Aus dem Institut für Tierzucht und Haustiergenetik
Professur für Tierzüchtung
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Charakterisierung von ernährungsphysiologischen und technologischen Eigenschaften der Milch und wirtschaftliche Analyse von Rinderrassen im Berggebiet

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Dipl. Ing. agr. Thomas Zanon
aus Bozen, Südtirol

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Dekan: Prof. Dr. Klaus Eder

Prüfungskommission:

1. Gutachter: Prof. Dr. Sven König

2. Gutachter: Prof. Dr. Dr. Matthias Gauly

Prüfer: Prof. Dr. Klaus Eder
Prüfer: Prof. Dr. Georg Erhardt
Vorsitzende: Prof. Dr. Gesine Lühken

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Es gibt mehr als eine bunte Kuh.

Es lebe die Vielfalt der Natur.

(Deutsches Sprichwort)

For a farm to achieve sustainability, it must be able

to take advantage of current opportunities, while

managing the conditions that expand future possibilities.

(Darnhofer et al. 2010)

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ZUSAMMENFASSUNG

Die Südtiroler Milchwirtschaft ist wie in vielen Berggebieten durch kleinstrukturierte Familienbetriebe gekennzeichnet, welche unter schwierigen Produktionsbedingungen Viehwirtschaft betreiben. Die topographischen und klimatischen Gegebenheiten erlauben in der Regel nicht die Erzeugung qualitativ und quantitativ hoher Futtererträge sowie den Bau von kostengünstigen Stall- und Lagergebäuden. Des Weiteren ist die Alpung (Transhumanz) der Tiere ein wichtiger Produktionsfaktor und entscheidend für den Erhalt der Kulturlandschaft und einiger damit verbundener Ecosystem-Services. Die höheren Produktionskosten im Vergleich zu landwirtschaftlichen Gunstlagen müssen durch die Veredelung der Milch zu Joghurt oder Käse und den daraus erzielten höheren Milchpreisen sowie durch Subventionen seitens der Europäischen Union ausgeglichen werden. Durch die Globalisierung des Milchmarktes ist es auch in Südtirol in den vergangenen Jahrzehnten zu einer Intensivierung der Milchproduktion gekommen, welche durch hohe Kraftfuttergaben und die Haltung von Hochleistungsrassen wie Holstein Friesian gekennzeichnet ist. Dennoch haben sich in Südtirol auch autochthone Zweinutzungsrassen allen voran das Südtiroler Grauvieh und das Pinzgauer Rind über die Jahre behaupten können. Die geringere Milchleistung im Vergleich zu spezialisierten Milchrassen wird teilweise durch die Eigenschaft der Doppelnutzung dieser Rassen sowie durch die hohe Anpassungsfähigkeit sowie Futtereffizienz kompensiert. In Zukunft werden, unter Umständen durch die COVID 19 Pandemie gestärkt, Ernährungssouveränität sowie regionale Produktionskreisläufe an Wichtigkeit zunehmen. Folglich kann und muss eine standortangepasste und standortabhängige Landwirtschaft forciert und als Chance solcher Gebiete erkannt werden. Dies kann beispielsweise mit Rinderrassen erreicht werden, welche mit lokal verfügbaren Ressourcen Milch und Fleisch produzieren können. Des Weiteren wird die Milchqualität und die Verbundenheit zum Standort vor allem für Südtirol an Bedeutung gewinnen, um den hohen Milchpreis halten und entsprechend rechtfertigen zu können.

Der erste Teil der Arbeit befasst sich mit dem Effekt der Rasse hinsichtlich erzeugter Milchqualitäten in Einzelmilch- und Tankmilchproben. Der Schwerpunkt liegt dabei auf den ernährungsphysiologischen und technologischen Eigenschaften der Milch. In einem zweiten Schritt wurde die Wirtschaftlichkeit, bezogen auf die Produktivität (Milch, Fleisch), für die in Südtirol gehaltenen Rassen berechnet. Die vorliegende Arbeit umfasst 6 Kapitel, wobei Kapitel 2

und 3 wie erwähnt die Milchqualität und die technologischen Eigenschaften auf Herdeneben analysieren und Kapitel 4 eine fundierte phänotypische Charakterisierung der vom Aussterben bedrohten Rasse Original Braunvieh durchführt. Abschließend wird im Kapitel 5 anhand von Versteigerungsdaten und Daten von der nationalen Milchleistungsprüfung (MLP) eine ökonomische Bewertung der meistgenutzten Rinderrassen in Südtirol durchgeführt.

Kapitel 1 gibt einen Überblick über die Milchwirtschaft in Südtirol, indem die durchschnittliche Betriebsstruktur sowie das Genossenschaftswesen und die Organisation der Zuchtverbände dargestellt werden. Zusätzlich werden die Gerinnungseigenschaften der Milch sowie der Mineralstoffgehalt genauer präzisiert und deren Begrifflichkeiten erläutert. Des Weiteren wird die Mittelinfrarot Spektroskopie als Analysemethode für Milchinhaltsstoffen diskutiert. Abschließend wird im Zuge dieses einleitenden Kapitels auf die Besonderheiten alpiner Zweinutzungsrassen und deren kulturelle Bedeutung und züchterischen Relevanz hingewiesen.

Kapitel 2 befasst sich im Speziellen mit unterschiedlichen Herdenzusammensetzungen (reinrassig, mehrrassig) und deren Effekt auf die Milchzusammensetzung und -qualität. Im Alpinen Raum ist die Kombination von mehreren Rassen in einer Herde eine gängige Praxis, um die Milchmenge und die Milchqualität auf gesamtbetrieblicher Ebene zu erhöhen und zu verbessern. Bis dato konnte keine vorhergehende Studie ausfindig gemacht werden, welche Sammelmilchproben in großem Umfang in puncto unterschiedlicher Rassezusammensetzung innerhalb einer Herde ausgewertet hat. Für die Analyse wurden die drei meistgenutzten Rassen in Südtirol, nämlich Braunvieh, Fleckvieh und Holstein Friesian, berücksichtigt. Grundlage für die statistische Auswertung waren Tankmilchproben und Herdbuchinformationen, welche vom Südtiroler Sennereiverband und von der Vereinigung der Südtiroler Zuchtverbände bereitgestellt wurden. Im finalen Datensatz wurden jeweils die unterschiedlichen Herdenkombinationen bestehend aus nur einer Rasse bzw. aus zwei oder drei Rassen miteinander verglichen, um jene Variante ausfindig zu machen, welche unter Südtiroler Verhältnisse die höchste Milchqualität erzielt. Zusätzlich zur statistischen Berechnung mit einem linearen gemischten Modell, in welchem unterschiedliche Qualitätsmerkmale auf die fixen Effekte der Herdenzusammensetzung, des Monats und des Jahres der Beprobung sowie auf deren Interaktionen erster Ordnung korrigiert wurden, wurden zusätzlich orthogonale Kontraste durchgeführt. Dadurch sollten etwaige Unterschiede zwischen den unterschiedlichen

Herdenzusammensetzungen herausgearbeitet werden. Die im Kapitel 2 veranschaulichten Ergebnisse beinhalten praxisrelevante Informationen, um die Milchqualität mit der entsprechenden Herdenzusammensetzung zu verbessern.

Kapitel 3 analysiert die Käsetauglichkeit und den Mineralstoffgehalt in Tankmilchproben von reinrassigen Grauvieh und Pinzgauer Herden. Zur Bewertung der Käsetauglichkeit wurden Milchgerinnungseigenschaften wie Labgerinnungszeit (Rennet coagulation time, RCT), Zeit für das Erreichen einer Gerinnungsfestigkeit bei 20 mm (Curd firming rate CF K20) und die Koagulationsrate nach 30 Minuten der Zugabe des Labenzyms (Curd firmness A30) in der Milch berücksichtigt. Dabei sollte auch der optimale Zeitraum für die Verkäsung der Milch ermittelt werden. Dieser ist entscheidend, um entsprechend qualitativ hochwertige Käsespezialitäten zu erzeugen, welche zum Erhalt des Südtiroler Grauviehs und des Pinzgauer Rindes beitragen können. Für die statistische Auswertung wurden ähnlich wie in Kapitel 1 zwei Datensätze mit Sammelmilchproben und Herdbuchinformationen berücksichtigt. Allerdings wurden im Gegensatz zu Kapitel 2 für die Auswertung nur reinrassige Pinzgauer oder Grauvieh Betriebe berücksichtigt. Ein linear gemischtes Modell hat die Gerinnungseigenschaften und die Mineralstoffgehalte auf die fixen Effekte der Rasse, der Jahreszeit sowie des Jahres der Beprobung korrigiert. Die Ergebnisse deuten auf eine gute Käsereitauglichkeit in beiden Rassen hin und zeigen eine Verschlechterung der Gerinnungseigenschaften in Sommer. Diese Studie hat den Zweck zum einen die beiden lokalen Zweinutzungsrassen aufzuwerten und zum anderen wichtige Erkenntnisse für Käser zu liefern.

Kapitel 4 hat das Ziel den phänotypischen Effekt auf die Milchproduktion und die Qualitätsmerkmale von dem vom Aussterben bedrohte Original Braunvieh zu untersuchen. Das Originale Braunvieh hat eine Jahrhunderte alte Tradition in Südtirol und ist die Urform der Hochleistungsrasse Brown Swiss. Für die Studie wurden ein Datensatz mit Einzelmilchproben und ein weiterer mit Herdbuchinformationen berücksichtigt. Diese wurden vom Südtiroler Sennereiverband und dem Südtiroler Braunviehzuchtverband zu Verfügung gestellt. Mittels linear gemischter Modellanalyse wurde der finale Datensatz bestehend aus 4034 Milchproben von 237 Kühen auf fixe Effekte der Parität, Tage Laktation, Kalbesaison und deren Interaktionen erster Ordnung korrigiert. Bei den Merkmalen handelte es sich um die klassischen Milchinhaltstoffe (Fett, Eiweiß, Kasein und Laktose), den Zellgehalt als Somatic Cell Score ausgedrückt, die

Kaseinfraktionen, die Gerinnungseigenschaften, die Mineralstoffe sowie die Fettsäurespektren. Das Originale Braunvieh zeigte eine sehr gute Käsereitauglichkeit und ein günstiges Fettsäuremuster in der Milch. In Bezug auf die Milchzusammensetzung und die Gerinnungseigenschaften konnte das Originale Braunvieh mit anderen Milchviehrassen konkurrieren. Hervorzuheben ist, dass Originale Braunvieh-Kühe typischerweise in extensiven Bergbauernhöfen gehalten werden, die sich durch geringe Futterqualität, Sommerweide und Transhumanz charakterisieren. Daher können OB-Kühe anderen Rassen, einschließlich Brown Swiss, in Bezug auf Effizienz, Anpassungsfähigkeit, Weidenutzung und Robustheit unter gleichen Bedingungen überlegen sein. Die Ergebnisse in Kapitel 4 zeigen im Allgemeinen eine sehr gute Eignung der Originalen Braunviehrasse für die alpine Milchwirtschaft in Südtirol, um qualitativ hochwertige Milch und Milchprodukte zu erzeugen. Daher kann empfohlen werden, diese Rasse wieder vermehrt in der Berglandwirtschaft einzusetzen.

Kapitel 5 veranschaulicht die Wirtschaftlichkeit der fünf meistgenutzten Rinderrassen in Südtirol in Bezug auf Fleisch und Milcherlöse im Zeitraum 2009 bis 2019. Hierfür wurden MLP-Daten sowie Kälber- und Schlachtkuhpreise berücksichtigt. Neben der deskriptiven Auswertung der Daten wurden eine Varianzanalyse sowie orthogonale Vergleiche für die Rassen berechnet. In der Berechnung zeigt sich eine ökonomische Überlegenheit der Rasse Holstein Friesian im Vergleich zu den anderen Rassen, da der gegenwärtig hohe Milchauszahlungspreis in Bezug auf das Milch-/Fleischpreisverhältnis eine hohe Milchleistung ökonomisch begünstigt. Nichtsdestotrotz wird in der Berechnung auch der Effekt der Doppelnutzung ersichtlich, welcher sich in den höheren Kälber- und Schlachtviehpreisen für Grauvieh, Pinzgauer und Fleckvieh im Vergleich zu Brown Swiss und Holstein Friesian wiederspiegelt. Im Verlauf des Beobachtungszeitraumes kam es zusehends zu einer Substitution von Brown Swiss durch Fleckvieh aufgrund der ähnlichen Milchleistung aber einer höherer Kälber- und Schlachtkuhpreise für Letztere. Darüber hinaus wird in den Ergebnissen die Beständigkeit der lokalen Rinderrasse Grauvieh und Pinzgauer über den untersuchten Zeitraum deutlich, obwohl deren ökonomischer Ertrag geringer ausfällt als bei Holstein Friesian und Fleckvieh. Diese Erkenntnis und die Tatsache, dass im Vergleich zu anderen Ländern in Südtirol nur in einem kleineren Maß eine „Holsteinisierung“ zustande gekommen ist, verdeutlicht das Potential für die Südtiroler Milchproduktion sich weiter zu diversifizieren, um die lokale Wertschöpfung und die Wirtschaftlichkeit der Betriebe zu steigern.

SUMMARY

South Tyrolean dairy production is characterized by small family run farms that operate livestock farming under difficult production conditions. The difficult topographical and climatic conditions allow only in certain cases to produce high fodder yields of good quality and to build cost-effective barn and storage buildings. Furthermore, the alpine pasturing (transhumance) of the animals is an important production factor and crucial for the preservation of the cultural landscape and some related ecosystem services. The higher production costs compared to agriculturally favoured locations must and will be largely compensated by the processing of milk into yoghurt or cheese and the resulting higher milk prices as well as subsidies from the European Union. The globalisation of the milk market has also led to an intensification of milk production in South Tyrol, which results in the high amounts of concentrated feed used and the use of high-performance breeds such as Holstein Friesian. Nevertheless, local dual-purpose breeds, especially the Alpine Grey cattle and the Pinzgauer cattle, have been able to compete with other cattle breeds over the years. The lower milk yield compared to specialized dairy breeds is partly compensated by the dual-purpose nature of those breeds, by their feed efficiency and by their high adaptability to alpine environment. In future, resource efficiency and regional production cycles will become increasingly important. Consequently, location-dependent agricultural practices must be promoted. This can be achieved, for example, with cattle breeds that can produce milk and meat using primarily locally available resources. Furthermore, milk quality will become increasingly important, especially for South Tyrol, in order to maintain the high milk price and to be able to justify it accordingly.

The first part of the thesis deals with the effect of the cattle breed on milk quality produced in individual milk and bulk milk samples. The focus is on the nutritional and technological properties of milk. In a second step the profitability, related to productivity (milk, beef), is calculated for the breeds kept in South Tyrol. The present work consists of 6 chapters, whereby chapters 2 and 3 analyse the milk quality and technological characteristics at herd level and chapter 4 carries out a phenotypic characterisation of the breed Original Brown cattle, which is currently threatened by extinction. Finally, in chapter 5, an economic assessment of the five most used cattle breeds in South Tyrol is carried out using auction data and data from the national milk performance testing.

Chapter 1 provides an introductory overview of dairy farming in South Tyrol by briefly describing the average farm structure as well as the cooperative system and the organisation of the breeding associations. In addition, coagulation properties and mineral content of milk are specified more precisely, and their terminology explained. Furthermore, mid-infrared spectroscopy is discussed as an analytical method for determine milk quality and milk composition. Finally, the phenotypic characteristics of alpine dual-purpose breeds and their cultural significance and breeding relevance are highlighted.

Chapter 2 deals with different herd compositions (single-breed, multi-breed) and their effect on milk composition and quality. In Alpine region, the combination of several breeds in one herd is a common practice to increase and improve milk yield and milk quality on a farm level. To date, no previous study has been able to identify which has evaluated bulk milk samples on a large scale analysing different breed composition within a herd. For the analysis the 3 most used cattle breeds in South Tyrol, namely Brown Swiss, Simmental and Holstein Friesian, were considered. For the statistical evaluation bulk milk samples and herd book information provided by the South Tyrolean Dairy Association and the Association of South Tyrolean Breeders' Associations were considered. The final data set comprised different herd combinations consisting of only one breed or of two or three breeds and was used to determine the herd composition that produces the highest milk quality under South Tyrolean production conditions. In addition to the statistical calculation with a linear mixed model, in which different quality characteristics were corrected for the fixed effects of herd composition, month and year of sampling and their first-order interactions, orthogonal contrasts were performed to identify differences between different herd compositions. Results provide practical information to improve milk quality in South Tyrolean dairy farms.

Chapter 3 analyses the cheese suitability and mineral content in bulk milk samples from single-breed Alpine Grey and Pinzgauer herds. For the evaluation of cheese suitability, milk coagulation properties such as rennet coagulation time (RCT, min), time to curd firmness of 20 mm (k20, min) and curd firmness after 30 minutes of rennet enzyme addition (a30, mm) were considered. One of the objectives in chapter 3 is to determine the optimal time period for cheese-making. This is crucial to produce high-quality cheese specialities. For the statistical analysis, two data sets with bulk milk samples and herd book information were considered. A linear mixed model corrected the analysed coagulation properties and mineral contents for the fixed effects of breed, season and year of sampling. The results indicate a good cheese suitability in both breeds and show a deterioration of the coagulation properties in summer. The purpose of this study is on the one hand to enhance the value of the two local dual-purpose breeds and on the other hand to provide important findings for cheese makers.

Chapter 4 aims to investigate the phenotypic effect on milk production and quality characteristics of the endangered Original Brown cattle. The Original Brown cattle has a centuries-old tradition in South Tyrol and is the original form of the high-performance breed Brown Swiss. For the study, one dataset with individual milk samples and another with herd book information were considered, both of which were provided by the South Tyrolean Dairy Association and the South Tyrolean Brown Swiss Breeders' Association. The final data set comprised 4,034 milk samples from 237 cows and was corrected for fixed effects of parity, days of lactation, calving season and their first order interactions using a linear mixed model. The investigated traits were the classical milk composition traits (fat, protein, casein and lactose), the cell content expressed as Somatic Cell Score, the casein fractions, the coagulation properties, the minerals and the fatty acid composition. The Original Brown cattle showed a good cheese suitability and a favourable fatty acid pattern in their milk. In terms of milk composition and coagulation properties, Original Brown could compete with other dairy cattle breeds. It should be emphasized that Original Brown cows are typically kept in extensive mountain farms, which are characterized by low forage quality, summer grazing and transhumance. Therefore, Original Brown cows might be superior to other breeds, including Brown Swiss, in terms of efficiency, adaptability, grazing and rusticity under the same conditions. In general, results in chapter 4 show a very good suitability of the Original Brown cattle breed for alpine dairy farming in South Tyrol to produce high quality milk and dairy products.

Chapter 5 assessed the profitability of the five most used cattle breeds in South Tyrol in terms of beef and milk revenues in the period 2009-2019. Milk performance test data as well as calf and slaughter cow auction prices were considered. In addition to the descriptive evaluation of the data, an analysis of variance and orthogonal contrasts were performed. Result show an economic superiority of Holstein Friesian breed compared to other breeds, as the current South Tyrolean milk price in relation to the milk/meat price ratio economically favours a high milk yield. Nevertheless, the calculation shows the dual-purpose effect, which is reflected in the higher calf and slaughter cattle prices for Alpine Grey, Pinzgauer and Simmental cattle compared to Brown Swiss and

Holstein Friesian. During the observation period, there was an increasing substitutional trend of Brown Swiss by Simmental cattle recognizable due to the similar milk yield and the higher calf and slaughter cow prices for latter. Furthermore, the results clearly show the stability of the local cattle breeds Alpine Grey and Pinzgauer over the last decade, albeit their total turnover is lower than that of Holstein Friesian and Simmental cattle. This insight and the fact that, compared to other countries, only a small degree of "Holsteinizing" has taken place in South Tyrol, illustrates the potential for South Tyrolean milk production to further diversify in order to increase local added value and profitability of the farms.

KAPITEL 1

Einleitung

Die alpine Berglandwirtschaft zeichnet sich durch kleinstrukturierte Betriebe aus, welche unter erschwerten klimatischen und topographischen Bedingungen und mit strukturellen und mechanischen Einschränkungen Landwirtschaft betreiben (MacDonald et al., 2000). Die landwirtschaftliche Tätigkeit ist eng verbunden mit der Entwicklung der Bevölkerung und des Lebensraumes im Alpenraum (Lampert 2019). Darüber hinaus erfüllt die Berglandwirtschaft eine Vielzahl von sogenannten „Ecosystem Services“. Zum einen trägt sie einen wichtigen Beitrag zur Ernährungssicherheit in den alpinen Regionen bei, indem lokale Produktionsfaktoren wie Grünland und Almweiden durch Wiederkäuer (Rind, Schaf, Ziege) zu landwirtschaftlichen Erzeugnissen umgewandelt werden (Van Soest, 1994). Darüber hinaus muss die Berglandwirtschaft als Kulturerbe angesehen werden, da viele Bräuche und Traditionen durch diese gepflegt und weitergetragen werden (z.B. Transhumanz). Schließlich fördert die Pflege und die Nutzung von alpinen Grünlandflächen die pflanzliche und tierische Biodiversität, den Erosionsschutz durch gut bestockte Wiesen, das Wasserhaltevermögen sowie die Kohlenstoffsenke und die Sauerstoffproduktion von fruchtbaren und intakten Böden (Buchgraber, 2018). Die Modernisierung und Optimierung der landwirtschaftlichen Produktion im Berggebiet ist von zunehmender Bedeutung, um die steigenden Produktionskosten sowie zukünftige klimatische und marketingtechnische Herausforderungen zu bewältigen. Daher müssen bestehende Produktionssysteme analysiert und bewertet werden, um anschließend praxisorientierte Lösungsansätze erarbeiten zu können, die das Fortbestehen der Berglandwirtschaft ermöglichen.

1.1 Milchwirtschaft in Südtirol

Die Provinz Südtirol liegt im nördlichsten Teil Italiens und zeichnet sich durch eine gebirgige Topografie und kleinstrukturierte Familienbetriebe aus. Rund 8.000 Südtiroler Bauernhöfe betreiben Viehwirtschaft, von denen 4.691 aktive Milchlieferanten sind. Die Betriebe bearbeiten 71.862 Hektar Gras-, Weide- und Ackerland und 113.536 Hektar Almweiden für die

Futterproduktion (Province of Bolzano, 2018). Insgesamt werden in Südtirol 128.000 Rinder gehalten, von denen 52% Milchkühe sind (Province of Bolzano, 2018). Ein durchschnittlicher Südtiroler Milchviehbetrieb besitzt 15 Milchkühe und produzierte 86.335 kg Milch pro Jahr (Sennereiverband, 2018). Im Produktionsjahr 2018 wurden 405.800 Tonnen Milch produziert, von denen 3,4% Bio- (davon sind 92% Bioheumilch) und 15,5% Heumilch waren (Sennereiverband, 2018). Die Milch der Südtiroler Bergbauernbetriebe wird fast zu 100 % von 9 Milchhöfen täglich gesammelt und zu Trinkmilch, Joghurt, Käsespezialitäten und weiteren Milchprodukten verarbeitet. Neben der Kuhmilch wird in einigen Milchhöfen auch Ziegenmilch verarbeitet, deren Anlieferungsmenge für das Jahr 2018 1.463.345 Kg betrug (Sennereiverband, 2018). Die Überwachung der Milch- und Produktqualität über die gesamten Produktions- und Verarbeitungskette wird landesweit vom Südtiroler Sennereiverband durchgeführt. Die Südtiroler Rinderzüchter sind in zwei verschiedenen Zuchtverbänden organisiert; zum einen der Südtiroler Braunviehzuchtverband, welcher die Rassen Brown Swiss, Original Braunvieh und Jersey betreut und zum anderen der Rinderzuchtverband Südtirol, der die Rassen Holstein Friesian, Fleckvieh, Grauvieh, Pinzgauer, Pustertaler Sprinzen sowie die in Südtirol genutzten Fleischrassen betreut. Über den Zuchtverbänden steht die Vereinigung der Südtiroler Tierzuchtverbände, welche eine landwirtschaftliche Genossenschaft zweiten Grades darstellt.

1.2 Gerinnungseigenschaften der Milch

Die Milchgerinnungseigenschaften werden durch die Labgerinnungszeit (rennet coagulation time, RCT), die Zeit für das Erreichen einer Gerinnungsfestigkeit von 20 mm (curd firming time, k20) und die gemessene Gerinnungsfestigkeit 30 Minuten nach der Zugabe des Labenzyms (curd firmness after enzyme addition, a30) in der Regel ausgedrückt und ermöglicht eine Bewertung hinsichtlich der Eignung der Milch für die Käseherstellung und die anschließende Käseausbeute und -qualität (Jõudu et al., 2008; Cipolat-Gotet et al., 2012; Bittante et al., 2013). Für die Analyse der Gerinnungseigenschaften werden physikalische und chemische Veränderungen in der Milch im Zuge der Labgerinnung gemessen (O'Callaghan et al., 2002; Cipolat-Gotet et al., 2012). Es gibt verschiedene Messmethoden deren Analysetechnik sich dabei auf mechanische, thermische, optische, sowie auf Schwingungs- und Ultraschallinstrumente stützt (Klandar et al., 2007;

O’Callaghan et al., 2002). Traditionell werden die Gerinnungseigenschaften über die Prüfzeit von 30 Minuten (Cipolat-Gotet et al., 2012; Ikonen et al., 1999a) bzw. 31 Minuten nach Labergänzung (Cassandro et al., 2008; De Marchi et al., 2013; Penasa et al., 2010) mit einem Laktodynamographen ermittelt. Der Anteil an Milch, welcher innerhalb der a priori vorgegebenen Prüfzeit keinen Käsebruch formt, wird als nicht koagulierte Milch bezeichnet. Für die Käseindustrie ist ein hoher Anteil an nicht koagulierter Milch mit wirtschaftlichen Einbußen verbunden, da eine langsame Gerinnung der Milch mit schlechter Bildung eines festen Käsebruchs nach der Zugabe des Labenzyms eine niedere Käseausbeute verursacht (Troch et al., 2017). Dementsprechend wurden beispielsweise für die Produktion von Parmeggiano-Reggiano Käse die Milchgerinnungseigenschaften als Qualitätskriterium in das Zahlungssystem der verarbeitenden Molkereien für die Ermittlung des Auszahlungspreises an die Landwirte aufgenommen (Pretto et al., 2013). Wichtige Faktoren, welche zu einer Variation der Gerinnungseigenschaften beitragen sind das Laktationsstadium und die Parität einer Kuh (Ikonen et al., 2004; Bittante et al. 2015), die Jahreszeit (De Marchi et al., 2007; Toffanin et al., 2012), die Fütterung (Macheboeuf et al., 1993), die Eutergesundheit (Bobbo et al., 2016), die Rinderrasse (Ikonen et al., 2004; De Marchi et al., 2007; Cassandro et al., 2008; Cecchinato et al., 2012) sowie der Milchproteinpolymorphismus (Caroli et al., 2009; Alim et al., 2014). Zusätzlich wurde in De Marchi et al. (2013) mithilfe des Beispiels der Hartkäseproduktion von Parmeggiano-Reggiano und Trentin Grana auf die Problematik aufmerksam gemacht, dass die wissenschaftlich anerkannte Prüfzeit des Laktodynamographen neben den Variationseffekten wie Umweltfaktoren, Rasseeffekten oder additiv genetischen Effekten einen Einfluss auf den Anteil von nicht koagulierter Milch haben könnte. In Cipolat-Gotet et al. (2012) wurde ersichtlich, dass eine Verlängerung der Prüfzeit bei der Anwendung eines Optigraphen den Anteil an nicht koagulierter Milch im Vergleich zum Laktodynamographen reduzieren konnte, da der Gerinnungsprozess bei ersterem länger andauerte. Darüber hinaus wurden mehrere populationsgenetische Studien durchzuführt, da es Beweise gibt, dass additiv-genetische Effekte (T. Ikonen et al., 1999b; Ikonen et al., 2004) sowie zwei Kandidatengene (Tyrisevä et al., 2008) für die genotypische Variation von nicht koagulierter Milch verantwortlich sein könnten. Mit den herkömmlichen laktodynamographischen Analyseverfahren zur direkten Ermittlung der Milchgerinnungseigenschaften ist es allerdings nicht möglich diese auf Populationsebene zu bestimmen aufgrund des großen Zeitaufwandes und der daraus resultierenden Kosten. Mehrere Studien haben die Mittelinfrarot-Spektroskopie (MIRS) für die Sammlung von Gerinnungseigenschaften für phänotypische und genotypische Zwecke auf Populationseben in Betracht gezogen (Cecchinato et al., 2009; De Marchi et al., 2009, 2013, 2014) und deren Potential für die genetische Selektion von Milchkühen zur Verbesserung der Milchgerinnungseigenschaften aufgezeigt. In Kapitel 1.4 wird das Prinzip von MIRS und deren Anwendung kurz erläutert.

1.3 Mineralstoffgehalt in der Milch

Milch ist essenziell für die Ernährung von jungen Säugetieren. Daher muss Milch die wesentlichen Nährstoffe beinhalten, welche für eine schnelles Wachstum und eine rasche Entwicklung erforderlich sind (Power and Schulkin, 2013). Milch und Milchprodukte sind wichtige Mineralstoffquellen für viele westliche Länder und machen dabei 10-20% des täglichen Bedarfes aus (Zamberlin et al. 2012). Mehrere Studien haben auf die Bedeutung und die strukturellen, katalytischen, biochemischen und ernährungsphysiologischen Funktionen von Mineralstoffen im menschlichen Körper und deren Auswirkung auf die menschliche Gesundheit hingewiesen (Haug et al., 2007; Zamberlin et al., 2012). Zusätzlich beeinflussen Mineralstoffe die technologischen Eigenschaften der Milch, wie z.B. die Milchgerinnung und die anschließende Käseherstellung (Tsioulpas et al., 2007; Malacarne et al., 2014). Vor allem Ca und P haben nachweislich einen positiven Effekt auf die Verkäsungseigenschaften der Milch und auf den Käseertrag und dessen Textur und Qualität (Lucey and Fox, 1993; Malacarne et al., 2014). Mineralstoffe machen ca. 8-9 g/L in der Milch aus und kommen in unterschiedlichen chemischen Formen vor; nämlich als Salze oder anorganischen Ionen bzw. als Bestandteile von Proteinen, Nukleinsäuren, Fetten und Kohlenhydraten (Gaucheron, 2005; Summer et al., 2009; Zamberlin et al., 2012). Der Mineralstoffgehalt der Milch hängt von mehreren Faktoren ab. Zum einen wurde gezeigt, dass die Eutergesundheit einen maßgeblichen Einfluss auf den Na, Cl und K Gehalt in der Milch hat, wobei Na und Cl das entzündete Eutergewebe aufgrund der höheren Permeabilität bedingt durch die geöffnete Blut-Euter-Schranke (tight junctions) passieren und infolge der osmotischen Regulation Laktose und K substituieren (Wheelock et al., 1966; Wegner and Stull, 1978; Costa et al., 2019a;2019b). Fernando et al. (1985) und Summer et al. (2009) zeigten, dass der Na und Cl Gehalt in der Milch Aufschluss über die Eutergesundheit gibt und eine frühzeitige Erkennung einer subklinischen Mastitis ermöglicht. Zusätzlich spielen Effekte wie Rasse, Laktation, Jahreszeit und die Fütterung eine wichtige Rolle für die Variation in der Milch. In Visentin et al. (2017) ist eine Zunahme der Mineralstoffe in der Milch im Verlauf der Laktation und eine Abnahme in höheren Paritäten, ausgenommen Na, ersichtlich. Darüber hinaus beobachteten Visentin et al. (2017) und Manuelian et al. (2018) einen höheren Mineralstoffgehalt in Zweinutzungsrassen wie Grauvieh und Fleckvieh im Vergleich zu spezialisierten Milchviehrassen wie Holstein-Friesian oder Brown Swiss. Schließlich beeinflusst auch die Fütterung und die Haltung der Tiere den Mineralstoffgehalt in der Milch. So wurde gezeigt, dass die Milch von Kühen aus Bergbetrieben mit einem hohen Anteil an Weidefutter einen höheren Mineralstoffgehalt (Ca, Mg, Na, K) besaßen als die Milch von Kühen aus intensiven Silobetrieben in der Ebene (Bartowska et al., 2006). Allerdings ist hierbei zu berücksichtigen, dass die Fütterung den Mineralstoffgehalt in der Milch teilweise indirekt beeinflusst, da der größte Teil von beispielsweise Ca und P in Form von kolloidalem Calciumphosphat vorliegt und an Kaseinmizellen gebunden ist (Bijl et al.,2013).

1.4 Mittelinfrarot Spektroskopie zur Bestimmung der Milchqualität

Die Mittelinfrarot Spektroskopie (MIRS) beschreibt eine Methode, welche es erlaubt kostengünstig und schnell eine große Anzahl an phänotypischen Daten zu sammeln (De Marchi et al., 2014). Sie ist ein physikalisches Analyseverfahren, welches die Interaktion von Photonen im elektromagnetischen Wellenspektrum mit einem Produkt untersucht. Die Photonen können auf unterschiedliche Weise mit dem Produkt interagieren, indem sie adsorbiert, reflektiert werden bzw. jenes durchströmen (Troch et al., 2017). Je nach Art und Intensität der Strahlungen werden die Moleküle im Produkt unterschiedlich angeregt. Die unterschiedliche Erregung der Moleküle und die daraus resultierende unterschiedliche Reflexion, Adsorption sowie Durchlässigkeit werden gemessen und anschließend mittels Algorithmen und mathematischen Spektrenvorbehandlungen ausgewertet und zur Bestimmung von chemischen Produkteigenschaften herangezogen (Troch et al. 2017). Gegenwärtig wird MIRS dazu verwendet, Einzel- und Tankmilchproben hinsichtlich klassischer Milchzusammensetzung (De Marchi et al., 2014; Penasa et al., 2014), Fettsäuren (De Marchi et al., 2011; Gottardo et al., 2017), Milchgerinnungseigenschaften (Cipolat-Gotet et al., 2012; De Marchi et al., 2013; Visentin et al., 2016), Proteinzusammensetzung (Bonfatti et al., 2011;

Franzoi et al., 2019) sowie dem Mineralstoffgehalt (Soyeurt et al., 2009; Toffanin et al., 2015) zu untersuchen. De Marchi et al. (2011) konnten eine hohe Übereinstimmung (0.71-0.77) zwischen der Vorhersage von Fettsäuren durch MIRS im Vergleich zur Fettsäurebestimmung mittels Gaschromatographie in der Milch von Brown Swiss Kühen nachweisen. In ähnlicher Weise zeigten Cecchinato et al. (2009) eine hohe Übereinstimmung zwischen gemessenen und vorhergesagten Milchgerinnungseigenschaften, indem für RCT die geschätzten genetischen Korrelationskoeffizienten zwischen 0,91-0,96 und für a30 zwischen 0,71-0,87 variierte. Schließlich konnten Soyeurt et al. (2009) und Toffanin et al. (2015) die Eignung von MIRS zur Vorhersage von Mineralstoffen, allen voran Ca und P, und des titrierbaren Säuregehaltes zur Bestimmung der Frische der Milch und zur Bestimmung der Verkäsungseigenschaften nachweisen.

1.5 Besonderheit von lokalen Rinderrassen

Autochthone Rinderrassen zeichnen sich durch eine gute Anpassungsfähigkeit an klimatische und topographische Gegebenheiten sowie an den verfügbaren Futterressourcen einer Region aus, in welcher sie über Jahrhunderte gezüchtet und gehalten wurde (Lampert, 2019). Durch den Strukturwandel von einer standortabhängigen hin zu einer marktorientierten Landwirtschaft, welcher auch in der Berglandwirtschaft ersichtlich ist (Battaglini et al., 2014; Marsoner et al., 2018), wurde die landwirtschaftliche Produktion immer intensiver und löste sich teilweise von den geographischen und wetterbedingten Einschränkungen (Marsoner et al., 2018). Folglich wurden lokale Rinderrassen zusehendes durch Hochleistungsrassen ersetzt, da für die intensive Produktionssysteme primär die Produktivität einer Rasse eine Rolle spielte und weniger deren Funktionalität und Anpassungsfähigkeit an alpine Verhältnisse (Battaglini et al., 2014). Nichtsdestotrotz ist die Erhaltung von autochthonen Rinderrassen von außerordentlicher Wichtigkeit für die Bewahrung von genetischen Ressourcen, das Fortbestehen der kleinstrukturierten, abgestuften Bewirtschaftungssysteme und das Pflegen lokaler Traditionen und Kulturgutes im Alpenraum (Pagnacco et al., 1988; Lampert, 2019). Darüber hinaus liefern lokale Rinderrassen neben der Produktion von Lebensmitteln (Milch, Fleisch), eine Vielzahl an „Ecosystem Services“, indem sie marginale pastorale Grünlandflächen nutzen und folglich alpine Agrarökosysteme mit hohem ökologischen Wert erhalten und die über Jahrhunderte entstandene

Kulturlandschaft pflegen (Hoffmann, 2011). Marsoner et al. (2018) zeigen in ihrer Studie das Potential für die Vermarktung von regionale Landwirtschaftliche Produkte von lokalen Nutztierrassen auf, um damit alpine Regionen durch Agrotourismus wirtschaftlich zu fördern. Allerdings wird dieses Potential gegenwärtig nur in einem begrenzten Umfang ausgeschöpft (Marsoner et al., 2018). Die Strategie für die Vermarktung von landwirtschaftlicher Erzeugnisse von lokalen Nutztierrassen als Nischenprodukt erfolgt bereits seit einigen Jahrzenten (Yarwood and Evans, 1998) und ist auf europäischer Ebene mit den Markenkennzeichnungen geschützte Ursprungsbezeichnung (g.U.) und geschützte geographische Angabe (g.g.A.) geregelt. Ziel der landwirtschaftlichen Diversifikation im Zuge der geschützten Nischenproduktion ist es den Marktwert durch qualitativ hochwertige Lebensmittel zu steigern, um die kleinstrukturierte Berglandwirtschaft nachhaltig zu sichern und lokale Rassen vor dem Aussterben zu bewahren (Verrier et al., 2005; Hoffmann, 2011; Marsoner et al., 2018). Beispiele für Produkte, welche eine Steigerung der Wertschöpfung und das Fortbestehen gefährdeter Rinderrassen gegenwärtig ermöglichen sind der Fontina der Valdostana Kühe im Aostatal (Fontina, 2020), der Beaufort der Rinderrassen Abondance und Tarentaise in der Region Auvergne-Rhône-Alpes (Verrier et al., 2005) und die Tiroler Edle von der Milch des Tiroler Grauviehs (Tiroler Edle, 2020). In Südtirol wird gegenwärtig nur im begrenzten Maße versucht durch spezielle Markenkonzepte lokale Rinderrassen zu fördern, indem beispielsweise für die Produktion von Rindfleisch der Marke Biobeef die Verwendung einer lokalen Rinderrasse als Mutterlinie vorausgesetzt wird, bzw. lokale Markenkonzepte wie das „Geislerrind“ oder „Barbianer Hornochs“ aufgebaut wurden oder werden.

Ziele der Arbeit

Ziel der vorliegenden Studie ist es, einen Herden- und Rassenvergleich von Südtiroler Milchviehbetrieben zu erarbeiten. Dabei werden Milchleistung, Milchqualität und Tierabsatz (Kälber, Schlachtvieh) betrachtet. Neben den besten Rassen in Bezug auf Milchqualität, Käsetauglichkeit und Wirtschaftlichkeit wird die optimale Herdenzusammensetzung in Ein- und Mehrrassenherden unter alpinen Produktionsbedingungen ermittelt.

Die Ziele der Studie teilen sich folgendermaßen auf:

1. Kapitel 2 beschäftigt sich mit der Ermittlung jener Herdenzusammensetzung (reinrassig, mehrrassig), welche es ermöglicht unter Südtiroler Produktionsbedingungen die höchste Milchqualität zu produzieren. Hierbei werden die meistgenutzten Rinderrassen Brown Swiss, Fleckvieh und Holstein Friesian betrachtet.
2. Kapitel 3 fokussiert die technologischen Eigenschaften von Pinzgauer- und Grauvieh Milch auf Herdeneben, mit dem Ziel Erkenntnisse für die Käseherstellung zu generieren und die Nutzung von lokalen Zweinutzungsrassen zu bestärken.
3. Kapitel 4 beinhaltet eine erstmalige gesamtheitliche phänotypische Charakterisierung der Milchbestandteile der Rasse Original Braunvieh. Dabei sollen neben den ernährungsphysiologischen Besonderheiten auch die technologischen Eigenschaften hervorgehoben werden, mit dem Ziel diese vom Aussterben bedrohte Rinderrasse für die Berglandwirtschaft zu bewerben.
4. Kapitel 5 stellt einen wirtschaftlichen Vergleich der fünf wichtigsten Rinderrassen in Südtirol an. Dabei sollen Milch- und Schlachtvieherlöse von 2009 bis 2019 die wirtschaftliche Entwicklung der Rassen unter alpinen Verhältnissen veranschaulichen, um ökonomische Potentiale für die Zukunft ableiten zu können.

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KAPITEL 2

BULK MILK QUALITY AS AFFECTED BY CATTLE BREED COMPOSITION OF THE HERD IN MOUNTAIN AREA

Thomas Zanon [1], Angela Costa [2], Massimo De Marchi [2], Mauro Penasa [2], Sven König [3], and Matthias Gauly [1]

[1] Faculty of Science and Technology, Free University of Bolzano, Piazza Università 5, 39100, Bolzano, Italy; [2] Department of Agronomy, Food, Natural resources, Animals and Environment, University of Padova, Viale dell'Università 16, 35020, Legnaro, Italy; [3] Institute of Animal Breeding and Genetics, Justus-Liebig University Giessen, Ludwigstr. 21b, 35390, Giessen, Germany

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Abstract

The aim of this study was to investigate the variation of gross composition, somatic cell count, urea content, and fatty acids (FA) composition of bulk milk from single-breed and multi-breed farms in alpine area, keeping either Brown Swiss (BS), Holstein Friesian (HF), Simmental (SI), or their combinations. Gross milk composition, urea content, and FA composition were predicted using mid-infrared spectroscopy. Observations were grouped in 7 combinations consisting of 3 single-breed and 4 multi-breed types of herd. A mixed linear model was used for data analysis, accounting for the fixed effects of herd composition (7 combinations), month of sampling, year of sampling, and the interactions between herd composition and month of sampling, and between herd composition and year of sampling. Farm was included as random effect. Results highlighted that about two thirds of South Tyrolean farms were single-breed and herds with more than 20 lactating cows changed herd structure over time, switching from multi- to single-breed. Single-breed BS farms produced milk with greater fat, protein, casein, lactose, and FA content than single-breed HF and SI farms. Further, multi-breed herds including BS cows produced milk with greater fat, protein, casein, and polyunsaturated FA content than multi-breed HF+SI herds. Overall, single-breed SI farms produced milk with lower somatic cell count than other herd combinations. Despite the number of BS cows in South Tyrol has decreased in favor of SI in the last years, this breed is still the most interesting for alpine dairy farming to achieve optimal milk quality in both single- and multi-breed scenarios. The tendency to move to SI is mainly related to good milk performance of SI cows coupled with their robustness, high carcass value, high market value of calves, and adaptability to mountain farming system.

Introduction

In South Tyrol (northeastern Italy), dairy farmers operate under difficult conditions because of climatic and environmental restrictions of alpine area. Production costs per kg of milk are considerably greater than in other Italian regions and European countries (Kühl et al., 2020). Thus, farmers have to maximize efficiency and profitability through enhanced nutritional and organoleptic quality of milk, cheese, and other dairy products. In mountain area, several local breeds are kept for biodiversity reason but also for their adaptive ability to harsh topographic conditions and local housing systems, and for their efficiency of grassland use (Mattiello et al., 2011; Sturaro et al., 2013; Koczura et al., 2019, 2020). However, local breeds are less productive than cosmopolitan Holstein Friesian (HF) and Brown Swiss (BS) cows (Kühl et al., 2020). In 2018, BS (31.7%), Simmental (SI; 29.0%), HF (19.9%), Alpine Grey (13.2%), Pinzgauer (1.8%), Jersey (1%), and other breeds (3.4%) were present in South Tyrol (Breeders Association of Bolzano province, 2018), with average herd size of 15 lactating cows (South Tyrolean Dairy Association, 2018).

Brown Swiss cows produce milk with greater fat (FC), protein (PC), and casein content (CC) than HF, SI, and Alpine Grey (Manuelian et al., 2019). In recent years, several studies have been carried out on these cattle breeds thank to the development of mid-infrared spectroscopy prediction models to study novel milk traits in Italy (Visentin et al., 2016, 2018) and in other European countries (De Marchi et al., 2014; Visentin et al., 2015; Mc Dermott et al., 2016). Franzoi et al. (2019a) investigated casein and whey protein fractions in milk of different breeds and showed that BS cows produced the greatest amount of casein. As regards fatty acids (FA) composition, Manuelian et al. (2019) reported that dual-purpose breeds produce milk with greater content of polyunsaturated (PUFA) and monounsaturated FA (MUFA), whereas milk of specialized dairy breeds is characterized by greater content of saturated FA (SFA). Therefore, from a nutritional point of view, dual-purpose breeds produce a “healthier” milk (Manuelian et al., 2019); in fact, cardiovascular diseases and high blood pressure in human beings seem to be favored by high SFA in the diet (Rasmussen et al., 2006; Wang et al., 2010). Furthermore, Faustini et al. (2016) observed greater contents of MUFA and PUFA, and lower desaturase indices for C14:0, C16:0, and C18:0 in some Italian local dual-purpose breeds compared with HF. Similarly, Stergiadis et al. (2015) reported greater concentrations of desirable MUFA and PUFA in milk from low input Braunvieh herds in Switzerland with low proportion of BS. Considering other quality traits, SI usually exhibits lower milk somatic cell count (SCC, cells/mL) than HF, BS, Alpine Grey, and Jersey (Penasa et al., 2014; Franzoi et al., 2019b; Manuelian et al., 2019). Supporting this, Litwińczuk et al. (2011) reported significant differences in susceptibility to mammary infections among breeds, with stronger negative correlation coefficients between SCC and daily milk yield in HF than SI cows. Finally, Rupp and Boichard (2003) stated that both BS and SI have lower SCC and incidence of clinical mastitis than HF. Although the effect of cattle breed on individual milk yield and composition has been widely investigated in literature, little is still known about the effect of herd composition on bulk milk quality. In alpine area, multi-breed herds are common, with the main purpose of balancing milk yield of certain breeds with milk quality of other breeds (Sturaro et al., 2013). To our knowledge, no studies have compared bulk milk quality traits of single-breed and multi-breed farms on a large scale. Therefore, the aim of the present study was to investigate the effects of breed structure of the herd on bulk milk gross composition, SCC, milk urea nitrogen (MUN), and FA composition in farms located in mountain region of Italy.

Material and methods

Data and herd composition

The initial dataset was retrieved from the Breeders Association of Bolzano province (Bolzano, Italy) and the South Tyrolean Dairy Association (Bolzano, Italy), and consisted of bulk milk samples (n = 1,601,201) and herd information collected between January 2014 and December 2018 in South Tyrol (northeastern Italy). No ethical permission of the animal welfare committee was needed as data were retrieved from the existing official milk recording database without interference with animals. Only specialized dairy HF and BS, and dual-purpose SI breeds were included in the study because they were the most common breeds in South Tyrol. In order to be retained in the dataset, farms were required to have ≥ 5 controlled cows per year and 3 to 10 bulk milk samples per month. Herd composition was obtained by calculating the proportion of breeds in the farm within each year: a farm was defined 'single-breed' when all cows were from only one breed in the specific year, whereas it was classified as 'multi-breed' when more than one breed was present in the specific year. Therefore, a farm could have changed breed structure during the 4 years of the observing period. At the end, 7 types of herd were defined on the basis of the breed structure, representing the majority of farms in South Tyrol: single-breed (BS, HF, and SI) and multi-breed herds (BS+SI, BS+HF, HF+SI, and BS+HF+SI).

Milk FC, PC, CC, lactose content (LC), MUN (mg/dl), and FA composition (MUFA, PUFA, SFA) were predicted through mid-infrared spectroscopy in the laboratory of the South Tyrolean Dairy Association (Bolzano, Italy), equipped with Milkoscan FT6000 (Foss, Hillerød, Denmark) and, from March 2017, with Milkoscan FT7 (Foss, Hillerød, Denmark). Values of FC, PC, CC, LC, MUN, SFA, MUFA, and PUFA outside the range mean ± 3 standard deviations were considered as missing data. The milk SCC (range: 1,000 to 1,000,000 cells/ml) was determined using Fossomatic (Foss, Hillerød, Denmark) and values were transformed to somatic cell score (SCS) using the formula of Ali and Shook (1980): SCS = 3 + log2(SCC/100,000). Fat to protein ratio (FPR) was calculated as: FPR = FC/PC. Following editing of the data as above, 198,235 bulk milk samples from 961 single-breed and 429 multi-breed farms were left for statistical analysis. Specific farm management characteristics (e.g. housing and feeding practices) were not available since the present study was conducted on a large scale, using data of 1,390 farms. Despite this, it is important to consider that dairy production system of South Tyrol is characterized by heterogeneous conditions and characteristics. In fact, both low-input small-scale farms with high amount of ground fodder and presence of summer pasture and high-input big-scale farms with year-round housing and use of maize silage coexist in this area, with all intermediate scenarios. In this study the effect of the farm was included as random in the statistical model and allowed to adjust, at least partly, for such differences.

Statistical analysis

Pearson´s correlations were calculated for the investigated traits using the CORR procedure of SAS software v. 9.4 (SAS Institute Inc., Cary, NC) and significance was set at $P<0.05$. In the same software, a mixed linear model was used to investigate sources of variation of bulk milk traits:

$$y_{ijklm} = \mu + breed_i + month_j + year_k + (breed \times month)_{ij} + (breed \times year)_{ik} + farm_l + e_{ijklm},$$

where y_{ijklm} is the dependent variable (FC, PC, CC, LC, FPR, SCS, MUN, MUFA, PUFA, or SFA); μ is the overall intercept of the model; $breed_i$ is the fixed effect of the ith breed structure of the herd (i = single-breed BS, HF, SI, and multi-breed BS+SI, BS+HF, HF+SI, BS+HF+SI); $month_j$ is the fixed effect of the jth month of sampling (j = 1 to 12); $year_k$ is the fixed effect of the kth year of sampling (k = 2014 to 2018); $(breed \times month)_{ij}$ is the fixed interaction effect between herd composition and month of sampling; (breed × year)$_{ik}$ is the fixed interaction effect between herd composition and year of sampling; farm$_l$ is the random effect of the lth farm (l = 1 to 1,390) ~N(0, σ2farm); and e_{ijklm} is the random residual ~N(0, σ2e). Post-hoc Bonferroni multiple-comparison test was used to test if differences between least squares means of the levels of the fixed effects were significant (P<0.05). Finally, contrast estimates for herd composition effect were calculated.

Results

Single-breed herds were the most prevalent and on average accounted for 67% of total farms per year (Table 1). Figure 1 depicts the frequency of single-breed and multi-breed herds according to different average herd size for the years 2014 and 2018; in particular, 50% and 20% of herds with more than 20 cows were multi-breed in 2014 and 2018, respectively. Descriptive statistics of gross milk composition, SCS, MUN, MUFA, PUFA, and SFA are reported in Table 2. The coefficient of variation ranged from 1.41% (LC) to 27.44% (SCS) and, on average, it was 10.05% for the three FA groups. After SCS, MUN was the second most variable trait with coefficient of variation of 23.63%.

The strongest Pearson's correlation was estimated between bulk milk PC and CC (0.98) and the weakest between MUN and LC (-0.01; Table 3). The FPR was moderately inversely associated with PC and CC, and LC was negatively associated with almost all traits, particularly with SCS (-0.28). Correlations between FA groups ranged from -0.14 (SFA and PUFA) to 0.51 (MUFA and PUFA). A negative weak correlation (-0.14) was observed between MUN and FPR.

Single-breed BS herds were characterized by greater FC, PC, CC, and LC than other types of herd (P<0.05), with the only exception of PC in BS+SI farms (Table 4). No significant differences were detected for the same traits between single-breed HF and SI herds. Among multi-breed herds, BS+HF produced milk with the greatest FC, BS+SI with the greatest PC and CC, and HF+SI with the lowest PC and CC (P<0.05; Table 4). Among all herds, single-breed BS and multi-breed BS+HF had the greatest SFA content (P<0.05; Table 4). Moreover, single-breed BS produced milk with greater SCS than single-breed SI and HF farms, and among multi-breed herds, BS+HF+SI had the greatest SCS (P<0.05; Table 4). There were differences in MUN content among types of herd (Table 4), with overall greater MUN in herds with BS.

In order to assess differences between single- and multi-breed herds, and dual-purpose and specialized dairy breeds, orthogonal contrasts were estimated. In terms of gross composition, single-breed herds produced milk with lower PC (P<0.05) and greater LC (P<0.001) than multi-breed herds (Table 5). Milk SFA content was slightly greater in single- than multi-breed herds (P<0.05), whereas MUN and SCS were lower in single-breed herds (P<0.05). Within single-breed herds, specialized BS and HF produced greater FC, PC, CC, and LC (P<0.01) than dual-purpose SI breed. Regarding multi-breed herds, farms with SI produced milk with greater FC and lower SCS than BS+HF herds (P<0.05). Finally, significant but numerically small differences were estimated for PUFA and SFA between BS+HF and multi-breed herds with SI (P<0.001; Table 5).

Discussion

A large number of farms moved from multi-breed to single-breed system in the last years. Farming one breed is easier in terms of management practices such as feeding strategies and milking. From the economic point of view, in fact, dual-purpose breeds like SI could be as convenient in alpine conditions as specialized dairy breeds, since the lower milk production is, at least partly, compensated by less udder issues (Litwińczuk et al., 2011), higher adaptability to alpine environmental and housing conditions (Mattiello et al., 2011), and moderate to high price for both calves and culled cows (Dal Zotto et al., 2009). Nevertheless, the inclusion of greater amount of concentrates in the ration is currently economically worthwhile considering the relatively high farm-gate milk price of South Tyrol and allows to produce more milk with specialized dairy breeds (Kühl et al., 2020).

In the present study means of FC, PC, and CC were similar to values reported by Penasa et al. (2014), who analyzed individual milk samples of multi-breed herds of HF, BS, and SI cows in lowland of Veneto region (Italy), whereas mean SCS (3.50) was higher than that (3.11) reported by Penasa et al. (2014). Milk FPR of individual milk provides information on the metabolic status of the cow and the optimal range is from 1.1 to 1.5 (Brinkmann et al., 2016). In the present study, average FPR was 1.16, i.e., within the abovementioned range. Buttchereit et al. (2011) reported an average FPR of 1.13 in milk of primiparous German HF cows sampled in the first 180 days in milk, and Negussie et al. (2013) reported mean test-day FPR of 1.28 in first-lactation cows. The average MUN content of our study was greater than the threshold commonly used in the field to identify the excess of urea in milk, which contributes to reduce fertility in dairy cows (Raboisson et al., 2017). In general, the main factors associated to an excess of urea in milk are the excessive protein in the ration and an improperly balanced ration or dehydration (Aguilar et al., 2012). In our case, the relatively high MUN could be the result of the combination of high amount of concentrates in the ration (Kühl et al., 2020) and ground fodder of low quality produced in South Tyrol (Perathoner et al., 2010). Moreover, nutritional and botanical composition of alpine pastures is highly variable and therefore it is difficult for farmers to make standard ration to meet the energy and nutritional demand of their animals (Gorlier et al., 2012). According to the coefficient of variation, LC is typically reported to be the less variable solid in bovine milk (Costa et al., 2019), and SCS the most variable (Penasa et al., 2014). Penasa et al. (2014) reported greater coefficients of variation of milk traits, likely due to the greater variability of individual milk in Penasa et al. (2014) compared with bulk milk data of the current study.

The correlation between LC and SCS was moderate and indicated lower LC in milk with high SCS. Such correlation fell within the range of estimates available in literature, i.e. from -0.66 (Vilas Boas et al., 2017) to -0.15 (Hossein-Zadeh and Ardalan, 2011). As described by Bruckmaier et al. (2004) and Costa et al. (2019), the decrease of LC in milk with high SCS may have two main causes: (i) part of lactose is lost in bloodstream due to damaged alveolar structures and epithelium, and (ii) mastitis pathogens use lactose as substrate, thus they convert LC to lactic acid. Associations of FC with PC and CC in the present study were stronger than those (0.30 and 0.39, respectively) reported by Ikonen et al. (2004). Finally, a positive relationship between PUFA and SFA was observed which was in contrast with the findings of Hein et al. (2018), who observed a strong negative (-0.99) correlation between MUFA and PUFA in Danish Holstein and Danish Jersey.

The quality of BS milk was superior than that of HF and SI milk. This has been observed also by Visentin et al. (2016), with BS milk exhibiting better cheesemaking properties than other breeds in terms of shorter rennet coagulation time and firmer curd, which allowed to produce 15% more cheese per kg of milk than HF milk. Considering FA composition, Kirchnerová and Vršková (2015) showed that dual-purpose SI cows produced milk with greater amount of favorable FA compared with specialized dairy breeds. However, this was only partially confirmed in the present study because single-breed BS herds had greater MUFA and PUFA content compared with all other types of herd. In general, considering gross composition and MUFA and PUFA, single-breed BS herds performed better than multi-breed herds with BS. A possible explanation is that a more specialized and tailored management of single-breed farms enables to exploit the full genetic potential of the breed, which is more difficult to be reached in multi-breed herds with different breeds and genetic potentials. For both SI and HF, the combination with BS seemed advantageous in terms of bulk milk quality, which is in line with results of Magne et al. (2016). The latter reported greater milk quality in multi-breed herds farming both specialized and dual-purpose breeds compared with single-breed herds. As regards SCS, in the present study the most favorable breed was SI, which agrees with Penasa et al. (2014), Franzoi et al. (2019b), and Manuelian et al. (2019). In particular, the greater resistance of SI cows to intramammary infections and mastitis is quite well established in literature. For instance, Litwińczuk et al. (2011) suggested dual-purpose breeds like SI to be more adaptable to suboptimal environment and structural conditions of farms in mountain regions. The greater MUN level of both single-breed and multi-breed herds with BS compared with other types of herd could be due to a different use of dietary nitrogen for milk protein synthesis in each breed; these results are consistent with those of Wattiaux et al. (2005), who observed greater test-day MUN in BS and Jersey compared with HF cows. Besides breed, MUN is affected by stage of lactation, production level (Rajala-Schultz and Saville, 2003), and protein concentration in both milk and feed (Fatehi et al., 2012). Contrast estimates revealed significant differences for milk traits among herds with different breed composition, which can be partly related to specific breeding goals of each breed or group of breeds. For instance, both BS and HF selection indexes put strong emphasis on milk features, whereas the index of SI combines meat and milk traits (ANAFIJ, 2020; ANAPRI, 2020; ANARB, 2020). This explains why single-breed SI farms were different from single-breed BS and HF herds for the investigated traits, with the only exception of FPR and MUFA. On the other hand, whenever SI was coupled with HF and/or BS, such differences were less evident. In fact, BS+HF herds produced milk with greater FC and FPR compared to multi-breed herds that reared also SI cows. Overall, milk from single-breed herds was characterized by lower SCS and MUN compared to multi-breed herds; again, this is feasible, as multi-breed farms have to deal with different genetic potentials of the breeds and thus should adapt feeding requirements, milking routine, and management practices.

Conclusions

In Italian Alps, the herd size tends to be smaller than in the lowland and often milk is produced under suboptimal structural and geographical conditions. Thus, to improve farmers' profitability, strategies should be adopted to enhance quality of both milk and dairy products. In this study, bulk milks of single-breed and multi-breed herds were compared on a large scale in order to identify the herd composition that better performs in terms of quality in alpine environment. Overall, results suggested that SI herds had lower milk SCS compared to other breed combinations. In fact, SI is a dual-purpose breed characterized by optimal resistance to intramammary infections and robustness. On the other hand, single-breed BS herds were superior in terms of gross and MUFA and PUFA compared with other single- and multi-breed herds. In addition, multi-breed herds with BS were characterized by greater PC and CC than HF+SI herds. Therefore, the presence of BS cows in combination with HF or SI might be a good compromise in multi-breed farms to achieve the best milk quality. Nevertheless, specific feeding, housing, and management conditions of farms should be taken into account when deciding which cattle breed is more suitable. However, dual-purpose SI may be preferred by South Tyrolean farmers due to its good robustness, favorable milk performance, optimal carcass characteristics of calves and cows, and efficiency in pasture use. Our findings are expected to be beneficial to farmers and breeders' associations in order to develop strategies aimed at improving profitability and efficiency of mountain dairy systems.

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Table 1 Frequency (%) of herds according to breed composition in the observed period

Herd composition	2014	2015	2016	2017	2018
Single-breed herd					
Brown Swiss	28.67	21.48	21.73	20.92	19.77
Holstein Friesian	15.05	14.40	14.84	13.95	19.56
Simmental	25.39	30.89	30.77	31.60	28.34
Multi-breed herd					
Brown Swiss + Holstein Friesian	13.74	13.43	13.63	14.39	13.57
Brown Swiss + Simmental	5.89	5.40	5.53	5.34	4.99
Holstein Friesian + Simmental	8.25	10.11	9.72	10.98	10.18
Brown Swiss + Holstein Friesian + Simmental	3.01	4.29	3.78	2.82	3.59
Total (n)	764	722	741	674	501

Table 2 Descriptive statistics of bulk milk samples

Trait	n	Mean	CV (%)	Minimum	Maximum
Milk composition (%)					
Fat	197,165	4.07	5.96	3.33	4.82
Protein	197,555	3.53	5.42	2.95	4.10
Casein	197,611	2.75	5.50	2.30	3.21
Lactose	197,235	4.76	1.41	4.55	4.96
Fat to protein ratio	198,171	1.16	5.57	0.76	1.88
Fatty acids (FA, %)					
Monounsaturated FA	184,278	0.99	9.17	0.67	1.32
Polyunsaturated FA	184,492	0.12	11.68	0.08	0.17
Saturated FA	185,274	2.75	9.31	1.97	3.52
Somatic cell score (units)	193,085	3.50	27.44	-3.64	6.32
Milk urea nitrogen (mg/dl)	196,786	22.54	23.63	6.20	39.00

CV – coefficient of variation.

Table 3 Pearson correlations (P<0.001) between the investigated milk traits

Trait	Protein	Casein	Lactose	FPR	MUFA	PUFA	SFA	SCS	MUN
Milk composition (%)									
Fat	0.55	0.56	-0.09	0.54	0.41	0.17	0.72	0.06	0.06
Protein	-	0.98	-0.03	-0.38	0.10	0.16	0.43	0.07	0.21
Casein		-	0.03	-0.35	0.07	0.20	0.37	0.04	0.17
Lactose			-	-0.06	-0.08	0.10	-0.14	-0.28	-0.01
FPR				-	0.36	0.04	0.36	-0.01^{ns}	-0.14
Fatty acids (%)									
MUFA					-	0.51	0.39	0.10	0.08
PUFA						-	-0.14	0.07	0.22
SFA							-	0.04	-0.05
SCS (units)								-	0.00^{ns}

FPR - fat to protein ratio.

MUFA – monounsaturated fatty acids.

PUFA – polyunsaturated fatty acids.

SFA – saturated fatty acids.

SCS – somatic cell score.

MUN – milk urea nitrogen (mg/dl).

ns - not significant, P≥0.05

Table 4 Least squares means (LSM) and standard errors (SE) of the investigated milk traits for the fixed effect of herd composition

Trait	Single-breed herds						Multi-breed herds							
	BS		SI		HF		BS+HF		BS+SI		HF+SI		BS + HF + SI	
	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE	LSM	SE
Milk composition (%)														
Fat	4.097^{a}	0.005	4.053^{cd}	0.005	4.046^{d}	0.005	4.074^{b}	0.005	4.058^{cd}	0.005	4.048^{d}	0.005	4.061^{c}	0.005
Protein	3.539^{a}	0.004	3.503^{cd}	0.004	3.496^{d}	0.004	3.512^{bc}	0.004	3.535^{a}	0.004	3.498^{d}	0.004	3.513^{b}	0.004
Casein	2.768^{a}	0.003	2.734^{d}	0.003	2.731^{d}	0.003	2.743^{c}	0.003	2.760^{b}	0.004	2.730^{d}	0.003	2.743^{c}	0.003
Lactose	4.765^{a}	0.001	4.758^{b}	0.001	4.758^{b}	0.001	4.758^{b}	0.001	4.753^{c}	0.002	4.758^{b}	0.001	4.760^{b}	0.002
FPR	1.158^{b}	0.001	1.160^{ab}	0.001	1.160^{ab}	0.001	1.161^{a}	0.001	1.149^{c}	0.002	1.160^{ab}	0.001	1.157^{b}	0.002
Fatty acids (%)														
MUFA	0.996^{a}	0.002	0.989^{bc}	0.001	0.986^{c}	0.002	0.991^{b}	0.001	0.989^{bc}	0.002	0.990^{b}	0.001	0.990^{bc}	0.002
PUFA	0.126^{a}	<0.001	0.122^{d}	<0.001	0.123^{cd}	<0.001	0.125^{b}	<0.001	0.124^{b}	<0.001	0.123^{c}	<0.001	0.124^{b}	<0.001
SFA	2.762^{a}	0.004	2.733^{c}	0.004	2.730^{c}	0.004	2.748^{b}	0.004	2.735^{c}	0.005	2.728^{c}	0.004	2.736^{c}	0.005
SCS (units)	3.461^{ab}	0.021	3.375^{d}	0.021	3.397^{cd}	0.022	3.435^{bc}	0.021	3.407^{bcd}	0.023	3.438^{bc}	0.021	3.505^{a}	0.023
MUN (mg/dl)	22.778^{a}	0.107	22.360^{b}	0.106	22.406^{b}	0.109	22.569^{ab}	0.105	22.842^{a}	0.122	22.366^{b}	0.105	22.755^{a}	0.118

a, b, c, d - LSM with different superscript letters within a row are significantly different ($P<0.05$).

FPR, MUFA, PUFA, SFA, SCS, and MUN – as in Table 3.

BS – Brown Swiss.

HF – Holstein Friesian.

SI – Simmental.

Table 5 Contrast estimates between different herd compositions

Trait	Single-breed herds vs. multi-breed herds			Single-breed BS or HF herds vs. single-breed SI herds			Multi-breed BS+HF herds vs. multi-breed herds with SI		
	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Milk composition (%)									
Fat	0.011	0.006	ns	0.034	0.008	***	-0.044	0.007	***
Protein	-0.009	0.004	*	0.029	0.005	***	0.007	0.005	ns
Casein	-0.005	0.003	ns	0.027	0.004	***	0.004	0.004	ns
Lactose	0.010	0.002	***	0.006	0.002	**	-0.003	0.002	ns
FPR	0.007	0.002	***	-0.004	0.002	ns	-0.012	0.002	***
Fatty acids (%)									
MUFA	0.001	0.002	ns	0.004	0.003	ns	-0.005	0.003	ns
PUFA	-0.001	0.000	ns	0.004	0.000	***	-0.002	0.000	***
SFA	0.010	0.005	*	0.023	0.007	***	-0.036	0.006	***
SCS (units)	-0.109	0.024	***	0.100	0.033	**	0.058	0.029	*
MUN (mg/dl)	-0.305	0.140	*	0.479	0.187	*	0.081	0.168	ns

FPR, MUFA, PUFA, SFA, SCS, and MUN – as in Table 3.

BS, HF, and SI – as in Table 4.

SE – standard error.

* – P<0.05.

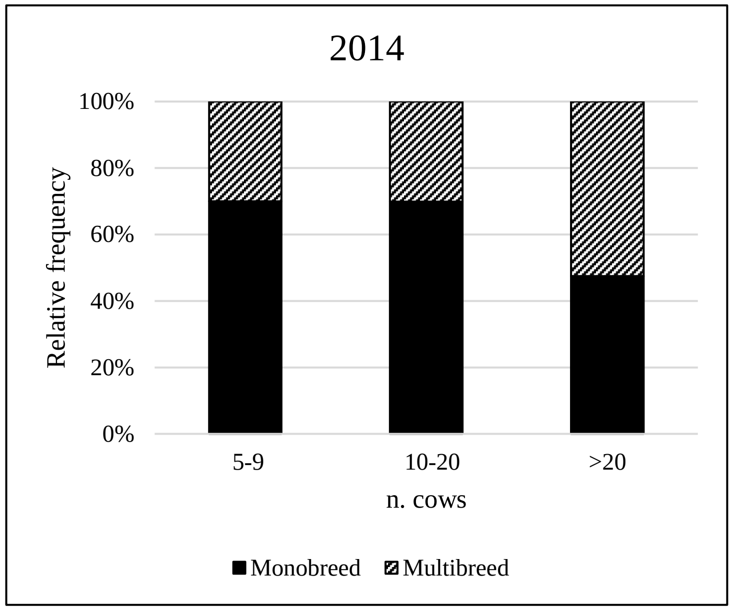
** – P<0.01.

*** – P<0.001.

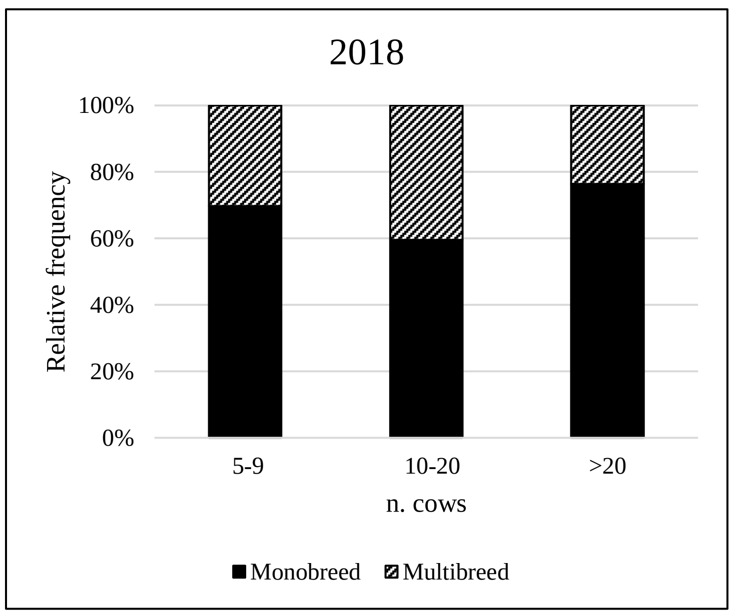
ns – not significant.

Figure 1 Frequency of single-breed (solid bar) and multi-breed herds (striped bar) according to different average herd size in (a) 2014 and (b) 2018

(a)



(b)



KAPITEL 3

QUALITY PROFILE OF SINGLE-BREED ALPINE GREY AND PINZGAUER BULK MILK

Thomas Zanon[1], Angela Costa[2], Massimo De Marchi[2], Mauro Penasa[2], Sven König[3]

and Matthias Gauly [1]

[1] Faculty of Science and Technology, Free University of Bolzano, Piazza Università 5, 39100 Bolzano, Italy; [2] Department of Agronomy, Food, Natural Resources, Animals and Environment, University of Padova, Viale dell'Università 16, 35020 Legnaro, Italy; [3] Institute of Animal Breeding and Genetics, Justus-Liebig University Giessen, Ludwigstr. 21b, 35390 Giessen,Germany;

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Abstract

The aim of the present study was to investigate sources of variation of bulk milk composition, somatic cell score, coagulation properties and mineral content of Alpine Grey and Pinzgauer single-breed herds in the Italian alpine area. A total of 56,914 bulk milk samples of 461 farms located in Bolzano province (northeast Italy) were available for statistical analysis. Least squares means revealed that Pinzgauer herds produced milk with greater fat content and shorter rennet coagulation time than Alpine Grey herds, but the latter had greater milk protein content and lower somatic cell score than Pinzgauer herds. The greatest content of Ca, protein, and casein and the most favourable coagulation properties were observed in milk sampled in autumn in both breeds. Results should serve for differentiating the milk of Alpine Grey cattle and Pinzgauer cattle from milk of other cattle breeds and thus provide necessary arguments for developing new production concepts that might expand future opportunities for further valorising these local-dual purpose breeds and therefore contribute long-term to their preservation.

1. Introduction

Dairy farming in alpine area is characterized by small family-run units often facing mechanical and structural limits MacDonald et al. (2000), resulting in higher production costs compared to lowland farms Zendri et al. (2013). Moreover, summer pasturing (transhumance) is a relevant production factor because of additional forage sources and higher revenues for milk transformation into high-value dairy products like cheese Koczura et al.; Koczura et al. (2019; 2020). Further, the cultivation of mountain pastures using livestock is crucial for preserving marginal areas and land fragmentation and thus preventing succession and simplification of landscape Giupponi et al. (2006). Therefore, local cattle breeds are commonly used because of their robustness and adaptability to alpine environment De Marchi et al. (2007). Despite this, nowadays the intensification of dairy production in alpine farms is visible too, especially in herds located at lower elevations, having less fragmented fields and gentler slope Zendri et al. (2013); Battaglini et al. (2014). Hence, alpine farmers progressively started to move to intensive farming systems with specialized breeds like Holstein Friesian and Brown Swiss Battaglini et al. (2014). This has been unfavourable for local dual-purpose breeds of Alpine region, like Pinzgauer (PI) and Alpine Grey (AG), both known for their feed efficiency, resilience, hard claws and strong legs Rinderzucht Austria (2020). Several authors have demonstrated local cattle breeds to be competitive with cosmopolitan dairy breeds in terms of milk composition and coagulation ability De Marchi et al. (2007); Visentin et al. (2015); this may enable alpine farmers to valorise milk produced by local breeds through niche and branded cheese products by which they partly compensate the higher production costs and lower milk production compared to intensive farming De Marchi et al. (2007); Marsoner et al. (2018). In fact, PI and AG farmers can only play on few aspects to maximize the profit; for instance, they should be involved in projects intended to valorise milk and dairy products quality. Therefore, information about technological traits and bulk milk quality considering PI and AG herds are essential for both farmers and local dairy industry. Though no prior study considering such aspects at a large data scale were found. Thus, the objectives of this study were to investigate the effect of season on bulk milk quality traits, including milk coagulation properties (MCP) and mineral content, and to compare milk of AG and PI single-breed herds for providing research results which might be relevant for milk processing practice in mountain area.

2. Materials and methods

2.1. Area of the study

The Province of Bolzano is located in the Northern part of Italy and is characterized by mountainous topography and small-scale family-run farms. Approximately 8,000 South Tyrolean farms are engaged in animal husbandry using 71,862 hectares of grass, pastural and arable land to produce forage Province of Bolzano (2020). In total 128,000 cattle are kept in South Tyrol of which 52% are dairy cows (approximately 13% and 2% out of them are AG and PI cows, respectively) producing approximately 400,000 tons of milk per year South Tyrolean Dairy Association (2020).

2.2. Bulk milk data

Information on bulk milk samples of AG and PI single-breed herds, collected between January 2014 and December 2018, were retrieved from the database of the South Tyrolean Dairy Association and the Breeders Association of Bolzano Province (Bolzano, Italy). The original data comprised 66,712 records of 463 farms, with information on fat content (FC), protein content (PC), casein content (CC), lactose content (LC) and somatic cell count (SCC, cells/mL). Mid-infrared spectroscopy analyses were performed in the laboratory of the South Tyrolean Dairy Association using Milkoscan FT6000 (Foss, Hillerød, Denmark) and, from March 2017, Milkoscan FT7 (Foss, Hillerød, Denmark). In the same laboratory SCC was determined by Fossomatic FC (Foss, Hillerød, Denmark). Milk MCP and mineral content (mg/kg) were predicted a posteriori using the prediction models developed by Visentin et al. (2016) on the stored milk spectra. Briefly, individual milk samples (n=923) of Holstein-Friesian, Brown Swiss and AG were used to analyse minerals and MCP with both Formagraph (Foss Electric A/S) and Mid-infrared spectroscopy. Prediction models were calibrated applying partial least square regression and uninformative variable elimination Visentin et al. (2016). Coefficients of determination were 70% for Mg, Ca, K and P, 40% for Na, 54% for RCT and 56% for k20 Visentin et al. (2016). In the following study, MCP included rennet coagulation time (RCT, min), curd-firming time (k20, min) and curd firmness 30 min after rennet addition to milk (a30, mm), and the milk minerals were Ca, K, Mg, Na and P. The coefficients of determination of the prediction models in external validation were 0.67, 0.69, 0.65, 0.40, 0.68, 0.54, 0.56 and 0.52 for Ca, K, Mg, Na, P, RCT, k20 and a30, respectively. Values of milk composition traits, MCP and minerals outside mean ± 3 standard deviations were considered outliers and treated as missing data. As regards SCC, values were treated as missing information when they were outside the range 1 to 1000 cells/mL. To normalize SCC, the somatic cell score (SCS, units) was conventionally calculated as:

$$SCS = \log2(SCC/100) + 3;$$

Only single-breed farms were kept, i.e. farms with 100% of cows tested in a year belonging either to AG or PI. In fact, farms keeping other breeds next to PI or AG or keeping both AG and PI in multi-breed herds were discarded due to very few observations available. Finally, farms that were sampled from a minimum of 3 to a maximum of 10 times in a month and that had at least 3 controlled cows per year were retained, resulting, on average, in 9 controlled cows per farm/year. The final dataset comprised 56,914 bulk milk samples of 461 herds: 85.55% of samples belonged to 405 AG farms and the remaining 14.45% to 56 PI farms.

2.3. Statistical analysis

An analysis of variance was performed using SAS software v. 9.4 (SAS Institute Inc., Cary, NC) according to the following linear mixed model:

$$y_{ijklm} = \mu + breed_i + season_j + year_k + (breed \times season)_{ij} + (breed \times year)_{ik} + herd_l(breed_i) + e_{ijklm},$$

where y_{ijklm} is FC, PC, CC, LC, SCS, minerals (Ca, K, Mg, Na or P) or MCP (a30, k20 or RCT); μ is the overall intercept of the model; $breed_i$ is the fixed effect of the ith cattle breed (i = AG, PI); $season_j$ is the fixed effect of the jth season of sampling [j = winter (December to February), spring (March to May), summer (June to August), autumn (September to November)]; $year_k$ is the fixed effect of the kth year of sampling (k = 2014 to 2018); $(breed \times season)_{ij}$ is the fixed interaction effect between breed and season of sampling; $(breed \times year)_{ik}$ is the fixed interaction effect between breed and year of sampling; $herd_l(breed_i)$ is the random effect of the lth herd nested within the ith breed; and e_{ijklm} is the random residual term. According to the data structure, the significance of the breed effect was tested on the herd within breed variance. Post-hoc Bonferroni adjustment was used to test if least squares means differed significantly ($P < 0.05$).

3. Results and Discussion

3.1. Descriptive statistics

Milk FC, PC, CC and LC averaged 3.80, 3.43, 2.68 and 4.82%, respectively (Table 1). These values resembled findings of Benedet et al. (2018), who reported means of 3.86, 3.34 and 2.58% for FC, PC and CC, respectively, in bulk milk samples of 627 herds located in 11 Italian regions and predominantly composed of Holstein Friesian, Brown Swiss and Simmental breeds. Milk SCS ranged from -3.64 to 6.32 and its mean was lower than the one (4.09) observed by Benedet et al. (2018). The coefficient of variation (CV) of traditional milk quality traits varied from 1.50% (LC) to 32.17% (SCS); except for SCS whose CV was lower (16.90%) compared to the present study, all other CV were similar to those reported by

Benedet et al. (2018). Rennet coagulation time, k20 and a30 averaged 22.75 min, 7.29 min and 16.02 mm, respectively (Table 1); these values indicate more favourable coagulation characteristics of AG and PI bulk milk compared to MCP obtained by Benedet et al. (2018) on bulk milk from mostly Holstein Friesian, Brown Swiss and Simmental cows. In contrast, Toffanin et al. (2012) observed more favourable MCP measured on 1570 bulk milk samples of 436 Holstein Friesian herds compared to our study. Moreover, Manuelian et al. (2018) reported similar RCT and a30 (22.66 min and 16.79 mm, respectively) and lower k20 (5.53 min) in individual milk samples of 1558 Pinzgauer cows compared to our results (Table 1). Finally, minerals content ranged from 136.28 mg/kg (Mg) to 1570.72 mg/kg (K) and showed quite low CV (< 10%; Table 1).

Niero et al. (2016) observed mean values ranging between 110.07 mg/kg (Mg) and 1493.53 mg/kg (K) and CV varying between 11.36% (K) and 39.75% (Na) in individual milk samples from 83 Burlina cows. Likewise, Manuelian et al. (2018) reported mean values between 141.41 mg/kg (Mg) and 1495.04 mg/kg (K) with a CV varying between 8.61% (K) and 17.59% (Mg) in Pinzgauer cows.

3.2. Correlations

Pearson correlations ($P < 0.05$) between the investigated traits are summarized in Table 2. The strongest relationships ($P < 0.05$) were estimated between PC and CC (0.98), a30 and RCT (-0.90), and Mg and P (0.73). Milk SCS was very weakly correlated with all traits, except with LC (-0.30: $P < 0.05$) and Na (0.26; $P < 0.05$) which is in line with correlations reported in Costa et al.; Costa et al. (2019a; 2019b). The positive correlations of Ca, Mg and P with PC and CC ($P < 0.05$) were expected since these minerals are involved in the structure of casein micelles and are crucial for casein micelle stability Franzoi et al. (2019); Holt

(2004). Moreover, the same minerals were favourably associated to MCP (P < 0.05), suggesting that greater Ca, Mg and P were associated to a faster coagulation and a greater curd firmness. On the other hand, greater milk Na and K were translated into worse MCP (P < 0.05), i.e. longer RCT and less firm curd (Table 2). Overall, the associations estimated in the present study were in agreement with those assessed on individual milks of Holstein Costa et al.(2019a); Visentin et al. (2017), Pinzgauer Manuelian et al. (2018) and other cattle breeds Franzoi et al. (2018). Finally, the strong inverse relationship between Na and LC (-0.60, P < 0.05; Table 2) was expected since Na acts as osmole when LC is low Costa et al. (2019b). In individual milk, both the genetic and the phenotypic correlations between these two traits are moderate to high and negative Costa et al. (2019a); Visentin et al. (2017).

3.3. Analysis of variance

To the best of our knowledge, this is the first study comparing bulk milk quality, MCP and minerals of AG and PI cows on a large scale. Results of the analysis of variance are summarized in Table 3. Overall, fixed effects introduced in the statistical model significantly explained the variation of the investigated traits (P < 0.05), except for the effect on breed for CC, LC, a30, k20, Ca and Na, and for the fixed interaction between breed and season for k20 and Ca.

The FC was lower in milk of AG than PI herds (P < 0.05) Table 4); typically, AG breed is known to produce less milk fat compared to other cattle breeds Breeders Association of Bolzano Province (2020). On the contrary, AG milk was characterized by greater PC than PI milk (P < 0.05). Further, more favourable SCS was observed in AG than PI herds (P < 0.05; Table 4) which agreed with the annual report of ZuchtData (2019) based on Austrian cows data, where PI has higher average SCC compared to AG. Small differences were observed between AG and PI for MCP and milk minerals (Table 4).

The significance of year and season of sampling effects on the studied traits (Table 3) might be due to the fluctuations of seasonal climatic conditions within and between years in the alpine area Napoli et al. (2019), which affects both feed quality and quantity Peratoner et al. (2010) and, indirectly, management practices (e.g. pasture use and transhumance). Least squares means of the interaction between breed and season effects are reported in Table 5. Milk FC was greater in PI than AG herds ($P < 0.05$) throughout the year and was maximum in autumn and winter for PI, and spring and winter for AG. As regards PC, significant differences between the two breeds were detected in spring and summer, with AG exhibiting greater PC compared to PI. Overall, PC and CC were maximum in autumn and minimum in summer for both breeds, whereas LC was the greatest in spring and the lowest in autumn ($P < 0.05$; Table 5). Milk SCS was greater in PI than AG ($P < 0.05$) across seasons, and it was maximum in summer and autumn, and minimum in winter and spring, whereas RCT and a30, while not significant different for all seasons, tended to be more favourable in PI than in AG milk across the year. In fact, the most unfavourable a30 and RCT were observed in AG milk sampled in summer (Table 5). In both breeds, when milk PC, CC, Ca, P and Mg were the greatest (autumn), good coagulation performances (a30 and RCT) were observed. This is in agreement with findings of De Marchi et al. (2007) who observed better RCT and a30 in autumn compared to other seasons.

4. Conclusion

This study compared bulk milk quality of single-breed farms of AG and PI, two dual-purpose breeds of the Alpine region. Milk of PI herds was characterized by greater FC and slightly better MCP than milk of AG herds. However, SCS was lower in milk of AG. The most favourable MCP were observed in milk collected in autumn in both breeds, i.e. when PC, CC, Ca, P and Mg were maximum. Considering that these two breeds have limited diffusion and are nowadays mostly kept in small single-breed farms, the milk quality investigation provided in this study is helpful to the local dairy industry to differentiate the milk of Alpine Grey cattle and Pinzgauer cattle from milk of other cattle breeds in order to have necessary arguments for developing new production concepts, e.g. producing location-bound cheese specialties. That might increase profitability and competitiveness of these local dual-purpose breeds and contribute long-term to their preservation and add value to alpine dairy farming. Nevertheless, special attention should be paid on feeding practices and management factors, since both have a great impact on milk composition and quality. Thus, specific information of farm housing and feeding should be collected on a large scale to allow fair comparisons.

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Table 1 Descriptive statistics of bulk milk traits.

Trait	*n*	Mean	CV (%)	Minimum	Maximum
Milk composition (%)					
Fat	56,541	3.80	6.17	3.09	4.52
Protein	56,682	3.43	5.09	2.90	3.95
Casein	56,650	2.68	5.12	2.27	3.08
Lactose	56,511	4.82	1.50	4.60	5.03
Somatic cell score (units)	56,435	3.17	32.17	-3.64	6.32
Milk coagulation properties[1]					
a_{30} (mm)	56,098	16.02	41.19	0.00	36.16
k_{20} (min)	56,517	7.29	9.35	5.16	9.39
RCT (min)	56,563	22.75	10.99	15.02	30.51
Milk mineral content (mg/kg)					
Ca	56,583	1,328.09	4.35	1,152.27	1,507.40
K	56,426	1,570.72	4.48	1,348.92	1,794.16
Mg	56,583	136.28	7.86	103.21	169.21
Na	56,417	398.42	8.84	287.05	509.86
P	56,823	1,075.66	9.50	771.98	1,382.99

n: number of observations; CV: coefficient of variation.

a_{30}: curd firmness 30 min after rennet addition to milk; k_{20}: curd-firming time; RCT: rennet coagulation time.

Table 2 Pearson correlations (P<0.05) between bulk milk composition traits, coagulation properties and minerals content (mg/kg).

Trait[1]	FC	PC	CC	LC	SCS	a_{30}	k_{20}	RCT	Ca	K	Mg	Na
PC	0.37											
CC	0.40	0.98										
LC	-0.06	-0.10	-0.03									
SCS	0.08	0.11	0.09	-0.30								
a_{30}	0.09	0.18	0.13	0.05	-0.04							
k_{20}	-0.23	-0.51	-0.50	-0.04	-0.01*ns*	-0.61						
RCT	-0.02	0.00*ns*	0.02	-0.06	0.07	-0.90	0.55					
Ca	0.27	0.47	0.40	-0.05	0.15	0.26	-0.39	-0.13				
K	-0.22	0.07	0.09	-0.10	-0.01*ns*	-0.27	-0.11	0.21	-0.22			
Mg	0.19	0.28	0.26	-0.12	0.08	0.11	-0.48	-0.09	0.49	0.40		
Na	0.02	0.08	0.07	-0.60	0.26	-0.28	-0.08	0.25	-0.02	0.48	0.40	
P	0.09	0.39	0.32	0.06	-0.02*ns*	0.27	-0.47	-0.20	0.57	0.18	0.73	-0.14

ns: not significant.

FC: fat content (%); PC: protein content (%); CC: casein content (%); LC: lactose content (%); SCS: somatic cell score (units); a_{30}: curd firmness 30 min after rennet addition to milk (mm); k_{20}: curd-firming time (min); RCT: rennet coagulation time (min).

Table 3 *F*-value and significance of fixed effects included in the analysis of variance for bulk milk traits.

Trait	Breed	Season	Year	Breed × Season	Breed × Year	RSD
Milk composition (%)						
Fat	81.52***	275.56***	50.74***	30.95***	4.07**	0.18
Protein	4.82*	547.04***	53.95***	61.39***	10.64***	0.13
Casein	1.84^{ns}	436.10***	216.26***	56.18***	13.90***	0.10
Lactose	2.07^{ns}	1005.15***	61.20***	20.93***	21.35***	0.05
Somatic cell score (units)	15.89***	139.22***	37.17***	9.95***	37.46***	0.60
Milk coagulation properties[1]						
a_{30} (mm)	2.96^{ns}	346.16***	2143.16***	28.21***	13.90***	5.14
k_{20} (min)	0.97^{ns}	467.90***	870.26***	1.99^{ns}	91.82***	0.55
RCT (min)	11.20***	279.67***	1358.40***	38.00***	17.07***	2.06
Milk mineral content (mg/kg)						
Ca	0.13^{ns}	414.80***	1500.54***	2.42^{ns}	10.90***	45.61
K	38.44***	257.78***	1069.77***	19.66***	5.70***	60.93
Mg	23.10***	685.01***	3094.51***	11.02***	3.28**	7.93
Na	0.42^{ns}	719.04***	530.41***	6.70***	17.74***	29.08
P	12.09***	1126.77***	4644.98***	5.26**	7.22***	66.75

RSD: residual standard deviation; *ns*: not significant; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

a_{30}: curd firmness 30 min after rennet addition to milk; k_{20}: curd-firming time; RCT: rennet coagulation time.

Table 4 Least squares means of bulk milk traits for the fixed effect of breed. Different superscript letters within a row indicate statistical significance ($P < 0.05$).

	AG		PI	
Trait	LSM	SE	LSM	SE
Milk composition (%)				
Fat	3.78[b]	0.01	3.95[a]	0.02
Protein	3.41[a]	0.01	3.37[b]	0.02
Casein	2.66[a]	0.00	2.65[a]	0.01
Lactose	4.82[a]	0.00	4.81[a]	0.01
SCS, units	3.03[b]	0.04	3.43[a]	0.09
Coagulation properties				
a30, mm	15.19[a]	0.13	15.84[a]	0.35
k20, min	7.35[a]	0.02	7.40[a]	0.05
RCT, min	22.89[a]	0.05	22.41[b]	0.13
Mineral content mg/kg				
Ca	1319.75[a]	1.39	1321.18[a]	3.68
K	1576.40[a]	1.10	1557.14[b]	2.90
Mg	135.35[b]	0.16	137.59[a]	0.44
Na	399.64[a]	0.92	401.32[a]	2.44
P	1066.33[a]	2.16	1044.97[b]	5.75

a_{30}: curd firmness 30 min after rennet addition to milk; k_{20}: curd-firming time; RCT: rennet coagulation time.

Table 5 Least squares means of bulk milk traits for the interaction between breed and seasons of sampling. Different superscript letters within row indicate statistical significance ($P < 0.05$).

	Winter		Spring		Summer		Autumn	
Trait	Alpine Grey	Pinzgauer	Alpine Grey	Pinzgauer	Alpine Grey	Pinzgauer	Alpine Grey	Pinzgauer
Milk composition (%)								
Fat	3.81^{d}	3.99^{a}	3.79^{e}	3.95^{b}	3.74^{g}	3.89^{c}	3.77^{f}	3.98^{a}
Protein	3.42^{cf}	3.40^{bfgh}	3.41^{dg}	3.35^{i}	3.38^{ehi}	3.32^{j}	3.44^{ab}	3.42^{acde}
Casein	2.67^{dfg}	2.66^{bfh}	2.67^{dfg}	2.64^{cgi}	2.64^{ehij}	2.60^{j}	2.68^{abc}	2.68^{ade}
Lactose	4.82^{ef}	4.80^{dfh}	4.84^{a}	4.84^{ab}	4.82^{bcd}	4.81^{ceg}	4.80^{ghi}	4.78^{i}
Somatic Cell Score, units	2.91^{e}	3.33^{bc}	3.00^{d}	3.33^{bc}	3.17^{b}	3.55^{a}	3.04^{c}	3.52^{a}
Coagulation properties								
a30, mm	15.53^{cd}	16.64^{ac}	14.74^{e}	16.00^{bd}	13.74^{f}	14.20^{ef}	16.72^{ab}	16.51^{abc}
k20, min	7.34^{fhi}	7.37^{dgh}	7.43^{beg}	7.46^{cef}	7.48^{acd}	7.54^{ab}	7.15^{j}	7.21^{ij}
RCT, min	22.93^{c}	22.31^{d}	23.14^{b}	22.39^{d}	23.35^{a}	22.85^{bc}	22.12^{de}	22.09^{e}
Mineral content mg/kg								
Ca	1319.71^{cef}	1323.10^{bcd}	1307.89^{hj}	1307.76^{fij}	1315.91^{dgi}	1318.22^{egh}	1335.47^{ab}	1335.64^{a}
K	1561.62^{def}	1540.48^{g}	1579.60^{b}	1569.79^{bcd}	1575.18^{c}	1555.08^{f}	1589.20^{a}	1563.21^{e}
Mg	134.49^{d}	136.06^{c}	133.48^{f}	136.53^{c}	134.14^{e}	136.55^{c}	139.29^{b}	141.22^{a}
Na	390.38^{df}	390.42^{ef}	393.95^{ce}	395.56^{cd}	406.74^{ab}	407.61^{b}	407.48^{ab}	411.69^{a}
P	1081.67^{b}	1058.68^{d}	1054.2^{cde}	1038.59^{ef}	1034.26^{f}	1011.26^{g}	1095.17^{a}	1071.36^{bc}

a_{30}: curd firmness 30 min after rennet addition to milk; k_{20}: curd-firming time; RCT: rennet coagulation time.

KAPITEL 4

MILK YIELD AND QUALITY OF ORIGINAL BROWN CATTLE FARMED IN ITALIAN ALPINE REGION

Thomas Zanon[1], Angela Costa[2], Massimo De Marchi[2], Mauro Penasa[2], Sven König[3], Matthias Gauly[1]

[1]Facoltà di Scienze e Tecnologie, Free University of Bolzano, Bolzano, Italy; [2]Dipartimento di Agronomia, Animali, Alimenti, Risorse naturali e Ambiente, University of Padova, Legnaro, Italy; [3]Institut für Tierzucht und Haustiergenetik, Justus-Liebig University Giessen, Giessen, Germany

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Abstract

The objective of this study was to investigate non-genetic sources of variation of milk production and quality traits of dual-purpose Original Brown (OB) cows farmed in Italian alpine region. Individual milk test-day records (n = 4034) of 237 cows in 23 farms were available for the period January 2014 to December 2019. Except for milk yield and somatic cell count, the phenotypes were predicted from milk mid-infrared spectra and included traditional composition traits, coagulation properties, casein fractions, minerals and fatty acids. Data were analysed using a mixed linear model which included calving season, parity, stage of lactation and first-order interactions as fixed effects, and cow and herd-test-date as random effects. Milk yield averaged 18.07 kg/d and means of fat, protein and casein were 4.03%, 3.40% and 2.68%, respectively. Primiparous OB cows produced milk with a greater content of unsaturated fatty acids compared with multiparous. Milk mineral content was generally greater in primiparous than multiparous cows except for Na. Minerals increased steadily from 30 days in milk onwards, except for K. Considering that OB milk exhibited good milk coagulation properties, which are a prerequisite for cheesemaking, strategies to valorise this endangered breed should mainly focus on the manufacturing of mountain cheeses made with its milk. In general, results for several milk-related performance coupled with the well-known strong adaptability of the breed to extensive mountain dairy farming systems are the starting point towards the valorisation and potential expansion of this local dual-purpose genetic resource, with the ultimate purpose of contributing to its conservation. Overall, the comparison with the literature demonstrated that OB cows produce milk with FA profile similar to that of Brown Swiss and Alpine Grey and with more favourable coagulation properties and mineral composition than Pinzgauer cows.

Introduction

Original Brown (OB) is an autochthonous cattle breed originating from Switzerland and mainly farmed in the alpine regions of Austria, Germany, Italy and Switzerland (Maxa et al. 2012). The OB is a middle framed dual-purpose breed of strong bone structure and good muscularity, producing 5000 kg of milk per lactation with fat and protein contents of 4.00% and 3.30%, respectively, and with carcass characteristics superior to Brown Swiss (BS; Südtiroler Braunviehzuchtverband 2020). Due to its phenotypic characteristics, such as robust feet and legs and feed efficiency, OB is highly suitable for alpine low input dairy and beef production systems and therefore might be recommended for mountain farming (Braunvieh Schweiz 2020).

At the end of the nineteenth century OB cows from Switzerland were exported to the US and underwent several selection programs aimed at improving dairy attitude, particularly milk yield (MY). This led to the birth of the specialized BS dairy breed (Yoder and Lush 1937), that was subsequently used in the 1960s through upgrading programs aimed to improve MY in European Brown populations (Maxa et al. 2012). As a result, OB has been mainly replaced by high yielding BS genetics and therefore has become an endangered breed (GEH 2020). In South Tyrol (Italian alpine region) OB has a long breeding history and it has been the first cattle breed organized in a breeders' association. Currently there are financial supports from EU (200 € per lactating cow; SBB 2020) and some valorisation strategies in South Tyrol (Biobeef 2020) to support the OB cattle breed.

Further, being an autochthonous cattle breed of alpine area, OB might incorporate potential for diversification when considered for social and economic purposes like marketing and branding of unique agricultural products from specific areas (Marsoner et al., 2018). In 2019, 241 lactating cows were farmed in South Tyrol averaging 5539 kg of MY, 3.93% of fat and

3.40% of protein per lactation (Südtiroler Braunviehzuchtverband 2020). To our knowledge, a comprehensive characterization of OB breed population for milk traits and their variation has not been reported yet. Thus, the aim of the present study was to describe and investigate sources of variation of quality traits of interest in milk of OB cows; in particular, the effects of season of calving, parity, and stage of lactation were estimated.

Materials and methods

Area of the study

Approximately 40% of Italian OB cows are reared in the province of Bolzano (South Tyrol, Italy) and the remaining are reared in the regions of Piedmont (40%) and Lombardy (20%; Rossoni A., personal communication). The geographical distribution of the 23 farms involved in this study is depicted in Figure 1. Being an autochthonous dual-purpose breed, OB cows are typically farmed in traditional alpine dairy systems, characterized by traditional feeding (mainly hay and concentrates) and use of summer pasture transhumance for part of the herd (Sturaro et al., 2013).

Data and editing

The initial data set comprised 6437 individual milk samples of 330 purebred OB cows collected during routine milk recording testing between January 2014 and December 2019. The list of purebred OB cows was retrieved from the Brown Cattle Breeders Federation of Bolzano Province (Südtiroler Braunviehzuchtverband, Bolzano, Italy). Milk fat (FC), protein (PC), casein (CC) and lactose content (LC), coagulation properties, casein (CN) fractions, minerals and fatty acid (FA) composition of OB cows were predicted from milk mid-infrared spectra in the laboratory of the South Tyrolean Dairy Association (Sennereiverband Südtirol, Bolzano, Italy). The laboratory was equipped with Milkoscan FT6000 (Foss, Hillerød, Denmark) and, from March 2017, with Milkoscan FT7 (Foss). Somatic cell count (SCC) was determined by Fossomatic FC (Foss). Contextually, coagulation properties and mineral composition were determined considering the prediction models developed and described by Visentin et al. (2016). Briefly, a data set composed of 923 milk samples from 60 single-breed herds containing the 4 major cattle breeds reared in the province of Bolzano was used in 2014 to develop prediction equations. In particular, the coefficients of determination in external validation were 0.54, 0.56, 0.52, 0.67, 0.69, 0.65, 0.40, and 0.68 for RCT, k20, a30, Ca, K, Mg, Na and P, respectively. Further, for the prediction of individual and groups of FA, the models developed by Gottardo et al. (2017) were used. Overall, the prediction accuracies of these traits were moderate (Gottardo et al., 2017). Finally, CN fractions were predicted with the models developed by Niero et al. (2016), who reported coefficients of determination in cross validation for α-CN, β-CN, and κ-CN that were 0.88, 0.60, and 0.74, respectively.

Information on MY (kg/d), days in milk (DIM), parity, herd and birth and calving dates of cows was provided by the Breeders Association of Bolzano Province (Bolzano, Italy). Test-day MY, FC, PC, CC, LC, α-CN, β-CN and κ-CN fractions (% of crude protein), rennet coagulation time (RCT, min), curd firmness 30 minutes after enzyme addition to milk (a30, mm), curd-firming time (k20, min), contents of Ca, K, P, Mg and Na (mg/kg), and FA composition (g/100 g total FA) were set to missing if they were outside the range mean ± 3 standard deviations. The FA composition included monounsaturated (MUFA), polyunsaturated (PUFA), saturated (SFA), unsaturated (UFA), trans (transFA), short chain (SCFA), medium chain (MCFA), long chain FA (LCFA), and individual C14:0, C16:0, C18:0 and C18:1. The SCC was considered if comprised between 1000 and 10,000,000 cells/mL and it was log-transformed to somatic cell score (SCS) according to Ali and Shook (1980). Cows were retained in the data set if they were from 5 to 420 DIM and from parity 1 to 11. Furthermore, only cows with at least 3 test-day observations within lactation and herd-test-date with at least 3 cows sampled were kept for the analysis. The final data included 4034 test-day records of 237 cows (520 lactations) farmed in 23 South Tyrolean herds; 30, 23, 18, 16, and 13% of lactations belonged to parity 1, 2, 3, 4, and ≥5, respectively. Farm-specific information regarding feeding practices, use of pasture in summer and feed ration composition were not available in this study.

Statistical analysis

A mixed linear model was implemented in SAS software v. 9.4 (SAS Institute Inc., Cary, NC) to study the sources of variation of milk traits. The model was as follows:

$y_{ijklmn} = \mu + season_i + parity_j + stage_k + (season \times parity)_{ij} + (season \times stage)_{ik} + (parity \times stage)_{jk} + HTD_l + cow_m + e_{ijklmn}$,

where y_{ijklmn} is the dependent variable (MY, milk composition traits, SCS, coagulation properties, CN fractions, minerals or FA), μ is the overall intercept of the model, $season_i$ is the fixed effect of the ith calving season of the cow [i = winter (December to February), spring (March to May), summer (June to August), autumn (September to November)], $parity_j$ is the fixed effect of the jth class of parity of the cow (j = 1 to 5, with the last class including parities from 5 to 11); $stage_k$ is the fixed effect of the kth class of stage of lactation of the cow (1 = 1 to 11, where the first class is 5 to 30 DIM, followed by 9 classes of 30 DIM each, and the last class including DIM from 301 to 420), $(season \times parity)_{ij}$ is the fixed interaction effect between calving season and parity, $(season \times stage)_{ik}$ is the fixed interaction effect between calving season and stage of lactation, $(parity \times stage)_{jk}$ is the fixed interaction effect between parity and stage of lactation, HTD_l is the random effect of the lth herd-test-date (l = 1 to 470), cow_m is the random effect of the mth cow (m = 1 to

237), and eijklmn is the random residual. Differences between least squares means of the fixed effects were tested using Bonferroni post-hoc test ($p < .05$). Pearson's correlations were also calculated using the CORR procedure of SAS software v. 9.4 (SAS Institute Inc., Cary, NC). Considering DIM classes, the frequency of test-day records ranged from 5.8% (class 10) to 10.5% (class 2). Finally, the frequency of test-day records was 24.4, 25.9, 18.8, and 30.9% in winter, spring, summer, and autumn, respectively.

Results and discussion

Descriptive statistics

It is well-known that feeding practices (e.g. pasture) and feed composition can affect milk FC and PC in cattle. For example, the access to pasture or fresh forage has an impact on milk FA profile, which tends to be significantly different compared with diet uniquely based on unifeed (Hanuš et al. 2018). For example, milk from cows at pasture tends to show greater content of n-3 FA and lower content of n-6 FA compared to milk from cows with TMR feeding (O´Callaghan et al., 2016). Further, cows in pasture-based systems produce significant higher MUFA and PUFA contents and lower SFA contents in milk compared to cows in indoor feeding systems (Hofstetter et al., 2014). Despite this, detailed information regarding access to summer pasture and other feeding practices were not available in the current study; in the light of these considerations, the comparisons of the present results with the literature should be considered with caution.

The highest frequency of calvings in primiparous cows was in autumn, whereas for multiparous cows the seasonal pattern was less evident (Figure 2). The high incidence of autumn calvings in primiparous cows may be due to management practices in alpine region. In fact, in alpine farms heifers usually spend the gestation at summer pastures before becoming milking cows. The lower quality (energy content) of summer highland pastures is reported to reduce the risk for high body condition score at calving (fat cows) and thus may limit the subsequent fertility and metabolic disorders caused by negative energy balance (Wathes et al. 2007; Roche et al. 2013).

Descriptive statistics for MY, composition, SCS, coagulation properties, CN fractions, minerals and FA composition are summarized in Table 1. Average MY of OB cows was lower than mean MY of BS cows (24.10 kg/d) reported by Penasa et al. (2014) and 1232 dual-purpose Pinzgauer cows (20.87 kg/d) reported by Manuelian et al. (2018c). The average FC was similar to that of Pinzgauer cows (4.01%; Manuelian et al. 2018c) but lower than that of BS cows (4.05%; Penasa et al. 2014. The coefficient of variation (CV) of traditional milk composition traits and SCS ranged from 4.6% (LC) to 62.5% (SCS), and resembled values observed in the literature for individual milk. In the present study, mean RCT was slightly greater and mean a30 was much lower than values of 18.57 min for RCT and 28.07 mm for a30 observed in multi-breed herds of Bolzano province (Visentin et al. 2015). Manuelian et al. (2018a) analysed milk coagulation properties and minerals content of 851 Pinzgauer cows, and reported average values of 22.66 min, 5.53 min and 16.79 mm for RCT, k20 and a30, respectively, i.e. less favourable than values observed in the current study. Cipolat-Gotet et al. (2012) assessed milk coagulation properties of 913 BS cows and reported RCT (19.95 min) and k20 (5.36 min) that were similar to those of our study. However, in the same study, a30 was firmer (30.09 mm) compared to a30 of OB cows (Table 1); this difference may be explained by the different methodology used to determine coagulation properties. In fact, Cipolat-Gotet et al. (2012) conducted a lactodynamographic analysis with Formagraph to determine milk coagulation properties, whereas in this study mid-infrared spectroscopy predictions were used. The CV of coagulation properties ranged from 20.7%

(RCT) to 57.7% (a30), i.e. higher than CV of RCT and a30 calculated by Manuelian et al. (2018a).

In the present study α-CN was greater, and β-CN and κ-CN were lower compared to Franzoi et al. (2019). In purebred Simmental cows De Marchi et al. (2009) observed lower α-CN and κ-CN (42.02% and 9.24%) and greater β-CN (36.86%) than our study. The increase of CN fractions in milk has been shown to improve cheese-making properties by shortening RCT and increasing curd firmness (Jõudu et al. 2008). Therefore, the high α-CN and κ-CN content of OB milk suggests a good suitability for cheese production.

In terms of minerals, greater Ca and Mg and lower P, Na and K contents were found in OB milk compared to the study of Visentin et al. (2018). In fact, the latter reported averages of 1364.56 (Ca), 1668.64 (K), 140.63 (Mg), 1035.57 (P) and 442.83 mg/kg (Na) in 132,380 individual milk samples of Holstein Friesian, BS, Alpine Grey and Simmental cows. Comparing OB performance of this study with Pinzgauer (Manuelian et al. 2018a), Ca, K and P were higher in OB milk. Overall, high contents of Ca, Mg and P in milk were shown to positively affect the coagulation ability and the stability of the micelles (Malacarne et al. 2014).

The overall means for groups of FA varied from 1.88 g/100 g total FA for transFA to 66.56 g/100 g total FA for SFA and CV ranged from 8.0% (SFA) to 38.8% (transFA). Means for individual FA varied from 10.17 g/100 g total FA for C18:0 to 29.76 g/100 g total FA for C16:0 with CV comprised between 12.7% (C16:0) and 22.4% (C18:0). Manuelian et al. (2018c) observed slightly greater SFA content (69.20 g/100 g total FA) and slightly lower MUFA and PUFA (25.43 and 3.19 g/100 g total FA, respectively) in Pinzgauer cattle compared to OB cows of the present study. Similarly, OB produced milk with greater PUFA and MUFA and lower SFA content than other cattle breeds (Manuelian et al. 2019). Gottardo et al. (2017) reported slightly greater SFA (70.18 g/100 g total FA) and PUFA (2.95 g/100 g total FA), and slightly lower MUFA (24.59 g/100 g total FA) in milk of BS cows compared to this study (Table 1). Moreover, progressively greater SFA and lower PUFA and MUFA contents in milk have been observed when moving from cows with low (< 25%) to high (75 to 99%) BS genetics (Stergiadis et al. 2015). It should be considered that, next to genetics, the effect of diet composition has an impact on milk characteristics. In particular, the common practice of summer pasture in farms of alpine area significantly affects milk FA (O'Callaghan et al., 2016; Hanuš et al., 2018). Therefore, particular attention should be paid to feeding management and practices, and on the type of forage for producing milk with a desirable FA composition.

Correlations

Overall, correlations between conventional milk composition traits are in line with estimates from the literature. The negative correlation between milk composition and MY (Table 2) was expected as higher milk production has usually a dilutive effect on FC, PC and CC. The positive correlation between SCS and Na is supported by Costa et al. (2019c) and Fernando et al. (1985) who related electrical conductivity of milk with mastitis in dairy cows. Indeed, Na reacts as an osmotic replacer of lactose during udder infection because permeability of alveolar epithelium changes and blood-milk barrier is disrupted (Wheelock et al. 1966; Wegner and Stull 1978; Costa et al. 2019b, 2019c). Summer et al. (2009) reported greater Na and K contents in milk with SCC >400,000 cells/mL compared to milk with SCC <400,000 cells/mL, supporting the positive correlation between Na and SCS in our study. In addition, SCS and LC were moderately negatively correlated (-0.41) and Na and LC were strongly negatively correlated (-0.83; Table 2). This confirmed low LC to be an additional indicator of udder infection and a useful tool for mastitis diagnosis (Costa et al. 2019b). The positive correlations of Ca, Mg and P with PC and CC are explained by the fact that these minerals are part of the structure of casein micelles and mainly responsible for casein micelle stability (Holt 2004; Bijl et al. 2013). Milk Ca, P and Mg were favourably associated with milk coagulation properties. Moreover, a30 and k20 showed favourable correlations with PC and CC (Table 2), as described by Cassandro et al. (2008) and Visentin et al. (2018). Further, a strong negative correlation was estimated between RCT and a30 (-0.72), in agreement with the literature (Ikonen et al. 2004; Cassandro et al. 2008). Moderate negative correlations were observed between α-CN and MUFA (-0.40) and PUFA (-0.36), whereas κ-CN was positively associated with MUFA (0.29) and PUFA (0.32; Table 3). Moreover, positive correlations of β-CN and α-CN fractions with SCFA and moderate negative correlation between κ-CN and SCFA were observed. On the contrary, a moderate negative correlation between α-CN and LCFA and weak positive correlations between β-CN and κ-CN fractions and LFCA were estimated. There is evidence that FA have an effect on size and structure of casein micelle. Panja et al. (2018) have observed interactions of UFA and SFA with casein micelles. Further, UFA increased more significantly the size and hydrophobicity of casein micelles than SFA. The correlations observed in our study and the results in Panja et al. (2018) might provide useful information for future studies to improve technological milk traits.

Effect of parity

Least squares means of milk traits for the fixed effect of parity are presented in Table 4. As in other breeds (Steinwidder and Greimel 1999; Miller et al. 2006; Siewert et al. 2019), daily MY increased from primiparous to multiparous cows, with a plateau from third parity onwards. Fat content of second-parity cows was the highest but did not differ significantly from that of first-parity cows; PC of second- and third-parity cows did not differ, and CC was similar in the first 3 parities (Table 4). Conversely, LC was maximum in primiparous cows and decreased in subsequent lactations, in agreement with findings of Costa et al. (2019c) in Holstein Friesian cows. On the contrary, SCS increased steadily ($p < .05$) with parity, as the combined result of a decrease of polymorphonuclear leukocytes (Mehrzad et al. 2002; Rainard and Riollet 2006), age-related physiological alteration of the teat canal resulting in an expansion of the sphincter muscle at the teat tip, and altered epithelial permeability of mammary gland alveolar structures (Guarín and Ruegg 2016; Costa et al. 2019a, 2019b). Variation of CN fractions across parities was generally low, with significance likely merely related to the sample size. Milk RCT, a30 and k20 were the most favourable in first-parity cows (Table 4). These results partly agreed with Penasa et al. (2014), who reported milk coagulation properties to be worse in multiparous than primiparous cows. In the study of Ikonen et al. (2004), lower a30 was observed in primiparous than multiparous cows. Mineral content was generally greater in primiparous cows except for Na, whose trend was opposite (Table 4) and confirmed results of Manuelian et al. (2018b) and Visentin et al. (2018). It is well known that the risk of hypocalcemia is higher in multiparous cows because of the presence of a previous lactation, unfavourable cations-anions equilibrium in the ration of the dry period, and reduced activity of parathyroid hormone which results in a disturbed Ca-homeostasis with lower Ca mobilization from bones to blood (Goff et al. 1986). The increase of Na across parities might be explained by the decrease of LC and the increase of SCS, as there is flow of extracellular liquid with high concentrations of Na inside alveolar lumen (Fernando et al. 1985; Batavani et al. 2007; Summer et al. 2009). Both MUFA and PUFA were maximum in primiparous cows and decreased thereafter ($p < .05$). On the other hand, least squares means of SFA of multiparous were greater than that of primiparous cows

($p < .05$; Table 4). These findings agreed with results of Manuelian et al. (2018c) in Pinzgauer cattle, where SFA was the lowest in primiparous. Likewise, Gottardo et al. (2017) observed decreasing values for MUFA and PUFA and increasing values for SFA from first- to later-parity Holstein, BS, Simmental and Alpine Grey cows. The MCFA and LCFA were the greatest in second and first parity, respectively, whereas SCFA was maximum in cows of parity ≥ 5 (Table 4). In Gottardo et al. (2017) greatest SCFA and LCFA were observed in primiparous cows and greatest MCFA in second-parity cows and cows in ≥ 5 parity. Similarly, Manuelian et al. (2018c) observed greatest SCFA and LCFA in first- and greatest MCFA in sixed- and later-parity cows. Moreover, transFA were minimum and maximum in parity ≥ 5 and 1, respectively ($p < .05$; Table 4). Finally, C18:0 and C18:1 were greater ($p < .05$) in first- than later-parity cows, whereas both C16:0 and C14:0 were the lowest in primiparous (Table 4). Overall, FA profile tends to be more favourable in primiparous than multiparous OB cows, as there were higher healthy UFA contents in first parity and higher undesired SFA contents in milk of multiparous cows. In general, such findings are in line with the literature (Artegoitia et al. 2013; Bilal et al. 2014; Hanuš et al. 2018). Higher milk SFA in multiparous cows might be explained by greater amounts of de novo synthesized SFA in older animals (Artegoitia et al. 2013). In fact, Miller et al. (2006) have observed metabolically less active mammary glands with a lower expression of fatty acid synthase and consequently lower de novo synthesized SFA in primiparous cows.

Effect of lactation stage

Milk yield decreased almost linearly across DIM, with least squares means ranging from 23.58 (0.72) kg/din early lactation (5 to 30 DIM) to 11.70 (0.29) kg/d in late lactation (301 to 420 DIM). Overall, the lactation curves of traditional milk quality traits followed the typical shape, with greater FC, PC and CC at the end of lactation (Figure 3a). Milk SCS reached its nadir between 31 and 60 DIM, and then progressively increased until the end of lactation (Figure 3b); on the contrary, LC peaked in the window from 31 to 60 DIM and decreased thereafter (Figure 3b). These two inverse trends confirmed observations of Costa et al. (2019b). Both RCT and a30 slightly increased at the end of lactation (Figure 4a), as observed by Penasa et al. (2014) and Visentin et al. (2015). However, while a30 decreased rapidly from first to second stage of lactation, RCT had overall an increasing trend for the entire lactation, with the minimum in first stage of lactation (17.29 ± 0.33 min). As regards k20, the lactation curve was similar to that of LC, with a peak in second stage of lactation and subsequent decrease up to 4.40 ± 0.09 min (301 to 420 DIM); this trend mirrored findings of Visentin et al. (2015). The β-CN fraction increased during lactation, whereas α-CN and κ-CN decreased (Figure 4b); in particular, the drop was more evident for α-CN, whose minimum and maximum were 0.43 ± 0.002 and 0.46 ± 0.002, respectively. Results resembled the findings reported by Franzoi et al. (2019). Milk Ca, P, Mg, and Na contents increased from 60 DIM onwards, while K slightly decreased across lactation (Figure 5); the same trend of milk K has been observed also by Manuelian et al. (2018b) and Visentin et al. (2018) in other dairy cattle breeds. As regards milk FA composition, MUFA and PUFA exhibited similar lactation curves and both decreased until 61-90 DIM and increased thereafter (Figure 6a). In agreement with Manuelian et al. (2018c), SFA increased until 61-90 DIM (peak) and then decreased until the end of lactation. Also, transFA increased at the beginning of lactation and then decreased, but in a more linear manner (Fgure 4b). Lactation curves of SCFA, MCFA, LCFA and individual FA resembled the patterns observed in other breeds (Gottardo et al. 2017; Manuelian et al. 2018c). In particular, C14:0 and C16:0 increased up to 61-90 DIM and, after a plateau, they slightly decreased. Instead

C18:0 and C18:1 were maximum in early lactation and then decreased till mid-lactation (Figure 6d).

Parity-specific lactation curves were plotted for all milk traits (data not shown). Overall, primiparous clustered differently from multiparous in the case of MUFA, PUFA, SFA, SCS, LC and MY. Both MUFA and PUFA showed greatest content in primiparous cows at the very beginning and at the end of lactation, whereas SFA was greatest between 61 and 90 DIM in second-parity cows. Regarding udder health, SCS was the highest throughout the entire lactation in multiparous cows, while, oppositely, LC was overall the highest in primiparous cows in all stages of lactation. Finally, MY was lower in primiparous cows during most of lactation but overlapped with MY of multiparous cows at the end of lactation.

Conclusions

The OB cattle breed is historically related to mountain farming system in alpine region of Italy. The present study provided the first comprehensive phenotypic investigation on milk composition and technological traits of OB population reared in mountain area. Overall, the comparison with the literature demonstrated that OB cows are able to compete with specialized dairy and other local (dual-purpose) cattle breeds in terms of milk quality and coagulation properties. In particular, milk of OB cows showed similar FA profile compared with BS and Alpine Grey cows and more favourable coagulation properties and mineral composition compared with Pinzgauer cows. However, it is worth underlying that OB cows are typically farmed in small farms with low forage quality, summer pasturing and transhumance, and mostly old-fashioned tie-stall husbandry systems. Therefore, considering these aspects, OB cows may be even superior to other breeds, including BS, in terms of efficiency, resilience, adaptability, pasture use and rusticity. In particular, results showed that multiparous cows were the most productive in terms of MY and primiparous cows were the most recommended for cheese-making in terms of coagulation properties. Conservation strategies for this endangered breed may thus focus on the production of cheeses and dairy foods exclusively from OB cows reared in extensive farming system. A more desirable FA composition (greater UFA and lower SFA) was observed in first-parity cows. Further investigations on cow functional traits are necessary to get better insights in OB in order to address future management choices and conservation plans. In perspective, specific experimental designs based on multi-breed herds and with detailed information on feeding practices would allow a fair comparison between OB and other cattle breeds.

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Table 1 Descriptive statistics of milk yield, composition, somatic cell score, coagulation properties, casein fractions, minerals and fatty acid (FA) composition of Original Brown cows.

Trait[a]	*n*	Mean	CV, %	Minimum	Maximum
Milk yield, kg/d	4007	18.07	29.8	2.90	35.00
Milk composition, %					
Fat	3948	4.03	17.8	1.24	7.02
Protein	4001	3.40	10.7	2.26	4.62
Casein	4005	2.68	10.9	1.79	3.65
Lactose	3986	4.83	4.6	3.80	5.59
Somatic cell score, units	4020	3.19	62.5	-2.06	9.29
Coagulation properties					
RCT, min	3230	19.78	20.7	5.65	29.00
a_{30}, mm	2797	19.34	57.7	0.05	55.30
k_{20}, min	3292	5.45	23.2	2.07	10.98
Casein fractions, % crude protein					
α-casein	3473	0.44	7.6	0.34	0.55
β-casein	3430	0.29	14.3	0.17	0.41
κ-casein	3425	0.18	20.6	0.08	0.29
Minerals, mg/kg					
Ca	2294	1431.80	10.7	963.84	1903.02
K	2308	1543.54	8.6	874.31	2066.54
P	2299	1010.95	10.6	703.52	1329.33
Mg	2009	145.34	15.7	62.24	193.50
Na	2310	397.63	14.3	135.13	603.44
Groups of FA, g/100 g total FA					
Monounsaturated FA	3435	25.60	17.5	12.20	40.16
Polyunsaturated FA	3431	3.27	20.4	1.21	5.50
Saturated FA	3460	66.56	8.0	47.31	81.09
Unsaturated FA	3447	31.44	15.3	17.50	46.73
*trans*FA	3396	1.88	38.8	0.01	4.22
Short chain FA	3458	11.29	16.4	5.53	17.05
Medium chain FA	3456	40.11	18.8	15.81	64.92
Long chain FA	3446	34.18	17.0	16.85	52.78
Individual FA, g/100 g total FA					
C14:0	3445	11.41	13.9	6.24	16.36
C16:0	3462	29.76	12.7	18.18	40.72
C18:0	3465	10.17	22.4	3.91	16.94
C18:1	3436	22.09	20.4	7.65	36.84

CV: coefficient of variation.

[a]RCT: rennet coagulation time; a_{30}: curd firmness 30 min after enzyme addition to milk; k_{20}: curd-firming time.

Table 2 Pearson correlations between milk yield (kg/d), composition traits, coagulation parameters, casein fractions (% crude protein), and minerals (mg/kg)

Trait[1]	**Milk yield**	**Fat, %**	**Protein, %**	**Casein, %**	**Lactose, %**	**SCS**	**RCT**	**a_{30}**	**k_{20}**	**α-casein**	**β-casein**	**κ-casein**	**Ca**	**K**	**P**	**Mg**
Fat, %	-0.22															
Protein, %	-0.4	0.3														
Casein, %	-0.38	0.32	0.98													
Lactose, %	0.23	-0.11	-0.09	-0.02[a]												
SCS	-0.24	0.14	0.08	0.03[a]	-0.41											
RCT	-0.06[a]	0.08	0.05[a]	0.05[a]	-0.22	0.33										
a_{30}	-0.05[a]	0.08	0.16	0.16	0.16	-0.22	-0.72									
k_{20}	0.17	-0.25	-0.55	-0.56	-0.17	0.13	0.38	-0.58								
α-casein	0.21	0.16	-0.08	-0.07[a]	-0.06[a]	0.12	0.1	-0.06[a]	0.16							
β-casein	0.01[a]	-0.02[a]	0.01[a]	0.01[a]	0.07	-0.14	0.09	-0.19	0.08	-0.52						
κ-casein	0.02[a]	0.04a	-0.17	-0.16	-0.11	0.08	0.22	-0.02[a]	-0.15	-0.2	0.00[a]					
Ca	-0.23	0.23	0.28	0.28	0.01[a]	-0.03[a]	-0.26	0.33	-0.39	-0.09	-0.16	-0.25				
K	0.01[a]	-0.31	-0.25	-0.28	-0.17	0.07[a]	-0.09	0.03[a]	0.04[a]	-0.04[a]	-0.05[a]	0.16	0.22			
P	-0.2	0.14	0.39	0.37	0.17	-0.11	-0.36	0.33	-0.37	-0.36	0.21	-0.23	0.47	0.22		
Mg	-0.13	0.12	0.24	0.22	-0.04[a]	-0.01[a]	-0.27	0.3	-0.4	0.1	-0.11	-0.39	0.54	0.13	0.35	
Na	-0.22	-0.23	0.08	0.01[a]	-0.83	0.4	0.25	-0.21	0.17	-0.07[a]	-0.09	0.07[a]	0.05[a]	0.33	-0.27	0.03[a]

[1]SCS: somatic cell score; RCT: rennet coagulation time (min); a30: curd firmness 30 min after enzyme addition to milk (mm); k20: curd-firming time (min)aCorrelations not different from zero (p > .05).

Table 3. Pearson correlations between individual and groups of milk fatty acids (g/100 g total FA) with milk yield, composition traits, coagulation parameters, casein fractions (% crude protein), and minerals (mg/kg)

Trait	MUFA	PUFA	SFA	UFA	*trans*FA	SCFA	MCFA	LCFA	C14:0	C16:0	C18:0	C18:1
Milk yield, kg/d	-0.1	-0.01[a]	0.07	-0.07	0.09	0.2	-0.14	-0.02[a]	0.1	-0.05[a]	0.09	-0.1
Fat, %	0.01[a]	-0.17	0.02[a]	-0.01[a]	-0.13	0.13	0.09	0.04[a]	-0.26	-0.02[a]	0.04[a]	0.07
Protein, %	-0.02[a]	-0.07	-0.00[a]	0.00[a]	-0.4	0.11	0.17	-0.09	-0.02[a]	-0.03[a]	-0.17	-0.04[a]
Casein, %	-0.02[a]	-0.07	-0.00[a]	-0.01[a]	-0.35	0.14	0.14	-0.08	-0.02[a]	-0.04[a]	-0.18	-0.04[a]
Lactose, %	-0.02	0.07	0.09	-0.11	0.27	0.08	-0.29	0.01[a]	0.16	0.07	0.08	-0.07
SCS	-0.02[a]	-0.04[a]	0.06[a]	-0.03[a]	-0.1	-0.17	0.17	-0.09	0.02[a]	0.14	-0.04[a]	0.00[a]
RCT	-0.12	-0.07[a]	0.01[a]	-0.03[a]	-0.02[a]	-0.03[a]	0.11	-0.1	0.03[a]	0.07[a]	-0.09	-0.11
a_{30}	0.25	0.14	0.13	0.00[a]	0.07[a]	-0.23	0.09	0.06[a]	0.01[a]	0.02[a]	0.28	0.22
k_{20}	-0.2	-0.1	-0.12	0.00[a]	-0.01[a]	0.13	-0.14	-0.05[a]	-0.05[a]	0.03[a]	-0.22	-0.16
α-casein	-0.4	-0.36	0.28	-0.32	-0.2	0.31	0.15	-0.3	0.18	0.22	-0.08	-0.34
β-casein	-0.00[a]	0.09	-0.33	0.21	0.03[a]	0.22	-0.31	0.15	-0.18	-0.28	-0.17	-0.01[a]
κ-casein	0.29	0.32	-0.00[a]	0.15	0.32	-0.32	0.15	0.17	-0.06[a]	-0.08	0.43	0.31
Ca	0.41	0.22	-0.27	0.3	-0.03[a]	-0.23	-0.01[a]	0.35	-0.36	-0.19	0.2	0.35
K	0.23	0.35	-0.23	0.19	0.1	-0.08[a]	-0.03[a]	0.22	-0.19	-0.18	0.07[a]	0.24
P	0.27	0.21	-0.19	0.18	-0.04[a]	0.11	-0.02[a]	0.23	-0.26	-0.19	0.05[a]	0.2
Mg	0.15	0.02[a]	0.04[a]	0.01[a]	-0.00[a]	-0.13	0.13	0.08[a]	-0.04[a]	-0.06[a]	0.11	0.1
Na	0.02[a]	0.09[a]	-0.14	0.13	-0.3	-0.24	0.11	-0.03	-0.02[a]	-0.06[a]	-0.18	0.02[a]
MUFA		0.75	-0.55	0.8	0.49	-0.52	-0.19	0.84	-0.63	-0.6	0.65	0.97
PUFA			-0.55	0.67	0.48	-0.29	-0.32	0.68	-0.44	-0.58	0.49	0.7
SFA				-0.88	-0.14	-0.06[a]	0.61	-0.81	0.83	0.86	-0.17	-0.55
UFA					0.27	-0.2	-0.44	0.91	-0.82	-0.83	0.43	0.79
trans FA						-0.44	-0.18	0.41	-0.16	-0.22	0.52	0.48
SCFA							-0.29	-0.24	0.01[a]	-0.03[a]	-0.61	-0.47
MCFA								-0.42	0.4	0.52	0.11	-0.22
LCFA									-0.84	-0.83	0.58	0.84
C14:0										0.81	-0.38	-0.68
C16:0											-0.38	-0.63
C18:0												0.64

SCS: somatic cell score; RCT: rennet coagulation time (min); a30: curd firmness 30 min after enzyme addition to milk (mm); k20: curd-firming time (min); MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids; UFA: unsaturated fatty acids; transFA: trans fatty acids; SCFA: short-chain fatty acids; MCFA: medium-chain fatty acids; LCFA: long-chain fatty acids; aCorrelations not different from zero (p > .05).

Table 3 Least squares means of milk yield, composition, somatic cell score, coagulation properties, casein fractions, minerals and fatty acid (FA) composition across parities.

Trait	Parity 1	Parity 2	Parity 3	Parity 4	Parity ≥ 5
Milk yield, kg/d	16.58[c]	17.47[b]	18.57[a]	18.56[a]	18.27[a]
Milk composition, %					
Fat	4.11[ab]	4.15[a]	4.04[c]	4.03[bc]	3.98[c]
Protein	3.44[b]	3.48[a]	3.47[a]	3.43[bc]	3.40[c]
Casein	2.72[ab]	2.74[a]	2.74[a]	2.70[b]	2.67[c]
Lactose	4.91[a]	4.81[b]	4.81[b]	4.78[c]	4.76[c]
SCS, units	2.37[e]	2.97[d]	3.30[c]	3.47[b]	3.67[a]
Coagulation properties					
RCT, min	19.20[b]	20.01[a]	19.48[b]	20.20[a]	20.16[a]
a_{30}, mm	27.74[a]	26.61[b]	27.32[ab]	25.02[c]	24.92[c]
k_{20}, min	4.89[c]	4.99[c]	4.97[c]	5.19[b]	5.37[a]
Protein fractions, % of protein					
α-casein	0.43[c]	0.44[b]	0.44[b]	0.44[a]	0.44[a]
β-casein	0.30[a]	0.30[ab]	0.30[bc]	0.29[d]	0.29[cd]
κ-casein	0.18[a]	0.18[a]	0.17[b]	0.17[b]	0.17[c]
Minerals, mg/kg					
Ca	1469.77[a]	1444.30[b]	1436.07[b]	1428.33[b]	1411.26[c]
K	1548.07[a]	1527.80[b]	1530.02[b]	1528.34[b]	1538.14[ab]
P	1059.90[a]	1019.66[b]	1009.62[c]	996.08[d]	1003.12[cd]
Mg	152.29[a]	149.90[bc]	150.64[b]	148.70[c]	148.08[c]
Na	368.98[d]	397.79[c]	402.60[c]	409.57[b]	417.14[a]
Groups of FA, g/100 g total FA					
Monounsaturated FA	27.23[a]	25.60[b]	25.34[bc]	25.17[cd]	24.92[d]
Polyunsaturated FA	3.47[a]	3.26[b]	3.23[bc]	3.20[c]	3.19[c]
Saturated FA	64.98[b]	66.22[a]	66.32[a]	66.15[a]	66.20[a]
Unsaturated FA	32.93[a]	31.75[b]	31.77[b]	31.88[b]	31.79[b]
*trans*FA	2.09[a]	1.81[b]	1.72[c]	1.69[cd]	1.63[d]
Short chain FA	11.30[b]	11.37[b]	11.44[b]	11.37[b]	11.63[a]
Medium chain FA	38.95[b]	39.59[a]	38.58[b]	38.57[b]	38.94[ab]
Long chain FA	36.23[a]	34.18[b]	33.98[b]	34.06[b]	34.11[b]
Individual FA, g/100 g total FA					
C14:0	10.89[b]	11.33[a]	11.43[a]	11.40[a]	11.39[a]
C16:0	28.83[b]	29.58[a]	29.48[a]	29.45[a]	29.42[a]
C18:0	10.56[a]	10.11[b]	9.86[c]	9.89[c]	9.82[c]
C18:1	23.48[a]	22.05[b]	21.78[bc]	21.58[cd]	21.23[d]

Least squares means with different superscript letters within a row are significantly different ($p < .05$).

RCT: rennet coagulation time; a_{30}: curd firmness 30 min after enzyme addition to milk; k_{20}: curd-firming time.

Figure 1. Location of the 23 farms involved in the study.

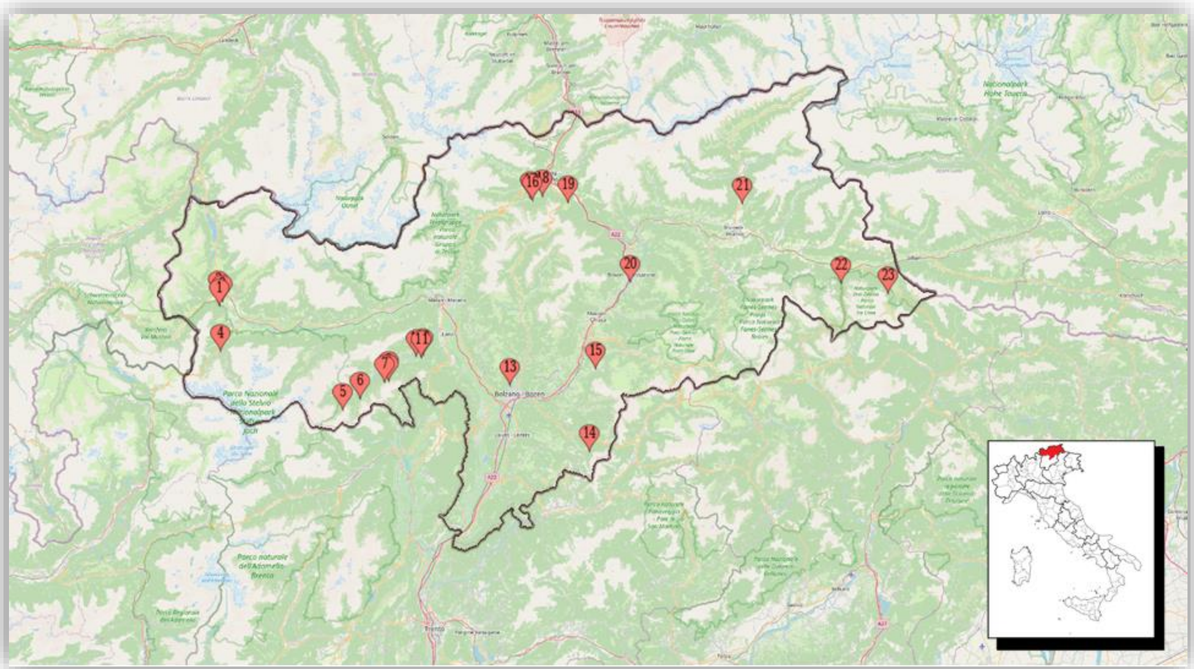


Figure 2 Distribution of calvings of primiparous (dashed bar, n = 154) and multiparous (solid bar, n = 366) cows across calving seasons.

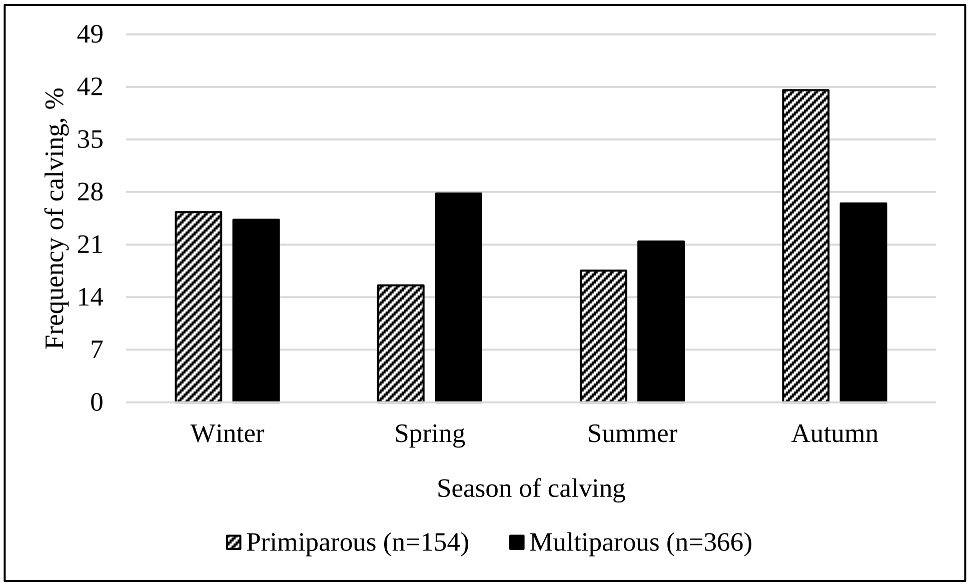
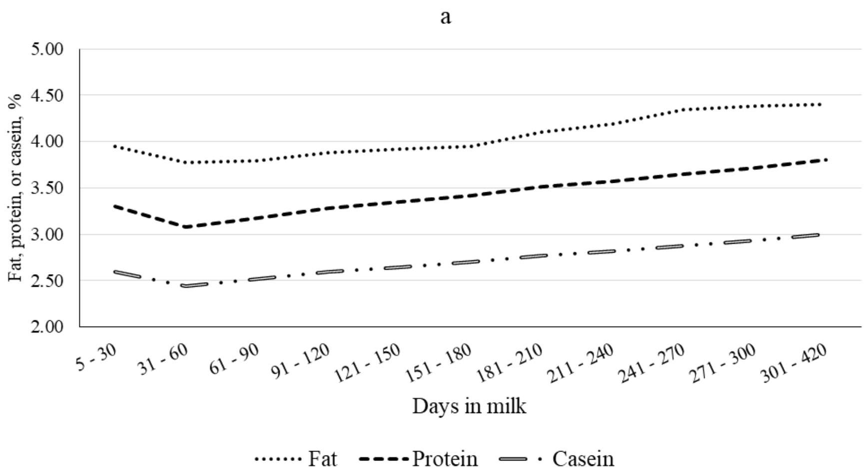


Figure 3 Least squares means of (a) fat, protein and casein content, and (b) lactose content and somatic cell score (SCS) throughout lactation.



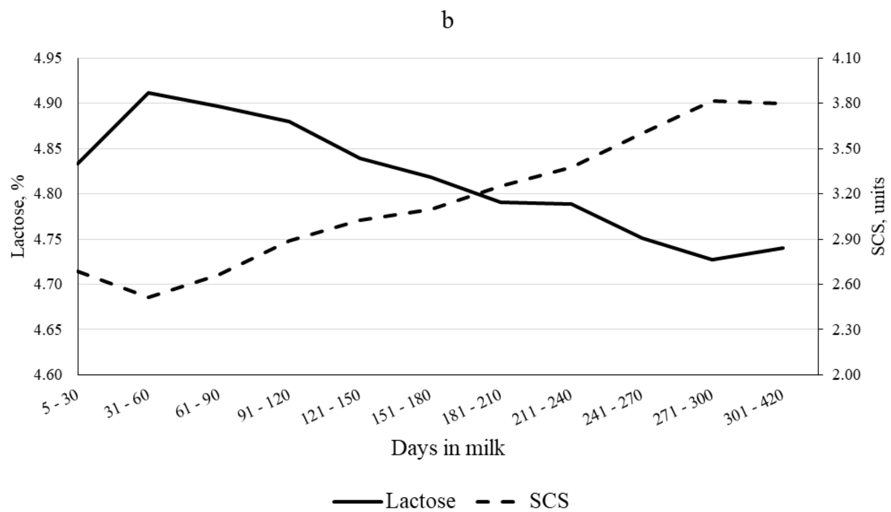


Figure 4 Least squares means of (a) rennet coagulation time (RCT), curd firmness 30 min after enzyme addition to milk (a_{30}) and curd-firming time (k_{20}), and (b) α-casein, β-casein and κ-casein fractions throughout lactation.

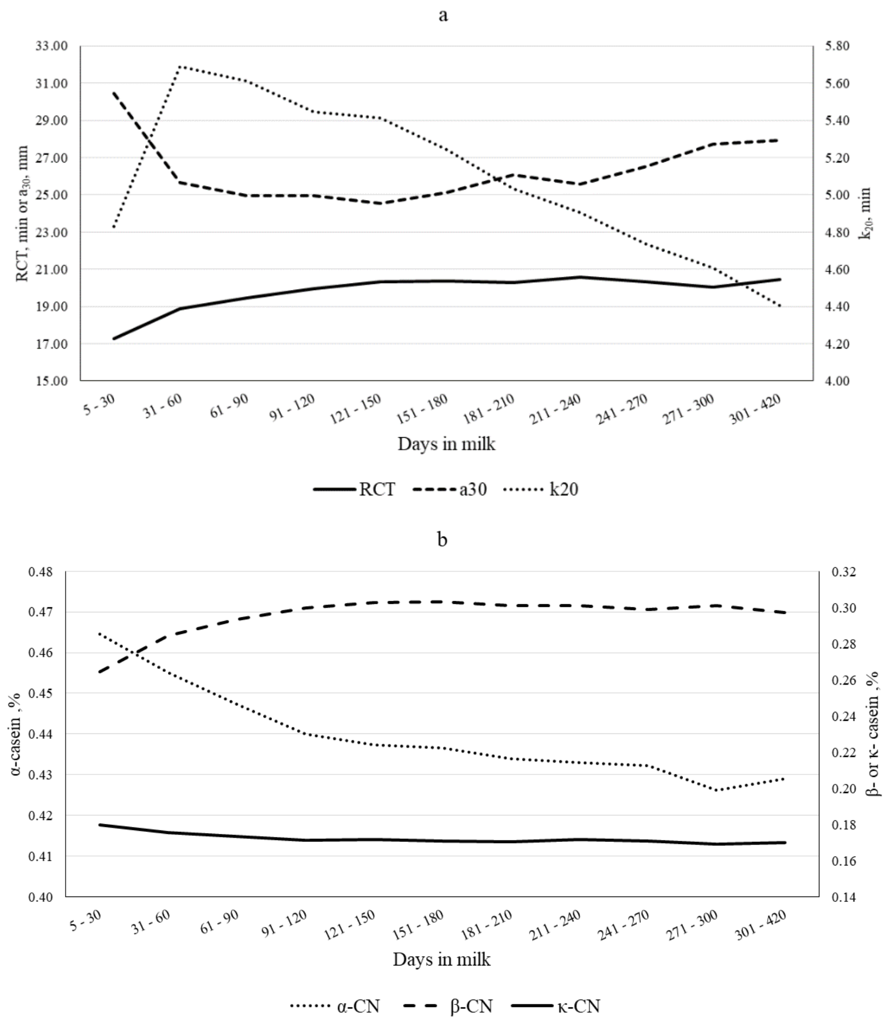


Figure 5 Least squares means of milk (a) Ca, K and P, and (b) Mg and Na throughout lactation.

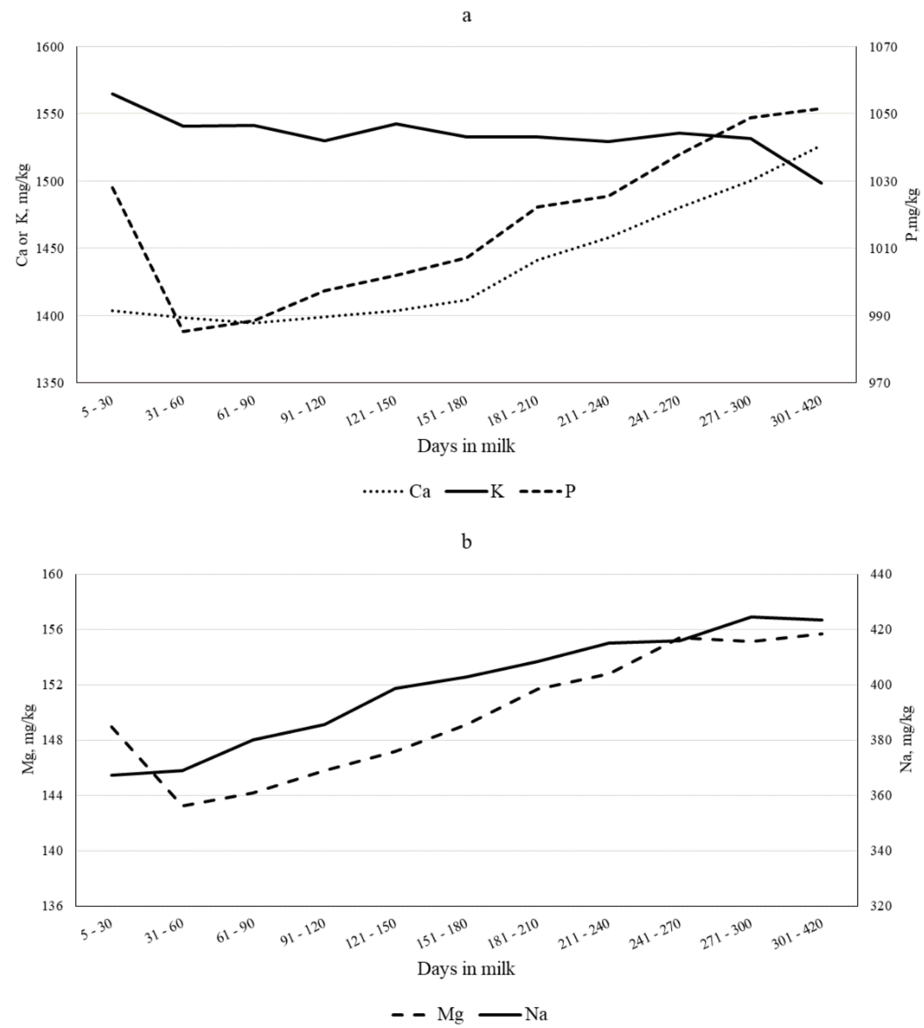
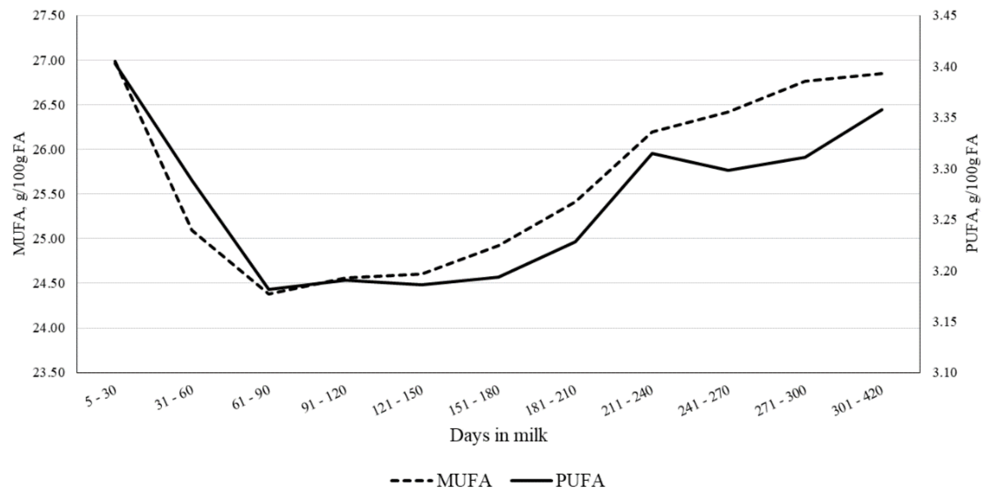
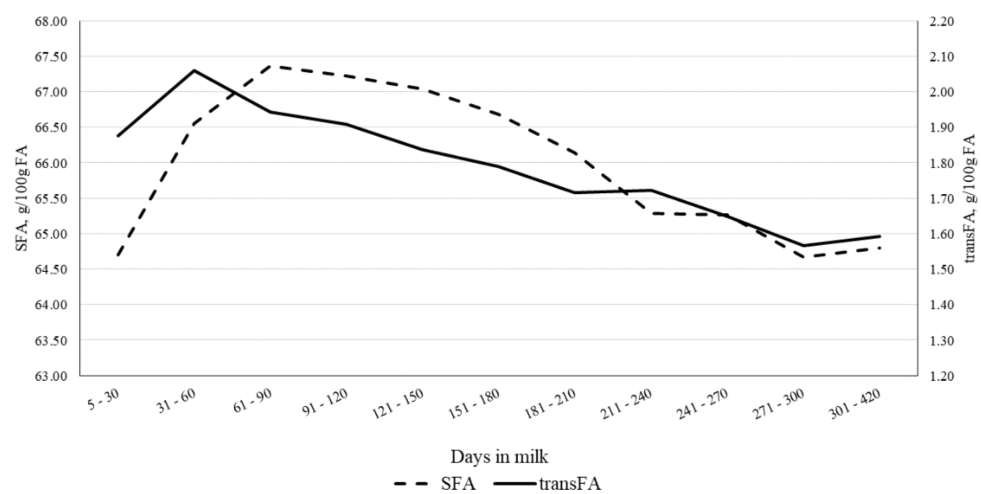


Figure 6 Least squares means of (a) monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA), (b) saturated (SFA) and *trans* fatty acids (*trans* FA), (c) short-chain (SCFA), medium-chain (MCFA) and long-chain fatty acids (LCFA), and (d) individual fatty acids throughout lactation.

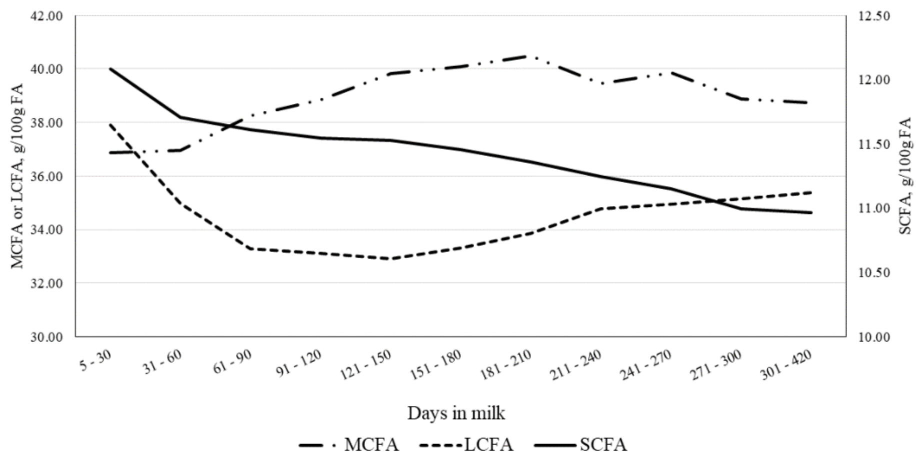
a



b

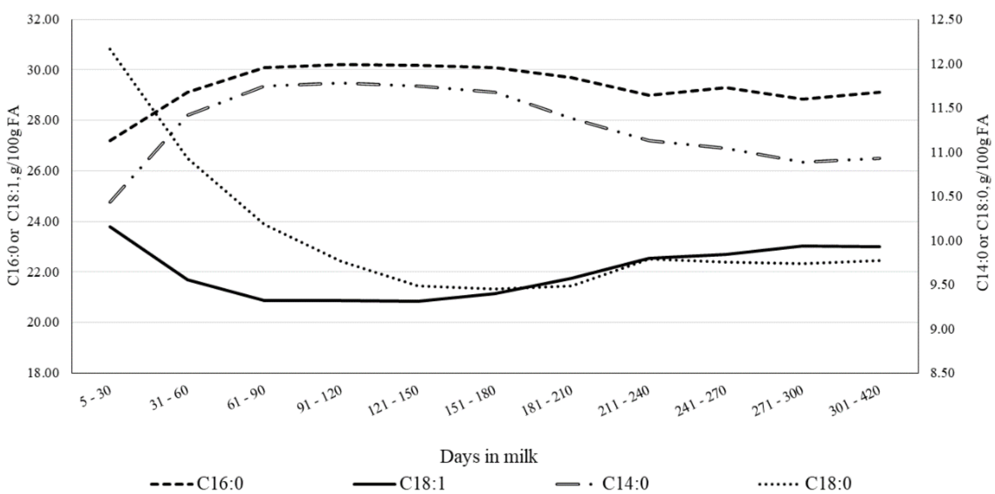


c



42.00
40.00
38.00
36.00
34.00
32.00
30.00
MCFA or LCFA, g/100g FA
12.50
12.00
11.50
11.00
10.50
10.00
SCFA, g/100g FA
5 - 30
31 - 60
61 - 90
91 - 120
121 - 150
151 - 180
181 - 210
211 - 240
241 - 270
271 - 300
301 - 420
Days in milk
MCFA
LCFA
SCFA

d



32.00
30.00
28.00
26.00
24.00
22.00
20.00
18.00
C16:0 or C18:1, g/100g FA
12.50
12.00
11.50
11.00
10.50
10.00
9.50
9.00
8.50
C14:0 or C18:0, g/100g FA
5 - 30
31 - 60
61 - 90
91 - 120
121 - 150
151 - 180
181 - 210
211 - 240
241 - 270
271 - 300
301 - 420
Days in milk
C16:0
C18:1
C14:0
C18:0

KAPITEL 5

A COMPARISON OF ANIMAL-RELATED FIGURES IN MILK AND MEAT PRODUCTION AND ECONOMIC REVENUES FROM MILK AND ANIMAL SALES OF FIVE CATTLE BREEDS REARED IN ALPS REGION

Thomas Zanon[1], Sven König[2], Matthias Gauly[1]

[1]Facoltà di Scienze e Tecnologie, Free University of Bolzano, Bolzano, Italy; [2]Institut für Tierzucht und Haustiergenetik, Justus-Liebig University Giessen, Giessen, Germany

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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 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 milk yield, 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.

Introduction

Mountain agriculture is characterized by small cultivation areas with heterogenic features, which are dispersed at different altitudes with different climates and limited use for mechanization (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 Parmeggiano-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. Kühl 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 meters 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 realized 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 Italian Breeders' Association (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 (EAFRD).

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:

$$y_{ij} = \mu + breed_i + year_j + e_{ij}$$

where y_{ij} is the observation value of the dependent variable (milk yield 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), μ is the overall intercept of the model, $breed_i$ is the fixed effect of the ith cattle breed (i=5; BS, HF, SI, AG, PI), $year_j$ is the fixed effect of the jth 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 (+85; R^2=0.62), showing a little increase in 2015 and 2016. 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 milk yield (MY) per lactation increased linearly, except for PI, across the observation period (Figure 2a). The highest increase for MY per lactation was observed in BS (88kg/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 2a). 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 2b) 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 2a, considering milk quality (fat%, protein %). On the other hand, however, animal sales per cow increased only to a small extend throughout the observation period (Figure 3a). Overall, animal sales per cow from SI cows was the greatest and that from BS was the smallest (Figure 3a). 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 was higher than that of specialized dairy breeds (Figure 3a). Finally, as Figure 3b 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 3a).

The effect of cattle breed on production and economic traits

Table 1 and Table 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 characterized 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 specialized 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 specialized 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 specialized 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). Specialized breeds and dual-purpose breeds differed significantly for all traits (Table 3). In fact, specialized 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 specialized 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 realized 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 specialized 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 realizing 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 characterized by various production systems, resulting in a high diversity of agricultural land types and farmed livestock breeds (Battaglini et al., 2014; Sturaro et al., 2009; 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 characterized 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 mechanization and specialization (MacDonald et al. 2000; Giupponi et al., 2006; Streifeneder et al., 2009). 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). On the other hand, 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 specialized 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 specialized 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 specialized 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 specialized 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 (Table 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 auction prices for calves and cull cows found in SI compared to BS are explained by the phenotypic characteristics of dual-purpose breeds, as next to milk also meat productivity is strongly recognized in the breeding programs of SI, PI and AG (ANAPRI, 2020; Rinderzucht Austria, 2020). Moreover, the dual-purpose effect becomes more evident when comparing MY per lactation and total revenue of specialized HF and BS and dual-purpose 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 Kaus (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 (Sennereiverband, 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 (Haiger and Knaus 2010; Sturaro et al., 2009). On the other hand, the yearly increase of 52.60 kg (R^2=0.95) in AG (Figure 2a) 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 mobilization 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 specialized 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 specialized 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 specialized 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, carcass 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 specialized 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 carcass weight for SI cull cows was compensated by the higher carcass 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 specialized 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 specialized 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 (Figure1). 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 specialized dairy breeds (Kühl et al., 2020).

Conclusion

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 optimization 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 specialized dairy breed and thus compensate partly the lower milk sales per cow. Unlike in other regions no Holsteinizing was observed in South Tyrol 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.

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Table 1 Least square means of production traits for dairy cattle breeds. Different superscript letters within row indicate statistical significance ($p < .05$).

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

Table 2 Least square means for economic traits between cattle breeds. Different superscript letters within row indicate statistical significance ($p < .05$).

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

Table 3 Contrast estimates between different breeds with standard error (SE) and *p*-value set at different significance level.

Trait	Specialized breed vs. Dual purpose breed			SI vs. AG and PI			BS vs. SI			AG vs. PI		
	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Production trais												
Milk, kg	1685.61	21.86	***	1331.68	29.32	***	70.45	33.86	*	-1151.73	33.86	***
Restocking rate, %	3.27	0.26	***	2.52	0.35	***	-0.95	0.4	*	-3.64	0.4	***
Days open, d	28.27	0.47	***	-5.05	0.63	***	27.45	0.73	***	-8.09	0.73	***
Intercalving period, d	26.94	0.47	***	-2.55	0.63	***	28.45	0.73	***	-7.09	0.73	***
Lactation lenght, d	25.18	0.33	***	3.55	0.44	***	19.73	0.51	***	-9.09	0.51	***
Weight bull calf, kg	-6.63	0.17	***	4.20	0.23	***	-6.01	0.26	***	1.57	0.26	***
Weight cow calf, kg	-8.10	0.74	***	5.90	2.40	*	10.40	1.15	***	3.45	2.77	ns
Weight cull cow, kg	16.80	2.04	***	58.38	2.74	***	26.18	3.17	***	-117.01	3.17	***
Economic traits												
Price bull calf, €/kg	-1.95	0.04	***	1.59	0.06	***	-3.17	0.07	***	0.99	0.07	***
Price for cow calf, €/kg	-1.60	0.07	***	1.42	0.09	***	-2.70	0.10	***	0.85	0.10	***
Price for cull cows, €/kg	-0.24	0.01	***	0.09	0.01	***	-0.27	0.01	***	0.07	0.01	***
Market value bull calf, €	-150.94	3.49	***	125.82	4.69	***	-237.00	5.41	***	72.00	5.41	***
Market value cow calf, €	-114.72	5.57	***	106.61	7.48	***	-192.40	8.63	***	61.32	8.63	***
Market value cull cow, €	-111.26	4.01	***	129.71	5.38	***	-187.25	6.21	***	-111.62	6.21	***
Milk revenue, €/cow	886.60	24.88	***	705.41	33.38	***	42.10	38.55	ns	-606.56	38.55	***
Animal revenue, €/cow	-103.75	2.3	***	118.86	3.08	***	-195.96	3.56	***	0.95	3.56	ns
Total turnover, €/cow	503.57	22.88	***	495.25	30.69	***	-169.83	35.44	***	-559.91	35.44	***

Figure 1 Population dynamics of milk recorded cows between January 2009 and December 2019

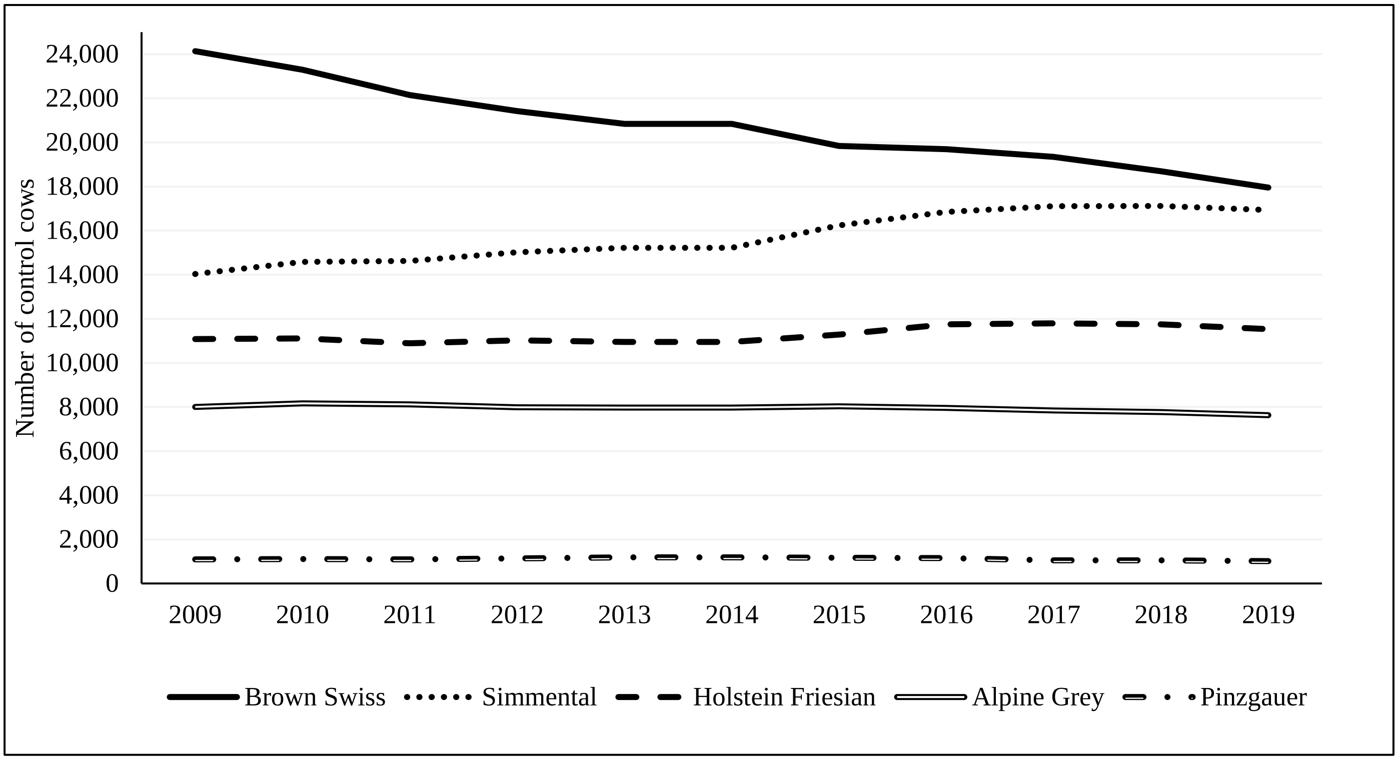


Figure 2 Variation of milk yield (a) and intercalving period (b) from 2009 to 2019.

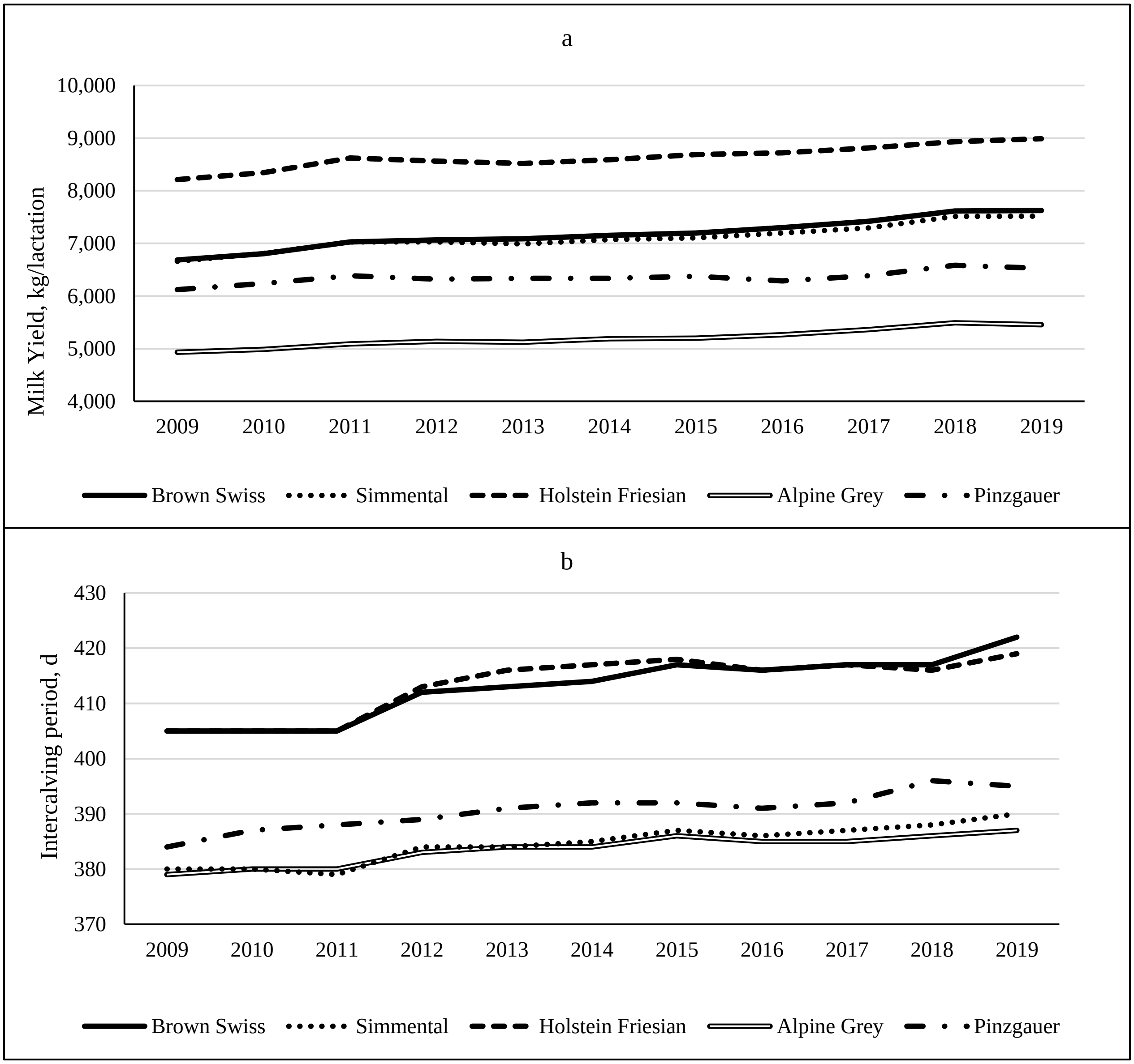
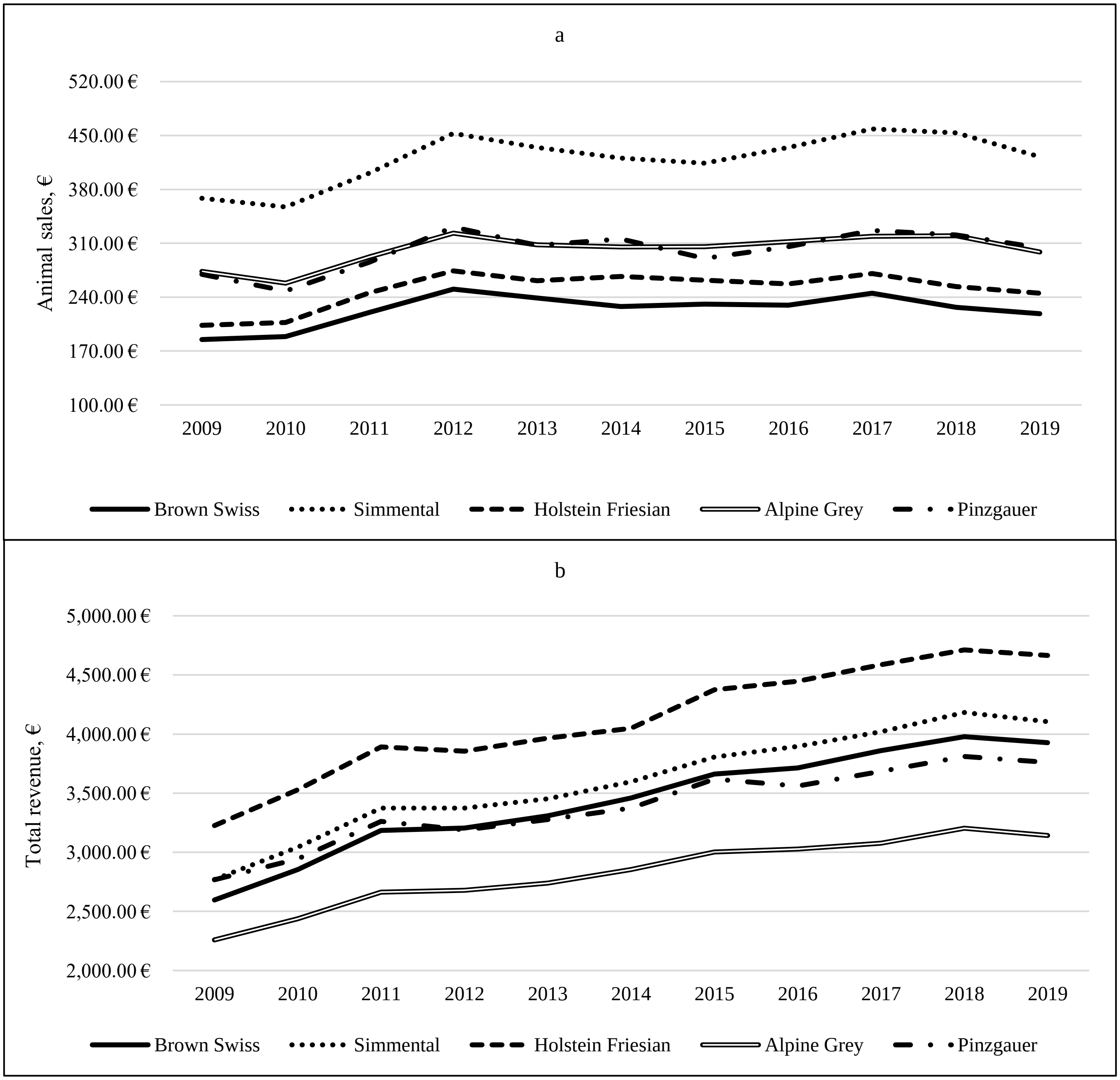


Figure 3 Variation of animal sales (a) and total return (b) from January 2009 to December 2019



KAPITEL 6

Übergreifende Diskussion

Die alpine Milchwirtschaft wird durch verschiedenste Produktionssysteme repräsentiert, die sich in der Struktur und dem Management der Betriebe (Fütterungspraxis, Weidezugang, Transhumanz) unterscheiden (Battaglini et al., 2014). Neben der Lebensmittelproduktion, die in der Regel durch Wiederkäuer erfolgt, welche Berg- und Almwiesen für die Erzeugung von Fleisch und Milch nutzen („Feed-to-Food-Uprading“), erfüllt die Berglandwirtschaft eine Reihe von sogenannten „non commodities“ -Leistungen (Streifenender, 2009). Zum einen werden durch eine abgestufte Bewirtschaftung der unterschiedlichen Berg- und Talflächen eine Vielzahl an unterschiedlichen Habitaten für Pflanzen und Tiere geschaffen und zusätzlich die über Jahrhunderte entstandene Kulturlandschaft gepflegt (Battaglini et al., 2014). Weiters werden die ländliche Entwicklung und eine dezentrale Besiedelung gefördert und ein regionaler Zerfall bedingt durch Abwanderung verhindert (Mountain Agriculture Platform, 2017). Zusätzlich wird durch die Bewirtschaftung der Alm- und Bergwiesen Naturgefahren und Erosionen vorgebeugt (Buchgraber, 2018) und Siedlungsraum gesichert, indem Sukzessionsprozesse reduziert werden (MacDonald et al., 2000). Schließlich werden kulturelle Bräuche und Traditionen durch die Berglandwirtschaft bewahrt. In Südtirol wird die landwirtschaftliche Tätigkeit durch klimatische und topographische Einschränkungen erschwert. Der hohe Arbeitsaufwand vor allem bedingt durch die Hangneigung (Peratoner, 2015) sowie die begrenzte Möglichkeit die Betriebsstrukturen zu erweitern, um über Fixkostendegression Skaleneffekte zu realisieren, verursachen erheblich höhere Produktionskosten pro kg Milch als in anderen italienischen Regionen und europäischen Ländern (Kühl et al., 2020). Diese müssen zusätzlich zu den Förderungen von einem höheren Milchpreis aufgefangen werden, um die Wirtschaftlichkeit der Betriebe zu gewährleisten. In den Studien von Marsoner et al. (2018) und Kühl et al. (2020) wird eine extensive Bewirtschaftungsweise und die Haltung von lokalen Rinderrassen als Möglichkeiten genannt, um sich in der Produktion von Milchprodukten weiter zu differenzieren, indem die besonderen Produkteigenschaften, die nachhaltige Bewirtschaftung sowie eine artgerechte Tierhaltung entsprechend kommuniziert werden. In Gusmeroli et al. (2006) wird die Überwindung von ressourcen- und energieintensiven landwirtschaftlichen Produktionssystemen im Berggebiet als

Möglichkeit angeführt, um Unabhängigkeit von externen Produktionsfaktoren und Marktentwicklungen zu erreichen und die Resilienz, sowie die ökonomische und soziale Nachhaltigkeit von Bergökosystemen nicht zu gefährden.

6.1 Bulk milk quality as affected by cattle breed composition of the herd in mountain area

Ziel der vorliegenden Arbeit war es, die Auswirkungen der Herdenzusammensetzung auf die Bruttozusammensetzung der Milch, den Zellgehalt, den Milch-Harnstoff und die Fettsäuren-Zusammensetzung zu untersuchen. Hierfür wurden Sammelmilchproben von Milchviehherden bestehend aus einer bzw. mehrerer Rassen verglichen. Der Gebrauch verschiedener Rassen in einer Herde ist gängige Praxis (in Südtirol ca. 30 % der Betriebe) und zielt darauf ab, die Milchqualität und/oder die Milchmenge auf gesamtbetrieblicher Ebene zu steigern. In der Studie wurde jedoch gezeigt, dass mit zunehmender Betriebsgröße der Trend hin zu Reinrasseherden steigt. In diesen Betrieben konnte ein geringerer Zell- und Harnstoffgehalt beobachtet werden. Zusätzlich wurde gezeigt, dass der Milch-Harnstoff im Vergleich zu den Richtwerten in der Literatur höher ausfiel. Als mögliche Gründe wurden die hohen Kraftfuttergaben (Kühl et al., 2020) bzw. die heterogene Grundfutterqualität angeführt (Peratoner et al. 2010), welche ein unausgeglichenes Nährstoffverhältnis in der Ration verursachen können. Darüber hinaus wurde eine Variabilität des Milchharnstoffgehaltes zwischen den unterschiedlichen Herdenstrukturen gezeigt, was durch den Effekt der Rasse (Wattiaux et al., 2005) bzw. durch eine unterschiedliche Fütterungsintensität erklärt werden könnte (Rajala-Schultz und Saville, 2003). Brown Swiss Herden produzierten eine höhere Milchqualität als Simmental und Holstein Friesian Herden, welche sich in einem höheren Fett-, Eiweiß- und Kaseingehalt sowie einem für die menschliche Ernährung günstigeres Fettsäuremuster wiederspiegelt. Weiterhin zeigen die Ergebnisse, dass die höchste Qualität bei Brown Swiss Herden im Vergleich zu allen anderen Herdenkonstellationen erzielt werden konnte. Fleckvieh Herden überzeugten mit dem niedrigsten Zellgehalt, was mit Ergebnissen aus anderen Studien konform ist (Penasa et al., 2014, Franzoi et al., 2019, Manuelian et al.,2019) und auf eine höhere Anpassungsfähigkeit dieser Rasse an den Haltungsbedingungen in Bergbetrieben hindeutet (Mattiello et al., 2011; Litwińczuk et al., 2011). Darüber hinaus wurde ersichtlich, dass die

Milchqualität von Fleckvieh und Holstein Friesian durch die Kombination mit Brown Swiss gesteigert werden konnte, was mit den Beobachtungen von Magne et al. (2016) konform ist.

6.2 Factors affecting bulk milk composition, somatic cell score, coagulation ability and mineral content of dual-purpose Alpine Grey and Pinzgauer cattle

In Kapitel 3 wurden Milchgerinnungseigenschaften und Mineralstoffgehalte in Sammelmilchproben von Grauvieh und Pinzgauer Herden untersucht. Ziel war es mögliche Effekte der jeweiligen Rasse und der Jahreszeit auf die Käsereitauglichkeit der Milch darzustellen. Zwischen den jeweiligen Herdentypen wurden nur geringfügige Unterschiede in puncto Milchzusammensetzung, Gerinnungseigenschaften und Mineralstoffgehalt beobachtet. Grauviehherden zeigten tendenziell einen geringeren Zellgehalt, wogegen Pinzgauerherden eine Milch mit geringfügig besseren Käsereitauglichkeit produzierten. Der Mineralstoffgehalt unterschied sich unwesentlich. Pinzgauer- und Grauviehherden zeigten im Vergleich mit Studien von Benedet et al. (2018) ähnliche Fett-, Eiweiß- und Kaseingehalte. Allerdings waren die Gerinnungseigenschaften in Grauvieh- und Pinzgauerherden besser als in Benedet et al. (2018). Toffanin et al. (2012) zeigte bessere Gerinnungseigenschaften in Holstein-Friesianherden im Vergleich zu den Ergebnissen aus der vorliegenden Arbeit, was mit einer stärkeren züchterischen Bearbeitung der Merkmale, welche für die Milchgerinnung verantwortlich sind, erklärt werden kann. In Bezug auf die Jahreszeit wurde ein höherer Zellgehalt in beiden Herdentypen im Sommer beobachtet, was durch Hitzestress und durch die höhere Keimbelastung im Stall in dieser Jahreszeit erklärt werden kann (Larry Smith et al., 1984; Lambertz et al., 2014;). Die besten Gerinnungseigenschaften wurden für beide Herdentypen im Herbst beobachtet, wogegen die schlechtesten Gerinnungseigenschaften im Sommer beobachtet wurden, was auf den hohen Zellgehalt in dieser Jahreszeit zurückgeführt werden kann. Le Maréchal et al. (2011) nennen eine schlechte Eutergesundheit als Grund für beeinträchtigte technologische Eigenschaften der Milch, da bei Mastitiden neben dem Zellgehalt auch der pH-Wert in der Milch ansteigt (Kandeel et al., 2019). Letzterer hat einen beeinträchtigenden Effekt auf die Enzymaktivität im Zuge der Milchgerinnung (Nájera et al., 2003). Die beobachtete Variabilität im Mineralstoffgehalt wurde zum größten Teil durch den Effekt der Jahreszeit erklärt, was evtl. durch saisonal bedingte Variationen in der Fütterung erklärt werden kann.

6.3 Milk yield and quality of Original Brown cattle farmed in Italian alpine region

In Kapitel 4 der vorliegenden Arbeit wurde eine ausführliche Studie zu Milchleistung und -qualität der Rasse Original Braunvieh durchgeführt, mit dem Ziel diese vom Aussterben bedrohte Rinderrasse phänotypisch zu charakterisieren. Neben dem erzeugten Tagesgemelk wurden die Milchzusammensetzung (Fett-, Eiweiß-, Kasein-, Laktosegehalt), der Zellgehalt, die Milchgerinnungseigenschaften, die Eiweißfraktionen, der Mineralstoffgehalt sowie das Fettsäurespektrum analysiert und der Effekt der Parität sowie der Laktation auf diese Merkmale untersucht. Original Braunviehkühe zeigten einen geringeren Fett- (4,03%) und Eiweißgehalt (3,40%) in der Milch als Brown Swiss Kühe (Macciotta et al. 2012; Pegolo et al., 2016), was mit der weniger intensiven Zuchtarbeit zusammenhängen könnte. In puncto, Milchgerinnungseigenschaften schnitt das Original Braunvieh besser ab als beispielsweise die Rasse Pinzgauer (Manuelian et al., 2018). Darüber hinaus zeigten Original Braunviehkühe im Vergleich zu anderen Rassen einen hohen Gehalt an α-CN and κ-CN (Maurmayr et al., 2018), was auf eine gute Käsetauglichkeit für deren Milch hindeutet. Zusätzlich wies die Rasse Original Braunvieh ein vergleichbares Fettsäurespektrum als Brown Swiss oder Pinzgauer auf, wobei der Gehalt an ernährungsphysiologisch erwünschten ungesättigten Fettsäuren beim Original Braunvieh etwas höher liegt. Diese Tatsache wird durch die Studie von Stergiadis et al. (2015) bestätigt. Die Autoren beschreiben, dass beim Original Braunvieh ein günstigeres Fettsäuremuster in der Milch vorliegt als bei Brown Swiss Kühen. Die beobachteten phänotypischen Korrelationen zwischen den untersuchten Parametern entsprachen weitgehend denen der Literatur. Die Milchleistung stieg mit der Anzahl an Paritäten und erreichte ein Plateau ab der dritten Laktation. Fett, Eiweiß sowie Kasein unterschieden sich unwesentlich innerhalb der ersten drei Laktationen. Im Verlauf einer Laktation erreichte der Zellgehalt seinen Tiefpunkt zwischen 31 und 60 Laktationstagen und stieg gegen Ende hin kontinuierlich an. Der Laktosegehalt zeigte einen inversen Trend zum Zellgehalt im Verlauf der Laktation, was mit den Beobachtungen in Costa et al. (2019) konform ist. Weiterhin konnte beobachtet werden, dass der Laktosegehalt in älteren Kühen abnahm, wogegen der Zell- sowie Natriumgehalt mit den Paritäten anstieg. Dies deutet auf eine größere Anfälligkeit für Euterentzündungen bei älteren Tieren hin, was mit der physiologischen Veränderung und Erweiterung des Strichkanals (Guarín und Ruegg, 2016) sowie der verminderten Leukozytenaktivität in höheren Laktationen (Mehrzad et al. 2002; Rainard und Riollet 2006) erklärt werden kann. Die β-CN-Fraktion nahm während der Laktation zu, während α-CN und κ-CN abnahmen; insbesondere war der Rückgang bei α-CN deutlicher ausgeprägt im Vergleich zu den anderen beiden Proteinfraktionen was sich in den Studien von Maurmayr et al. (2018) und Franzoi et al. (2019) widerspiegelt. Milchgerinnungseigenschaften waren in primiparen Kühen am günstigsten. Weiters wurden zu Beginn und am Ende einer Laktation eine geringere Zeit für das Erreichen einer Gerinnungsfestigkeit von 20 mm (k_{20}) und eine höhere Gerinnungsfestigkeit 30 Minuten nach der Zugabe des Labenzyms (a_{30}) beobachtet, was auf eine bessere Käsetauglichkeit in diesen Laktationsphasen hindeutet. Der Mineralstoffgehalt, allen voran der Kalziumgehalt war bei erstlaktierenden Tieren höher als bei pluriparen Tieren. Die Kalziumhomöostase ist bei älteren Kühen bedingt durch eine verminderte Parathormonaktivität leichter gestört, wodurch das Risiko einer Hypocalcämie in höheren Paritäten ansteigt (Reinhardt et al., 2011; Rodriguez et al., 2017; Venjakob et al., 2017). Über die Laktation gesehen, stiegen alle untersuchten Mineralstoffe mit Ausnahme von K gegen Ende hin an. Letzteres zeigte einen leicht abnehmenden Trend im Verlauf der Laktation. Zusätzlich wurden höhere Werte für einfach und mehrfach ungesättigte Fettsäuren in primiparen Tieren zu Beginn und am Ende der Laktation beobachtet. Werte für gesättigte Fettsäuren stiegen mit zunehmender Anzahl an Paritäten an. Artegoitia et al. (2013) nennt als Grund eine höhere *de novo* Synthese von gesättigten Fettsäuren bei älteren Tieren, was durch die höhere metabolische Aktivität in den Milchdrüsen sowie eine stärkere Expression von Fettsäure-Synthasen in multiparen Tieren erklärt werden kann (Miller et al., 2006).

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

Im abschließenden Kapitel der vorliegenden Arbeit war es das Ziel die ökonomischen Erlöse aus Milch und Tierverkauf von den fünf meistgenutzten Rinderrassen in Südtirol von Januar 2009 bis Dezember 2019 zu vergleichen. Hierfür wurden Milchleistungskontrolldaten des nationalen Zuchtverbandes (AIA) und der Vereinigung der Südtiroler Tierzuchtverbände, Kälber und Schlachtviehpreise von den Versteigerungen in Südtirol (Kovieh) sowie Zuchtviehpreise von dem Rinderzuchtverband Südtirol und dem Südtiroler Braunviehzuchtverband berücksichtigt. In Bezug auf die Anzahl an Kontrollkühen wird ersichtlich, dass in Südtirol keine „Holsteinisierung" wie in anderen Ländern stattgefunden hat. Zusätzlich wird ersichtlich, dass Brown Swiss zunehmend durch Fleckvieh über das letzte Jahrzehnt ersetzt wird. Weiterhin sind die Anzahl an Kontrollkühen von lokalen Zweinutzungsrassen wie Grauvieh oder Pinzgauer seit 2009 stabil geblieben. Mehrere Gründe sprechen für diese Beständigkeit. Zum einen konnte für lokale Zweinutzungsrassen gezeigt werden, dass die Fütterungskosten, v.a. bedingt durch Kraftfutter, im Vergleich zu Hochleistungsrassen geringer waren (Kühl et al., 2020), da erstere aufgrund der geringeren Milchleistung auch einen geringeren Nährstoffbedarf aufweisen und folglich der ernährungsphysiologische Bedarf bereits zum großen Teil durch ein qualitativ hochwertiges Grundfutter gedeckt werden kann. Zusätzlich beobachtete Kühl et al. (2020) geringere Tierarzt-, Remontierungs- und Besamungskosten für Grauvieh im Vergleich zu Brown Swiss Kühe, was mit der Tatsache begründet werden kann, dass die lokale Rasse aufgrund der geringeren Milchleistung sowie der besseren Anpassungsfähigkeit an die alpinen Verhältnisse (Mattiello et al., 2011) eine höhere Fruchtbarkeit und Langlebigkeit vorweist. Ferner spielt die Alpung in Südtirol eine wichtige Rolle, was mit der Tatsache belegt wird, dass 44.236 von 128.329 Rindern im Jahr 2018 gealpt wurden (Province, 2018). Mehrere Studien konnten zeigen (Zendri et al., 2016; Faccioni et al., 2016), dass lokale Zweinutzungsrassen sich während der Almperiode besser an die veränderten Umgebungen anpassen konnten, was wiederum den stabilen Trend für Grauvieh und Pinzgauer unterstreicht.

Zusätzlich wurde aus dem Rassevergleich ersichtlich, dass Zweinutzungsrassen aufgrund höhere Kälber- und Schlachtkuhpreise die geringere Milchleistung im Vergleich zu den spezialisierten

Milchviehrassen teilweise kompensieren konnten. Diese Ergebnisse spiegeln sich auch in der Studie von Haiger und Knaus (2010) wider, wonach Fleckvieh den 14% geringeren Milcherlös im Vergleich zu Holstein Friesian durch höhere Preise für Stierkälber und Altkühe auf 7 % Unterschied reduzieren konnte. Weiters unterstrichen Bazzoli et al. (2014) in ihrer Arbeit die Möglichkeit, die Rentabilität von Bergbetrieben durch den Altkuhverkauf zu steigern, was mit den Ergebnissen der vorliegenden Studie konform ist, wonach Fleckvieh und Pinzgauer höhere Schlachtkuherlöse erzielten im Vergleich zu Brown Swiss und Holstein Friesian. Nichtsdestotrotz wird von der Auswertung der Daten ersichtlich, dass die lokale Wertschöpfung für Rindfleisch gering ausfällt, da Schlachtkühe und Kälber primär in Nachbarregionen verkauft werden. Darüber hinaus wird für die Rassen Grauvieh und Pinzgauer eine gewisse finanzielle Abhängigkeit seitens EU Förderungen deutlich, da beide Rassen trotz Berücksichtigung der Fördermaßnahmen für alte gefährdete Nutztierrassen gemäß Artikel 39 Absatz 4 der Verordnung (EG) Nr. 1698/2005 und Artikel 28 Absatz 8 der Verordnung (EG) Nr. 1305/2013 einen geringeren Umsatz im Vergleich zu den spezialisierten Milchviehrassen Holstein Friesian und Brown Swiss generierten. Nach Marsoner et al. (2018) besteht allerdings das Potential die Rentabilität für autochthone Rinderrassen durch standortgebundene Marketingkonzepte und spezielle Produktdeklarierung zu steigern.

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Schlussfolgerungen der Arbeit

Durch die klimatischen und geographischen Einschränkungen sind die Produktionskosten für Südtiroler Milchviehbetriebe im Vergleich zu intensiven Milchviehregionen wesentlich höher und die Produktivität wesentlich geringer. Dementsprechend muss der Fokus der Genossenschaften und der Landwirte weiterhin primär auf Qualitätskriterien und Diversifikation der Produktion gelegt werden. Nur dadurch kann mit der Veredelung langfristig ein höherer Milchpreis erzielt und gesichert werden. Dieser ist neben anderen Förderungen die Voraussetzung dafür, dass die kleinstrukturierte Landwirtschaft in Südtirol bewahrt werden kann, welche wiederum für die Biodiversität und die Erhaltung des Landschaftsbildes und der sozialen Strukturen der Dorfgemeinden essenziell ist. Im Zuge dieser Dissertation wurden eine Reihe an Möglichkeiten erarbeitet, welche es erlauben einerseits die technologischen Eigenschaften und die Qualität der Milch auf betrieblicher Ebene zu verbessern und andererseits Potentiale für eine künftige Produktdifferenzierung aufzuzeigen.

Aus der vorliegenden Arbeit können folgende Schlussfolgerungen gezogen werden:

- Die Kombination mehrerer Rassen mit unterschiedlichen phänotypischen Eigenschaften ermöglicht es im Berggebiet die Milchqualität auf gesamtbetrieblicher Ebene zu verbessern.
- Die Milchgerinnungseigenschaften werden stark durch Eutergesundheit und Fütterung beeinflusst. Dementsprechend sollte das Betriebsmanagement so angepasst werden, um Milch mit einer guten Käsereitauglichkeit ganzjährig produzieren zu können.

- Die Nutzung lokaler Rinderrassen, wie Pinzgauer, Grauvieh und Original Braunvieh eröffnet in Kombination mit einer standortangepassten und nachhaltigen Flächenbewirtschaftung besondere Potentiale für die Südtiroler Milchwirtschaft, einzigartige landwirtschaftliche Produkte zu produzieren, die streng an die Ursprungsregion gebunden sind. Folglich kann eine besondere Unterscheidung vom breiten Markt erreicht werden, welche notwendig ist, um die Wettbewerbsfähigkeit der Südtiroler Betriebe weiter zu verbessern.
- Die Ergebnisse der phänotypischen Charakterisierung des Original Braunviehs verdeutlichen die Besonderheiten und Vorzüge dieser Rasse im Berggebiet. Die Arbeit soll Anstoß geben, die Renaissance dieser vom Aussterben bedrohten Zweinutzungsrasse weiter voranzutreiben.
- Die lokale Wertschöpfung von Kälbern und Schlachtkühen für die Rindfleischproduktion muss weiter gesteigert werden, damit einerseits die Haltung lokaler Zweinutzungsrassen ökonomisch attraktiver wird und andererseits lokale Produktionskreisläufe geschlossen werden können.

ERKLÄRUNG

Erklärung gemäß der Promotionsordnung des Fachbereichs 09 vom 7. Juli 2004 § 17 (2)

„Ich erkläre: Ich habe die vorgelegte Dissertation selbstständig und ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe.

Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht.

Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der „Satzung der Justus-Liebig-Universität Gießen zur Sicherung guter wissenschaftlicher Praxis“ niedergelegt sind, eingehalten“.

Gießen, den

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Thomas Zanon