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Determining Relationships between Marbling Scores and Carcass Yield Traits of German Beef Bull Carcasses Using Video-Image Analysis at the 12th and 10th Rib Position of *Longissimus Thoracis* and EUROP Classification

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Abstract: In contrast to other international beef classification systems, the European EUROP system disregards marbling in meat quality assessment. Instead, it focuses primarily on the assessment of conformation and fat score. Due to the lack of more specific assessment, beef quality in Germany is less known than beef produced in other countries and is largely incomparable to international standards. The aim of this study was to explore the potential of video-image analysis (VIA) for the assessment of bull carcasses for the commercial beef market in Germany. Marbling scores and carcass traits of 170 carcasses were assessed at the 10th/11th and 12th/13th rib-eye sections of *longissimus thoracis*. Results showed that VIA is able to precisely assess marbling scores at a German cutting position with a close relation (r = 0.83) to the US position. Furthermore, carcass traits integral to the US Yield Grade, such as rib fat (mean 112 mm) and a modified trait of fat/meat ratio, were assessed at the 10th/11th rib-eye position in a process reliably corresponding to the US position (mean 98 mm). EUROP traits showed only weak relationships with marbling scores, VIA measured rib fat thickness, and carcass weights. Although complete validation of video image analysis requires further research with a higher number of test animals, VIA is a viable tool for classifying the variation of German beef carcasses more reliably during the slaughter line and it could valuably supplement EUROP classification traits.

Keywords: Video-Image Analysis; marbling scores; carcass classification

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1. Introduction

In Germany, the classification of beef carcasses focuses almost exclusively on the European EUROP system, which includes the semi-quantitative estimation of conformation and fat score according to weight, age and sex of animal [1]. This system was developed in different European countries as a basis for common trade of carcasses and to have comparability in the amount of saleable meat from each carcass [2]. Although limitations and disadvantages of the EUROP concept have been criticized at length for the subjectivity of the assessment and having no link to meat quality traits [1,3,4], German industrial beef classification still disregards quality attributes such as marbling scores and the instrumental assessment of carcass traits in the slaughter line. Furthermore, European beef breeders primarily produce highly muscled beef carcasses with moderate fat, which is well known for contradicting sensory quality attributes [1,3].

As the subjective assessment of carcass conformation no longer fulfills the increasing demand for quality attributes on the European market, Monteils et al. [1] and Bonny et al. [3] emphasized the need for additional traits and the implementation of objective systems to better classify, and in the long term, increase the value of high-quality beef carcasses within the industrial slaughter line. It is not by accident that marbling has become the determinant trait in international beef grading systems as it is highly correlated to the

sensory traits of juiciness, tenderness and flavor of meat [5–7]. In Australia, Japan, the United States (US), Canada and South Korea, grading systems based on yield and quality grades, including video-image analysis (VIA)-based solutions, have been implemented since the 1980s to assess carcass traits at different rib positions of *longissimus thoracis* within the slaughter line without any destruction to the carcass [8–11]. As the demand for highly marbled beef increases in Germany, and at least a few European countries are already trying to explore improved grading schemes based on Meat Standards Australia (MSA) [12] for the assessment of carcass traits, the need for a viable solution for the assessment of marbling score as well as yield grade is evident.

Besides a general hesitation to include meat quality traits in the EUROP classification system, the use of video-image analysis in the German process line is also hampered by varying cutting positions. While US beef carcasses are ribbed and graded at the 12th/13th rib position of *longissimus thoracis*, the German beef market does not demand any standard rib-eye cutting position. Carcass cuts differ due to regional and marketing reasons as well as different processing steps [13]. Therefore, comparability of quality and yield traits between European carcasses is not given.

To adapt the VIA system to different cutting systems, information about the comparability of assessed marbling scores at different positions is necessary, but has been insufficiently studied [14–18]. Instead, most recent research is concerned with the comparison of intramuscular fat content and visual appraisal of marbling. In a previous study, the correlation of VIA marbling scores at the 10th/11th rib-eye position and the 12th/13th rib-eye position was assessed on carcasses of young heifers [18]. But as this study included only carcasses of heifers, information about marbling scores of bulls' carcasses representing the German industrial beef market is needed. As the German beef market is mainly dominated by carcasses of young bulls and heifers only represent a small number of carcasses slaughtered in Germany, additional information about marbling scores and yield grade traits from carcasses of bulls which differ in conformation score to optimize the validation of the VIA system is inevitable. The aim of the current study was to explore the use of a VIA system to estimate marbling score and yield grade of young bull carcasses at the cutting positions at the 10th/11th rib of *longissimus thoracis* in relation to the US cutting position. This position was chosen because older studies indicated that marbling scores at this position had the highest correlations to visual appraisal and intramuscular fat content at the 10th–13th rib position of *longissimus thoracis* [19]. Additionally, this position is already established as one of the industrial standardized positions in northern Germany. Furthermore, the relationship between marbling scores and EUROP fat classes and trade grades were analyzed to investigate the usability of EUROP traits for the prediction of beef quality attributes.

2. Materials and Methods

2.1. Selection of Carcasses

The investigation was carried out at six different dates in a slaughterhouse in the north-east of Germany. The carcasses were those of 300 young bulls of various breeds such as Holstein Friesian, Angus, Simmental, Uckermarker as well as different crossbreds from north-east Germany. They are representative of the different types of young bull carcasses that are slaughtered for the German beef trade. Information about the feeding regime and the housing conditions was not available. Carcass halves were stored between 2 to 7 days at 0–2 °C. Hot carcass weights ranged from 357 up to 430 kg (mean: 318.4 kg). Animals were between 18 and 28 months old (mean: 22 months). EUROP trade grades and fat classes were estimated by graders at the slaughterhouse. Carcasses were classified with fat classes from 1 to 3+, while trade classes ranged from P to U.

2.2. Assessing Marbling Scores and Yield Grades

The left or right halves of the 300 carcasses were ribbed. Marbling scores and yield grades were directly estimated using the VIA-based camera system VBG 2000 (e+v, Oranien-

burg) at the rib-eye cut between the 10th/11th rib interfaces of *longissimus thoracis*. All halves were further ribbed to assess marbling scores and yield grades (including meat surface, rib fat thickness and carcass weight) at the US grading position between the 12th/13th rib section. The official numerical USDA (United States Department of Agriculture) marbling scores, Practically Devoid (100–199) Traces (200–299) Slight (300–399), Small (400–499), Modest (500–599), Moderate (600–699) and Slightly Abundant (700–799), were used. Assessment of the yield grades at the 12th/13th rib-(eye section included the parameters of hot carcass weight, measured subcutaneous fat thickness and rib-eye area using the established yield formula of VBG 2000.

VBG 2000 was initially created to classify US beef carcasses. It is a camera-based system with special lighting to photograph the rib-eye. It is positioned at the spinal channel, the ribs and the meat surface [18]. All measurements were taken on the same flat surface. Images of each rib-eye were linked to processing software. The images erroneously included the outside area of the rib-eye *musculus spinalis* because of its different size at the 10th/11th rib-eye section. Software predictors and colour values of VBG 2000 were generated for the larger 12th/13th rib-eye position. Therefore, it was later necessary to modify the digital estimation thresholds and colour values with the developer of VBG 2000 (e+v, Oranienburg, Germany) [18].

The process line and the butchers were not familiar with the new cutting position and the changed size of the rib-eye, resulting in improper cuts of the meat surface. Thus, 126 of the 300 selected carcasses could not be assessed in the slaughterhouse. A correct camera assessment requires a very accurate cut but as this was not always provided, it was not possible to capture all carcasses in pictures. Consequently, with some carcasses, not all parameters could be reliably assessed. In total, complete data could be assessed for 174 carcasses.

VBG 2000 usually includes kidney pelvic heart (KPH) fat as a yield parameter but this was not possible to assess at the 10th rib position in the current study because there was no occasion to scan the whole carcass. Furthermore, the rib-eye size at the 10th/11th rib-eye position could not be determined precisely in this investigation due to the inaccurate rib-eye cut. Instead, the images were segmented into pixels of beef and fat and the ratio of beef pixels/fat pixels in the defined surface of rib-eye muscle was calculated to better determine the amount of saleable beef in the muscle (Figure 1, left image). In all cases, yield grade at the 10th/11th rib-eye section was assessed retrospectively with a modified formula adapted to the modified image thresholds: 25.1088 + hot carcass weight $\times$ 0.002488168 + number of meat pixels $\times$ $-$16.72879 + meat/fat ratio $\times-$0.4330382 + number of fat pixels 23 $\times$ 0.01327071 + number of meat pixels $\times$ 0.001183337+ number of fat pixels 12 $\times$ $-$0.1445752. Rib fat thickness was measured at the same position as the US position (Figure 1).

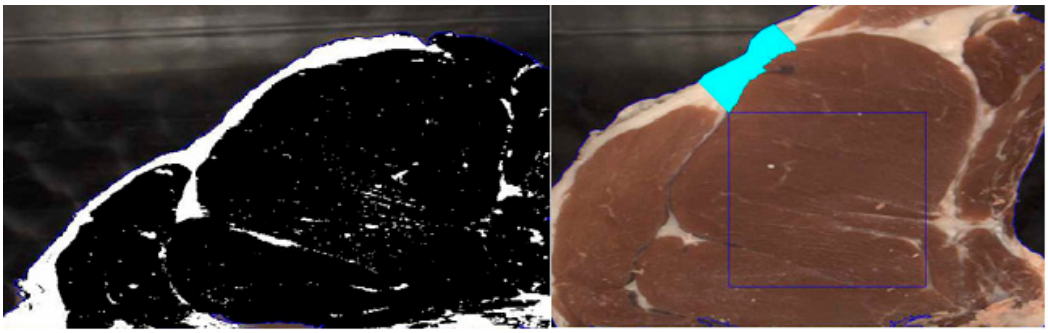

Figure 1. Visualisation of the segmentation of meat and fat pixels (**left**) and the standardized position for the assessment of the rib-eye fat thickness at the 10th/11th rib position (**right**).

2.3. Statistical Analysis

After grading in the slaughterhouse, the slaughter data of carcasses was linked with assessed EUROP trade grades and information about breed, weight, age and sex. Statistical analysis was carried out using SPSS (version 19.0, IBM Inc., Ehningen, Germany). EUROP trade grades and fat classes (1 to 4) were conformed numerically from E to P into a 15-point scale, using the upper (+) and lower (−) categories [18]. Pearson correlation coefficients were calculated for marbling score at both positions, EUROP trade grade and fat class, slaughter weight, subcutaneous fat (rib fat thickness) yield grades at both positions and calculated fat/meat ratio determined by the described formula.

3. Results

Estimated marbling scores and results from the assessment of main carcass traits are given in Table 1. In total, yield grade traits and marbling scores of 170 carcasses were assessed. The marbling scores ranged from 228 to 803 at the US position and from 200.2 to 942 at the 10th/11th rib position. Average marbling scores at the 12th/13th rib position (392) were comparable to those at the 10th/11th rib position (385). The differences between the marbling scores at both positions ranged between −139 and −118 marbling points. 107 of the carcasses had higher marbling scores at the 12th/13th rib eye section. Only four carcasses were categorized in the different trade classes Prime, Choice or Select, at the two different positions. All in all, the calculated yield grades showed similar results at both positions. Subcutaneous fat was slightly higher at the 10th/11th rib position than at the12th/13th rib position.

Table 1. Assessed marbling scores and measured carcass traits.

	Marbling 10th/11th rib	Marbling 12th/13th rib	YG 10th/11th rib	YG 12th/13th rib	Subcutaneous Fat 10th/11th rib (cm)	Subcutaneous Fat 12th/13th rib Position (cm)
Mean	385	392	2.0	2.0	1.12	0.98
Min	200	228	1	1	0.27	0.27
Max	943	803	3.8	3.9	2.57	1.92
SD	76.6	76.8	**0.7**	**0.4**	**0.52**	0.41

SD = Standard deviation.

Pearson correlation coefficients of all carcass traits are shown in Table 2. Close and significant relations were calculated between marbling scores at the 10th/11th and the 12th/13th rib position of *longissimus thoracis* (r = 0.82 ** and R = 0.64). The correlation of marbling scores at both positions is highly significant.

Table 2. Pearson correlation coefficients of the assessed carcass traits.

	Marbling 10./11.	Marbling 12./13.	Age	YG 10./11.	YG 12./13.	Rib Fat 10./11.	Rib Fat 12./13.	Weight	EUROP Trade	EUROP Fat
Marbling 10./11.	1.00	0.831 **	0.09	0.15	0.04	0.12	0.04	−0.04	−0.48	−0.04
Marbling 12./13.		1.00	0.09	0.16	0.10	0.07	0.07	0.03	−0.36	−0.21
Age			1.00	−0.09	−0.12 *	0.04	0.15	−0.14	0.27	−0.27
YG 10./11.				1.00	00.65 **	0.33 **	0.46 **	0.27 **	0.03	−0.41
YG 12./13.					1.00	0.37 **	0.41 **	0.41 **	−0.04	−0.52
Rib fat 10./11.						1.00	0.37 **	0.40 **	0.75	−0.52
Rib fat 12./13.							1.00	0.17 *	0.43	−0.41
weight								1.00	0.64	−0.28
EUROP trade									1.00	−0.36
EUROP fat										1.00

(*) statistical significance $p < 0.01$. (**) statistical significance $p < 0.05$.

The distribution of marbling scores at both positions is visualized in Figure 2. The mean difference of marbling scores at both positions was 5 marbling points (SD: 46). The differences between both positions varied between −93 and 193 marbling points. With higher marbling scores (>800), the differences between marbling scores at the two positions increased. In general, the distribution of grading categories Select, Choice and Prime were only slightly influenced by the different positions. In total, 8 carcasses were categorized into different categories according to the rib-eye position. Marbling scores and EUROP fat classes showed no relationship at the German position (r = 0.1) and slightly negative relationships at the US position (r = −0.2). EUROP trade grades and marbling scores showed slightly negative correlation coefficients at the US rib position (r = −0.36) and at the 10th/11th rib position (r = −0.04). Furthermore, weak negative relationships were found for subcutaneous fat at both positions and EUROP fat classes (r = −0.41 and r = −0.52).

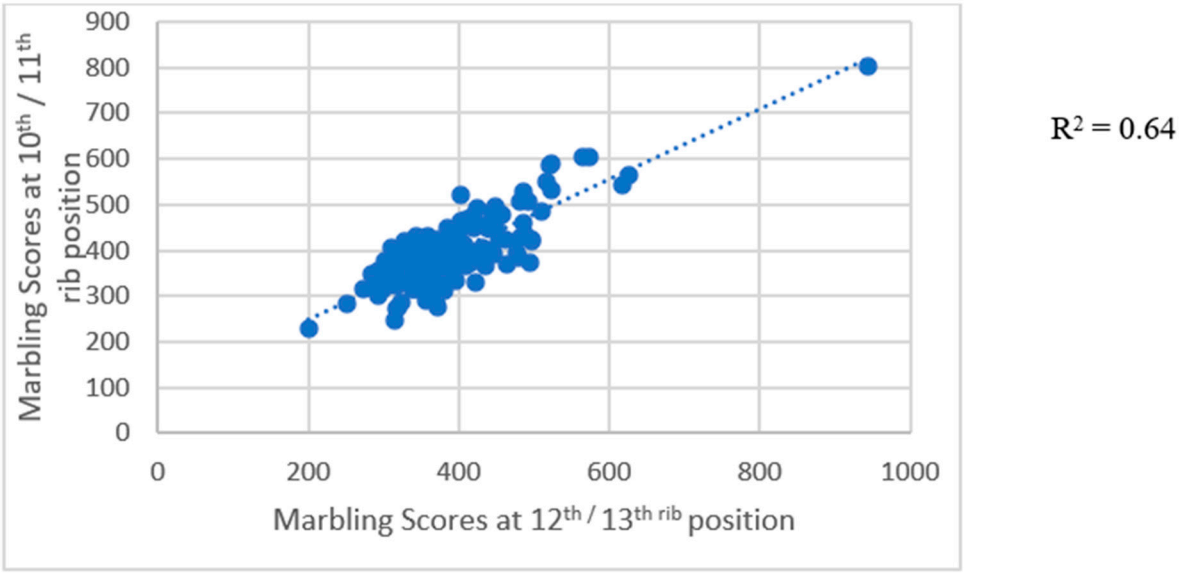

Figure 2. Distribution of marbling scores at the 10th/11th and the 12th/13th rib-eye position.

4. Discussion

4.1. Methodology

The main object of this study was to assess the marbling level of carcasses from young bulls produced for the German beef market. This study included only 174 carcasses of bulls and the selection of the sample was limited. It needs to be increased to a representative sample of German bull carcasses. However, the very heterogeneous nature of the sample enabled comparisons of the results of VIA at different positions in a wide variation of carcasses. Furthermore, when butchers are not familiar with the different cuts, and when the process line is not adapted to the US rib-eye cutting systems, training for accurate rib-eye cutting is essential.

In the current study, a high number (n = 126) of carcasses could not be assessed because of the lack of cutting routines. In future, this obstacle could be easily solved by adapting the slaughter line and the VIA hardware to focus on the 10th/11th rib section and training slaughterers. Other international beef grading systems show that new cuts can be quickly learned and routinely adapted into the slaughter line. To develop and validate a general formula, the VBG 2000 camera has to be adapted to the different size of the 10th/11th rib position to reduce the type of placement errors which occurred in the current study and further research has to be conducted. The assessment of marbling scores using VBG 2000 has been validated in earlier studies with high accuracy and repeatability at the 12th rib-eye position [10,20–22]. VBG 2000 showed close relationships (r = 0.94 and r = 0.84)

with the chemical analysis of Intramuscular fat content (IMF) [21,23]. The close correlations of marbling scores at the 10th/11th rib-eye position and the 12th/13th rib-eye position in this study are in accordance with the results of a recent explorative investigation using VBG 2000 at these two positions [18]. In contrast, Konarska et al. [16] compared French and Polish beef carcasses at different muscles using near-infrared spectroscopy and image analysis based on Beef Analyzer II Software. The results of trained graders using the USDA marbling scores and the Australian grades reached a lower correlation coefficient (r = 0.53) between the different positions. The authors emphasized that the prediction of marbling at one position might be used for the classification of the entire carcass quality, but the variation of marbling between different positions needs to be considered. Vote et al. [23] used BeefCam, a technique that is based on VIA (n = 288) to classify Uruguayan beef carcasses at the 10th rib-eye section and explored the use of self-created software to assess marbling scores at the 12th/13th rib position. The authors concluded that marbling could not be estimated precisely with the applied equipment. Considering the high correlations of assessed marbling scores at both positions in the current study, VBG 2000 could be easily used to assess marbling scores at the 10th rib with high comparability to the US position, although the threshold borders of rib-eye would have to be adapted to the different rib-eye size at the 10th/11th rib-eye position.

4.2. Marbling Scores

The marbling scores assessed by VIA at both rib positions in this investigation were slightly higher than marbling scores of young bull carcasses that were assessed at the 10th rib position using the Australian MSA grading scheme with trained graders [12]. The comparison of the results with other assessed marbling scores is difficult as there are only a few studies about VIA-assessed marbling scores of young bull carcasses. Carcasses from bulls are mostly classified using EUROP traits or intramuscular fat content. Although VIA marbling scores and the analysis of intramuscular fat content reached high correlations [20,21], visual marbling and intramuscular fat content describe different carcass traits. Fiems et al. [24] investigated very low mean values for the amount of intramuscular fat content at the 8th rib section of *longissimus thoracis* for double-muscled bulls (0.9%) and higher mean values for non-double-muscled bulls of different Belgian breeds (3.0%) that had higher carcass weights (413 kg) than in the current study. Yang et al. [25] found low intramuscular fat contents (2.5%) of German Charolais crossbreeds and German Holstein bulls. In contrast to a recent study [18], the assessed marbling scores were slightly higher at the 12th/13th rib-eye section. In the same recent investigation [18], carcasses of young German heifers of different breeds reached slightly lower marbling scores than in the current study assessed with VBG 2000 at the 10th/11th rib-eye position of *longissimus thoracis*. However, the authors emphasized the low quality of the German carcasses in comparison to carcasses used in US studies with larger samples [18]. Based on the large number of studies which emphasize that heifers and steers tend to show higher marbling scores than bulls [26], these differences may be explained by the very low quality of the assessed carcasses from these particular heifers.

The variation of marbling scores (385 to 942 marbling points) obtained in the current study was higher than that found in other studies [18]. This is mainly due to the targeted heterogeneity of the carcass samples to include beef and dairy cattle of different age and slaughter weight, and deriving from different farms and genotypes. Although the carcasses were heterogeneous, they were all produced for the German beef market and reflect high inconsistency in beef quality. Thus, the need for viable tools to standardly assess and classify the different marbling levels of German carcasses is obvious.

EUROP fat classes showed only weak correlations with the marbling scores at both positions. In accordance with this, a study done by Bonny et al. [3] indicated that EUROP fat classes were not useful for predicting sensory eating quality traits. In contrast, Schulz and Sundrum [18] found higher correlations between visually assessed EUROP fat classes and VIA-assessed marbling scores of carcasses from heifers at the 10th/11th rib position

(r = 0.40) and the US position (r = 0.36). Konarska et al. [16] determined slightly lower correlations (r = 0.30) between EUROP fat class and MSA marbling scores of male and female beef and dairy breed carcasses at the 12th/13th rib-eye section. In the current study, EUROP trade grades showed even higher correlations with marbling scores than with EUROP fat classes. Since the relationships between the degree of marbling and the amount of fat of the whole carcass have been discussed at length [27], weak relations between EUROP fat class and marbling were expected. However, the precision of EUROP fat classes is not sufficiently guaranteed. The current results support the conclusions made by others [1,3,8,12,16] that EUROP traits are not suitable for classifying beef quality attributes and need to be modified.

4.3. Yield Grades

The European classification system of beef focuses on the estimation of subcutaneous fat and muscling of the carcass. The question arose as to whether this system could be modified to improve classification of European carcasses. At German abattoirs, quantifying KPH-fat and rib-eye size is not part of the routine. Therefore, the parameters describing the yield grade of carcasses using VIA had to be modified and are, thus, not directly equivalent to the results obtained by the US approach. Furthermore, it must be considered that the absence of an accurate rib-eye cut, a necessity for the VIA assessment, hampered the assessment in the slaughter line.

Carcasses assessed in the current study had similar carcass weights to those in recent studies with European beef breeds [28]. In contrast, variation of slaughter age was higher than in other studies [28,29]. Although targeted for heterogeneity, the carcasses were randomly chosen in a commercial slaughterhouse and the results represent a typical sample of carcasses produced for the German beef market. Measured rib fat thickness varied widely between the different positions. Rib fat thickness measurements at the 12th rib positions in the current study were slightly higher than in other studies on beef steers [30] and lower than on carcasses on Yearling bulls measured at the 12th rib position. In contrast, rib fat at the 10th rib position was lower than in a comparable study [30]. Weak correlations between the measured rib fat thickness at both positions highlighted the amount of variation/the variation of fat distribution in muscles, which corresponds with the results in other studies [16].

Calculated correlation coefficients showed positive trends between EUROP trade grade and the yield grade, but weak negative correlations between EUROP fat class and subcutaneous fat at both positions. In contrast, weaker positive relations for measured rib fat and EUROP fat class for bulls (r = 0.47), heifers (r = 0.5) and steers (r = 0.4) were found by Liu et al. [12]. While a weak relationship between the graded fat class and the measured subcutaneous fat was expected, the results of the current study indicate that the measurement of subcutaneous fat thickness might replace subjective grading of the EUROP fat score. As rib fatness can be easily measured by VIA at the rib-eye positions, the implementation of VIA-measured rib fat in European classification systems would be useful in classifying carcasses in a more objective and reliable way. Correlations between measured subcutaneous fat at both rib positions were lower (r = 0.65) than correlations between marbling scores (r = 0.8), but highly significant. Considering its high precision and the reliable use of VIA as the gold standard in US grading systems, results of measured rib fat thickness may easily supplement the subjective EUROP grading system. However, this does not provide information for predicting the meat quality of carcasses [16].

The current study explored only a few traits that are included in US yield grading. Since the European classification contains different parameters to those used in other international beef grading schemes, a complete adoption of the American system is not necessary. Rather, it is a matter of integrating important parameters, such as marbling and rib fat, into the classification in order to supplement EUROP traits and enrich the information about qualitative aspects of carcasses used in processing and marketing strategies. Classifying the different quality levels may lead to an adapted distribution of carcasses

according to the different requirements of the various markets, processors or consumers in the process line [31]. Considering the fact that other studies already emphasize the high accuracy of VIA in predicting carcass traits [20–22], the implementation of VIA in European classification systems is highly recommendable, if not essential.

Given the standardized use of VIA in international grading systems as well as the importance of qualifying sensory traits of beef carcasses, the need for modification to the European classification system is evident. The given VIA system and other comparable solutions might be usable in different sizes of abattoirs and at different levels of industrialization. Given the long use of VIA in international grading systems, its adaptation to different slaughterhouses might be easy.

The VIA system not only considers EUROP traits such as carcass weight and fat thickness, it also enables, in contrast to the subjective EUROP fat score graders, a highly objective assessment of fat scores at the rib-eye section. Due to its objective assessment of carcass traits, classification and, in a further step, categorization of carcasses could become easier and more reliable using VIA. Currently, there is insufficient knowledge about meat quality in carcasses of fattened bulls raised in Germany and thus a lack of quality differentiation. This lack, together with the large variation in the composition of German beef, calls for an objective assessment of the quality of every single carcass. This assessment might be undertaken using different methods of assessment, but finally, different evaluation methods need to be comparable. This would provide pertinent information about quality differences and set highly marbled carcasses apart from average quality carcasses.

Further, a standardized assessment of beef quality would allow both better classification of carcasses and differentiation of quality traits during the slaughter line process. As the demand for highly marbled beef increases, the European beef market must produce beef which satisfies demands for various levels of quality.

5. Conclusions

The EUROP classification system of beef carcasses does not include the assessment of marbling as a pertinent quality trait. Although further research including larger samples of carcasses from different regions is needed, the results of the current study showed that the VIA-based system can assess the marbling scores of bull carcasses at the 10th rib position of *longissimus thoracis* that correspond to the US position. Considering its long use as the gold standard and the high accuracy of VIA in international beef classification, this system could also be a viable solution for the European beef market to assess marbling as well as the conformation score and yield grade of European beef carcasses in a profound and objective way. Modification to the EUROP classification scheme is highly recommended to better differentiate the high variation of beef carcass traits and, consequently, support quality-orientated beef production.

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