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Study of beef blade muscles' differentiation depending on conformation and fat class

Dominika GUZEK[1,*], Dominika GŁĄBSKA[2], Ewa LANGE[2], Krzysztof GŁĄBSKI[3], Agnieszka WIERZBICKA[1]
[1]Division of Engineering in Nutrition, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences, Warsaw, Poland
[2]Chair of Dietetics, Department of Dietetics, Faculty of Human Nutrition and Consumer Sciences, Warsaw University of Life Sciences, Warsaw, Poland
[3]Department of Microbial Biochemistry, Institute of Biochemistry and Biophysics, Polish Academy of Sciences, Warsaw, Poland

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Abstract: The object of this study was to identify variation of the intramuscular fat and connective tissue content in different blade muscles in carcasses characterized by various quality grades. It was found that there is a cumulative impact of muscle and conformation class on intramuscular fat in blade muscle ($P = 0.0330$), as well as type of muscle and fat class ($P = 0.0424$), but there is no cumulative impact of conformation class and fat class ($P = 0.1788$). There is no cumulative influence of muscle type, conformation class, and fat class on amount of connective tissue in blade muscle, but the infraspinatus muscle was characterized by the highest quantity of connective tissue. The differences in the content of intramuscular fat in blade muscles depend on type of muscle as well as fat or conformation class, but there is no cumulative effect of fat and conformation class.

Key words: Connective tissue, conformation class, fat class, computer image analysis

1. Introduction

Income in beef cattle production all over the world is nowadays to a great extent connected with consumer desire to eat high-quality beef, as well as carcass-specific quality traits (1). In Europe, beef producers profit on the basis of animal weight at slaughter, conformation class (EUROP), and fat class scores (classes 1–5) (2). In other countries such as Australia, the United States, or Japan, the quality grade of beef is also based on marbling score. Marbling is defined as a visible adipose tissue located between muscle fibers (3). Intramuscular fat can also be quantified chemically, but such measurement is not included in the definition of marbling. The authors of some studies stated that marbling is positively correlated with the carcass fatness (4), the indirect improvement in tenderness (5,6), and, as a result, the general eating quality. Marbling is increasingly used to evaluate quality of beef in the meat industry (7).

It is well known that cuts may be perceived in different ways by consumers, but the quality is mainly associated with the type of cut, as was shown in the research of Lorenzen et al. (8). The type of cut is the factor that determines muscle function in vivo as well as marbling, connective tissue proportion, and other factors (9).

The objective of this study was to identify variation of the intramuscular fat and connective tissue content in different blade muscles in carcasses characterized by various quality grades.

2. Materials and methods

The materials of the study were beef blade muscles samples (infraspinatus, supraspinatus, triceps brachii caput laterale, triceps brachii caput longum, and triceps brachii caput mediale) obtained from 33 beef crossbreds of Limousine bull and Holstein Friesian cows obtained in the project 'Optimizing beef production in Poland according to strategy from fork to farm' (Contract No. UDA-POIG.01.03.01-00-204/09-06). For each sample of the blade muscle, conformation class and fat class were defined according to the EUROP system (10). In the case of some carcasses, blades from both sides were analyzed. Samples were packed and stored for 5 days at 4 ± 2 °C (each group in the same conditions) until the instrumental analyses were conducted.

2.1. Computer image analysis

Visible fat and connective tissue content in raw muscles were determined by computer image analysis as published previously (11). Samples of raw meat were 2.5-cm-thick steaks. The pictures of beef steaks after blooming for 30 min were taken with a CD QImaging MicroPublisher 5.0 RTV

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* Correspondence: dominika_guzek@sggw.pl

camera to ensure consistent color development. Samples were placed on a matte green background to ensure easier segmentation. The photos were taken under fluorescent light in standard conditions (color temperature 5400 K, similar to sunlight) for both sides of the sample. The images were captured and saved as pictures (.tif format). Noises were removed effectively with a 3 × 3 median filter. The ratios of area of fat tissue and connective tissue were calculated separately using Image-Pro Plus 7 (Media Cybernetics, Silver Spring, MD, USA).

2.2. Statistical analysis

To characterize the relationships between the analyzed factors, analysis of variance (ANOVA) and the post hoc Scheffe test were used. To define the significance of correlations, a level of significance of $P \leq 0.05$ was accepted. Statistical analysis was conducted using the Statistica 8.0 by StatSoft (Tulsa, OK, USA).

3. Results and discussion

3.1. Influence of the analyzed traits on intramuscular fat

The condition of beef cattle production in Poland is similar to the situation in other countries where there is no tradition of high-quality beef production with a modest or high degree of marbling. Despite the fact that carcasses are characterized by varying thicknesses of fat cover, sometimes very high, they have low or very low levels of marbling (12). Consequently, identification of the decisive factors affecting marbling level would be of great value.

An ANOVA analysis was performed to investigate the impact of muscle type and conformation class (Table 1) on intramuscular fat in blade muscle ($P = 0.0330$). Post hoc analysis indicated, in comparison between individual samples, that there was significant difference in the fat class O between supraspinatus and triceps brachii caput mediale muscle. Triceps brachii caput mediale muscle was characterized by higher levels of fat tissue ($P = 0.0113$). There were no other differences between muscles.

Studies of other authors indicate a general relationship between conformation class and the composition of the carcass measured by bioimpedance (13). Therefore, it seems to be necessary to determine the influence on intramuscular fat, which is exerted not only by the cuts, but also by single muscles, as their characteristics within a single cut may be different.

The results of Bohuslávek (13) indicate the important role played by the size of the carcass, as well as its composition, in determining the conformation class and thus final meat quality. This study was limited to assessment of only one cut, blade, and strong dependencies were not observed, which might result from the small differences in quantity of fat tissue in the case of blade rated as O and P classes. However, another issue should be taken into account — the significant difference in intramuscular fat content — in the case of analyzed O class samples, which depends on the muscle. The observed differences between supraspinatus and triceps brachii caput mediale muscle were probably the result of the characteristics of muscles and their function in vivo, which might be different for muscles from the same cut.

Table 1. The amount of intramuscular fat and connective tissue in blade muscle samples characterized by various conformation class: results of 2-way ANOVA analysis.

Muscle	Conformation class*	n	The amount of intramuscular fat		The amount of connective tissue	
			Mean ± SD	Min–max (median)	Mean ± SD	Min–max (median)
Infraspinatus	O	16	1.7 ± 0.4ab	1.1–2.3 (1.8)	11.9 ± 2.2a	8.7–14.3 (12.2)
	P+	4	2.3 ± 0.3ab	2.1–2.5 (2.3)	9.2 ± 0.7ab	8.7–9.7 (9.2)
Supraspinatus	O	12	0.7 ± 0.7a	0.1–1.8 (0.4)	1.3 ± 0.8b	0.7–2.5 (0.9)
	O–	4	0.4 ± 0.1ab	0.3–0.4 (0.4)	0.7 ± 0.2b	0.5–0.8 (0.7)
Triceps brachii caput laterale	O	4	1.5 ± 0.4ab	1.2–1.8 (1.5)	7.3 ± 0.2ab	7.1–7.4 (7.3)
Triceps brachii caput longum	P+	8	2.1 ± 0.2ab	1.8–2.4 (2.1)	6.4 ± 0.6ab	5.6–7.0 (6.5)
Triceps brachii caput mediale	O	36	1.9 ± 0.5b	0.8–2.8 (2.0)	3.6 ± 1.9b	0.5–7.0 (4.0)
	O–	36	1.3 ± 0.6ab	0.5–2.5 (1.3)	5.0 ± 4.1b	1.1–16.1 (3.7)
	P+	12	1.2 ± 0.2ab	0.8–1.4 (1.2)	3.7 ± 1.8b	1.4–5.9 (3.9)

Values in the same columns with different letters are significantly different ($P \leq 0.05$).

*: Conformation classes in the EUROP system. O classes – Fair – Profiles straight to concave, average muscle development; P classes – Poor – All profiles concave to very concave, poor muscle development.

As support for our findings, Totland and Kryvi (14) reported in their studies on the characteristics of bulls muscles that the blade muscles are significantly diverse because supraspinatus muscle consists of the muscle fibers of type I whereas triceps brachii (caput longum and caput laterale) consists of muscle fibers of type IIB and IIA.

The muscle type and fat class (Table 2) significantly affected the amount of intramuscular fat in blade muscle according to the ANOVA analysis (P = 0.0424) in this study. Post hoc analysis indicated that the supraspinatus muscle in class 1+ was different from most other muscles. This muscle was significantly different from triceps brachii caput mediale muscle in fat classes 1+ (P = 0.0060), 2– (P = 0.0073), and 2 (P = 0.0093), as well as from triceps brachii caput longum muscle in fat class 2– (P = 0.0032) and infraspinatus muscle in fat classes 1+ (P = 0.0353) and 2– (P = 0.0009). There were no other significant differences between muscles.

In this case, an interesting relationship was also observed. It was indicated that samples from different muscles within the same fat class had different contents of intramuscular fat, but there was no difference for the same muscle samples from different fat classes. This could indicate the relatively minor association between fat class and marbling score in the case of blade muscle samples. Another study also indicated that the degree of correlation between marbling and fat cover, which largely determines the fat class, depends on other factors, including beef breed or feeding (15). The authors stated that fat cover does not have high predictive value for marbling (16,17); therefore, it is appropriate to determine the score of marbling as one of quality traits.

Using ANOVA, it was found that there was no cumulative effect of conformation class and fat class (Table 3) on the intramuscular fat (P = 0.1788). Post hoc analysis indicated that there were no differences between individual samples, although the general effect of fat class on the amount of intramuscular fat was observed (P = 0.0188).

It should be mentioned that in the case of the analyzed samples, the type of muscle was the main factor influencing marbling. In the case of cuts such as blade, which consist of many types of muscles including the anconeus, brachialis, coracobrachialis, deltoideus, extensor carpi radialis, infraspinatus, latissimus dorsi, subscapularis, tensor fasciae antebrachii, teres major, teres minor, triceps brachii caput laterale, triceps brachii caput longum, and triceps brachii caput mediale (18), this research could be very important to broaden the knowledge of muscle and to understand the differences between samples from various muscles.

Taking into account that the cutting of the carcass depends on the country and that sometimes in cuts there are muscles with different functions and characteristics (19), it may mask the effect of other factors, such as conformation or fat class in explanation of intramuscular fat.

3.2. Influence of the analyzed traits on connective tissue

Connective tissue in beef meat has a critical influence on the sensory characteristics of meat due to the fact that it affects the tenderness (20), which is the main textual trait of beef in consumer evaluation. An excessive proportion of connective tissue has negative impacts on beef quality,

Table 2. The amount of intramuscular fat and connective tissue in blade muscle samples characterized by various fat class: results of 2-way ANOVA analysis.

Muscle	Fat class*	n	The amount of intramuscular fat		The amount of connective tissue	
			Mean ± SD	Min–max (median)	Mean ± SD	Min–max (median)
Infraspinatus	1+	12	1.6 ± 0.4b	1.1–2.0 (1.7)	11.3 ± 2.2a	8.7–14.3 (11.0)
	2–	8	2.2 ± 0.2b	2.0–2.5 (2.2)	11.4 ± 2.6ac	8.7–14.0 (11.5)
Supraspinatus	1+	12	0.3 ± 0.1a	0.1–0.4 (0.3)	0.7 ± 0.1bd	0.5–0.9 (0.8)
	2	4	1.7 ± 0.1ab	1.6–1.8 (1.7)	2.2 ± 0.3abd	2.0–2.5 (2.2)
Triceps brachii caput laterale	2–	4	1.5 ± 0.4ab	1.2–1.8 (1.5)	7.2 ± 0.2abd	7.1–7.4 (7.2)
Triceps brachii caput longum	2–	8	2.1 ± 0.2b	1.8–2.4 (2.0)	6.4 ± 0.6abd	5.6–7.0 (6.5)
Triceps brachii caput mediale	1+	48	1.5 ± 0.6b	0.5–2.8 (1.4)	4.1 ± 4.0bd	0.5–16.1 (2.5)
	2–	24	1.6 ± 0.6b	0.8–2.5 (1.5)	4.4 ± 1.0bd	2.8–5.9 (4.3)
	2	12	1.8 ± 2.1b	0.8– 2.4 (2.1)	4.5 ± 0.8cd	3.2–5.3 (4.8)

Values in the same columns with different letters are significantly different (P ≤ 0.05).

*: Fat classes in the EUROP system. 1 – Low – None up to low fat cover; 2 – Slight – Slight fat cover, flesh visible almost everywhere.

Table 3. The amount of intramuscular fat and connective tissue in blade muscle samples characterized by various conformation and fat classes: results of 2-way ANOVA analysis.

Conformation class*	Fat class**	n	The amount of intramuscular fat		The amount of connective tissue	
			Mean ± SD	Min–max (median)	Mean ± SD	Min–max (median)
O	1+	40	1.5 ± 0.8a	0.1–2.8 (1.6)	5.0 ± 4.7a	0.5–14.3 (2.9)
	2–	12	1.9 ± 0.4a	1.2–2.3 (1.9)	8.4 ± 4.3a	4.0–14.0 (7.2)
	2	16	1.7 ± 0.6a	0.8–2.4 (1.9)	3.9 ± 1.3a	2.0–5.3 (4.1)
O–	1+	28	1.0 ± 0.5a	0.3–1.7 (1.0)	4.7 ± 4.9a	0.5–16.1 (3.1)
	2–	12	1.8 ± 0.7a	0.8–2.5 (2.0)	4.2 ± 1.2a	2.8–5.8 (4.1)
P+	1+	4	1.3 ± 0.1a	1.2–1.4 (1.3)	1.6 ± 0.3a	1.4–1.9 (1.6)
	2–	20	1.7 ± 0.6a	0.8–2.5 (1.9)	6.3 ± 1.9a	3.4–9.7 (6.2)

Values in the same columns with different letters are significantly different (P ≤ 0.05).

*: Conformation classes in the EUROP system. O classes – Fair – Profiles straight to concave, average muscle development; P classes – Poor – All profiles concave to very concave, poor muscle development.

**: Fat classes in the EUROP system. 1 – Low – None up to low fat cover; 2 – Slight – Slight fat cover, flesh visible almost everywhere.

because it has been shown that connective tissue could be the crucial factor determining meat tenderness (21).

Using ANOVA, we proved that there was no cumulative effect of muscle type and fat class (Table 1) on amount of connective tissue (P = 0.4027). However, post hoc analysis indicated that infraspinatus muscle was different from most other samples in fat class O. This muscle had significantly higher amounts of connective tissue than triceps brachii caput mediale muscle in fat classes O (P = 0.0000), O– (P = 0.0002), and P+ (P = 0.0009), as well as than supraspinatus muscle in fat classes O (P = 0.0000) and O– (P = 0.0023). There were no other differences between other muscles. Similar results were observed in the research of other authors, where significant differences in quantity of connective tissue (analyzed histometrically, as well as by using the hydroxyproline method) were proven for infraspinatus and triceps brachii muscle (22). In the mentioned research, as in our own presented research, infraspinatus muscle was characterized by the highest quantity of all analyzed muscles. On the other hand, another study indicated that quantity of collagen, being the main component of connective tissue in infraspinatus muscle, depends on animal being a dairy or beef animal, being comparable with triceps brachii and supraspinatus (23).

The muscle type and fat class (Table 2) did not significantly affect the amount of connective tissue in blade muscle according to the ANOVA analysis (P = 0.9078). However, post hoc analysis showed that 2 samples were significantly different from the others. Infraspinatus muscle in fat class 1+ was different from triceps brachii caput mediale muscle in fat classes 1+ (P = 0.0007), 2– (P = 0.0057), and 2 (P = 0.0359), as well as from supraspinatus muscle in fat class 1+ (P = 0.0000). Simultaneously, infraspinatus in fat class 2– was significantly different from triceps brachii caput mediale muscle in fat classes 1+ (P = 0.0065) and 2– (P = 0.0233), as well as from supraspinatus muscle in fat class 1+ (P = 0.0002). There were no other differences among the muscles.

It may be concluded that, for the quantity of connective tissue in blade muscles, neither conformation nor fat class is important. Significant differences are only visible in comparison of infraspinatus muscle, characterized by the highest quantity of connective tissue, with other muscles. Similar observations were indicated in previously cited research (22,23). It may be confirmed by analyzing the effect of conformation class and fat class on connective tissue content. There was no cumulative effect in blade muscle when taking into account ANOVA (P = 0.2122), as well as post hoc analysis (Table 3).

In conclusion, the overall impact of muscle type, carcass conformation class, and fat class on amount of intramuscular fat may be related to the functions of these muscles in vivo. The differences in the content of intramuscular fat in blade muscle depend on type of muscle and fat class or conformation class, but there is no cumulative effect of fat class and conformation class on this trait. In this study, no significant effect of muscle type and conformation or fat classes on connective tissue quantity was observed, but infraspinatus muscle was characterized by the highest quantity of connective tissue. It seems to be vital to conduct further research to evaluate the precise influence of muscle type on intramuscular fat and EUROP classification on intramuscular fat.

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