Factors associated with age at slaughter and carcass weight, price, and value of dairy cull cows

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ABSTRACT

The sale of cull cows contributes to the overall profit of dairy herds. The objective of this study was to quantify the factors associated with slaughter age (mo), cow carcass weight (kg), price (€/kg of carcass weight), and value (€/head) of dairy cull cows. Data included 20,995 slaughter records in the period from 2003 to 2011 of 5 different breeds: 2 dairy [Holstein Friesian (HF) and Brown Swiss (BS)] and 3 dual-purpose [Simmental (Si), Alpine Grey (AG), and Rendena (Re)]. Associations of breed, age of cow (except when the dependent variable was slaughter age), and year and month of slaughter with slaughter age, carcass weight, price, and value were quantified using a mixed linear model; herd was included as a random effect. The seasonal trends in cow price and value traits were inversely related to the number of cows slaughtered, whereas annual variation in external factors affected market conditions. Relative to BS cows, HF cows were younger at slaughter (73.1 vs. 80.7 mo), yielded slightly lighter carcasses (242 vs. 246 kg), and received a slightly lower price (1.69 vs. 1.73 €/kg) and total value (394 vs. 417 €/head). Dual-purpose breeds were older and heavier and received a much greater price and total value at slaughter (521, 516, and 549 €/head, respectively for Si, Re, and AG) than either dairy breed. Of the dual-purpose cows, Si carcasses were heavier (271 kg), whereas the carcasses of local breeds received a higher price (2.05 and 2.18 €/kg for Re and AG, respectively) and Alpine Grey cows were the oldest at slaughter (93.3 mo). The price per kilogram of cull cow carcasses was greatest for very young cows (i.e., <3 yr of age) and the differential in price and value between younger and older cows was greater in dual-purpose than in dairy breeds. Large differences in cull cow whole carcass value (carcass weight × unit price) among dairy breeds suggest that such a trait could be considered in the breeding objectives of the breeds.

Key words: cull cow, carcass price, carcass value, age at culling

INTRODUCTION

The sale of cull cows represents a revenue source for dairy farms. Beef originating from culled dairy cows accounts for approximately 13% of domestically produced beef in the United States (USDA, 2005). Similarly, cull cows can represent 10 to 15% of the revenues of dairy farms in most European countries (Cabaraux et al., 2005); meat originating from cull cows can represent most of the beef consumed in some countries (Liboriusen, 1980; Vestergaard et al., 2007).

Factors influencing the decision to cull dairy cows include reproductive failure, mastitis and udder problems, low milk production, and old age. Several studies (Beaudeau et al., 1993; Esslemont and Kossaibati, 1997; Bascom and Young, 1998) have documented reproductive failure as the primary reason for culling, accounting for approximately 23% of culling events (Allaire et al., 1976). Mastitis and udder problems were identified as the second most important reason for culling (Bascom and Young, 1998; Smith et al., 2000; Cesarini et al., 2003), accounting for approximately 16% of culling decisions.

Breed of cow has been reported to influence culling rate (Heikkilä et al., 2012) but has also been documented to influence carcass weight and the value of cull cows (De Boer, 1980; Wiemer et al., 1982) as well as meat quality characteristics of beef cows (Dransfield et al., 2003). Several studies have quantified the effect of plane of nutrition on slaughter and meat traits, particularly in beef cull cows. Vestergaard et al. (2007) and Schnell et al. (1997) both reported clear differences in carcass characteristics of cull cows fed different diets. Increasing the nutritional plane of cull cows through supplementation before slaughter improved carcass characteristics (Matulis et al., 1987; Brown and Johnson, 1991; Minchin et al., 2009), as well as conformation and carcass fat level (Apple, 1999) and tenderness of meat (Miller et al., 1987).

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Furthermore, several studies have documented an effect of age at slaughter on carcass traits of dairy and beef cull cows (van Arendonk et al., 1984; Seegers et al., 1998) and also on BCS and carcass conformation (Vestergaard et al., 2007). The majority of studies on culled dairy cows were, however, undertaken under intensive production conditions or on extensive pasture environments, and there remains a paucity of knowledge of such in mountainous dairy production systems.

The aim of this study was to investigate the association between cow breed and year and month of slaughtering with age at slaughter, carcass weight, price, and value in culled dairy and dual-purpose cows reared in Alpine conditions.

MATERIALS AND METHODS

Animal care and use committee approval was not obtained for the present study because all of the data originated from a preexisting database from the Breeders Federation of the Trento Province (Trento, Italy) and the Unipeg Cooperative of Pegognaga (Mantova, Italy).

Data

Slaughter records on 20,995 cull cows of 5 breeds [2 dairy: Holstein Friesian (**HF**) and Brown Swiss (**BS**) and 3 dual-purpose: Simmental (**Si**), Rendena (**Re**), and Alpine Grey (**AG**)] originating from 486 dairy herds, between the years 2003 and 2011, were provided by the Breeders Federation of Trento (Trento, Italy), located in northern Italy. Crossbred cows were not included in the analysis due to a paucity of data. The farming systems of the area were described in detail by Sturaro et al. (2009, 2013). Cull cows were collected from dairy farms each Wednesday by the Breeders Federation and transported to a commercial slaughterhouse (Unipeg, Pegognaga, Italy) on Thursday. Information available on each animal included herd, breed, birth date, slaughter date, carcass weight (kg), and carcass value (€). Age at slaughter (mo) and carcass price (€/kg) were computed.

After examination of the distribution of the data available, only purebred dairy and dual-purpose cows between 24 and 200 mo of age at slaughter, a carcass weight between 170 and 400 kg, and a carcass value between €200 and €1,200 were retained. Furthermore, only animals from herds that supplied at least 10 cull cows across the whole study period were retained. In total, 6,931 records were discarded during the editing process; 8,927 HF, 9,555 BS, 1,117 Si, 917 Re, and 479 AG cull cows remained after editing. In 25.5% of the herds only 1 breed of cow was represented, whereas

in 39.3% and 28.0% of the herds, 2 and 3 breeds were represented, respectively.

Statistical Analysis

Factors associated with age at slaughter (mo), carcass weight (kg), carcass price (€/kg), and carcass value (€) of cull cows were quantified using REML in a linear mixed model framework in PROC MIXED (SAS Institute, 2008). The significance of fixed effects in the model was based on the F-statistic and the significance of the random effects in accounting for the variation in the dependent variable was determined using the Akaike's information criterion (**AIC**; Akaike, 1969; Agresti, 2002) between models. The lower the AIC, the more parsimonious the model. The AIC includes a penalty for over-parameterization, to obtain a balance between fit and number of parameters to be estimated, and was calculated as follows:

$$\text{AIC} = -2 \times \log L - 2 \times (k + s),$$

where k represents the number of response levels minus 1, and s is the number of predictive effects.

In all models, the random terms of herd and residuals were assumed to be independently and normally distributed with a mean of zero and variance of σ_H^2 and σ_e^2 , respectively. The general model fitted (based on biological plausibility) was:

$$\begin{aligned} y_{ijklm} = & \mu + H_i + B_j + YS_k + MS_l + A_m + bCW \\ & + (B \times A)_{jm} + (B \times YS)_{jk} + (B \times MS)_{jl} \\ & + (YS \times MS)_{kl} + e_{ijklmn}, \end{aligned}$$

where y_{ijklm} is the observed trait; μ is the overall intercept of the model; H_i is the random effect of the i th herd ($i = 1, \dots, 486$); B_j is the fixed effect of the j th breed ($j = \text{HF, BS, Si, Re, AG}$); YS_k is the fixed effect of the k th year of slaughter ($k = 2003, \dots, 2011$); MS_l is the fixed effect of the l th month of slaughter ($l = 1, \dots, 12$); A_m is the fixed effect of the m th class of age of cull cow ($m = 1 = <3$ yr of age; $2 =$ between 3 and 4 yr; $4 =$ between 4 and 5 yr; $5 =$ between 5 and 6 yr; $6 =$ between 6 and 7 yr; $7 = >7$ yr); CW is the linear covariate of carcass weight; $(B \times A)_{jm}$ is the interaction effect between breed and age of cows at slaughter; $(B \times YS)_{jk}$ is the interaction effect between breed and the year of slaughter; $(B \times MS)_{jl}$ is the interaction effect between breed and month of slaughter; $(YS \times MS)_{kl}$ is the interaction between the year and month of slaughter; and e_{ijklmn} is a random residual.

This model was used to analyze carcass price data (€/kg). Carcass weight (kg) and carcass value (€/head)

Figure 1. Frequency distribution, mean, standard deviation (SD), skewness, and kurtosis for slaughter age (mo), carcass weight (kg), carcass price (€/kg), and carcass value (€/head) of culled cows.

were analyzed using the same model but without the linear covariate of carcass weight, and, in a separate analysis, carcass value was analyzed including in a 2-way interaction between carcass weight (continuous variable) and breed to quantify how carcass value changed per kilogram of carcass weight in different breeds. Finally, age at culling (mo) was analyzed using a simplified model without carcass weight, age of cow, and its interaction with breed.

Least squares means for the fixed effects of interest were averaged across all other fixed effects in the respective models. Orthogonal contrasts were undertaken to quantify the breed effect differences between dairy breeds and dual-purpose breeds [(HF + BS) vs. (Si + Re + AG)], between the 2 dairy breeds (HF vs. BS), between Si and the local dual-purpose breeds [Si vs. (Re + AG)], and between the 2 local dual-purpose breeds (Re vs. AG).

The correlation between age at slaughter, carcass weight, carcass price, and carcass value were calculated using the Spearman correlation procedure (SAS Institute, 2008) to determine potential relationships that may exist between the studied traits.

RESULTS

The frequency distribution of age at slaughter, carcass weight, carcass price, and carcass value is shown

in Figure 1. Cows were slaughtered, on average, at 74 mo of age (i.e., >6 yr of age) with an average carcass weight, price, and value of 257 kg, 1.71 €/kg, and 455 €/head, respectively. All distributions were skewed and, in the case of price and value of the carcass, were also bimodal.

Results from the statistical analysis of slaughter traits are summarized in Table 1. The herd effect represented 6.3 to 19.8% of the variance of the traits assessed (Table 1). All of the main fixed effects included in the model were strongly associated ($P < 0.0001$) with each dependent variable except for the association between age at slaughter with year ($P = 0.02$) and month of slaughter and between carcass weight with year of slaughter ($P = 0.13$). The interaction breed $\times$ month was not associated ($P = 0.40$) with carcass weight.

Spearman rank correlations between traits suggested a strong positive correlation between carcass weight and price (0.77; $P < 0.001$) and, as expected, between carcass value and its constituent traits carcass weight (0.91; $P < 0.001$) and price (0.96; $P < 0.001$). Near-zero correlations existed between slaughter age and carcass price (0.06; $P < 0.001$) and value (0.02; $P < 0.01$).

Year and Month of Slaughter

Carcass weight, price per kilogram, and total carcass value varied across the months of the year (Figure 2).

Table 1. Results of ANOVA of slaughter age (mo), carcass weight (kg), carcass price (€/kg), and carcass value (€/head) of 20,995 culled cows

Effect ¹	df	Slaughter age		Carcass weight		Carcass price		Carcass value	
		<i>F</i> -value	<i>P</i> -value	<i>F</i> -value	<i>P</i> -value	<i>F</i> -value	<i>P</i> -value	<i>F</i> -value	<i>P</i> -value
Breed (B)	4	55.68	<0.0001	57.90	<0.0001	304.32	<0.0001	88.57	<0.0001
Age of cow (A)	5	—	—	13.35	<0.0001	77.71	<0.0001	7.29	<0.0001
Year of slaughter (Y)	8	2.21	0.02	1.05	0.40	451.84	<0.0001	43.07	<0.0001
Month of slaughter (M)	11	1.49	0.13	4.86	<0.0001	13.45	<0.0001	4.38	<0.0001
Carcass weight (CW)	1	—	—	—	—	57,049.10	<0.0001	—	—
B × A	20	—	—	2.14	0.002	7.39	<0.0001	3.24	<0.0001
B × Y	32	2.27	0.0001	1.85	0.003	9.01	<0.0001	3.21	<0.0001
B × M	44	1.48	0.02	1.02	0.44	3.06	<0.0001	1.66	0.004
Y × M	88	1.28	0.04	2.17	<0.0001	25.03	<0.0001	3.66	<0.0001
Herd effect	485	0.140	—	0.198	—	0.063	—	0.180	—
RMSE ²	—	27.56	—	40.40	—	0.20	—	170	—

¹The regression coefficient of carcass price on CW was $+0.00797 \pm 0.00003$ €/kg; herd effect expressed as proportion of variance explained by herd was calculated by dividing the corresponding component of variance by the total variance.

²RMSE = root mean square error.

However, carcass weight varied ($\pm 2.5\%$) to a lesser extent across the months of the year than either carcass price ($\pm 4.9\%$) or value ($\pm 5.3\%$). Cows slaughtered during winter had the heaviest carcass weight, whereas those slaughtered in September were lightest. Price per kilogram exhibited an almost opposite annual trend to carcass weight, with the trend in carcass value being intermediate.

Variation in carcass weight across years was small, ranging from 250 to 253 kg in 2003 and 2011, respectively. The annual pattern in both carcass price and value was much more evident, increasing from 2003 to 2011 by 38.8% (from 1.52 to 2.11 €/kg) and 46.8% (from 374 to 549 €/head), respectively (Figure 3). However, the association between month of slaughter and carcass weight, value, and price differed by year of slaughter (Table 1).

Breed of Cow

The majority (88%) of the data in the present study originated from cows of the 2 dairy breeds (HF and BS); the remaining cows were from dual-purpose breeds (Si, Re, and AG). Breed was the most strongly associated ($P < 0.001$) factor for all traits analyzed.

The dairy breeds were younger at slaughter, had lighter carcasses, and received the lowest price (at a constant carcass weight) and value than dual-purpose breeds (Table 2). Within the dairy breeds, HF was inferior to BS for all traits considered (i.e., HF cows, on average, were younger, lighter, and received lower carcass price per kg and total value than BS cows).

Among the dual-purpose breeds, Si cows, on average, yielded heavier carcasses, whereas the cows of the local breeds were characterized by older age at slaughter and by a higher price per kilogram of carcass. We observed no difference in carcass value between Si and the local

Figure 2. Monthly least squares means (1 SE represented each side of the mean as an error bar) for carcass value (€/head), carcass price (€/kg), carcass weight (kg), and number of culled cows.

Figure 3. Annual least squares means (SE represented as error bar) for carcass price (€/kg; gray line) and carcass value (€/head; black line) of culled cows.

dual-purpose breeds (Table 2). Of the local breeds, AG were oldest at culling and received the greatest carcass price.

The association between breed with the slaughter traits differed significantly by year of slaughter (Table 1). Age at slaughter decreased from 2003 to 2011 and was more marked for dairy breeds (-5.7 and -7.3 mo for HF and BS cows, respectively) than for dual-purpose breeds (-2.1 , -0.7 , and -2.0 mo for Si, Re, and AG, respectively). Additionally, the association between breed and carcass weight differed by year (Table 1); variation in carcass weight of the BS, HF, AG, and Re breeds across years was limited, whereas that of Si increased by 18 kg from 2003 to 2011.

The difference in carcass price between breeds varied across time (Table 1); carcass price increased more for HF and BS cull cows (0.67 and 0.65 €/kg, respectively) and less for the dual-purpose breeds (0.58, 0.49, and 0.57 €/kg for Si, Re, and AG, respectively). The in-

crease in carcass value across years (from 2003 to 2011) was very similar for the 2 dairy breeds and for AG (164, 164, and 176 €/head for HF, BS, and AG, respectively), whereas it was greatest for Si and least for Re (237 and 135 €/head, respectively).

Carcass price per kilogram was highly dependent on carcass weight, as demonstrated by the regression coefficient (Table 1); as a consequence, the increase in carcass value with increasing carcass weight was greater than the average carcass price and varied across breeds (Figure 4).

Age at Slaughter

Young cull cows (<3 yr old) had lighter carcasses (236 kg) but received the greatest carcass price (€2.19/kg) and a high value (€502/head; Table 3). Carcass weight increased with age at slaughter until 5 to 6 yr (Table 3). Carcass price of cows slaughtered after 3 yr remained relatively constant, whereas carcass value tended to increase up to 5 to 6 yr of age, after which the value decreased.

DISCUSSION

Dairy Farming in the Alps

Different dairy production systems exist in the Alps, varying from very traditional to the more intensive (Sturaro et al., 2009, 2013; Cocca et al., 2012). The typical traditional mountain farm is based on a small number of cows from the Alpine breeds, such as the Brown breeds, Red and White Simmental-derived breeds, and local breeds (Bittante, 2011). From autumn to late spring, cows are kept tied in the barn of the main farm

Table 2. Least squares means (LSM), SE, and contrasts of breed effect for slaughter age (mo), carcass weight (kg), carcass price (€/kg), and carcass value (€/head) of culled cows

Breed	No.	Slaughter age		Carcass weight		Carcass price		Carcass value	
		LSM	SE	LSM	SE	LSM	SE	LSM	SE
Holstein-Friesian (HF)	8,927	73.1	0.70	242	1.2	1.69	0.004	394	4.8
Brown Swiss (BS)	9,555	80.7	0.63	246	1.1	1.73	0.004	417	4.4
Simmental (Si)	1,117	79.7	1.16	271	1.9	1.74	0.008	521	8.1
Rendena (Re)	917	84.7	1.78	249	3.0	2.05	0.013	516	12.6
Alpine Grey (AG)	479	93.3	2.31	249	4.7	2.18	0.022	549	19.7
Contrast (<i>P</i> -value)									
¹ (HF + BS) vs. (Si + Re + AG)		***		***		***		***	
² HF vs. BS		***		***		***		***	
³ Si vs. (Re + AG)		***		***		***		NS	
⁴ Re vs. AG		**		NS		***		NS	

¹(HF + BS) vs. (Si + Re + AG) = contrast between dairy and dual-purpose breeds.

²HF vs. BS = contrast between the dairy breeds.

³Si vs. (Re + AG) = contrast between Simmental and the local dual-purpose breeds.

⁴Re vs. AG = contrast between the local dual-purpose breeds.

** $P < 0.01$; *** $P < 0.001$.

Figure 4. Within-breed regression coefficients of carcass value on carcass weight (CW; $P < 0.0001$; SE of estimates vary from 0.01 €/kg of CW for Holstein-Friesian to 0.07 €/kg of CW for Alpine Grey).

in the valleys, and feeding is based on hay and some concentrate, with limited access to pasture (Sturaro et al., 2009). During the summer, cows and replacement heifers are transported to the Alpine highland pastures for summer transhumance, at about 1,500 to 2,200 m above sea level. Alpine summer highland pastures are often the property of local communities, and animals from several farms graze together. Traditional stone and wooden buildings are used to house the animals overnight. Milk is processed locally for the production of “Malga” typical cheeses. The traditional dairy systems of the Alps are based on seasonality, with calving concentrated in the autumn and concentrated mating during the winter, so that the majority of cows are in late lactation when moved to the highlands. Barren cows identified after returning to the valley’s main farm at the end of summer highland pasture are generally culled.

Traditional dairy farms in the Alpine regions are characterized by lower average milk yield than more intensive farming systems and by greater labor input per unit of milk (Sturaro et al., 2013). The traditional dairy farms partly compensate economically for this lower output by also having lower costs of production (Tiezzi

et al., 2011, 2012), and especially, reduced capital costs, and external (feed) input costs. Moreover, in some areas such as Trento Province, traditional farms receive a milk price premium (20 to 40% greater; Sturaro et al., 2013) because of the superior technological properties of the milk produced (De Marchi et al., 2007; Bittante et al., 2012; Cipolat-Gotet et al., 2012) and the absence of silage and genetically modified organisms in the diet that qualify their milk for high-priced cheeses (De Marchi et al., 2008; Bittante et al., 2011a,b).

In the Alpine region, the number of traditional dairy farms is declining and they are being partly substituted by more modern and intensive farming systems based on loose rearing of cows, milking parlors, TMR, year-round calving, summer transhumance for heifers only, specialized dairy breeds (i.e., mainly HF), and higher productivity and income (Sturaro et al., 2009, 2013).

One option to partly compensate for the lower milk output in the traditional farming systems is to increase income from meat production, both as surplus calves and culled cows. Traditional mountainous dairy producers sell a higher proportion of newborn calves, because of the superior fertility and longevity of their cows, and therefore have a reduced requirement for replacement females. These surplus calves belong to breeds characterized by, on average, higher selling price and weight. Moreover, a higher proportion of cows from these herds are mated to beef bulls, often Belgian Blue sires, for the production of high-priced crossbred calves (Dal Zotto et al., 2009). The value of cull cows is also an important revenue source and the effect of different breeds on cull cow price is, to date, not well documented.

Age at Slaughter of Culled Cows

The average age of cows in the Trento Province at culling (74 mo, Figure 1) was greater than that in more intensive dairy areas (Ahlman et al., 2011; Hultgren et al., 2011; Sasaki et al., 2012). Age at culling, however, had a high coefficient of variability (41%, Figure 1). The most important sources of variation were herd and breed of the cow.

Table 3. Least squares means (LSM) and SE of carcass weight (kg), carcass price (€/kg), and carcass value (€/head) of cull cows at different age at slaughter

Slaughter age (yr)	No.	Carcass weight		Carcass price		Carcass value	
		LSM	SE	LSM	SE	LSM	SE
<3	1,363	236	4.43	2.19	0.02	502	18.61
3–4	2,871	245	2.29	1.85	0.01	446	9.53
4–5	3,639	253	2.11	1.81	0.01	470	8.77
5–6	3,465	261	1.94	1.82	0.01	504	8.07
6–7	2,857	257	1.88	1.81	0.01	481	7.79
>7	6,800	257	1.43	1.78	0.01	473	5.84

Even if the average age at slaughter of cull cows in the Trento Province was greater than the longevity of the cows enrolled in the national herdbooks, the differences among the dairy and dual-purpose breeds of the Alpine province reflect the differences in longevity documented at the national level. Differences in longevity of cows are influenced by both genetic and environmental factors. The international breeding goals of dairy breeds has broadened to include fertility, longevity, and correlated type traits (Miglior et al., 2005) to halt or reverse the decline in functional longevity observed in dairy cattle. Comparing the longevity of HF, BS, and Jersey cows in alternative regions of the United States, Garcia-Peniche et al. (2006) obtained different results when the breeds were compared using data from single-breed herds and mixed-breed herds. Moreover, Garcia-Peniche et al. (2006) documented similar overall longevity for HF and BS cows but reported a highly significant interaction between breed and region, concluding that an important component of the differences among breeds were differences among the production systems and environments. Vukasinovic et al. (2001), studying BS, Si, and HF cows in Switzerland, found that the risk of culling was much lower for cows moved to summer Alpine pastures than for cows in the lowland barns year round. This may be a contributing factor to the different age at slaughter of dairy and dual-purpose breeds in the present study, given that the latter are more represented in traditional farms practicing summer transhumance, whereas the former are more represented in the more intensive farms (Sturaro et al., 2009, 2013). In the Irish pasture system, dual-purpose breeds had superior longevity to Holsteins (Evans et al., 2004).

The more rapid decrease in age at slaughter from 2003 to 2011 in HF and BS cows but not in the dual-purpose breeds (interaction between breed and year effects) can be explained more by environmental than genetic reasons. In fact, the tendency toward the abandonment of the traditional farming system and the increase of modern intensive farms affected, in particular, the 2 specialized dairy breeds (Giupponi et al., 2006; Sturaro et al., 2013).

Carcass Weight of Culled Cows

Carcass weight of cull cows was heaviest during winter and lightest during autumn (Figure 2), concomitant with the return from summer pastures and the end of lactation in the more traditional farming systems. Culling rate in September and October was almost double that in June, July, and August (the months of the summer pasture). McHugh et al. (2010) observed that in Ireland the number of cows sold at market exhibited a bimodal distribution, with greater numbers sold in

spring (postpartum period) and autumn (end of lactation). It should be noted that, in that case, only a proportion of the cows sold at markets were slaughtered within a few days and these data referred to both dairy and beef cows. Considering only slaughtered animals in Ireland, Maher et al. (2008) found that the greatest number of cows were culled in October and November, 1 mo later than in the present study, although the grazing season is expected to be longer in Ireland than in the Alpine highland regions.

Average carcass weight of the HF cull cows in the present study was greater than that documented for the same breed by Yan et al. (2009) in lactating cows, but was similar to that reported by Vestergaard et al. (2007) and by Minchin et al. (2009) for dry cows slaughtered without a fattening period, and less than that documented by Seegers et al. (1998), Jurie et al. (2007), and Węglarz (2011) for cows subjected to an extra feeding period. Heavier liveweight and carcass weight is expected when cull cows are subjected to a finishing period, as confirmed by several studies (Allen et al., 2009; Franco et al., 2009; Minchin et al., 2009). No detailed information is available on the feeding regimen of cull cows by farmers in Trento Province but, except for cows slaughtered with urgency (e.g., due to calving problems, severe mastitis, accidents, lameness), cows are normally slaughtered toward the end of lactation when the marginal profit of milk production per day becomes negative.

Compared with the number of studies on HF cull cows, little information exists on cull cows from other dairy breeds. Often when comparisons do exist, the different dairy breeds are simply grouped as “dairy cows” whereas data on dual-purpose breeds generally originate from beef herds. Whether the slightly heavier carcass weight for BS cows compared with HF in the present study was due to a greater liveweight or a superior dressing percentage is not known. It is worth noting, however, that the least squares means in Table 2 were obtained from a model that included age at slaughter; considering the younger age at culling of HF cows and the increase of carcass weight with age, larger differences between actual breed averages are expected.

The dual-purpose Alpine breeds had heavier carcasses than cows from specialized dairy breeds, with Si cows yielding the heaviest average carcass weight; this was consistent with results documented by Habermann et al. (2000) on Simmental cows slaughtered after drying off without any finishing period. Habermann et al. (2000) found that, after 98 d of finishing, average liveweight increased 147 kg and carcass weight 104 kg, confirming a high finishing weight gain, which characterizes the Simmental breed.

The Re and AG local breeds are known as medium-framed, dual-purpose breeds with lesser average liveweight than HF and BS cows. The heavier carcass of the local breeds in the present study is therefore most likely due to a greater dressing percentage. Greater dressing percentage is also the result of a breeding program that included, in the case of Re, a combined index of growth capacity, in vivo estimated dressing percentage, and carcass muscularity (Bittante et al., 2007). Comparisons carried out on fattening young bulls of the 3 dual-purpose breeds confirmed the superiority of Si breed in terms of body size and weight gain, but also the good dressing percentage and meat quality of both local Alpine breeds (Bonsembiante et al., 1988; Cozzi et al., 2009).

Carcass Price and Value of Culled Cows

Few studies have quantified the factors associated with cull cow market value. Differences in yield and value of individual retail cuts of HF and Si cow carcasses were studied by Kaufmann et al. (1996). The carcasses of young Si females in the study of Kaufmann et al. (1996) were 21.9% more valuable than those of HF cows but this difference in value was reduced to 8.5% in older cows; in the present study, the difference in carcass values was 33.1 and 24.2% in young and older cows, respectively. In our study, the association between cow breed and both carcass price and value also differed by age of cow at slaughter, confirming that the superiority of dual-purpose cows was greatest when they were younger.

More recently, McHugh et al. (2010), analyzing the value of cows sold at auctions in Ireland, reported that Si received a 20.3% price premium compared with HF without correcting for liveweight; this reduced to 15.2% after adjustment for differences in liveweight. In the study of McHugh et al. (2010), however, the data were obtained on live animals, only some of which were slaughtered within a few days of purchase. Moreover, Si cows in Ireland generally reside in beef herds as suckler cows and are generally not used for milk production, thus influencing the results. McHugh et al. (2010) also reported that the dual-purpose breeds of Montbéliarde and Normande were worth 9.9 and 16.6% more, respectively, than Holstein; when liveweight was included in the model, the respective values were 14.1 and 16.8%. Dal Zotto et al. (2009), analyzing the auction price of Italian calves produced by 4 of the 5 breeds considered in the present study in the same environment, reported greater prices for Si calves, followed by AG, and subsequently by the 2 dairy breeds (HF and BS).

McHugh et al. (2011) reported that the value of beef and dairy cows sold at auction was heritable, even

though the heritability of animal value was approximately half that of liveweight and much lower than heritability estimates for animal value of calves, weanlings and postweanlings. Penasa et al. (2012) found, using BS calves sold at auction and produced in the same environment as in the present study, that animal value is heritable, as is body weight. Moreover, other studies (Otto et al., 1991; Gregory et al., 1998; Minchin et al. 2009) documented the positive effect of cow body condition on quantity and quality traits of the cull cow at slaughter. Body condition score of dairy cows is heritable (Gallo et al., 2001) and selection for increased BCS improves cow fertility (Berry et al., 2003; Dal Zotto et al., 2007); this indirect selection could increase the value of cull cows.

It is interesting to note that the increase in carcass value, within breed, per unit increase in carcass weight was much greater (2 to 2.5 times) than that of the average price per kilogram of carcass (Figure 4). This implies a greater emphasis by the purchaser on quality than on quantity (i.e., carcass weight). Several studies demonstrated that fattening of cull cows increased not only liveweight but also dressing percentage, the muscularity and fatness of carcasses, the incidence of superior retail cuts, and quality attributes (Habermann et al., 2000; Vestergaard et al., 2007; Allen et al., 2009; Franco et al., 2009). None of these studies attempted to quantify the increase in price and value due to fattening of cull cows.

CONCLUSIONS

The value of cull cows at slaughter represents a source of income for dairy farms. However, considerable variation in cull cow value exists. The main sources of variation were breed, herd, age, and weight of carcass, as well as year and season of slaughter. Holstein-Friesian cows were younger at slaughter, yielded lighter carcasses, and received a lower price and total value compared with Brown Swiss cows. Dual-purpose breeds were older and heavier and received a greater price and value at slaughter than either dairy breed. Thus, in traditional small Alpine farms, the value of dual-purpose cull cows, combined with better longevity, fertility, value of purebred calves, lower feed inputs, and better milk quality, can partially compensate for the lower milk production yields of dual-purpose cows relative to specialized dairy breeds. Of the dual-purpose cows, Simmental cows were heaviest, whereas Rendena and Alpine Grey cows received the greater price, resulting in no difference in carcass value among the dual-purpose breeds. The large differences among different breeds in cull cow value highlight the importance of cull cow characteristics, especially in traditional moun-

tain dairy systems characterized by limited milk productivity. This suggests the possibility to include such traits in the breeding objectives of these breeds, but underlines the need for better comprehension of the interactions between breed of cow and the alternative dairy production systems of mountainous areas, moving from traditional to modern dairy farms. Moreover, the quantification of the combined effect of weight and price on the increase in value of the carcass highlights the possible economic advantage of fattening culled cow before slaughtering.

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