A comparison of purebred Holstein-Friesian and Holstein-Friesian × beef breed bulls for beef production and carcass traits

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The objective of this study was to determine beef production traits of purebred Holstein-Friesian (Hol) and Hol×beef breed crossbred bulls. The data collected from slaughterhouses included observations of 87323 purebred Hol, 783 Hol×Aberdeen angus (Hol×Ab), 621 Hol×Blonde d'Aquitaine (Hol×Ba), 562 Hol×Charolais (Hol×Ch), 349 Hol×Hereford (Hol×Hf), 1691 Hol×Limousin (Hol×Li) and 570 Hol×Simmental (Hol×Si) bulls. For estimating valuable cuttings also a separate dataset was collected and included observations of 8806 purebred Hol, 57 Hol×Ab, 29 Hol×Ba, 22 Hol×Ch, 15 Hol×Hf, 111 Hol×Li and 58 Hol×Si bulls. Crossbreeding Hol cows with late maturing breeds (Ba, Ch, Li, Si) had favorable effects on carcass gain, conformation and proportion of high value joints of the progeny when compared to purebred Hol bulls. No advantages in proportion of valuable cuttings seemed to be obtained by crossbreeding with Ab or Hf breeds, while the improvements in gain and conformation were intermediate compared to the late maturing crossbreds.

Key words: beef production, breeds, bulls, carcass characteristics, crossbreeding

Introduction

Traditionally the majority of beef in Finland has been produced by dairy breeds, and Finnish Ayrshire (Ay) and Holstein-Friesian (Hol) are the two most frequently used breeds. However, the decrease in the number of dairy cows has diminished the supply of calves for beef production originating from dairy herds (Karhula and Kässi 2010). Because the supply of domestic beef has been decreasing, there is nowadays a clear discrepancy between the demand for and supply of domestic beef. Consequently, slaughterhouse pricing favours heavy carcasses and the average carcass weights of slaughtered animals have clearly increased during recent years (Karhula and Kässi 2010). However, the current situation is complicated because fatness generally increases with higher carcass weight (Keane and Allen 1998) and, on the other hand, market demand in Scandinavia concerning carcass fat is different from those beef markets where marbled beef is favoured (Herva et al. 2011). Consumers generally favour low-fat products in Finland, and the beef industry has stated that optimally two thirds of the carcasses would have a EUROP fat score of 2 and one third a EUROP fat score of 3 (Herva et al. 2011). Lean carcasses are favoured in setting prices. There are penalties for carcasses under 320 kg with fat scores 3–5 and for carcasses over 320 kg with fat scores 4–5.

One possible approach for current situation could be crossbreeding dairy cows and beef-breed bulls. Currently beef breed semen is used only in 6% of the dairy cow inseminations in Finland. There is a clear possibility to increase usage of beef breed semen for crossbreeding in dairy cows. Crossbreeding has improved carcass production compared to pure dairy breeds in several experiments during many decades (e.g. Andersen et al. 1976, Kempster et al. 1982, More O'Ferrall and Keane 1990, Aass and Vangen 1998, Keane and Allen 2002). Generally, proportions of hind quarter and/or proportions of hind quarter lean or muscle tissue are higher for beef crosses than for purebred Friesians so crossbreds have produced more valuable carcasses (Kempster et al. 1982, Keane et al. 1989, Keane 1994). However, the number of experimental animals is often limited when growth and carcass characteristics of different breed groups are compared (usually not more than dozens of animals per breed group). Consequently, there is a concern about the representativeness of the experimental animals compared with other animals from the same breed groups, i.e. whether they cover the whole variation in their respective populations. In addition, breed comparisons are mainly relevant for their specific production conditions and genetic level. Therefore, the main objective of the present research based on a large dataset collected from Finnish slaughterhouses was to study the potential for improvement of growth and carcass characteristics through Holstein-Friesian×beef breed crossbreeding compared to purebred Hol bulls. The second objective was to evaluate carcass traits (conformation, fat score) in relation to carcass weight in different breed groups. It was hypothesized that the use of beef breed crossbreeding improves carcass production compared to purebred Hol bulls. Furthermore, it was hypothesized that production traits improve more by using late maturing (Continental) beef breeds compared to early maturing (British) breeds.

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Materials and methods

Dataset – complete slaughter data

Dataset used in the present study was collected from four Finnish slaughterhouses (A-Tuottajat Ltd., P.O. Box 908, FI-60061 Atria, Finland; HK-Agri Ltd., P.O. Box 50, FI-20521 Turku, Finland; Saarioinen Lihanjalostus Ltd., P.O. Box 108, FI-33101 Tampere, Finland, and Snellman Lihanjalostus Ltd., Kuusisaarentie 1, FI-68600 Pietarsaari, Finland). These slaughterhouses are the major meat companies in Finland, which, as a part of their business operations, transfer calves from dairy farms, or suckler cow herds, to co-operating farms for fattening, and slaughter the animals. A raw slaughter data for each animal included individual animal identification number on ear tag, date of birth, date of slaughter, sex, carcass weight, carcass conformation score and carcass fat score. Identities of breeds (dam and sire breed) were collected from the National Animal Identification Register for Cattle (ProAgria Agricultural Data Processing Centre, P.O. Box 25, FI-01301 Vantaa, Finland). Slaughtering data and identities of breeds for individual animals were linked through individual animal identification numbers. All purebred Hol and Hol×beef-breed crossbred bulls slaughtered by above-mentioned slaughterhouses in 2009–2011 were selected for the study but the animals slaughtered under 365 or above 730 days of age were excluded.

After slaughter the carcasses were weighed hot in all of the slaughterhouses. The cold carcass weight was estimated as 0.98 of the hot carcass weight. The carcasses were classified for conformation and fatness using the EUROP quality classification (EC 2006). For conformation, development of carcass profiles, in particular the essential parts (round, back, shoulder), was taken into consideration according to the EUROP classification (E: excellent, U: very good, R: good, O: fair, P: poor), and for fat cover, the amount of fat on the outside of the carcass and in the thoracic cavity was taken into account using a classification range from 1 to 5 (1: low, 2: slight, 3: average, 4: high, 5: very high). Each level of the conformation scale was subdivided into three sub-classes (e.g. O+, O, O-) to produce a transformed scale ranging from 1 to 15, with 15 being the best conformation.

Birth weight assumptions used in calculations were 40 kg live weight and 16 kg carcass weight for bull calves, since the same values were used by A-Tuottajat Ltd. in daily extension work (Herva et al. 2009, 2011). An estimated daily carcass gain was calculated by subtracting 16 kg birth carcass weight from the reported slaughter weight and dividing the result by age at slaughter. The complete final slaughter data comprised 91 899 slaughtered bulls; the average slaughter age was 587 days and the mean carcass weight 335 kg (Table 1). The average estimated daily carcass gain was 545 g d^{-1}, the EUROP conformation score 4.3 and the carcass fat score 2.4.

Table 1. Description of the experimental data.

Variable	n	Mean	SD [a]	$q_{0.05}$ [b]	$q_{0.95}$ [c]
Dataset, complete slaughter data					
Age at slaughter, d	91 899	587	62.8	484	697
Carcass gain, g d^{-1}	91 899	545	78.8	411	667
Carcass weight, kg	91 899	335	49.1	250	410
Conformation score [d]	91 710	4.3	1.11	3	6
Fat score [e]	91 885	2.4	0.66	1	3
Dataset, commercial cutting					
Carcass weight, kg	9 098	322	45.7	245	392
Conformation score [d]	9 098	4.2	0.90	3	6
Fat score [e]	9 098	2.4	0.65	2	3
From yield, %					
Subcutaneous fat	9 098	4.7	1.44	2.6	7.3
Loin [f]	8 682	3.7	0.34	3.2	4.2
Tender loin [g]	8 694	1.4	0.12	1.2	1.6
Inside round [h]	8 863	3.8	0.35	3.3	4.4
Outside round [i]	8 892	5.8	0.59	4.9	6.6
Corner round [j]	8 880	3.6	0.28	3.2	4.0
Roast beef [k]	8 925	1.8	0.18	1.5	2.1

[a] Standard deviation. [b] 0.05-quantile (approximately 5% of the data has a value less than the 0.05-quantile). [c] 0.95-quantile (approximately 95% of the data has a value less than the 0.95-quantile). [d] Conformation: (1 = poorest, 15 = excellent). [e] Fat cover: (1 = leanest, 5 = fattest). [f] *Musculus longissimus*. [g] *Musculus psoas major*. [h] *Musculus semimembranosus*. [i] *Musculus semitendinosus*. [j] *Musculus quadriceps femoris*. [k] *Musculus gluteus medius*.

Dataset – commercial cutting

For estimating valuable cuttings for studied breed groups a separate dataset was collected in 2010–2011 from Snellman Lihanjalostus Ltd. In addition to above-mentioned variables this dataset included also information of commercial cuttings. Each carcass was cut into valuable cuts (outside round, *Musculus semitendinosus*; inside round, *Musculus semimembranosus;* corner round, *Musculus quadriceps femoris*; roast beef, *Musculus gluteus medius*; tenderloin, *Musculus psoas major*, and loin, *Musculus longissimus*) and subcutaneous fat as described by Manninen et al. (2011). All these cuttings were weighed automatically in line and their yields were expressed as percentages of the carcass cold weight (0.98 × carcass hot weight, 50 min post mortem). This dataset comprised 9 098 slaughtered bulls (Table 1). The mean carcass weight was 4% lower than that in the complete slaughter data but the average conformation and fat scores were almost the same in both datasets.

Statistical methods

The results are shown as least squares means. The normality of residuals and the homogeneity of variances were checked using graphical methods: box-plots and scatter plots of residuals and fitted values. The data were subjected the analysis of variance using the SAS Mixed procedure (version 9.2, SAS Institute Inc., Cary, NC). Differences between the breeds were compared using Dunnett's test so that purebred Hol was used as a control breed.

Results

The complete slaughter data included 87 323 purebred Hol bulls (Table 2). The most popular beef breed sires were Limousin (Li, 1 691 observations), Aberdeen angus (Ab, 783) and Blonde d'Aquitaine (Ba, 621), while Simmental (Si, 570), Charolais (Ch, 562) and Hereford (Hf, 349) were used less. The average slaughter age for purebred Hol bulls was 587 days, and there were no remarkable differences in the average slaughter ages among breed groups. However, the Ch bulls were 12 days younger (p<0.001) than the Hol bulls.

All crossbred groups differed significantly (p<0.001) from Hol bulls in both carcass weight and carcass gain (Table 2). The estimated average daily carcass gain of the Hol bulls was 542 g d^{-1}, and it improved by 7, 16, 20, 10, 13 and 17% with Hol×Ab, Hol×Ba, Hol×Ch, Hol×Hf, Hol×Li and Hol×Si crossbreds, respectively, compared to pure Hol bulls. The EUROP conformation score of the Hol bulls was 4.1, and improved most (71–78%) by using Ba, Li and Ch sires (p<0.001). Hol×Ab and Hol×Hf crossbreds produced 41% and Hol×Si crossbreds 54% better conformed carcasses compared to purebred Hol bulls (p<0.001). The carcass fat score of the Hol bulls (2.4) was 14% higher than that of the Hol×Ba bulls (p<0.001). With Hol×Ab, Hol×Ch, Hol×Hf, Hol×Li and Hol×Si crossbreds the carcass fat score was 25, 4, 33, 4 and 13% higher compared to purebred Hol bulls, respectively (p<0.001).

Dataset from commercial cuttings included 8 806 purebred Hol bulls but the amount of the crossbreds was limited (15–111 bulls/breed group) (Table 2). The carcass weights were somewhat lower than those in the complete slaughter data. Breed group had clear effects on the yield (%) of valuable cuts. The yields of loin, tenderloin, inside round, outside round, corner round and roast beef were higher with Hol×Ba and Hol×Li bulls than with Hol bulls (Table 2). Additionally, the yields of loin, tenderloin, outside round and roast beef were higher with Hol×Si bulls than with Hol bulls. However, the yield of corner round was 3% lower with Hol×Si bulls than with Hol bulls (p<0.001). With Hol×Ch bulls the yields of loin (p<0.001), outside round (p<0.001) and roast beef (p<0.01) were higher compared to purebred Hol bulls. Furthermore, the yield of corner round was 6% higher with purebred Hol bulls compared to Hol×Ab bulls (p<0.001). The yield of subcutaneous fat was significantly lower in the Hol bulls than in the Hol×Ab, Hol×Hf and Hol×Si bulls. On the other hand, the yield of subcutaneous fat was 57% higher with purebred Hol bulls compared to Hol×Ba bulls (p<0.001).

Average carcass weights in different EUROP fat score classes and the incidence of different fat scores in breed groups are presented in Table 3. The most common class for Hol, Hol×Ba, Hol×Ch and Hol×Li bulls was fat score 2, including 54, 69, 47 and 45% of all observations within breed group, respectively. For Hol×Ab, Hol×Hf and Hol×Si bulls fat score 3 incidence was greater than score 2, being 48, 46 and 50%, respectively. Considering fat score 4, it is noticed that 25 and 28% of Hol×Ab and Hol×Hf carcasses were placed to this category. For other breed groups less than 10% of carcasses ranked to class 4. In addition, 3 and 6% of Hol×Ab and Hol×Hf carcasses, respectively, and less than 1% carcasses for other breed groups were placed to fat score 5. In general, the average carcass weight of the crossbred bulls in different fat score classes was higher than that of the purebred Hol bulls (Table 3). For example, in fat score 3 the average carcass weights were 2, 13, 15, 3, 10 and 14% higher with Hol×Ab, Hol×Ba, Hol×Ch, Hol×Hf, Hol×Li and Hol×Si crossbreds, respectively, compared to pure Hol bulls.

Table 2. Carcass gain, carcass characteristics and valuable cuts of purebred Holstein-Friesian (Hol) and Hol×beef breed crossbred bulls in Finnish slaughter dataset. (Ab = Aberdeen angus, Ba = Blonde d'Aquitaine, Ch = Charolais, Hf = Hereford, Li = Limousin, Si = Simmental).

	Breed group									Statistical significance [b]					
	Hol×Hol	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si	SEM[a]	*p*-value	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si
Dataset, complete slaughter data															
n	87323	783	621	562	349	1 691	570								
Age at slaughter, d	587	592	582	575	592	586	582	3.4	<0.001	*	*	***			*
Carcass gain, g d^{-1}	542	580	627	649	594	611	634	4.1	<0.001	***	***	***	***	***	***
Carcass weight, kg	333	357	379	387	366	372	383	2.6	<0.001	***	***	***	***	***	***
Conformation [c]	4.1	5.8	7.3	7.0	5.8	7.1	6.3	0.05	<0.001	***	***	***	***	***	***
Fat score [d]	2.4	3.0	2.1	2.5	3.2	2.5	2.7	0.03	<0.001	***	***	***	***	***	***
Dataset, commercial cutting															
n	8806	57	29	22	15	111	58								
Carcass weight, kg	321	340	354	364	327	354	362	11.7	<0.001	**	***	***		***	***
Conformation [c]	4.2	5.7	6.6	6.4	5.3	6.9	6.1	0.21	<0.001	***	***	***	***	***	***
Fat score [d]	2.4	2.8	2.0	2.6	3.3	2.5	2.9	0.17	<0.001	***	**		***		***
From yield, %															
Subcutaneous fat	4.7	5.5	3.0	4.2	6.6	4.4	5.4	0.37	<0.001	***	***		***		**
Loin [e]	3.7	3.8	4.3	3.9	3.8	4.3	3.9	0.08	<0.001	o	***	***		***	***
Tender loin [f]	1.4	1.4	1.6	1.4	1.4	1.5	1.5	0.03	<0.001		***			***	***
Inside round [g]	3.8	3.7	4.3	4.0	3.7	4.2	3.9	0.09	<0.001		***			***	
Outside round [h]	5.8	5.9	6.7	6.4	5.7	6.6	6.2	0.15	<0.001		***	***		***	***
Corner round [i]	3.6	3.4	3.8	3.7	3.5	3.7	3.5	0.07	<0.001	***	*			***	***
Roast beef [j]	1.8	1.7	2.0	1.9	1.7	1.9	1.9	0.05	<0.001		***	**		***	***

[a] SEM = Standard error of mean (complete slaughter data: n=349; commercial cutting: n=15).

[b] Differences between the breed groups were compared using an a priori test (Dunnett's test) so that purebred Hol was used as a control breed.

*** (p<0.001), ** (p<0.01), * (p<0.05) and o (p<0.10).

[c] Conformation: (1 = poorest, 15 = excellent).

[d] Fat cover: (1 = leanest, 5 = fattest).

[e] *Musculus longissimus*.

[f] *Musculus psoas major*.

[g] *Musculus semimembranosus*.

[h] *Musculus semitendinosus*.

[i] *Musculus quadriceps femoris*.

[j] *Musculus gluteus medius*.

Table 3. Average carcass weights of purebred Holstein-Friesian (Hol) and Hol×beef breed crossbred bulls in different EUROP fat score classes (1 = leanest, 5 = fattest). (Ab = Aberdeen angus, Ba = Blonde d'Aquitaine, Ch = Charolais, Hf = Hereford, Li = Limousin, Si = Simmental).

	Breed group									Statistical significance [b]					
	Hol×Hol	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si	SEM[a]	*p*-value	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si
Total, n	87310	783	621	562	349	1 690	570								
Fat score	n (observations/fat score)														
1	4914	16	54	21	2	78	14								
2	47203	182	431	265	68	762	217								
3	32180	372	128	242	159	715	286								
4	2952	193	7	32	98	131	51								
5	61	20	1	2	22	4	2								
Fat score	Carcass weight (kg) in different fat score classes														
1	267	262	316	298	208	298	316	40.8	<0.001		***	o		***	**
2	323	330	380	370	327	358	358	5.4	<0.001	o	***	***		***	***
3	353	360	400	407	363	389	401	3.3	<0.001	**	***	***	**	***	***
4	378	382	427	443	390	412	405	14.2	<0.001		**	***		***	***
5	398	398	423	438	412	421	403	43.4	0.65						

[a] SEM = Standard error of mean.
[b] Differences between the breed groups were compared using an a priori test (Dunnett's test) so that purebred Hol was used as a control breed.
*** (p<0.001), ** (p<0.01), * (p<0.05) and o (p<0.10).

Table 4. Average carcass weights of purebred Holstein-Friesian (Hol) and Hol×beef breed crossbred bulls in different EUROP conformation score classes (1 = poorest, 15 = excellent). (Ab = Aberdeen angus, Ba = Blonde d'Aquitaine, Ch = Charolais, Hf = Hereford, Li = Limousin, Si = Simmental).

	Breed group									Statistical significance [b]					
	Hol×Hol	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si	SEM[a]	*p*-value	Hol×Ab	Hol×Ba	Hol×Ch	Hol×Hf	Hol×Li	Hol×Si
Total n	87 140	781	619	562	348	1 690	570								
Conformation	n (observations / conformation score)														
1 (P-)	242	1	0	0	0	0	0								
2 (P)	2190	1	0	1	0	2	1								
3 (P+)	17054	10	1	3	10	5	6								
4 (O-)	39567	79	15	20	39	47	37								
5 (O)	23054	259	51	51	99	154	111								
6 (O+)	4004	234	102	127	97	340	157								
7 (R-)	929	141	204	168	68	546	151								
8 (R)	98	44	137	122	23	386	85								
9 (R+)	2	11	80	44	9	140	14								
10 (U-)	0	0	7	13	2	21	1								
Conformation	Carcass weight (kg) in different conformation score classes														
1 (P-)	187	92	-	-	-	-	-	53.7	0.08						
2 (P)	241	227	-	122	-	167	170	45.8	0.006			*		o	
3 (P+)	297	257	194	242	232	204	263	41.0	<0.001	*	o		***	***	
4 (O-)	334	309	298	291	305	284	329	9.7	<0.001	***	***	***	***	***	
5 (O)	357	338	323	338	349	313	355	4.9	<0.001	***	***	***		***	
6 (O+)	384	369	353	363	379	348	382	3.5	<0.001	***	***	***		***	
7 (R-)	411	396	377	391	393	378	392	4.4	<0.001	***	***	***	***	***	***
8 (R)	417	397	399	417	427	400	420	8.4	<0.001	*	**			***	
9 (R+)	434	394	419	433	434	407	447	28.5	<0.001						
10 (U-)	-	-	435	451	437	423	483	30.6	0.36						

[a] SEM = Standard error of mean.
[b] Differences between the breed groups were compared using an a priori test (Dunnett's test) so that purebred Hol was used as a control breed.
*** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$) and o ($p<0.10$).

For purebred Hol bulls majority of carcasses (91%) were placed to conformation scores 3 (P+) to 5 (O), and the most common conformation class was O- (45% of all observations) (Table 4). Considering Hol×Ab, Hol×Hf and Hol×Si crossbreds, 81, 76 and 74% of carcasses were placed to scores 5 (O) to 7 (R-). For Hol×Ba, Hol×Ch and Hol×Li bulls a notable (more than 20%) amount of carcasses ranked to class 8 (R). In total, only 94 carcasses were classified to scores 11 (U) to 15 (E+), and these observations are not shown in Table 4. Considering the most common conformation classes (4–7), the average carcass weights of crossbred bulls were lower compared to purebred Hol bulls. For example, in conformation score 7 (R-) the average carcass weights were 4, 8, 5, 4, 8 and 5% lower with Hol×Ab, Hol×Ba, Hol×Ch, Hol×Hf, Hol×Li and Hol×Si crossbreds, respectively, compared to pure Hol bulls. In other words, the crossbred bulls were classified better than the Hol bulls in the same carcass weight.

Discussion

Lifetime daily carcass gain (545 g d^{-1} on average) observed in the present data was in line with the observations reported by Herva et al. (2009) (538 g d^{-1}) based on results of 55 375 bull calves delivered by Atria Ltd. in 2003. Compared to the recent Finnish experimental data sets for dairy bulls with typical Finnish grass silage-based diets (e.g. Huuskonen et al. 2007, 2008, 2011, Huuskonen 2009, 2011, Huuskonen and Joki-Tokola 2010), the average lifetime carcass gain was approximately 10% lower in the present field data. This difference probably illustrates variable feeding regimes and management factors at farm level compared to the controlled experimental environments. Typically all bull calves transferred from dairy farms are housed and fed consistently in finishing farms i.e. different methods are not used for pure dairy breeds and dairy×beef crossbred bulls within a finishing farm. Therefore it can be assumed that the results of the present data represent well the differences between the breed groups in Finnish cattle population.

The higher growth capacity of the dairy×late maturing beef breed crosses compared to the pure dairy breeds has been demonstrated in numerous studies (e.g. Andersen et al. 1977, More O'Ferrall and Keane 1990). However, it can be inferred from data compiled by Kempster and Southgate (1984) and Keane et al. (1989) that there was little difference in growth rate between Friesians and Limousin crosses in some trials. Also Andersen et al. (1977) found that Limousin cross young bulls from dairy cows had lower daily live weight gains than and similar daily carcass gains as Danish Red and White young bulls. Southgate et al. (1988) reported similar live growth rates for Friesian, Friesian×Hereford and Friesian×Limousin steers in a 16-month beef system but in a 24-month system the Limousin crosses were superior. In many early mentioned British and Irish studies with the progeny of Friesian dairy cows, purebred Friesians have performed better in relation to beef breed crosses than in the present experiment. This indicates weak growth properties in current Finnish Holstein-Friesian population.

The fact that there are differences between breed types in conformation and fat scores has been well established previously in experimental data sets (Kempster et al. 1982, More O'Ferrall and Keane 1990, Keane and Allen 2002), and this was also the case in the present large field data. For example, the superiority of the Hol×Li and Hol×Ba crossbred bulls for carcass conformation compared to purebred Hol bulls corresponded to the results reported by Keane et al. (1989) with Friesian, Friesian×Limousin and Friesian× Blonde d'Aquitaine steers. Furthermore, Keane and More O'Ferrall (1992) observed that Friesian×Hereford and Friesian×Simmental steers conformed 36 and 40% better than purebred Friesians, respectively.

Aass and Vangen (1998) suggested that commercial conformation grading is in general an imprecise method for evaluation of carcass composition. Also in the present study the differences in conformation score suggested a superior muscling of the Hol×Ab and Hol×Hf crosses compared to pure Hol bulls. However, in terms of valuable cuts there were only limited differences between Hol, Hol×Ab and Hol×Hf bulls. Instead, Hol×late maturing breed bulls had higher proportions of many high value joints (rounds, loins) compared to purebred Hol bulls. Other studies have also shown that the late maturing breed type cattle have higher proportions of high value joints than early maturing breed crosses or pure dairy breeds (Andersen et al. 1977, Keane et al. 1989, 1990, Keane and More O'Ferrall 1992). In general, carcass conformation and fat scores have explained moderate to high proportions of the variation (R^2 ranged from 0.47 to 0.70) in carcass meat yield (Perry et al. 1993, Drennan et al. 2008, Conroy et al. 2009, 2010). Craigie et al. (2012) reported how point changes in the EUROP grid relate to changes in the yield of lean meat in the whole beef carcass as well as in to the yield of high value cuts relative to carcass weight. Studies summarized by Craigie et al. (2012) indicated that the percentage of variation (R^2 range 0.55–0.75) in carcass lean meat yield explained by the EUROP grid was much greater using the entire carcass than using high-value cuts only (R^2 range 0.28–0.57). While these high-value cuts are a small percentage of the carcass lean meat yield, they account for a large proportion of carcass value. Craigie et al. (2012) concluded that there is a clear need for an accurate commercial measurement or prediction methods for true value of the carcasses which is supported also by the present data.

Although measures of carcass fatness generally increase with increasing carcass weight (Keane and Allen 1998), the carcass fat score of the Hol×Ba bulls was lower than that of the Hol bulls at a constant age in the present study. This disagrees with findings by Aass and Vangen (1998) who reported that sire breed differences in carcass fatness traits became insignificant when comparisons were made at a constant age instead of weight. However, the carcass weights were considerably higher in the present study compared to those reported by Aass and Vangen (1998). In accordance with our results, Wheeler et al. (2005) observed that Hf-sired steers were fatter than Ch-sired steers when slaughtered at constant age. Similarly, Schenkel et al. (2004) reported with purebred beef bulls that Blonde d'Aquitaine bulls showed the least back fat thickness, followed by Limousin, Charolais and Simmental when breed differences for growth and body composition traits were studied in Ontario bull test stations from 1991 to 2000. In that case, the Hf bulls had the highest level and the Ab bulls the second highest level of back fat thickness (Schenkel et al. 2004). Also Bartoň et al. (2006) concluded that, in general, the animals of earlier maturing breeds (Hf, Ab) produced relatively more fat than later maturing (Ch, Si) in spite of the fact that they were slaughtered at a significantly lower live weight. This statement is supported by the present data with crossbred bulls.

The decrease in the number of dairy cows has reduced the number of dairy bred calves available for beef production in Finland and while the beef cow herd has increased (Karhula and Kässi 2010), it is not sufficient to offset the fall in the dairy cow number. Consequently, if beef output is to be maintained, carcass weights must increase. However, increasing carcass weight with the present breed distribution is not desirable, as beef carcasses are already adequately fat or over-fat at existing carcass weights (Herva et al. 2011). The way by which carcass weight can increase without a subsequent increase in fatness is through a change in breed distribution. According to the present data the Hol, Hol×Ab, and Hol×Hf bulls would obtain carcass fat class 3 at carcass weights of ca. 350–360 kg but Hol×late maturing crossbreds at carcass weights of ca. 390–400 kg. Thus the use of late maturing rather than early maturing bulls on Hol dairy cows would permit carcass weight of the progeny to increase 10-15% without an increase in carcass fatness. Alternatively, in recognition of the growing consumer demand for beef with less fat, the fat content of Hol×late maturing carcasses would be lower than that of purebred Hol or Hol×early maturing carcasses of similar weight. However, the decision to opt for a breed when crossbreeding dairy cattle depends not only on the growth performance and carcass characteristics of the calf but also on the aspects affecting the dairy production, such as gestation length, calving difficulty or occurrence of stillbirth (Fouz et al. 2013). In the present study we didn't have possibility to evaluate those aspects affecting the dairy production but several published articles are available (e.g. Nadarajah et al. 1989, Olson et al. 2009, Fouz et al. 2013). Based on Finnish statistics (Ilola 2012) the proportion of stillbirths was 5.2% for purebred dairy calves (Hol and Ayrshire breeds, on average) in Finnish dairy farms during 1.8.2011–31.7.2012. For Ab, Ba, Ch, Hf, Li and Si crossbreds proportions of stillbirth were 4.4, 4.4, 4.9, 5.1, 5.1 and 4.0%, respectively.

Conclusions

The large dataset collected in this study describes well the growth and carcass traits of slaughtered bulls in Finnish Holstein-Friesian population. Improvements in beef production traits obtained by crossbreeding Holstein-Friesian dairy cows with beef breed sires are highly dependent of the choice of sire breed. Crossbreeding Hol cows with late maturing beef breeds (Ba, Ch, Li, Si) had favorable effects both on daily carcass gain and carcass quality traits (conformation, proportion of high value joints) of the progeny when compared to purebred Hol bulls. The effects of crossbreeding Hol cows with Ab or Hf sires were variable. No advantages in proportion of high value joints seemed to be obtained by crossbreeding Hol cows with these early maturing breeds, while the improvements in daily carcass gain and carcass conformation score were intermediate compared to the late maturing crossbreds. Crossbreeding, especially with late maturing bulls, largely improves carcass production compared to purebred Hol bulls.

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