A comparison of animal-related figures in milk and meat production and economic revenues from milk and animal sales of five dairy cattle breeds reared in Alps region

Thomas Zanon\textsuperscript{a}, Sven König\textsuperscript{b} and Matthias Gauly\textsuperscript{a}

\textsuperscript{a}Facoltà di Scienze e Tecnologie, Free University of Bolzano, Bolzano, Italy; \textsuperscript{b}Institut für Tierzucht und Haustiergenetik, Justus-Liebig University Giessen, Giessen, Germany

ABSTRACT
The objective of this study was to compare animal-related figures in milk and meat production and economic revenues from milk and animal sales over the last decade of the five most-common dairy cattle breeds in South Tyrol. Auction prices and milk performance control data were considered to calculate milk sales, animal sales and total revenue per cow of the respective breed between January 2009 and December 2019. Results highlight a stepwise substitution of Brown Swiss breed by Simmental breed over the last decade. This is probably related to the greater animal sales and greater total revenue per cow thanks to the dual-purpose characteristics in latter. No significant trend towards the breed Holstein-Friesian was observed although cows of this breed were shown to produce the highest milk yield (MY) per lactation and generated the highest total revenue per cow. Moreover, the local breeds Pinzgauer and Alpine Grey were able to compete in sense of importance as the number of cows remained mainly unaltered over the last decade. Thus, results indicate that although less productive, in sense of MY, local dual-purpose breeds seem to be of high interest for dairy farming systems in an alpine area as the decision for breeds is obviously not only driven by farm income.

HIGHLIGHTS
- Holstein-Friesian is the most productive cattle breed considering milk production per lactation
- Simmental breed has a similar milk yield as Brown Swiss breed but received higher auction prices for calves and cull cows than latter
- Pinzgauer and Alpine Grey cows can compete with other breeds thanks to their dual-purpose characteristics, adaptability to alpine farming systems and additional subsidies

Introduction
Mountain agriculture is characterised by small cultivation areas with heterogenic features, which are dispersed at different altitudes with different climates and limited use for mechanisation (FAO 2019). Likewise, there are different cattle breeds used in different farming systems (Sturaro et al. 2009). Next to management and husbandry factors, it is believed that mainly the economic potential of a cattle breed plays a decisive role, when deciding which breed is most suitable for a farm. The latter depends on the fertility and health parameters as well as on milk production and animal sales (calves, cull cows) (Evans et al. 2004; Kühl et al. 2020). Several studies have already compared the profitability of different cattle breeds. Gandini et al. (2007) concluded that Holstein-Friesian (HF) was more profitable in milk production systems due to higher milk yield (MY). However, while processing milk of Reggiana cows to Parmiggiano-Reggiano cheese and considering the compensation for endangered livestock breeds according to the regulation (EU) 1698/2005 in the calculation for Reggiana breed, latter was more economical than HF. Similarly, Pretto et al. (2009) showed a reduction of the difference in profitability between Burlina and HF cows when transforming Burlina milk to Morlacco cheese, with the EU...
compensation for Burlina breed being included in that calculation. In Haiger and Knaus (2010) HF cows exhibited higher milk sales than Simmental (SI) cows, but higher cull cow and bull calf prices for latter reduced the difference of profitability between the breeds. Similarly, Evans et al. (2004) observed a higher profitability for dual-purpose breed Montbéliard compared to HF, due to lower restocking costs, greater beef revenue and greater milk sales due to higher fat and protein content in milk. Kühler et al. (2020) investigated profitability of dairy farms in South Tyrol and showed that local dual-purpose breed Alpine Grey (AG) could compete with specialised dairy breed Brown Swiss (BS) in terms of profitability. Dal Zotto et al. (2009) analysed the effects of crossbreeding with beef bulls on age, body weight, price and market value of calves on South Tyrolean dairy farms, considering calf sales only, and stated higher revenues for dual-purpose and cross-bred animals. Nevertheless, no previous study has examined productive and economic parameters of several cattle breeds over a longer period, which is, however, an important evaluation criterion to assess the development of their productivity and to estimate their economic potential for the future. Therefore, the aim of this study was to compare animal-related figures of milk and meat production and economic revenues from milk and animal sales of the five most-used cattle breeds in South Tyrol over a decade between January 2009 and December 2019. The province of South Tyrol is in the north-eastern part of Italy and it is characterised by family-run small scale dairy farms with on average 15 dairy cows (Province 2018). Two thirds of all dairy farms in South Tyrol are run on a part-time basis. Eight percent of them are located above 1000 m above sea level with almost half of the agricultural land having a slope inclination of more than 30%. Nevertheless, dairy farming is still the most important economic pillar for 92% of the mountain farmers (Raiffeisen 2020).

Materials and methods

Data collection

The economic assessment was carried out for the specialised dairy breeds BS, HF and for the dual-purpose breeds AG, Pinzgauer (PI) and SI, currently kept in South Tyrol (Northern Italy), considering averages for production and for economic parameters. Population figures of milk recorded cows and official statistics of milk performance controls were retrieved from the annual reports of the Animal Breeders’ Associations South Tyrol (APA di Bolzano) and from the Italian Breeders’ Association (AIA). Auction prices for primiparous cows of respective breed were provided by the Brown Cattle Breeders Federation of Bolzano Province (Südtiroler Braunviehzuchtverband; Bolzano, Italy) and the South Tyrolean Cattle Breeders’ Association (Rinderzuchtverband Südtirol; Bolzano, Italy). Finally, auction price, weight at auction and market value realised at calf and slaughter cattle auctions were provided by the South Tyrolean Livestock Marketing Consortium (Kovieh; Bolzano, Italy). Calves were sold at an age between 14 and 40 days. Average values for successful pregnancy followed by calving, days open, lactation length and gender distribution among calves were calculated using national milk recording data, retrieved from the AIA, for each breed for corresponding year. The average gestation length of respective breed was estimated considering the official limits of the ‘Rinderdatenverbund (RDV)’ for Austria, used by the breeding organisation Austria (ZAR) (Kraßnitzer 2009). Restocking rate was estimated considering the number of primiparous cows in relation to the total number of milk recorded cows for respective breed and year. Rearing losses were quantified at 9% (Zuccali et al. 2013). The number of calves per year was calculated considering the intercalving period, the probability for successful pregnancy followed by calving and rearing losses. The number of potentially sold calves corresponded to the number of bull calves, as well as the number of cow calves not used for restocking. The number of cull cows was determined considering the restocking rate for respective breed. The observation period was from January 2009 to December 2019. Differences in feeding practices, feed intake and -efficiency, labour costs, machine costs and veterinary treatment were not included in the assessment.

Estimation of total revenue

The economic data are expressed in Euros (€) and Eurocents (c) and refer to the corresponding year (2009–2019). Milk sales per cow were calculated considering the average milk price of Mila Bergmilch Südtirol, which is the largest dairy in the province of Bolzano, considering all different price scenarios for different milk (conventional milk, hay-milk, organic hay-milk, organic milk). Further, milk price was adjusted according to the average milk composition (fat%, protein%) produced by each investigated cattle breed in respective lactation and year.

Similarly, market value for calves and cull cows was determined using average action price and weight at
auction for corresponding years. Restocking costs were estimated by considering the market value for primiparous cows and the restocking rate of respective breeds. Animal sales per cow was estimated by summing the market value of available calves and cull cows putting it in relation to the number of milk recorded cows for corresponding breed. Finally, the total revenue per cow was calculated for each breed and for each year considering the milk sales per cow, the animal sales per cow and the restocking costs per cow. For AG and PI incentive payment for local breeds in danger of being lost to farming of 200 € per year were included in the estimation of total revenue, following Article 39 (4) of Regulation (EC) No 1698/2005 and Article 28 (8) of Regulation (EC) No 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development.

Statistical analysis

An ANOVA was performed using the proc GLM procedure in SAS software v. 9.4 (SAS Institute Inc., Cary, NC). The calculated LSM values were checked for their significance by post hoc Tukey’s test. The calculated p values refer to a confidence level of 95% unless otherwise stated. The model used was as follows:

\[ y_{ij} = \mu + \text{breed}_i + \text{year}_j + e_{ij} \]

where \( y_{ij} \) is the observation value of the dependent variable (MY per lactation, restocking rate, days open, intercalving period, lactation length, weight of bull and cow calf, weight of cull cow, auction price for bull and cow calves, auction price for cull cow, market value for bull and cow calves, market value for cull cow, milk price per breed, milk sales per cow, animal sales per cow, total revenue per cow), \( \mu \) is the overall intercept of the model, \( \text{breed}_i \) is the fixed effect of the \( i \)th cattle breed (\( i = 5; \) BS, HF, SI, AG, PI), \( \text{year}_j \) is the fixed effect of the \( j \)th observation year (\( j = 11; \) 2009–2019) and \( e_{ij} \) is the random residual. Moreover, in order to assess differences between groups of breeds contrast estimates for breed effect were calculated.

Results

Descriptive statistics of milk recorded cows

Figure 1 depicts the population dynamics of milk recorded cows from January 2009 to December 2019, which approximately describes 85% of all cows present in the province of Bolzano (Province 2018). The number of BS cows decreased sharply following a slope of -565 cows/year with a coefficient of determination \( R^2 = 0.97 \), whereas, the number of SI cows increased steadily (+335 cows/year; \( R^2 = 0.93 \)). Further, the number of HF cows remained mainly unaltered throughout the observation period (+335 cows/year; \( R^2 = 0.93 \)). The number of BS cows decreased sharply following a slope of -565 cows/year with a coefficient of determination \( R^2 = 0.97 \), whereas, the number of SI cows increased steadily (+335 cows/year; \( R^2 = 0.93 \)). Further, the number of HF cows remained mainly unaltered throughout the observation period (+335 cows/year; \( R^2 = 0.93 \)).

Regarding local dual-purpose breeds, population numbers of AG and PI remained almost constant (-39, \( R^2 = 0.70; -6.44, R^2 = 0.14 \), respectively).

Development of production performance

The average MY per lactation increased linearly, except for PI, across the observation period (Figure 2(a)). The
highest increase for MY per lactation was observed in BS (88 kg/year; $R^2 = 0.96$), while the lowest increase was found in PI (30.65 kg/year; $R^2 = 0.65$). Moreover, the yearly increase in MY per lactation of HF and AG averaged 66.27 kg and 52.60 kg with a coefficient of determination of 0.90 and 0.95, respectively. The greatest MY per lactation for all years was observed in HF cows, while the lowest was registered for AG (Figure 2(a)). Both, SI and BS showed a similar trend for MY per lactation during the observation period. The calculated restocking rate for all breeds showed little variation throughout the years and averaged 24, 25, 29, 21 and 25% for BS, SI, HF, AG and PI, respectively. Average lactation lengths for each breed showed no strong alteration as the yearly increase varied between +0.34 ($R^2 = 0.36$) and +0.69 ($R^2 = 0.88$) days per year for PI and BS, respectively. The yearly increase for the intercalving period (Figure 2(b)) was more pronounced in BS and HF (+1.65, $R^2 = 0.90$ and +1.44, $R^2 = 0.73$ days/year) than in dual-purpose breeds SI, AG and PI (+1.03, $R^2 = 0.90$; +0.77, $R^2 = 0.88$; +0.98, $R^2 = 0.88$, days/year, respectively).

**Development of estimated economic revenue**

Similarly, as MY per lactation, milk sales per cow increased in a linear way (data not shown), showing a similar trend as illustrated in Figure 2(a), considering milk quality (fat%, protein %). Conversely, however, animal sales per cow increased only to a small extend throughout the observation period (Figure 3(a)). Overall, animal sales per cow from SI cows was the greatest and that from BS was the smallest (Figure 3(a)). Both, PI and AG showed a similar trend for animal sales per cow throughout the years. In general, animal sales per cow of dual-purpose breeds were higher than that of specialised dairy breeds (Figure 3(a)). Finally, as Figure 3(b) illustrates, total revenue per cow was highest in HF and lowest in AG over the last decade. The trend for total revenue per cow of PI resembled to some extend that of BS across the years (Figure 3(a)).
Table 1. Least square means of production traits for dairy cattle breeds.

| Production traits                  | Brown Swiss | Holstein-Friesian | Simmental | Alpine Grey | Pinzgauer |
|-----------------------------------|-------------|-------------------|-----------|-------------|-----------|
| Milk, kg per lactation            | 7180.3b     | 8635.0a           | 7109.8b   | 5202.3d     | 6354.0c   |
| Restocking rate, %                | 24b         | 29a               | 25b       | 21c         | 25b       |
| Days open, d                      | 122.0b      | 130.4a            | 94.5d     | 95.5d       | 103.6d    |
| Intercalving period, d            | 413.0a      | 413.4a            | 384.5c    | 383.5c      | 390.6c    |
| Lactation length, d               | 329.8b      | 336.0a            | 310.1c    | 302.0d      | 311.1c    |
| Weight bull calf at auction, kg   | 66.0d       | 59.2e             | 72.0a     | 68.6b       | 67.1c     |
| Weight cow calf at auction, kg    | 58.4cd      | 55.2d             | 68.8a     | 64.7b       | 61.2c     |
| Weight cull cow at auction, kg    | 616.7b      | 624.9b            | 642.9a    | 526.0c      | 643.0c    |

Different superscript letters within row indicate statistical significance ($p < .05$).

Table 2. Least square means of economic traits for dairy cattle breeds.

| Economic traits                  | Brown Swiss | Holstein-Friesian | Simmental | Alpine Grey | Pinzgauer |
|----------------------------------|-------------|-------------------|-----------|-------------|-----------|
| Price bull calf, €/kg            | 1.86a       | 2.19d             | 5.03a     | 3.94b       | 2.95c     |
| Price cow calf, €/kg             | 1.37a       | 1.67d             | 4.07a     | 3.08b       | 2.22c     |
| Price cull cow, €/kg             | 1.05d       | 1.00e             | 1.32a     | 1.27d       | 1.20c     |
| Market value bull calf, €        | 126.22d     | 130.57d           | 363.22a   | 273.39b     | 201.40c   |
| Market value for cow calf, €      | 86.11d      | 99.33d            | 278.51a   | 202.56c     | 141.24c   |
| Market value for cull cows, €     | 653.86c     | 632.89d           | 841.11a   | 655.59c     | 767.21d   |
| Milk sales, €/cow                | 3724.35b    | 4472.80a          | 3682.25a  | 2673.55b    | 3280.12c  |
| Animal sales, €/cow              | 223.84d     | 249.79c           | 419.80c   | 301.41b     | 300.46b   |
| Total revenue, €/cow             | 3431.66c    | 4118.14a          | 3601.49b  | 2826.29b    | 3386.21c  |

Different superscript letters within row indicate statistical significance ($p < .05$).
The effects of cattle breed on production and economic traits

Tables 1 and 2 list the calculated least square means for investigated production and economic traits. MY per lactation differed significantly ($p < .05$) between breeds (Table 1). The highest ($p < .05$) MY per lactation was observed in HF cows, while the lowest ($p < .05$) was found in AG cows. Restocking rate was significantly lower in dual-purpose breeds and BS compared to HF (Table 1). Further, HF was characterised by the longest days open period and lactation length ($p < .05$) when compared with the other breeds. Moreover, from Table 1 emerges no significant difference for days open between SI and AG. Likewise, no statistical differences were found for intercalving period between specialised dairy breeds and between SI and AG. In addition, weight of bull and cow calves differed significantly among breeds and showed higher LSM in dual-purpose breed than in specialised dairy breeds, except for cow calves of PI and BS, with highest values for both sexes found in SI breed (Table 1). Lastly, weight of cull cows was significant greatest ($p < .05$) in PI and SI and the lowest in AG. In terms of economic parameters, again, dual-purpose breeds showed significant higher ($p < .05$) auction price and market value for bull and cow calves (Table 2). Similarly, auction price for cull cows of dual-purpose breed (SI, PI) was significant higher compared to HF and BS (Table 1). Considering milk sales per cow, HF was superior to all breeds ($p < .05$), while that of BS and SI not differed significantly ($p < .05$). Moreover, PI showed higher milk sales per cow compared to AG. Among all breeds, SI had the greatest animal sales per cow ($p < .05$), followed by PI and AG, showing no significant differences between each other, and BS with the lowest animal sales per cow (Table 2). Total revenue per cow was significant ($p < .05$) highest in HF and lowest in AG breed. Dual-purpose SI exhibited higher total revenue per cow than local dual-purpose breeds and BS. Latter showed no significant differences from PI.

To assess the differences between specialised and dual-purpose breed, SI breed and local dual-purpose breeds, BS breed and SI breed and AG breed and PI breed, contrast estimates for breed effect were calculated (Table 3). Specialised breeds and dual-purpose breeds differed significantly for all traits (Table 3). In fact, specialised breeds produced 1685.61 kg ($p < .001$) more milk than dual-purpose breeds, which is reflected in the higher milk sales per cow (886.60 €; $p < .001$, Table 3). Moreover, longer ($p < .001$) intercalving period (26.94 d), days open (28.27 d) and lactation length (25.18 d) were observed in specialised dairy breeds (Table 3). Dual-purpose breeds exhibited higher weights for calves of both sexes (6.63 kg and 8.10 kg, respectively) and higher realised auction price and market value ($p < .001$) for both, calves and cull cows, which resulted in the higher animal sales per cow (103.75 €) compared to specialised dairy breeds (Table 3). Furthermore, SI performed significantly better in terms of production and economic traits.
compared to local dual-purpose breeds (Table 3), producing 1331.68 kg more milk (p < .001) and realising 118.86 € higher animal sales per cow (p < .001). BS performed slightly better (p < .05) in terms of MY (70.45 kg) compared to SI, which albeit not resulted in a significant different milk sales per cow, although considering milk quality parameters (fat%, protein%) for the payment, while for animal sales per cow and total revenue per cow SI showed greater values (p < .001). Regarding local dual-purpose breeds, AG received higher auction prices (0.99 and 0.85 €/kg) and higher market values (p < .001) for both sexes of calves (72.00 € and 61.32 €, respectively) and exhibited shorter lactation and intercalving periods, while PI produced 1151.73 kg more milk (p < .001) with higher quality (data not shown) and obtained higher market value (p < .001) for cull cows (111.62 €), resulting in an similar animal sales per cow and significant higher (p < .001) total revenue per cow (559.91 €) in favour of PI.

Discussion

Mountain agriculture is characterised by various production systems, resulting in a high diversity of agricultural land types and farmed livestock breeds (Sturaro et al. 2009; Battaglini et al. 2014; Marsoner et al. 2018). Further, traditional mountain farming, as defined in Sturaro et al. (2009), makes an important contribution for achieving the EU-wide climate targets for 2030, as using high amounts of pasture feed and low supply of concentrates comes along with a greater ecologic sustainability when compared with dairy farming systems characterised by year-round stable-feeding and high amounts of external resources (Sutter et al. 2013). Likewise, low-input grass-based dairy production was demonstrated to increase net food production (Ertl et al. 2015), and therefore, might contribute to improve food security (Godfray et al. 2010). In the last decades, the abandonment of farms and marginal agricultural areas located in Alpine region became more and more evident, leading to an increase in farm structures with a higher degree of mechanisation and specialisation (MacDonald et al. 2000; Giupponi et al. 2006; Streifeneder et al. 2007). That shift towards a more profit-oriented agricultural practice enhanced the focus on intensive farming practice and the use of high-yielding cattle breeds for dairy production (Marsoner et al. 2018). In South Tyrol, however, the so called ‘Holsteinizing’ (Cunningham 1983) is not as visible as in the rest of Italy or in other European countries, because the number of HF cows did not change dramatically since 2009 (Figure 1). Conversely, however, the number of local dual-purpose breeds like AG and PI mostly remained unaltered over the last decade. This might be related to several factors. First of all, Kühl et al. (2020) showed that local breeds can compete in economic terms with specialised dairy breeds as feeding cost are lower, which is mainly explainable by the lower amount of concentrates required in the ratio to fulfil nutritional demand because MY is lower compared to specialised dairy breeds (Table 3). Moreover, in the same study AG exhibited lower veterinary, insemination and stock replacement cost compared to BS which might be related to the high adaptation of former breed to mountain farming and related housing and management factors. Furthermore, Mattiello et al. (2011) showed less prevalence for welfare problems in local dual-purpose breeds compared to specialised dairy breeds, both farmed in alpine husbandry systems (mainly tie barns). Transhumance is traditionally practiced in South Tyrol which is confirmed by the fact that in 2018 about 44.236 out of 128.329 total cattle were brought to alpine pastures (Province 2018). Local breeds were shown to cope better with the stressful period during transhumance and to exploit alpine pastures more efficiently as they showed fewer negative alterations regarding milk production and physiology than specialised breeds (Faccioni et al. 2016; Niero et al. 2018; Koczura et al. 2019, 2020). Further, Figure 1 displays a sharp decrease of BS cows and a strong increase in SI cows that could indicate a substitution of BS by SI breed. MY per lactation of both breeds was similar, but auction prices for calves and cull cows was significant greater in SI breed (Tables 1 and 2). Consequently, the greater generated animal sales per cow compared to BS (Table 3) is responsible for the higher generated total revenue per cow of SI breed in our estimation, which could partly explain the substitutional trend illustrated in Figure 1. Further, BS cows are known for producing a higher milk quality with better technological properties (e.g. coagulation properties, protein fractions) than SI (Penasa et al. 2014; Franzoi et al. 2019; Manuelian et al. 2019). Nevertheless, no significant difference regarding milk sales could be observed albeit considering milk quality parameters (fat%, protein%) for determine the milk price. Moreover, other factors like higher immunity against mastitis infections (Litwińczuk et al. 2011) or better fertility due to higher herd productivity compared to BS (Toledo-Alvarado et al. 2017) could be additional factors explaining the continuous decrease of population numbers of BS in favour of SI. Higher
The milk production efficiency, not considering milk on the base of the data of Table 1 (slaughter cow), when expressing milk production per kg bodyweight, notwithstanding it is worth to be considered that crossbreeding was shown to not be relevant. In PI breed between 1992 and 2004, whereas for AG percentages of foreign blood, mainly of dairy breeds, attributed to the refining cross with Red Friesian, as former produced 1151.7 kg more milk shown to be significant higher in PI cows compared to BS, SI and PI in Table 1. The 21.5% greater MY per lactation generated with HF breed compared to SI breed was reduced to 14.3% when adding animal sales per cow. Similarly, PI breed was able to compensate 13.0% of lower MY per lactation with greater animal sales per cow compared to BS breed. The results resemble those reported in Haiger and Knaus (2010), were SI breed was able to partly compensate the 14% lower milk sales per cow compared to HF breed with the higher animal sales per cow generated by higher bull calf and cull cow auction prices. Furthermore, results highlight an increase of MY in the last decade, which next to breeding progress might be explained by the intensification of South Tyrolean milk production. This becomes evident by the yearly increase of total MY in the region although decreasing numbers of dairy farms (Sennerreiverband 2020). Regarding breeds, the more significant increase for MY per lactation in BS, SI and HF might be attributed to intensification, as all breeds are suitable for intensive farming thanks to their genetic merit (Sturaro et al. 2009; Haiger and Knaus 2010). Conversely, the yearly increase of 52.60 kg ($R^2 = 0.95$) in AG (Figure 2(a)) displays an intensification of farms using local dual-purpose as well. The moderate increase of MY per lactation observed in PI is next to farming factors partly caused by the limited breeding activity in South Tyrol, which is related to the absence of a well-structure breeding program and the lack of genetic evaluation in the region. Nevertheless, MY was shown to be significant higher in PI cows compared to AG cows, as former produced 1151.7 kg more milk (Table 3) with higher quality (fat %) (data not shown). The higher MY found in PI breed might partly be attributed to the refining cross with Red Friesian, as Egger-Danner and Fürst (2005) exhibited increasing percentages of foreign blood, mainly of dairy breeds, in PI breed between 1992 and 2004, whereas for AG crossbreeding was shown to not be relevant. Notwithstanding, it is worth to be considered that when expressing milk production per kg bodyweight, on the base of the data of Table 1 (slaughter cow), the milk production efficiency, not considering milk quality, of the two breeds is similar.

The calculated restocking rate depicted in Table 1 was significant lower in dual-purpose breeds and BS compared to HF. The significant lowest restocking rate observed in AG breed was expected as latter is known for its longevity (Bazzoli et al. 2014). It is well known that milk production and fertility show an antagonistic genetic relationship (Laben et al. 1982; Berry et al. 2016). Nevertheless, good management and feeding practice can improve fertility in cows as stated in Laben et al. (1982) and Walsh et al. (2011). In our results, high yielding HF showed a longer day open period compared to other breeds (Table 1), which is in line with Friggens et al. (2010) where the selection on body fat mobilisation in high yielding cows was stated a major effect for supressed fertility. Further, results indicate high fertility in SI cows as difference of day open was not significant different from AG breed and lower compared to other breeds (Table 1). Longer lactation lengths in specialised dairy breeds compared to local PI and AG breed may be due to higher milk production (Table 1). In fact, Niozas et al. (2019) assumed a better reproductive performance for high-yielding cows when lactation is extended. Nevertheless, no significant difference ($p < .05$) was detected between SI and PI in lactation length though significant higher ($p < .05$) MY per lactation for former breed (Table 1). That result confirms the higher productivity in SI compared to PI, which next to farming factors might be related to the greater breeding progress and breeding activity for SI due to greater populations and international collaboration between breeding organisations for many years (Edel et al. 2011).

The higher observed weight of calves of both sexes in SI, AG and PI, as already mentioned, might be mainly related to the dual-purpose characteristics, as latter were bred for both, milk and meat production in contrast to the specialised dairy breeds, where the main emphasis is primarily put on milk production traits. Further, higher auction price for bull calves of SI, PI and AG are consistent with the results in Dal Zotto et al. (2009) where SI and AG calves received greater auction prices than calves from specialised dairy breeds. Higher auction prices for dual-purpose bull calves might be related to the greater demand for latter as they are known for good fattening performance. Several studies highlighted that SI and PI were able to compete with conventional beef cattle breeds in terms of daily weight gain, carcase conformation and beef quality (Bulla et al. 2013; LfL 2020). Furthermore, Bulla et al. (2013) stressed the high suitability of PI breed for beef production in extensive
mountain production systems with seasonal grazing on permanent pastures. Moreover, Dal Zotto et al. (2009) highlight the possibility to increase auction price and market value when crossbreeding with specialised beef cattle breeds like Blue Belgian or Limousin for both dairy and dual-purpose breeds.

Cull cows were stated an important source of income for mountain farming systems (Bazzoli et al. 2014). The significant higher ($p < .001$) market value of SI compared to local dual-purpose breeds in Table 3 is in contrast with Bazzoli et al. (2014). The authors observed no significant difference between SI, AG and Rendena as higher carcase weight for SI cull cows was compensated by the higher carcase price for the local dual-purpose breeds in that study. Likewise, in our results PI was able to compensate the significant lower ($p < .05$) auction price with significant greater weight for cull cows than AG (Table 3). Moreover, no significant differences were displayed for cull cow weight between SI and PI (Table 1). The lowest cull cow weight found in AG compared to all other breeds is related to its phenotypic characteristics for being a small to medium framed cattle breed.

The greatest total revenue per cow, including MY per lactation, milk quality, restocking and animal sales (bull and cow calves, slaughter cattle), found in HF (Table 1) is mainly related to the milk to meat relationship in favour of MY due to the high milk price in South Tyrol, which was shown to economically pay off high-input farming (Kühl et al. 2020). This is in line with Zaugg (1976), where an economic superiority was observed for HF over BS and SI, explaining that result next to greater MY and prematurity in former breed by the greater economic remuneration for milk than for beef. The greater economic impact of MY on total revenue per cow in our results is partly explained by the fact that beef yield cannot be increased via breeding progress in the same way as MY. Moreover, there is still unused potential to increase profitability for beef production in South Tyrol, since the current local added value is poor because calves and cull cows are largely exported to neighbour regions (data not shown).

Further, although we have included the incentive payment for endangered livestock breeds, as prescribed by Article 39(4) of Regulation (EC) No 1698/2005 and Article 28(8) of Regulation (EC) No 1305/2013, both, PI and AG showed significant lower total revenue per cow compared to specialised dairy breeds and SI breed. However, it must be considered that we have not included feeding cost or veterinary treatment cost, as latter were shown to be significantly higher in specialised dairy breeds than local dual-purpose breeds (Kühl et al. 2020). Therefore, as AG and PI are mostly kept in low input mountain farms, it can be hypothesised that they might be more economic when compared with conventional dairy breeds in terms of adaptability, rusticity and use of roughage, which, again, is highlighted with the stable trend of AG and PI population over the last years (Figure 1). Nevertheless, our results indicate a financial dependency of local dual-purpose breed from EU funds as they showed lower total revenue compared to conventional dairy breeds (Giupponi et al. 2006). In order to improve profitability Marsoner et al. (2018) have indicated the possibility to diversify production and increase value of food products produced by local cattle breeds via special branding and product declaration. Special branding and diversification allowed local breeds to compete with HF, as shown in Gandini et al. (2007) and Pretto et al. (2009).

**General considerations**

Differences between cattle breeds should be considered with caution as next to genetic factors the respective dairy system, in particular, farm management factors like feeding management, feed composition, housing systems and veterinary treatments, which were not included in the estimation, largely effect herd and animal productivity and farm profitability. Further, machinery and capital investments were shown to be greater for intensive farms that often are rearing specialised dairy breeds (Kühl et al. 2020).

**Conclusions**

Our results partially confirm previous studies were intensive dairy production with high yielding cows in South Tyrol was shown to economically pay off. Nevertheless, the optimisation of resource efficiency will become more and more important for promoting a sustainable agriculture with a high degree of self-sufficiency and independence from external resources. Our findings highlight the advantage of dual-purpose breeds to increase farm income through higher calf and cull cow prices compared to specialised dairy breeds, and thus, compensate partly the lower milk sales per cow. Unlike in other regions the so called "Holsteinizing" observed in South Tyrol was not as pronounced as in other regions of Italy and Europe, as the number of HF cows remained mostly unaltered.
over the observation period. Furthermore, although less productive in terms of MY per lactation, local breeds were shown to be competitive in terms of population numbers, which might be explained by the high adaptability to alpine area and the lower production costs (feeding costs, veterinary costs, machinery costs) as shown in previous studies. In general, the preservation of local breeds is crucial as they provide several non-market products, like ecosystem services and genetic resources. Moreover, local breeds have the big potential for producing unique agricultural products with high added value and high quality that are strictly related to the region of origin or to a traditional production concept with the finality to diversify on the market and increase the income of the farms.

Acknowledgements

The authors acknowledge Annemarie Kaser (Association of South Tyrolean Animal Breeders’ Associations (APA di Bolzano)), Martin Tröger (South Tyrolean Livestock Marketing Consortium (Kovieh) Peter Zischg (Brown Cattle Breeders Federation of Bolzano Province (Südtiroler Braunviehzuchtverband; Bolzano, Italy), Herbert Lang (South Tyrolean Cattle Breeding Association (Rinderzuchtverband Südtirol) and Reinhard Schuster (Mila Bergmlich Südtirol Gen. u. landw. Ges.) for providing data. This work was supported by the Open Access Publishing Fund of the Free University of Bozen-Bolzano.

Ethical Approval

For this study economic and productive figures were used and the approval of the Ethical Committee for the Care and Use of Experimental Animals of the Free University of Bolzano not required.

Disclosure statement

The authors declare no conflict of interest associated with the paper. The authors are fully responsible for the content of the manuscript.

Funding

This research was conducted within the project EIFEAL-European Region Tyrol-South Tyrol-Trentino as Land of Solutions 2019 [CUP-Kodex I56C18002030002].

ORCID

Sven König http://orcid.org/0000-0003-4226-3696
Matthias Gauly http://orcid.org/0000-0003-4212-5437

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