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RESEARCH ARTICLE

The Effect of Meat Sample Preparation on the Results of Drip Loss and Cooking Loss Analysis

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Abstract

The aim of this study was to determine the effect of muscle sample size on the results of drip loss and cooking loss analysis. In the first stage of the study, the experimental materials comprised *longissimus lumborum (LL*) and *quadriceps femoris (QF)* muscles obtained from nine Kamieniec ewes at 18 months of age. Cuboidal and cylindrical samples of different sizes (surface area and volume) were cut from the muscles and used to evaluate drip loss and cooking loss, respectively. The remaining parts of the *LL* and *QF* muscles were subjected to chemical and physicochemical analyses. In the second stage of the study, the results of previous own studies involving sheep, goats, rabbits, red deer, roe deer, and pheasants were analyzed to determine the correlations between drip loss and cooking loss vs. the weight of muscle samples.

The present study demonstrated that the size of *LL* and *QF* muscle samples collected from Kamieniec ewes had no significant (P>0.05) effect on drip loss or cooking loss (stage 1). No significant correlations, expressed as the linear correlation coefficient (r), were found between these two parameters and the weight of muscle samples collected from different animal species (stage 2). Due to small differences in the size and weight of the analyzed muscle samples, further research is needed to determine the importance of sample standardization in terms of shape, size, and weight in the assessment of the water-holding capacity of muscles based on measurements of drip loss and cooking loss.

KEYWORDS

meat, sample size, drip loss, cooking loss

Introduction

Drip loss is one of disadvantageous phenomena associated with meat processing. It can be referred to as natural loss, storage loss, thawing loss, and cooking loss, depending on the stage and type of meat processing [Cheng, Sun 2008; Warner 2014]. In general, drip loss is unavoidable due to the high water content of meat and the form of water in meat. Lean muscle contains approximately 75% water [Honikel 2004], and most of the water (approx. 95%) is classified as free water, and the remainder – as bound water [Zhang et al. 1995; Boler, Woerner 2017]. Water that is tightly bound in meat (in the chemical sense) accounts for a very small proportion of total tissue water (approx. 0.1%) [Honikel 2004]. Free water is held in meat (in the spaces between myofilaments, between myofibrils, and outside the fibers) by weak capillary forces and can leave the tissue relatively easily [Huff-Lonergan, Lonergan 2005]. In turn, water bound via interactions between electrostatic forces and muscle proteins [Puolanne, Halonen 2010] can be lost due to irreversible changes in the latter [Hishida et al. 2023; van Laack 1999]. Both types of water retained in muscle tissue are released during various meat processing operations and technological processes (cutting, grinding, packaging, heating, pressing, etc.) and under the influence of physical

factors such as pressure and temperature [Szmańko et al. 2021]. Drip loss from fresh meat leads to economic loss (due to weight loss), compromises the visual appearance and consumer appeal of the product (due to the presence of exudate in the vacuum packaging), and reduces its shelf life (due to the rapid growth of bacterial microbiota in the exudate that comes into contact with the product in the packaging) [Watanabe et al. 2018]. Drip loss and cooking loss not only cause weight loss but also reduce the content of water-soluble components in meat (pigments, amino acids, nucleotides, minerals, vitamins, etc.) [Elbir, Oz 2021; Oswell et al. 2021], which affects the nutritional value and flavor of the product. Water loss due to dripping during the heat treatment of meat can also potentially reduce the juiciness and tenderness of dishes, as these parameters are interrelated. Therefore, the ability to retain its own and/or added water (i.e. water-holding capacity) is one of the key characteristics of meat that is considered very important by meat producers, suppliers, and consumers [Barbut 2024; Cornet et al. 2021]. An analysis of the water-holding capacity of meat plays a key role in the evaluation of meat quality. The results of such an analysis are clearly influenced by the applied research method [Honikel, Hamm 1994; Oswell et al. 2021]. However, the method of sample preparation for analysis is an equally important consideration, although it has rarely been investigated. In view of the above, the research hypothesis postulated that the method of meat sample preparation affects the results of drip loss and cooking loss analysis. In order to test this hypothesis, the effect of muscle sample size (surface area, volume, and weight) on the results of drip loss and cooking loss analysis was determined in this study.

MATERIALS AND METHODS

Materials

Stage 1

At this stage of the study, muscle samples were collected from nine carcasses of Kamieniec ewes. The animals were slaughtered at 18 months of age in a meat processing plant, in accordance with current meat industry standards. Prior to slaughter, they were fasted for 24 h. After slaughter, the carcasses were chilled at a temperature of 3-4°C for approximately 24 h. During dressing of the right half-carcasses, samples of the l*ongissimus lumborum (LL)* and *quadriceps femoris (QF)* muscles were collected for laboratory analyses. The samples were packaged in polyethylene bags, transported to the laboratory in containers on ice, and stored in a cooling chamber at a temperature of 4°C. The samples were analyzed approximately 48 h post mortem.

Sample preparation for analyses

Fat and muscle epimysium were removed from *LL* and *QF* muscles, and the following samples were collected:

- two cuboidal samples measuring 2.5 cm x 2.5 cm x 3 cm (surface area – 42.5 cm², volume – 18.75 cm³) and 2 cm x 2 cm x 3 cm (surface area – 32.00 cm², volume - 12 cm³),
- two cylindrical samples measuring 2.8 cm x 3 cm (surface area – 38.70 cm², volume – 18.47 cm³) and 2.2 cm x 3 cm (surface area – 28.34 cm², volume – 11.40 cm³).

Cuboidal and cylindrical samples were used to determine the amount of drip loss and cooking loss, respectively. The remainder of each sample was passed through a 3 mm plate in a meat grinder, thoroughly mixed, and used for analyses requiring ground samples.

Stage 2

At this stage of the study, coefficients of linear correlation (r) were calculated between the weight of meat samples (g) vs. drip loss and cooking loss. The following data were used in the calculations: numerical data obtained in the first stage of the study, and the results of previous own studies in which meat samples were collected from wild animals: red deer *(Cervus elaphus L.)*, roe deer *(Capreolus capreolus L.)*, and pheasants *(Phasianus colchicus L.)*, and farmed animals: Alpine goats, Kamieniec sheep (young rams), and New Zealand White rabbits. The data from the above studies were selected so as to obtain standardized experimental materials. Therefore, only groups exposed to the same experimental factor or control groups within each species were included in the analysis. Additionally, in the presented study, one of the criteria for selecting samples for testing was a ultimate pH value range 5.7 and 6.1 for pheasant and rabbit meat, and 5.4 and 6.2 for red meat, to eliminate PSE and DFD meat. The detailed characteristics of animals from which muscle samples were collected are presented in **Table 1**.

Table 1. Characteristics of animals from which muscle samples were collected

Species	Gender	Age	Number of animals/samples	Muscle
red deer	male	4-6 years	20	*m. longissimus lumborum* (*LL*)
	female		19	
roe deer	female	3-4 years	25	*m. longissimus lumborum* (*LL*)
	male		16	
pheasant	male	17 weeks	8	*m. pectoralis major* (*PM*)
	female		8	
Alpine goat	male	90 days	10	*m. quadriceps femoris* (*QF*)
Kamieniec long-wool sheep	male	106 days	19	*m. longissimus lumborum* (*LL*)
New Zealand White rabbit	male	91 days	10	*m. longissimus thoracis* (*LT*)

Methods

The values of the parameters analyzed in the first and second stage of the study were obtained using the same research methods. Moisture content was measured by drying the sample at 105°C (laboratory dryer AQARIUS S100, AQUA LAB, Warsaw, Poland) to constant weight (PN-ISO 1442:2000). Fat content was determined by the Soxhlet method (PN-ISO 1444:2000), with diethyl ether as the solvent, in the Soxtec™ 2050 Auto Fat Extraction System (FOSS Analytical, Hilleroed, Denmark). Total protein content was determined by the Kjeldahl method (PN-75/A-04018/Az3:2002) in the Kjeltec™ 8400 Auto Distillation Unit (FOSS Analytical, Hillerod, Denmark). The water, fat, and crude protein content of meat was determined according to Standards PN-ISO 1442:2000, PN-ISO 1444:2000, and PN-75/A-04018/Az3:2002, respectively. Drip loss and cooking loss were measured using the methods proposed by Honikel [1998]. Regular-shaped muscle samples (weighing approximately 20 g) cut along the fibre direction of the muscle were used in the second stage of the study. To determine drip loss, samples were suspended in a plastic bag and stored in this manner at 4°C for 48 hrs (laboratory incubator ILW 53, POL-EKO-APARATURA, Wodzisław Śląski, Poland). Drip loss was expressed as the percentage of weight loss after storage relative to the initial weight of the sample. Cooking loss was expressed as the percentage of weight loss of the meat sample during cooking (in a polyethylene bag in a water bath AQARIUS M/150 (Warsaw, Poland) set at 80°C for 60 min. After cooking (and before weighing), the samples were cooled under tap water

for 30 min. The pH of muscle samples was measured in water homogenates (meat to redistilled water ratio of 1:1, m/v) using a Polilyte Lab combination electrode (Hamilton Bonaduz AG, Bonaduz, SwitzerlanHamilton) and the inoLab Level 2 pH-meter with a TFK 325 temperature sensor (WTW Wissenschaftlich-TechnischeWerkstätten, Weilheim, Germany).

Reagents and solutions

The following reagents were used in the research: diethyl ether (Chempur, Piekary Śląskie, Poland), sulfuric acid (STANLAB, Lublin, Poland), sodium hydroxide (AKTYN, Suchy Las, Poland), boric acid (Sigma-Aldrich, St. Louis, MO, USA), indicator Tashiro (POCH, Gliwice, Poland), hydrochloric acid (TARCHEM, Tarnowskie Góry, Poland), Kjeltabs - copper sulfate pentahydrate, potassium sulphate (FOSS Analytical, Hilleroed, Denmark).

Statistical analysis

Arithmetic means (), standard deviations (s), coefficients of variation, and coefficients of simple correlation (r) between the analyzed parameters were calculated. The results were processed statistically using STATISTICA ver. 13.3 software (TIBCO Software Inc., Palo Alto, CA, USA 2017).

RESULTS AND DISCUSSION

The results of the analysis of the effect of the size of *LL* and *QF* muscle samples collected from Kamieniec ewes on drip loss and cooking loss are presented in **Table 2**. It was found that sample size had no significant (P>0.05) effect on the values of the above parameters, regardless of muscle type. In both muscles, drip loss was slightly greater in smaller samples. The results of cooking loss assessment were more equivocal. In *LL* muscle samples, smaller sample size was associated with slightly greater cooking loss. In *QF* muscle samples, cooking loss was greater in larger samples. In the present study, drip loss tended to be greater in smaller muscle samples, which is consistent with the findings of Diamante and Tran [2016], who found that drip loss was significantly greater in smaller meat (beef brisket) samples due to their lower surface-to-volume ratio. The cited study also demonstrated that drip loss was affected by sample shape, and was significantly greater in samples with rectangular cross-sections than in those with cubic and square cross-sections.

In the current study, a comparison of *LL* and *QF* muscle samples revealed that regardless of their size, samples of the *LL* muscle were characterized by greater drip loss. The difference between the mean values of this parameter in larger samples was significant at P≤0.01. In turn, cooking loss was comparable (P>0.05) in smaller and larger samples of *LL* and *QF* muscles. The difference between means was 2.19 percentage points in smaller samples and 0.06 percentage points in larger samples.

The difference in drip loss between *LL* and *QF* muscle samples was not related to their proximate chemical composition (Table 3). Samples of the *LL* muscle were characterized by a lower (P≤0.01) content of water that could be lost as drip and a higher (P≤0.01) content of protein that binds water. Based on the data in **Table 3**, the only explanation for the greater drip loss in *LL* muscle samples is their slightly (0.04 units) lower pH (lower distance from the isoelectric point of proteins), which translates into a lower water-holding capacity of proteins [Lucarini et al. 2020].

Table 2. Results of the analysis of the effect of the size (surface area and volume) of *quadriceps femoris* and l*ongissimus lumborum* muscle samples collected from Kamieniec ewes on drip loss and cooking loss

Species	Muscle	Parameter	Statistical measure	Sample size	
				smaller surface area and volume	larger surface area and volume
Kamieniec sheep (stage 1)	*LL*	weight of the sample for drip loss assessment (g)	$\bar{x}$ s	11.10 1.36	14.26^{A}* 3.23
		drip loss (%)	$\bar{x}$ s	2.37 0.71	2.21^{B} 0.86
		weight of the sample for cooking loss assessment (g)	$\bar{x}$ s	7.11^{a} 0.96	13.95** 0.91
		cooking loss (%)	$\bar{x}$ s	36.91 1.51	35.67 1.99
	QF	weight of the sample for drip loss assessment (g)	$\bar{x}$ s	11.91 1.81	18.15^{A}** 1.42
		drip loss (%)	$\bar{x}$ s	1.46 1.03	1.14^{B} 0.52
		weight of the sample for cooking loss assessment (g)	$\bar{x}$ s	8.80^{a} 1.29	14.25** 1.56
		cooking loss (%)	$\bar{x}$ s	34.72 3.02	35.61 3.45

LL - *m. longissimus lumborum*, *QF* - *m. quadriceps femoris*.
Values in rows are significantly different at: * - P≤0.05, ** - P≤0.01.
Values in columns followed by identical superscript letters are significantly different at: ^{aa} - P≤0.05, $^{AA, BB}$ - P≤0.01.

Table 3. Arithmetic means $(\bar{x})$ and standard deviations (s) for the analyzed parameters

Species	Gender / Muscle	Statistical measure	Parameter					
			water (%)	protein (%)	fat (%)	pH	drip loss (%)	cooking loss (%)
Kamieniec sheep[1]	female/ (*LL*)	$\bar{x}$ s	72.82 0.51	20.09** 0.49	4.87 0.69	5.57 0.07	Tab. 2	Tab. 2
	female/ (*QF*)	$\bar{x}$ s	74.09** 0.60	19.28 0.60	4.41 0.73	5.61 0.06	Tab. 2	Tab. 2
red deer[2]	female/ (*LL*)	$\bar{x}$ s	74.40 0.60	22.49* 0.56	0.90** 0.32	5.46 0.05	2.92 1.24	32.41 2.44
	male/ (*LL*)	$\bar{x}$ s	75.22** 0.52	22.01 0.82	0.56 0.21	5.49 0.05	2.92 1.03	36.35** 1.55
roe deer[2]	female/ (*LL*)	$\bar{x}$ s	73.80 0.56	22.79** 0.67	1.46** 0.55	5.55 0.05	3.14** 1.21	31.79 1.17
	male/ (*LL*)	$\bar{x}$ s	75.32** 0.47	21.84 0.32	0.83 0.39	5.60** 0.07	2.13 0.56	31.84 0.96
pheasant[2]	male/ (*PM*)	$\bar{x}$ s	72.31 0.87	25.75 0.93	0.29 0.10	5.70 0.08	5.85 1.86	24.87* 1.26
	female/ (*PM*)	$\bar{x}$ s	71.84 1.13	26.08 0.50	0.24 0.12	5.67 0.08	5.72 1.48	23.33 1.23
Alpine goat[2]	male/ (*QF*)	$\bar{x}$ s	78.29 0.58	19.61 0.80	0.66 0.24	6.16 0.10	-	32.93 5.14
New Zealand White rabbit[2]	male/ (*LT*)	$\bar{x}$ s	76.12 0.49	22.18 1.00	0.27 0.10	5.91 0.13	1.41 0.51	30.26 2.03
Kamieniec sheep[2]	male/ (*LL*)	$\bar{x}$ s	74.00 0.90	20.98 0.50	3.50 0.98	5.44 0.06	3.65 2.32	33.73 3.34

[1] – results obtained in stage 1 of the study; [2] - results obtained in stage 2 of the study. *LL* - *m. longissimus lumborum*, *LT* - *m. longissimus thoracis*, *QF* - *m. quadriceps femoris*, *PM* - *m. pectoralis major*. * - P≤0.05, ** - P≤0.01 for the parameters analyzed within each species.

The coefficients of linear correlation (r) between the weight of meat samples collected from different animal species vs. drip loss and cooking loss are presented in **Table 4**. The mean values of r ranged from -0.39 to 0.11 for drip loss, and from -0.64 to 0.01 for cooking loss. The values of r were negative in most cases, and statistical significance (P>0.05) was not found for any of the values.

Table 4. Coefficients of linear correlation (r) between drip loss and cooking loss vs. the weight of meat samples (g) used to analyze these parameters

Species	Gender/muscle	Parameter		
			weight of the sample for drip loss assessment (g)	weight of the sample for cooking loss assessment (g)
Kamieniec sheep (stage 1)	female/(*LL*)	drip loss (%)	-0.01	-
	female/(*QF*)		-0.22	-
red deer	female/(*LL*)		-0.21	-
	male/(*LL*)		-0.39	-
roe deer	female/(*LL*)		-0.30	-
	male/(*LL*)		0.09	-
pheasant	male/(*PM*)		-0.08	-
	female/(*PM*)		-0.16	-
Alpine goat	male/(*QF*)		-	-
New Zealand White rabbit	male/(*LT*)		0.09	-
Kamieniec sheep	male/(*LL*)		0.11	-
Kamieniec sheep (stage 1)	female/(*LL*)	cooking loss (%)	-	-0.29
	female/(*QF*)		-	0.27
red deer	female/(*LL*)		-	-0.13
	male/(*LL*)		-	-0.43
roe deer	female/(*LL*)		-	-0.18
	male/(*LL*)		-	-0.26
pheasant	male/(*PM*)		-	-0.21
	female/(*PM*)		-	-0.64
Alpine goat	male/(*QF*)		-	0.01
New Zealand White rabbit	male/(*LT*)		-	-0.21
Kamieniec sheep	male/(*LL*)		-	-0.24

LL - m. longissimus lumborum, *LT - m. longissimus thoracis*, *QF - m. quadriceps femoris*, *PM - m. pectoralis major*.

Khan and Lentz ([1977)] analyzed the influence of different sizes of meat samples (10-200 g) collected from different beef muscles *(biceps femoris, semimembranosus, semitendinosus)* on the volume of drip loss and found that it decreased with increasing sample weights. According to the cited authors, this was due to the effects exerted by sample thickness and the surface-to-volume ratio. The curve illustrating the relationship between sample weight and drip loss showed that it was much more pronounced for samples weighing 50 g to 150 g than for those weighing less than 50 g and more than 150 g. This may explain the results of the present study where sample weight was not significantly correlated with drip loss or cooking loss because the weight of all analyzed meat samples was less than 50 g. Similar observations were made by Van Moeseke and De Smet [1999] who reported that the average volume of drip loss was greater in pork samples with standardized weight (average weight of 79 g) than in those with non-standardized weight (average weight of 151 g - 169 g). Similarly to the previously cited researchers, the authors of the above study also attributed their findings to the different surface-to-weight ratios of weight-standardized and non-standardized samples. According to Otto et al. [2004], the differences in drip loss between samples of the porcine *longissimus dorsi* muscle were due to their different surface-to-weight ratios. Drip loss was measured by two different methods using samples of considerably different weights. The findings of other researchers indicate that the correlation between sample weight and drip loss is not always negative. Logan et al. [2019] analyzed the effect of weight (60 g and 80 g) of muscle samples *(musculus longissimus thoracis et lumborum)* on drip loss in alpacas and found that heavier samples were characterized by greater drip loss.

The experiments conducted by Christensen [2003] and Otto et al. [2004] suggest that drip loss is affected by both sample size and sampling position on the muscle. In their studies, samples of the porcine *longissimus dorsi* collected at the dorsal position (top) were characterized by lower drip loss than samples collected at the ventral position (bottom). Christensen [2003] also observed that drip loss was greater when samples were collected from the caudal part of the muscle, compared with the caudal part. The above data show that not only sample weight (size), but also the muscle sampling region are important considerations in the methodology of water-holding capacity assessment, due to the heterogeneity of the measured object (muscle). Therefore, both the results of the present study and the findings of other authors should pave the way for further research, including the standardization of methods for assessing drip loss. The practical problems faced by researchers during muscle sampling should also be considered. The collected samples need to be large enough to perform multiple laboratory analyses [Logan et al. 2019], which can be challenging especially in small animals such as rabbits and lambs. An example could be the measurement of drip loss by the popular bag method where samples weighing 80 g - 100 g should be used, as described by Honikel [1987].

CONCLUSION

1. The size (surface area and volume) of *LL* and *QF* muscle samples of standard shape, collected from Kamieniec lambs, had no significant (P>0.05) effect on drip loss or cooking loss (stage 1 of the study). Samples of the LL muscle, regardless of their size, were characterized by slightly greater drip loss.
2. The values of the linear correlation coefficient (r) between the weight of muscle samples collected from different animal species (sheep, goats, rabbits, red deer, roe deer, and pheasants) vs. drip loss and cooking loss were not significant and negative in most cases (stage 2 of the study).
3. Due to small differences in the size and weight of the analyzed muscle samples, further research is needed to determine the importance of sample standardization in terms of shape, size, and weight in the assessment of the water-holding capacity of muscles based on measurements of drip loss and cooking loss.

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