5.79	57.3±6.4^{a}	56.33±9.9^{a}	55.93±5.72	54.45±5.4^{a}	55.89±8.4^{a}	54.83±6.1^{a}
	TX	31±12.28^{b}	31.21±5.3^{b}	34.81±8.9^{b}	50.13±9.24^{b}	57.17±7.78	54.05±7.21	49.72±7.52	47.44±5.8^{b}	50.1±6.47	47.44±7.8^{b}	43.92±5.9^{b}	49.01±7.2	44.26±8.3^{b}	42.58±4.3^{b}	45.88±7.1^{b}
RMP231	AT	54.24±8.4^{a}	51.75±13.1^{a}	50±10.6^{a}	60.83±5.8^{a}	58.38±8.61	58.56±7	58.69±9.77	58.08±11^{a}	60.07±7.46	59.93±9.6^{a}	57.04±9.8^{a}	57.64±5.14	57.7±8.0^{a}	55.38±9.4^{a}	56.43±6.5^{a}
	TX	64.86±9.9^{b}	68.81±7.9^{b}	59.24±5.5^{b}	62.09±9.7^{b}	68.12±7.58	62.23±6.26	66.1±8.75	66.33±6.3^{b}	60.86 ±6.06	66.4±8.6^{b}	67.1 ±7.8^{b}	61.94±6.66	64.98±8.5^{b}	66.83±7.0^{b}	59.85±5.8b
STR045	AT	35.7±11.22^{a}	37.53±12.8^{a}	42.51±11.5^{a}	58.2±8.33	55.83±9.0^{a}	57.49±10.3^{a}	51.66 ±10.2^{a}	51.31±8.4^{a}	55.7±8.99	47.69±9.0^{a}	49.01±10.3^{a}	52.98±9.6^{a}	46.32±8.47a	47.25±9.0^{a}	51.27±8.53a
	TX	46.17±9.37^{Ab}	55.44±10.3^{Bb}	55.68±10.3^{Bb}	62.86±7.95	63.56±6.9^{b}	63.74±7.49^{b}	58.38±5.2^{b}	58.38±7.6^{b}	60.24±7.25	57.3±5.1^{b}	58.14±7.6^{b}	60.71±7.5^{b}	54.21±5.03^{Ab}	57.63±7.3^{ABb}	58.99±7.32^{Bb}
TDR062	AT	72.45±7.03	71.92±6.81	70.83±6.86	69.64±6.5^{a}	68.73±5.71	68.79±6.15	66.77±7.04	69.45±6.44	69.02±5.3	67.91±6.42	70.18±7.24	70.21±5.17	68.64±6.21	69.66±6.67	69.33±4.93
	TX	68.71±8.64	71.51±6.19	71.22±7.34	65.65±6.4^{b}	67.87±6.59	69.68±7.01	67.06±7.49	68.66±6.52	68.09±7.69	68.71±7.71	71.55±6.23	69.82±7.72	67.45±7.11	69.23±5.94	68.72±7.2
TOP001	AT	45.54±10.96^{a}	41.82 ±7.7^{a}	41.89±8.52	52.62±11.1^{a}	55.69±6.75	52.73±5.45	54.88±9.1	54.71±8.33	52.89±7.24	54.21±9.98	52.72±9.78	49.61±8.16	51.87±9.63	50.07±7.86	48.74±3.86
	TX	48.33±5.92^{b}	48.33±5.9^{b}	48.33±5.92	65.52±7.5^{b}	57.68±12.7	56.94±8.82	58.88±4.98	57.18±7.75	53.21±7.11	60.67±4.47	57.76±10.1	53.41±3.7	57.83±4.36	55.23±9.29	51.61 ±4.17
TOP073	AT	29.39±5.72^{Aa}	35.53 ±8.95^{B}	34.63±8.4^{ABa}	47.9±8.06	47.17±8.95	44.92±7.1^{a}	49.77±5.16	51.44±5.3	51.87±7.88	47.19±4.84	48.64±5.67	48.78±9.9^{a}	43.31±4.1^{a}	45.59±5.4	45.3±7.7^{a}
	TX	38.99±9.61^{b}	39.74±9.46	44.18±8b	48.77±7.7	50.75±8.07	52.34±7^{b}	51.84±7.34	53.43±6.58	54.88±5.77	49.96±8.36	51.72±8.02	54.53±6.6b	47.16±7.5^{b}	48.85±7.5	51.22±6.1^{b}
TOP033	AT	52.23±15.82	62.06 ±12.03	54.44±13.06	54.02±7.8	61.54±7.93	52.94±9.1	56.69±5.03	60.29±9.3	55.67±9.3	56.6±5.2	64.19±9.4	57.15±7.21	54.52±6.69	61.89±9.21	55.14±8.28
	TX	51.19±7.95^{A}	64.19±6.97^{B}	57.4±11.94^{AB}	55.38±4.93	61.58±7.8	57.17±10.8	56.14±5.81	62.75±5.61	53.69±10.3	55.71±4.07	64.75±8.31	57.48±10.7	53.57±5.35	62.47±6.44	56.77±8.96

^{AB}Within rows means bearing different superscripts differ significantly at P≤0.01.
^{ab}Within columns means bearing different superscripts differ significantly at P≤0.05.

suspension method , because it is located on the *longissimus thoracis* muscle and the suspension by the hip bone did not significantly stretch it, as well this muscle is generally very tender, therefore the change of the suspension did not cause differences significant for consumers.

When analyzing the effect of tenderstretches on the tenderness of hind limb muscles, a significant positive effect of the suspension method for six muscles (*rectus femoris, vastus lateralis, biceps femoris*-OUT, *gluteus profundus, adductor femoris, semimembranosus*) was noticed. Carcass suspension by the hip bone made it possible to change the position of the hind limb causing stretching of these muscles. While in the case of *tensor fasciae latae* muscle, the negative effect of hanging behind the hip bone was noted, the fall of the hind leg caused the contraction of this muscle and, as a result [Warner *et al.* 2010], a significant decrease in its tenderness. There was no significant effect of the suspension method on the *gracilis, semitendinosus* and *biceps femoris*-RMP muscles.

Post slaughter meat aging may contribute to its tenderness [Perry 2012]. Table 1 shows that aging process improved the tenderness of the *longissimus lumborum, semimembranosus* and *gracilis muscles*. It turned out that aging for 21 days did not result in meat with a higher tenderness than aging for 14 days. No muscle was noted in which aging significantly affected tenderness in both methods of suspension. A significant improvement in the tenderness of the *longissimus lumborum* and *gracilis* muscles was obtained in tenderstretched beef. However, in the case of suspension by the Achilles tendon, a positive effect of maturation was observed for the *semimembranosus* muscle. In the *adductor femoris* and *biceps femoris* - OUT muscles aging compensate for the differences caused by the suspension method, while it enhanced this difference when the *rectus femoris* muscle was aged for 21 days.

Juiciness

As shown in Table 1, tenderstretch did not affect significantly the juiciness of half of the tested muscles, while its positive effect was observed in five muscles and negative in two. Analyzing the loin cuts, no effect of suspending carcass by the hip bone on the juiciness of the *longissimus thoracis* muscle was observed, but its positive effect on the juiciness of the *spinalis dorsi* and *longissimus lumborum* muscles was noted a similar relationship was observed by Park [2008], while the negative effect of tenderstretch was found on the juiciness of the *psoas major* muscle. It turned out that stretching the *longissimus lumborum* and *spinalis dorsi* muscles caused an increase in juiciness, while contraction of the *psoas major* muscle caused a decrease in its juiciness. Tenderstretch had a positive effect on the juiciness of the three muscles (*gluteus profundus, adductor femoris* and *semimembranosus*), of the hindlimb and negatively on the tensor *fasciae latae* muscle.

The aging process had a positive effect on the *spinalis dorsi* and *rectus femoris* muscles, but to observe its effect it was necessary to conduct this process for 21 days. This resulted in significant differences between the first and last aging periods, but no

differences in juiciness for these muscles were observed between the middle (14days) period and the first (7days) and last (21days). We can also observe that the aging process accentuated the differences in juiciness resulting from the hanging method for *spinalis dorsi* muscle aged 14 days and *semimembranosus* muscle aged 21days. As in the Lepper-Blilie *et al.* [2016] study, no effect of the aging period on the juiciness of the *longissimus lumborum* muscle was observed. In contrast, Joseph and Connolly [1977] observed a decrease in *longissimus lumborum* muscles juiciness under the influence of aging.

Flavour

The use of carcass pelvic suspension instead of Achilles tendon had a positive effect on flavour in five tested muscles which is supported by Baldassini *et al.* [2023] research. Although a negative effect was observed in two. Among the loin muscles, the positive effect of changing the carcass suspension can be observed in the *longissimus thoracis, spinalis dorsi* and *longissimus lumborum* muscles in contrast to the observations of Joseph and Connolly [1977], while no effect was noted for the *psoas major* muscle. The positive effect of changing the suspension was shown by the loin muscles that were stretched under its influence, while the muscle that was contracted showed no difference in flavour. No effect of the suspension method on flavour was observed on six hindlimb muscles showed, while two (*vastus lateralis* and *gluteus profundus*) showed a positive effect and another two (*semitendinosus* and tensor *fasciae latae*) showed a negative effect.

Analyzing the effect of aging, no differences in flavour were found in meat samples from carcasses suspended by the hip bone or the Achilles tendon. On the other hand, it was noted that in some cases, aging affected the appearance of differences resulting from suspension method, in the second aging period, differences in flavour were observed between the hanging methods, however they were not found in the first aging period. Although in the case of one muscle (*semitendinosus*) a negative effect of the suspension method was found in the first aging period, it did not occur in the following periods.

Overall liking

Table 1 shows that changing the carcass hanging method from achilles tendon to hip bone had no effect on consumers overall liking of the seven tested muscles what stands in opposition to Baldassini *et al*. [2023] research. In three loin muscles, tenderstretch had a positive effect on overall liking, while no effect was observed on the *psoas major* muscle. Among the analyzed hindlimb muscles, no differences in overall liking were observed in six muscles, in three (*semimembranosus, gluteus profundus* and *vastus lateralis*) the positive effect of suspending carcassess by the hip bone was observed, while the *tensor fasciae latae* muscle showed its negative effect.

There was no effect of the aging process on the overall liking of any of the analyzed muscles, similarly noted by Pogorzelski *et al.* [2021], although, as in the case

of Flavour, the aging process had an impact on the appearance of differences in the case of some muscles and the lack of them in the case of others. For *spinalis dorsi* and *semimembranosus* muscles, differences were observed due to the suspension method at 14 days and 21 days of aging, respectively, and no differences were observed at other aging periods for this muscles. On the other hand, in the case of *tensor fasciae latae* and *gluteus profundus* muscles, no differences were observed due to the suspension method at 21 days of aging, although they were observed in previous aging periods.

Eating quality

A method developed by MSA was used to express eating quality as one coherent outcome. Based on the results of consumer tests, the MQ4 score was calculated for each sample. Table 1 shows the differences in eating quality (MQ4) resulting from the change of the suspension method from the achilles tendon to the hip bone. This change resulted in significant differences in seven of the fourteen tested muscles.

Analyzing the results for the loin muscles, the pelvic suspension had a positive effect on three of them (*longissimus thoracis, spinalis dorsi* and *longissimus lumborum*), no effect of the suspension method on the eating quality of the *psoas major* muscle was observed. In the case of hindlimb muscles, the tenderstretch affected the eating quality of four muscles. Three muscles had a positive effect (*vastus lateralis, gluteus profundus* and *semimembranosus*), while the tensor *fasciae latae* muscle had a negative effect. While Park et al. [2008] and Thompson et al. [2008] in their research noted the positive effect of hip suspension on eating quality of *Mm. semimembranosus* and *longissimus lumborum* but did not notice this effect on the *triceps brachii* muscle.

Table 1 shows that maturation had a positive effect on the eating quality of only the *longissimus lumborum* muscle, similar results were observed by Pogorzelski *et al.* [2021]. Samples aged 14 and 21 days differed significantly from those aged 7 days, while the samples aged 14 and 21 days did not differ from each other. We can also observe that the aging process caused the differences resulting from the hanging method to become visible, differences were observed between the suspension methods on the 14th day of aging, but no differences were observed in the meat aged 7 and 21 days.

Conclusions

The use of different hanging methods showed their varied impact on tenderness, flavour overall liking and eating quality of beef cuts. Tenderstretch did not significantly affect the juiciness of half of the tested muscles, while its positive effect was observed in five muscles and negative in two. A positive effect of tenderstretch on eating quality was observed for six of the cuts, no effect was observed for seven, and a negative effect of suspending carcass by hip bone was noted for just one cut. This is due to the difference in the position of the cuts in the carcass, e.g. the *longissimus lumborum* and *longissimus thoracis* muscles are located on the outer side of the spine (back), therefore the suspension by the hip bone straightened the spine and stretched these two muscles, which contributed to the increase in eating quality. On the other hand, the

psoas major muscle is located on the side of the abdominal cavity and straightening the spine caused its contraction but due to the generally high tenderness of this muscle, consumers did not notice a significant difference. While in the case of *tensor fasciae latae* muscle, the negative effect of hanging by the hip bone was noted, the fall of the hind leg caused the contraction of this muscle and a significant decrease in its eating quality. This study showed that the use of tenderstretch can increase the market share of premium beef and increase the eating quality of good everyday quality cuts. This can be a significant added value to the production economics of meat processors.

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Conflict of interest statement

None of the authors have any conflict of interest to declare.

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