The effect of slaughter weight and fattening intensity on changes in carcass fatness in young Holstein-Friesian bulls

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Abstract

The objective of this study was to determine the effect of body weight (BW) at slaughter and fattening intensity on carcass fatness and meat fatty acid profile in young Holstein-Friesian bulls. One-hundred bulls fattened on two levels of intensity a semi-intensive (SI) and an intensive (I) were used. Fattening was carried out to BW of 500, 550, 600, 650 and 700 kg. Live ultrasound measurements were performed to determine back fat thickness. Carcass dressing percentage, carcass conformation and fatness, intramuscular fat content of m. longissimus dorsi and fatty acid profile (by gas chromatography) were determined after slaughter. Intensively fattened bulls were characterised by a greater carcass dressing percentage – by 1.17% on average, greater carcass conformation scores, greater external fat thickness and a greater intramuscular fat content than bulls SI fattened. Fat from intensively fattened bulls contained higher levels of polyunsaturated fatty acids (PUFAs) – by 1.0% on average. In view of the above, it would be interesting to determine the optimal final BWs of cattle kept in different fattening intensity, in order to enhance the health-promoting properties of beef.

Materials and methods

Experimental material

In the experiment 100 young bull Holstein-Friesian bulls were used. The calves were raised in a traditional system to 120 kg BW,
Table 1. Chemical composition and nutritional value ingredients of experimental diets (mean±SD).

| Specification | Silage (n=9) | Triticale (n=1) | Rapeseed meal (n=1) | Concentrate I (n=7) | Concentrate II (n=7) |
|---------------|-------------|----------------|--------------------|---------------------|---------------------|
| Dry Matter, g/kg DM | 397.00±109.30 | 881.00 | 887 | 883.90±7.10 | 885.50±8.20 |
| Organic matter, g/kg DM | 920.00±30.60 | 881.00 | 927.00 | 932±13.10 | 925±18.20 |
| Crude protein, g/kg DM | 141.00±11.40 | 133.00 | 388.00 | 189±15.10 | 163±7.10 |
| NDF, g/kg DM | 569.00±52.30 | 193.00 | 310.00 | 202±11.20 | 184±9.70 |
| ADF, g/kg DM | 387.00±59.20 | 44.00 | 228.00 | 72±5.80 | 31±8.20 |
| DOMD, g/kg DM | 741.00±55.90 | 932.00±26.50 | 848±0.40 | - | - |
| UFV, g/kg DM | 0.60±0.03 | 1.21 | 1.01 | 1.18±0.03 | 1.21±0.02 |
| PDIN, g/kg DM | 82.20±6.64 | 89.00 | 259.00 | 122±2.40 | 112±4.20 |
| PDIE°, g/kg DM | 69.50±2.28 | 109.00 | 163.00 | 129±2.40 | 121±2.40 |

DM, dry matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; DOMD, digestible organic matter in DM; UFV, meat fodder units; PDIN, protein digested in the small intestine when rumen fermentable N is limiting; PDIE, protein digested in the small intestine when rumen fermentable energy is limiting. *Fermentation characteristics of silage: pH 4.8±0.3, lactic acid, 54±20 g/kg DM; volatile fatty acids, 0.1±0.3 g/kg DM; water soluble carbohydrates, 82±15.6 g/kg DM; N-NH₃, 101±87.4 g/kg N; true protein, 51±48.6 g/kg crude protein.

Table 2. Chemical composition and nutritional value of total mixed ration.

| Specification | SI<300 kg BW | I<300 kg BW | SI>300 kg BW | I>300 kg BW |
|---------------|-------------|-------------|--------------|-------------|
| Grass silage, % | 75.00° | 60.00° | 75.00° | 60.00° |
| Concentrate I, % | 25.00 | 40.00 | - | - |
| Concentrate II, % | - | - | 25.00 | 40.00 |
| DM, g/kg DM | 518.50 | 591.40 | 519.00 | 502.00 |
| NDF, g/kg DM | 473.00 | 415.00 | 466.00 | 405.00 |
| ADF, g/kg DM | 308.00 | 194.00 | 298.00 | 167.00 |
| UFV, g/kg DM | 0.90 | 0.96 | 0.91 | 0.97 |
| PDIN, g/kg DM | 92.20 | 98.20 | 89.80 | 94.30 |
| PDIE, g/kg DM | 83.50 | 93.50 | 82.40 | 91.10 |

SI, semi-intensive fattening; BW, body weight; I, intensive fattening; DM, dry matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; UFV, meat fodder units; PDIN, protein digested in the small intestine when rumen fermentable N is limiting; PDIE, protein digested in the small intestine when rumen fermentable energy is limiting. *Ratios=75:25 in dry and 67:33 in fresh matter; 60:40 in dry and 77:23 in fresh matter.

and then they were transported to a cattle fattening farm where they were allocated to two groups and were kept in pens (10 animals per pen). Bulls were allocated to the pens randomly. The animals fattened on two levels: semi-intensive (SI) and intensive (I) group, and they were fed *ad libitum* a total mixed ration (TMR) composed of grass silage and concentrate (Tables 1 and 2). Fattening intensity was defined as the proportion of concentrate energy in relation to the net energy requirements according to the National Institute of Agronomical Research (INRA) at the start of the experiment. It was assumed that in the I fattening at the beginning of the fattening concentrate would satisfy 50% of the energy requirements according to INRA, while in the semi-intensity would satisfy 30%. Changing the concentrate composition at a weight of 300 kg was a correction associated with declining ratio of protein to energy connected with age. Bulls with BW below 300 kg were fed a TMR containing concentrate I (triticale, 71%; rapeseed meal, 25% and premix, 4%), and bulls with BW above 300 kg were fed a TMR containing concentrate II (triticale, 77%; rapeseed meal, 19% and premix, 4%). Commercial mineral-vitamin premix for fattening cattle (code of product 7619, Cargill Poland Ltd., Warsaw, Poland) consisting of per kg: Ca, 235 g; Na, 79 g; P, 48 g; Mg, 28 g; Fe, 500 g; Mn, 2000 mg; Cu, 375 mg; Zn, 3750 mg; J, 50 mg; Co, 13.5 mg; Se, 12.5 mg; vitamin A, 250,000 IU; vitamin D₃, 50,000 IU; vitamin E, 1000 mg; dl-alpha-tocopherol, 909.10 mg. The silage to concentrate ratio, on a DM basis, was 25:75 (SI) and 40:60 (I) (Table 2). The ratio was adjusted every four weeks, based on analysis of grass silage for its dry matter (DM). Fattening was carried out until 10 bulls in each fattening intensity reached BW of 500, 550, 600, 650 and 700 kg. Animals were weighed weekly. The animals that reached the desired BWs were transported to a meat processing plant where they were kept in individual boxes with access to water for 15-20 h (In total, 12 of slaughtering carried out after 6-10 bulls in each). Before slaughter, the animals were weighed and back fat thickness (BFT) was measured at half-height of *m. longissimus dorsi*, over the 13th rib, with the use of the ultrasound scanner (Mysono 201; Medison Co., Seoul, Korea) equipped with a 170 mm linear probe, operating in the 2.5 MHz frequency range. Slaughter and post-slaughter processing were carried out in accordance with the current meat industry regulations. Half-carcasses were weighed within an accuracy of 0.5 kg and conformation and fatness was evaluated based on EUROsystem criteria by a trained grader (Kien, 2004). After 96 h of carcass chilling, samples weighing about 200 g were taken from the loin (*m. longissimus dorsi*, between the 11th and 13th thoracic vertebrae). Vacuum-packaged samples were transported (+4°C) to the laboratory of the Department of Cattle Breeding and Milk Quality Evaluation, University of Warmia and Mazury in Olsztyn, Poland.

**Fat extraction**

Fat was extracted from ground meat samples by the Soxhlet method (ISO 1444:2000; ISO, 2000) using the Büchi B-811 extraction system (Büchi Labortechnik AG, Flawil, Switzerland), with hexane as a solvent.

**Fatty acid profile**

Fatty acid methyl esters were obtained by dissolving the extracted fat in a methanol-chloroform-H₂SO₄ mixture, followed by methylation according to the modified Peisker method (Zegarska et al., 1991) and standard EN ISO 5509:2001 (ISO, 2001). Animal and vegetable fats and oils. Preparation of methyl esters of fatty acids (EN ISO 5509:2001; ISO, 2001). The percentage share of 31 fatty acids was determined by gas chromatography, using the Varian CP 3800 system with a split/splitless inactivation of the Department of Cattle Breeding and Milk Quality Evaluation, University of Warmia and Mazury in Olsztyn, Poland.

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injector and a flame-ionisation detector (Varian Medical Systems Inc., Palo Alto, CA, USA). Samples (1 µL) of fatty acid methyl esters were placed on a CP-Sil 88 capillary column (length: 100 m, inner diameter: 0.25 mm; Varian Medical Systems Inc.). Data were processed using the GALAXIE Chromatography Data System (Varian Medical Systems Inc.). Fatty acids were identified by comparing their retention times with those of commercially available reference standards purchased from Supelco Inc. (Sigma Aldrich, St. Louis, MO, USA). Analyses of samples and reference standards were performed under identical conditions, i.e. carrier gas helium, injector temperature 260°C, detector temperature 260°C, initial oven temperature 110°C, raised to 249°C. The fatty acids were divided into the following categories: saturated fatty acids (SFAs), unsaturated fatty acids (UFAs), including monounsaturated fatty acids (MUFAs) and PUFAs. The following ratios were calculated: UFA/SFA, PUFA/SFA and n-6/n-3 PUFAs.

**Statistical analysis**

Within the SI and I fattening, bulls were divided into five groups, based on their slaughter weight: 500, 550, 600, 650 and 700 kg. There was no significant difference in weight between the initial and final groups SI and I. The results obtained were processed by means of ANOVA, using a linear model which considered fattening intensity, BW at slaughter and their interaction effects. Statistical analysis was performed using Statistica version 10.0 (StatSoft Inc., 2011). Differences between means were estimated by Tukey’s test.

### Table 3. Average age at slaughter and selected traits of intensively and semi-intensively fattened Holstein-Friesian bulls.

| Traits                        | SI fattening (n=50) | SEM | I fattening (n=50) | SEM | Significance |
|-------------------------------|---------------------|-----|--------------------|-----|--------------|
| At beginning of fattening     |                     |     |                    |     |              |
| Average age, d                | 103.00              | 0.22| 98.00              | 0.32| ns           |
| Average weight, kg            | 121.00              | 0.12| 124.00             | 0.21| ns           |
| At slaughter                  |                     |     |                    |     |              |
| Average age, d                | 696.00              | 0.24| 552.00             | 0.26| **           |
| Average weight at slaughter, kg| 603.00              | 7.71| 611.00             | 7.42| ns           |
| Average daily gain, kg d⁻¹    | 0.811               | 0.0113| 1.037            | 0.0131| **           |
| Dressing percentage, %        | 54.24               | 0.263| 55.41             | 0.211| *            |
| Conformation score, pts°      | 5.50                | 0.15 | 6.50              | 0.13 | **           |
| Fatness score, pts#           | 3.50                | 0.14 | 4.50              | 0.13 | **           |
| BFT, mm                       | 4.40                | 0.27 | 5.30              | 0.26 | *            |
| Intramuscular fat, %          | 1.18                | 0.166| 1.69              | 0.248| *            |

SI, semi-intensive; I, intensive fattening; BFT, back fat thickness. *EUROP conformation: 1 to 15, with 1=very lean, and 15=muscled outstanding; EUROP degree of fat cover: 1 to 15, with 1=very low, and 15=very fat. **P<0.05; ***P<0.01; ns, not significant (P>0.05).
Results

Intensively-fattened (group I) bulls were characterised by significantly higher daily gains (Table 3), which is why they reached the desired final BW within a significantly shorter period of time than SI-fattened bulls. The average carcass dressing percentage was 1.17% (P≤0.05) greater in I-fattened bulls, in comparison with that of those fattened under a SI system. In the I and SI fattening, the maximum dressing percentage was noted in bulls weighing 550 and 650 kg, respectively (Figure 1).

Intensive fattening contributed to significantly greater conformation scores. In group I, the highest conformation scores were noted at 550 kg BW, and in group SI – at 600 kg BW (Figure 2).

There was a significant effect of fattening intensity on carcass fatness measured by EUROP system (P≤0.01) and by BFT (P≤0.05) (Table 3). Regardless of the fattening intensity, the carcass fat content increased with an increase in slaughter weight (Figures 3 and 4). The average BFT of bulls slaughtered at the highest BW was over 7 mm.

The intramuscular fat content was significantly higher in I-fed bulls in comparison to SI-fed (Table 3). In animals with the lowest BW, the fat content of m. longissimus dorsi did not exceed 1% (Figure 5), and it increased with an increase in slaughter weight. In I-fattened bulls, the intramuscular fat content was higher than 2% at 650 kg BW, and in SI-fattened bulls it reached the highest value (1.62%) at 600 kg BW. The differences between fattening intensity were significant at P≤0.01 at 650 kg BW, and at P≤0.05 at 700 kg BW.

The fattening intensity had a significant effect on the share of PUFAs in the total fatty acid pool in intramuscular fat (Table 4). The

![Figure 3. Effect of fattening intensity and body weight at slaughter on carcass fatness score.](image)

![Figure 4. Effect of fattening intensity and body weight at slaughter on back fat thickness.](image)

### Table 4. The effect of fattening intensity on fatty acid groups and ratios in intramuscular fat.

| Fatty acid of total fatty acids, g/100 g | SI fattening | I fattening | Significance |
|----------------------------------------|--------------|-------------|--------------|
|                                        | Mean (SEM)   | Mean (SEM)  |              |
| SFA                                    | 49.42 (1.706)| 48.90 (0.868)| ns           |
| UFA                                    | 50.58 (1.711)| 51.10 (0.851)| ns           |
| MUFA                                   | 45.91 (1.626)| 47.39 (0.887)| ns           |
| PUFA                                   | 4.67 (0.487) | 3.71 (0.211) | *            |
| UFA/SFA                                | 1.05 (0.071) | 1.06 (0.036) | ns           |
| PUFA/SFA                               | 0.897 (0.011)| 0.076 (0.005)| *            |
| n-3                                    | 0.741 (0.108)| 0.551 (0.048)| ns           |
| n-6                                    | 3.18 (0.289) | 2.56 (0.162) | *            |
| n-6/n-3                                 | 4.29 (0.272)| 4.64 (0.395) | ns           |

SI, semi-intensive; I, intensive fattening; SFA, saturated fatty acid; UFA, unsaturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid. *P≤0.05; ns, not significant (P>0.05).
fat of bulls fattened in a SI system contained more PUFAs (by 0.96/100 g on average) than the fat of group I bulls. Semi-intensive fattening contributed to a increase in the levels of n-6 (P≤0.05) and n-3 PUFAs, which resulted in a smaller n-6/n-3 PUFA ratio. Irrespective of the fattening intensity, the n-6/n-3 ratio was greater in heavier bulls (Figure 6).

The content of essential fatty acids in intramuscular fat was not affected by the fattening intensity (Table 5). Significant differences were noted with respect to the concentrations of linoleic acid (LA) and AA, which were higher in the fat of bulls fattened SI. Meat from group SI bulls had also insignificantly greater concentrations of trans-vaccenic acid (TVA), linolenic acid (LNA), EPA and docosapentaenoic acid (DPA), and smaller levels of oleic acid (OA) and CLA.

**Discussion**

It can be assumed that the higher gains in the I-fattening group was resulted of the higher total DM intake and a higher concentration of energy in 1 kg of diet DM. A higher proportion of concentrate containing rapeseed meal in the I group increased also protein digested parenterally intake. Higher share of protein in the I diet improved supply of histidine, which is a limiting amino acid of protein synthesis in the diets based on grass silage (Huhtanen et al., 2002). In Huuskonen et al. (2007), bulls were fattened grass silage with 30, 50 and 70% concentrate. Growth response of bulls to increase the share of concentrate in the diet was linear. Slaughter value is affected by the animal’s sex, age, genetic background, nutritional regime and BW (Litwiniczuk et al., 2006; Nogalski and Kijak, 2001). As expected, I-fattened bulls were characterised by a greater

![Figure 5. Effect of fattening intensity and body weight at slaughter on the fat content of m. longissimus dorsi.](image1)

![Figure 6. Effect of fattening intensity and body weight at slaughter on the n-6/n-3 PUFA ratio.](image2)

### Table 5. The effect of fattening intensity on functional fatty acids in intramuscular fat.

| Fatty acid of total fatty acids, g/100 g | SI fattening | I fattening | Significance |
|----------------------------------------|--------------|-------------|--------------|
|                                        | Mean         | SEM         | Mean         | SEM          |              |
| C 18:1 trans 11 (TVA)                  | 1.153        | 0.163       | 1.051        | 0.095        | ns           |
| C 18:1 cis (OA)                        | 37.84        | 1.441       | 38.79        | 0.686        | ns           |
| C 18:2 (LA)                            | 2.72         | 0.197       | 2.17         | 0.125        |              |
| C 18:3 cis 9 trans 11 (CLA)            | 0.217        | 0.034       | 0.241        | 0.015        | ns           |
| C 18:3 (LNA)                           | 0.647        | 0.085       | 0.516        | 0.041        | ns           |
| C 20:4 (AA)                            | 0.456        | 0.097       | 0.288        | 0.051        | *            |
| C 20:5 (EPA)                           | 0.094        | 0.025       | 0.056        | 0.011        | ns           |
| C 22:5 (DPA)                           | 0.223        | 0.052       | 0.154        | 0.024        | ns           |

SI, semi-intensive; I, intensive fattening; TVA, trans-vaccenic acid; OA, oleic acid; LA, linoleic acid; CLA, conjugated linoleic acid; LNA, linolenic acid; AA, arachidonic acid; EPA, eicosapentaenoic acid; DPA, docosapentaenoic acid. *P≤0.05; ns, not significant (P>0.05).
carcass dressing percentage and a higher fat content. In a study by Barton et al. (2003), young Holstein-Friesian bulls fattened to BW of 550 kg had an average dressing percentage of 54.88% and average daily gains of approximately 1 kg. Litwiczuk et al. (2006) evidenced that dressing percentage and conformation score increased with increasing BW at slaughter. In the present study, the hypothesis that carcass conformation improves with an increase in BW at slaughter was not validated. Bruns et al. (2004) evidenced that intramuscular fat content increases with increasing BW. However, the cited authors analysed beef breeds which differ considerably from dairy breeds, including Holstein-Friesians, with respect to, among others, the rate of muscle and fat deposition. Dairy cows, in particular Holstein-Friesians, accumulate fat reserves that can be used as an additional energy source at the beginning of lactation when their nutrient requirements exceed feed intake (Nogalski et al., 2012). It is the result of many years of cow selection, which to some extent may affect the accumulation of fat in bulls of the breed (Pfuhl et al., 2007). A study by Maher et al. (2004) on Holstein Friesian bulls found that when slaughter BW was increased from 620 to 720 kg there was a weak decrease of conformation score and an increase of carcass fatness. In our study, I-fattened bulls had a higher fat content of loin than a group of SI bulls. Carcass fatness and BFT increased with higher fat content of loin than a group of SI bulls. Carcass fatness and BFT increased with an increase in slaughter weight, while the intramuscular fat content decreased in the heaviest bulls, which was highly undesirable. Dairy cattle accumulates fat as an energy reserve. It is mostly subcutaneous and inner fat and to a lesser extent, intramuscular fat (Pfuhl et al., 2007). A low intramuscular fat content, especially in meat from bulls fattened in a SI system, could adversely affect consumer acceptance. The optimal intramuscular fat content of ca. 2% has a beneficial influence on meat tenderness, colour, taste, aroma and juiciness (Nogalski and Kijak, 2001; Wichłacz et al., 1998). The tendency towards greater values of fattening performance and slaughter traits and a higher crude fat content of meat from I-fed bulls, noted in the present study, corroborates the findings of Berthiaume et al. (2006). Both studies showed that excessive reduction in the energy and protein concentration of the diet can negatively affect the fattening and slaughter traits of cattle while reducing fattening efficiency. A diet rich in n-6 PUFAs and poor in n-3 PUFAs, leading to a high n-6/n-3 ratio, is a risk factor for cardiovascular disease in humans (Breslow, 2006). In the current study, meat from group SI bulls had a smaller intramuscular fat content, but their fat had a more favourable fatty acid profile, compared with I-fattened bulls. However, having the fat content of meat and the fatty acids content of fat, PUFA content (mg/100 g) in meat was 55.1 (SI) and 62.7 (I). The n-6/n-3 PUFA ratio did not exceed the value of 5 recommended by cardiologists, and it was more favourable in animals fed high amounts of green fodder and in animals with lower BWs at slaughter (Holló et al., 2001). Blik et al. (2009) showed that the fatty acid composition of meat from bulls was more favourable when they were fattened SI with a greater proportion of bulky feeds in the diet, compared with I fattening. Furthermore fat from cattle slaughtered in the summer season has a higher nutritional value and more health-promoting properties (Sobczuk Szul et al., 2013). De Smet et al. (2000), feeding maize silage and concentrate, demonstrated that an increased fat content of bovine meat was paralleled by increased proportions of SFAs and MUFAs and a decreased proportion of PUFAs. In our experiment, a higher intramuscular fat content of meat from I-fattened bulls was not accompanied by an increase in SFA levels, which could result from ad libitum feeding of grass silage.

Conclusions

Intensive fattening young Holstein-Friesian bulls, compared with the SI contributed to an increase growth rate, carcass dressing percentage, carcass conformation scores and intramuscular fat content of m. longissimus dorsi, and it did not reduce fat quality. Irrespective of the fattening intensity, the n-6/n-3 ratio was greater in heavier bulls. Greater BW at slaughter was correlated with greater external fat thickness, whereas the highest intramuscular fat content was noted at BW of 600-650 kg. The best results were achieved when bulls were I-fattened to a BW of 650 kg.

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