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Carcass characteristics of Nordic native cattle breeds

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Abstract: Native livestock breeds are part of the history of the Nordic people and comprise a resource for future food production. In this study, net gain and carcass characteristics of two Danish, three Finnish, one Icelandic, six Norwegian and five Swedish native cattle breeds were retrieved and compared to commercial breeds: two beef breeds and two dairy breeds.

Breed data were collected from national databases and sorted into six animal categories: young bull, bull, steer, heifer, young cow and cow, for which means and standard deviations were calculated within each country. The native breeds ranged from small-sized milking type breeds with low net gain, carcass weights and EUROP classification to larger multipurpose breeds with high net gains, carcass weights and EUROP classification.

All Finnish and most of the Norwegian and Swedish native breeds had lower net gain and carcass weight than the dairy breeds in the same category and country, but with similar carcass conformation and fatness scores. The two Danish native breeds had higher net gain, carcass weight and conformation class than the reference dairy breed, but lower than the reference beef breeds. The net gain and carcass traits of the Icelandic native breed were similar to the smallest-sized native breeds from the other countries. The carcass traits of the native breeds indicate that they have comparative advantages in an extensive production system based on forage and marginal grasslands. They may also succeed better in the value-added markets than in mainstream beef production.

Keywords: Native cattle breeds, genetic resources, weight gain, carcass conformation, carcass fatness, carcass weight, meat production, cattle production, slaughter categories

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Introduction

Genetic diversity of farm animals is a key factor in addressing some of the challenges posed by climate change. The variability of genetic resources underpins sustainable agriculture and food security and provides a broad spectrum of farm product quality characteristics (FAO, 2007). Moreover, diversity contributes to the achievement of several UN Sustainable Development Goals (SDGs), such as SDG2 (Zero hunger) and SDG15 (Life on land) (https://sdgs.un.org/goals). Finding profitable ways to utilize native livestock breeds is one of the biggest challenges in conserving rare livestock breeds. Detailed characterizations of beef production carcass and meat quality traits of several European beef and dairy breeds have been reported (Albertí *et al*, 2008; Christensen *et al*, 2011; Sevane *et al*, 2014). However, none of the native Nordic cattle breeds were included in those studies. There is a severe shortage of characterization studies for many Nordic native breeds (Kierkegaard *et al*, 2020). In addition, Nordic native cattle breeds are often low in numbers and are mostly kept as a hobby, thus little information has been gathered on their specific characteristics or the marketing of their products. This may suggest that these rare breeds are underutilized (Tienhaara, 2020). Traditionally, native Nordic cattle were raised as dual-purpose breeds giving both milk and meat. The combined production of milk and meat can reduce the total climate impact compared to the specialized separate production of milk and meat (De Vries *et al*, 2015). Today, however, part of the native cattle breed population is kept in suckler-based beef production systems, not selling milk for the dairy, and used for obtaining beef only (Hessle, 2009; Holene and Sæther, 2021).

During evolution, native animals have adapted to their environment and the available resources have been optimally utilized for different biological processes to maximize the animal's fitness in that environment (Beilharz *et al*, 1993). In the Nordic countries, cattle foraging historically took place mainly in the marginal outlands, i.e. forests and mountains (Dahlström, 2006; Emanuelsson, 2009; Bläuer, 2015). Adaptation to a harsh environment with low-energy diets is the reason for native breeds being small-sized with low maintenance requirements and high feed-intake capacity, categorizing them as early maturing breeds. Today's native breeds show more active foraging behaviour when roaming freely on outlands compared with modern commercial breeds (Sæther *et al*, 2006; Hessle *et al*, 2014), whereas breed differences in limited pasture areas are less pronounced (Hessle *et al*, 2008).

When it comes to the commercial beef breeds in the Nordic countries, results from a Norwegian study with Angus, Hereford and Charolais kept under various feeding levels revealed that Angus had higher production than Hereford in the extensive feeding system while Charolais needed the most intensive feeding system to reach their production potential (Wetlesen *et al*, 2018). In a Danish study, Hereford, Limousine, Simmental and Holstein suckler cows were compared at two feeding intensities in the suckling period (Olesen *et al*, 2004). The beef breed suckler cows had an extensive but breed-specific ability to adapt to various feeding levels. At the high feeding level, the response in Simmental was a large increase in milk yield and thus a large increase in calf growth, while the response in Hereford and Limousine was an increased live weight and body condition in the cows. At the low feeding level, the cows lost weight and body condition, and reduced milk yield but the response was much lower for Limousine than for Simmental (Olesen *et al*, 2004). Based on this, genotype x environment effects exist, but no data are available from experiments comparing native breeds and commercial breeds at various feeding intensities. However, it is hypothesized that commercial breeds are more efficient than native breeds in intensive production systems, whereas native breeds are more efficient in extensive systems with minor breed differences when fed medium-quality diets.

Beef producers in the Nordic countries are paid from slaughterhouses based on the European carcass classification system EUROP (Council of the European Union, 2013; Commission of the European Union, 2017). Most of the slaughterhouses favour carcasses of a specific weight range with high EUROP conformation class and medium fatness. However, the payment models are adjusted weekly due to changes in the market, and there is a variation between countries due to policies protecting national products. In general, rare native breeds have difficulties fulfilling the requirement for optimal pricing. Often, the small-sized and early-maturing native breeds do not reach the minimum carcass weight and carcass conformation for obtaining the best payment before the animal has deposited too much fat and has become inefficient. In early life, a growing animal will deposit a high proportion of muscles and later a higher proportion of fat. To avoid a too-high fat deposition before a desirable carcass weight is reached, the feeding intensity should be kept at a moderate level, especially for females (Robelin and Daenicke, 1980). Thus, the breeders of rare native breeds are challenged and often left with low prices unless they sell the beef on other markets.

This study aimed to characterize weight gain and carcass traits of Nordic native cattle breeds according to sex and age categories, and further categorize them in relation to commercial breeds found in four of the five countries. The study represents the most comprehensive comparison of variation among Nordic breeds and may as such be helpful to find opportunities for keeping them *in situ* for a later utilization of their inherent resources.

Materials and methods

Based on a Nordic network of animal and meat scientists, nine years of data describing the net gain (i.e. carcass gain) and carcass characteristics of Nordic native cattle breeds from Denmark, Finland, Iceland, Norway and Sweden were collected and compared with similar

data from commercial beef and dairy breeds in each country.

Data collection

Data included in the survey cover animals slaughtered from 2010 to 2018, except for Iceland where data were collected from 2018–2020, based on the national databases on cattle recordings and information obtained at slaughter. In Denmark, data was collected from the Danish Cattle Database (https://www.seges.dk/da-dk/fagomraader/kvaeg/raadgivning/kvaeg-it), in Finland from the official livestock register held by Mtech Digital Solutions (https://www.mtech.fi/en/), in Iceland from Huppa (https://www.rml.is/is/forrit-og-skyrsluhald/nautgriparaekt), in Norway from Animalia (https://www.animalia.no/no/kjott--egg/klassifisering/klassifisering-av-storfe/) and in Sweden from Kokontrollen (Växa Sverige https://www.vxa.se/kokontrollen). Due to variations in data ownership in the different countries and a need to keep data anonymous, this work used simple means of traits within each animal category and breed. Thus, a statistical comparison across countries, breeds and categories was not possible.

Definition of categories and traits

The data collection included six categories of cattle, based on their sex and age as shown in Table 1.

The traits included in the data collection are presented in Table 2 and were selected based on similar types of information available from the national databases and records in all five countries.

Description of breeds included in the study

The characterization was conducted for native breeds selected in each country for which the requested data were available. From Denmark: Jysk Kvæg and RDM-1970; from Finland: Länsisuomenkarja (Western Finncattle), Itäsuomenkarja (Eastern Finncattle) and Pohjoissuomenkarja (Northern Finncattle); from Iceland: Íslenska kúakynið; from Norway: Sidet Trønderfe og Nordlandsfe (STN), Telemarksfe, Dølafe, Østlandsk rødkolle, Vestlandsk Raudkolle and Vestlandsk Fjordfe; and from Sweden: Fjällko, Rödkulla, Väneko, Bohuskulla and Ringamålako. The characterization also included reference beef and dairy breeds: sub-populations of Charolais, Hereford, Holstein and Red dairy cattle (NRF and SRB) raised in the Nordic countries. A description of the breeds can be found in Supplemental Data.

Data handling and statistics

Within each country and breed, simple means and standard deviations were calculated for the traits: daily net gain, carcass weight, carcass conformation class and carcass fatness class (Table 2) for the six animal categories: young bull, bull, steer, heifer, young cow and cow (Table 1). A comparison between the native breeds and the reference breeds within a country was undertaken on the basic data. For across country comparison of the reference and native breeds, a standardization was made for representatives of full-grown animals for slaughter, i.e. bulls and young cows. The commercial beef breeds, Hereford and Charolais, were used for the between-country adjustment of data. The average slaughter age of bulls of Hereford and Charolais across countries was 21.5 months calculated as the mean slaughter age of Charolais and Hereford bulls in Denmark (20.7 and 23.8 months, respectively), Finland (21.72 and 22.89 months, respectively), Norway (19.8 and 20.4 months, respectively) and Sweden (19.62 and 23.05 months, respectively). Thus, the carcass weight of the category bulls of all breeds was adjusted to a live weight at 21.5 months of age by multiplying the net gain per day by the days of difference in slaughter age deviating from 21.5 months, e.g. Danish Charolais bull had a net gain of 696g/d and a carcass weight of 384.5kg at slaughter thus the adjusted carcass weight at 21.5 months was 401.2kg (384.5kg + (0.8 months*30 days*696g/day/1,000)). In the same way, the carcass weight of the category young cows of all breeds was adjusted to the live weight at 34.3 months based on the average age at slaughter of young cows of Hereford and Charolais across countries. The figures were produced using R (R Core Team, 2020) with the R-package 'ggplot2' (Wickham, 2016).

Results

The number of animals and the average age of each category of the reference cattle used from Denmark, Finland, Norway, and Sweden are presented in Supplemental Table 1 and the same numbers of the native breeds from Denmark, Finland, Iceland, Norway and Sweden are presented in Supplemental Tables 2, 3, 4, 5 and 6, respectively.

Daily net gain and carcass characteristics

Danish breeds

The daily net gain of young bulls of Jysk Kvæg and RDM-1970 was high and only 5% lower than Holstein's (Figure 1a). For steers and heifers, this difference was 17% and 13%, respectively. A comparison for bulls is not relevant due to marked age differences in slaughter age between Holstein (14 months) and Jysk Kvæg and RDM-1970 (23 months). For all categories except young cows and cows, Jysk Kvæg, RDM-1970 and Holstein had numerically lower net gain than the two beef breeds. On the other hand, the variation in net gain specifically for the young bulls and bulls was numerically larger for the beef breeds compared with Holstein, and with the native breeds in between.

The average carcass weight of young bulls of Jysk Kvæg, RDM-1970 and Holstein was approximately 200 kg, with RDM-1970 being the highest and Jysk Kvæg being the lowest of the three (Figure 1b). Likewise, for the other categories, the native breeds were similar to Holstein but had lower carcass weights than the beef

Table 1. Definition of categories of cattle and national deviations used in the study

Category of cattle	Definition	Deviation
Young bull	Bull slaughtered younger than 12 months	
Bull	Bull slaughtered older than 12 months	In Iceland: 12–30 months
Steer	Steer slaughtered older than 12 months	
Heifer	Heifer slaughtered older than 12 months	In Norway: 12–24 months; in Iceland 12–30 months
Young cow	Cow slaughtered younger than 48 months	In Norway: Female 24–48 months
Cow	Cow slaughtered older than 48 months	

Table 2. Traits, definitions and national deviations used in the study

Trait	Definition	Deviation
Age, months	Age at slaughter	
Carcass weight, kg	Carcass weight at slaughter	
Daily net gain, g/day	(Cold carcass weight $-\frac{1}{2}$ birth weight)/age at slaughter	In Finland and Sweden, breed-specific birth weights[a] were used, in other cases, 20kg was used
Carcass conformation	EUROP classification, from class 1 (poor) to 15 (excellent)[b]	In Iceland E, U, R+, R, R-, O+, O, O-, P+, P, P. Converted to the 1–15 scale[c]
Carcass fatness	EUROP classification from class 1 (lean) to 15 (fat)[d]	In Denmark and Finland, the scale is 1–5, thus these numbers were multiplied by three, for comparison

[a] Växa Sverige (2021)
[b] Council of the European Union (2013); Commission of the European Union (2017) where original scale E, U, R, O, P has been extended with a –, 0, or + after each letter
[c] Iceland Regulation 500 (2017)
[d] Council of the European Union (2013); Commission of the European Union (2017), where original scale 1, 2, 3, 4, 5 has been extended with a –, 0 or + after each figure

breeds for young cows, cows, young bulls and bulls. For heifers and steers, the average carcass weights were quite similar between breeds, only the Charolais steers were heavier compared to the other breeds. In addition, for carcass weight, there was a large variation among the young bulls and bulls of the beef breeds whereas the variation was smaller among dairy and intermediate among native breeds.

The breeds differed more in carcass conformation, where the Holstein cattle of all categories had the numerically lowest carcass conformation, and with little variation, whereas the native breeds had carcass conformation above Holstein and close to Hereford, but below Charolais (Figure 1c). For the bull category, the mean carcass conformation was 6.2, 5.2 and 3.5 for Jysk Kvæg, RDM-1970 and Holstein, respectively. In comparison, Hereford bulls had 7.7 and Charolais 10.6. Despite cows being not specifically intended for beef production, the same ranking was seen for heifers, young cows and cows. No matter the category of animal, the Holstein cattle had the numerically lowest variation in carcass conformation, whereas the variation for beef breeds and native breeds were similar except for the young bulls, where the beef breeds again showed a larger variation compared with the native breeds.

The variation in carcass fatness was large, however, mean carcass fatness was similar for Jysk Kvæg, RDM-1970, Holstein and Charolais in the young bull, bull and steer category, and somewhat lower than Hereford (Figure 1d). For heifers, Jysk Kvæg was similar to Hereford. For heifer and cow categories, Jysk Kvæg had higher carcass fatness than Holstein with RDM-1970 being in between.

Finnish breeds

In general, the mean daily net gain was higher in beef breeds and dairy breeds than in native breeds in all animal categories except for the cows (Figure 2a). The within-breed variation was numerically higher in beef breeds than in native breeds, especially in the categories of young bulls and bulls. Among native breeds, growing animals of Länsisuomenkarja had the highest daily net gain and largest variation within the group.

The mean carcass weight was lowest in native breeds of all animal categories (Figure 2b). In the native breed bulls, which was the category with the highest number of carcasses (Supplemental Table 3), Länsisuomenkarja had the heaviest carcasses, which was at the same level as the carcasses of beef breed heifers. The second heaviest native breed bull carcasses were Pohjoissuomenkarja and third Itäsuomenkarja. The within-breed variation was numerically higher in beef breeds than in other breeds in all animal categories except for heifers where the variation was equal in all studied breeds.

The two beef breeds had the numerically highest mean carcass conformation and within-breed variation in all studied animal categories (Figure 2c). The carcass conformation was at the same level in native breeds and the dairy breed.

The mean carcass fatness was in general numerically highest for Hereford, lowest for the dairy breed and

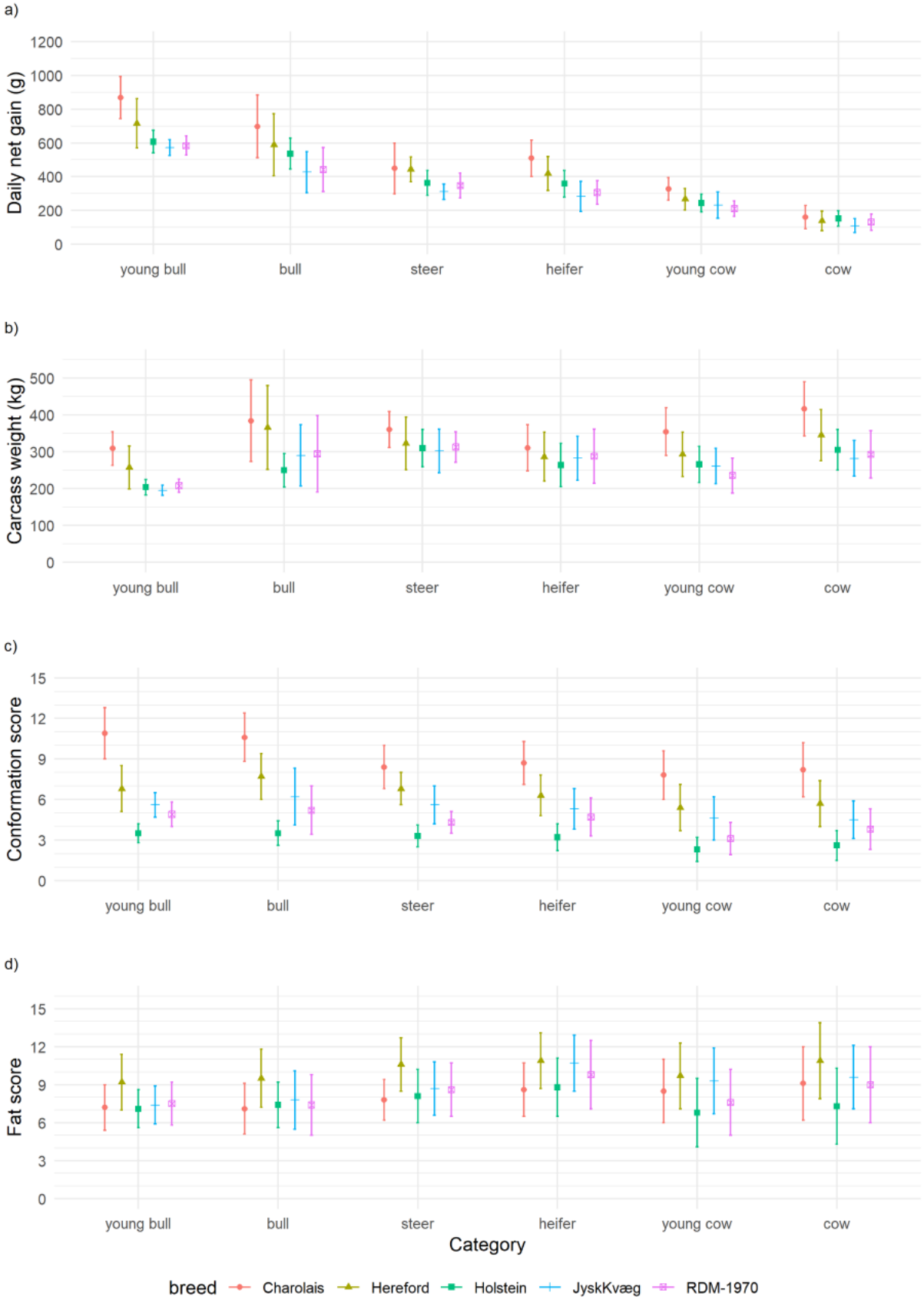

Figure 1. Daily net gain (a), carcass weight (b), conformation score (c) and fatness score (d) in six animal categories of three reference (Charolais, Hereford, Holstein) and two native (Jysk Kvæg, RDM-1970) breeds of Danish cattle, where the dots are means and bars are standard deviations.

Charolais with the native breeds in between (Figure 2d). Among the native breeds, carcass fatness was similar among heifers, young cows and bulls. In cows, young bulls and steers of native breeds, it was highest in Itäsuomenkarja and lowest in Länsisuomenkarja, but the differences were small. The numerical within-breed variation for carcass fatness was similar between breeds and larger among females than in intact males.

Icelandic breed

The daily net gain in the Íslenska kúakyniðbreed followed a similar pattern between categories as the other Nordic native breeds (Figure 3a). The daily net gain decreased with the age of the animal in females, where the daily net gain of heifers was approximately 200g, while it was around 150g for cows. The daily net gain of young bulls and bulls was around 300g.

The carcass weight of young bulls of the Íslenska kúakynið breed was lower (100kg) compared to the other categories (Figure 3b). The average carcass weight for heifers, young cows and cows was around 200kg, whereas bulls obtained an average carcass weight of 250kg.

All the female animals had similar carcass conformation around 3 (Figure 3c), while bulls showed a numerically higher carcass conformation (approximately 5) compared to young bulls (around 2).

Similar trends were observed for carcass fatness (Figure 3d), where no differences were observed among the female categories. However, large standard deviations indicate a high variation in carcass fatness of these animals. Bulls had carcass fatness around 5 whereas young bulls scored around 3, showing that carcass fatness of the male animals increased with maturity.

Norwegian breeds

All four reference breeds had higher daily net gain than the native breeds in all animal categories with the highest net gain in Charolais, which also had the largest variation in net gain (Figure 4a). Østlandsk Rødkolle was the native breed with the highest net gain in all categories (Figure 4a). Their mean net gain was close to the gains of Hereford and the dairy breeds Holstein and NRF for young bulls (441g). All the other native breeds had lower net gains. Telemarkfe had the lowest daily net gain among young bulls, whereas the lowest net gain for steers was found in Dølafe and Vestlandsk Raukolle.

The carcass weights in Norwegian young bulls are in general low compared to the other countries, probably due to a lower average slaughter age (Supplemental Tables 1 and 5). The carcass weights of the native breeds were lower than all the reference breeds (Figure 4b). Østlandsk Rødkolle was the native breed with the highest carcass weights (112kg) similar to the reference breeds Hereford, Holstein and NRF for young bulls (Figure 4b). Females of Vestlandsk Fjordfe had the lowest carcass weights. Variations in carcass weights were similar among all breeds, but with large variations in the small groups of steers in Dølafe and Vestlandsk Raukolle.

Between the reference breeds, the two beef breeds had the numerically highest carcass conformation and the largest variation among all breeds, whereas Holstein had the numerically lowest and NRF intermediate carcass conformation (Figure 4c). The carcass conformation of the native breeds was similar to NRF for young cows and cows, similar to Holstein for bulls, and varying for young bulls, steers and heifers. Østlandsk Rødkolle had the numerically highest carcass conformation in all categories among the native breeds, except for the cow category where Dølafe had the numerically highest carcass conformation (Figure 4c). The variation in carcass conformation within the native breeds was largest in the small groups of steers in Dølafe and Vestlandsk Raukolle.

Hereford had the highest carcass fatness in all animal categories with more than 100 animals. Furthermore, Hereford was one of the breeds with the largest variation in carcass fatness for females and steers. Holstein had the lowest carcass fatness in the two cow categories and young bulls (Figure 4d). Among the native breeds, there was no general trend for one breed being either fatter or leaner across all animal categories.

Swedish breeds

The daily net gain was lowest in the native breeds, intermediate in the dairy breeds and highest in the beef breeds (Figure 5a). The breed difference was more pronounced in growing cattle than in adult cows, where also varying life span influenced the results. The within-breed variation in net gain was highest in the two bull categories, especially for beef breeds, followed by the native breeds Fjällko and Rödkulla.

The carcass weights were lowest in the native breeds, followed by dairy breeds and highest in the beef breeds (Figure 5b). For some of the categories, however, the native breed Väneko had carcass weights similar to dairy breeds. The variation of carcass weight within breed x category was extensive with a standard deviation of 55kg across breeds and categories (Figure 5b). The within-breed variation in carcass weight was larger for the native breeds than for the reference beef and dairy breeds for the heifer, bull and steer categories. For young bulls, the within-breed variation was highest for beef breeds followed by the native breeds Fjällko and Rödkulla.

The native breeds Väneko, Ringamålako and Rödkulla had similar carcass conformation as the dairy breed SRB, whereas the native breeds Fjällko and Bohuskulla had numerically lower carcass conformation, similar to the dairy breed Holstein (Figure 5c). Carcass conformation was numerically highest for the beef breeds.

There was no pattern related to breeds regarding carcass fatness (Figure 5d). Four breed x category with numerically extreme high or low carcass fatness were due to very few ($n = 2 - 7$) animals per group. Carcass fatness was more related to sex than breed, with

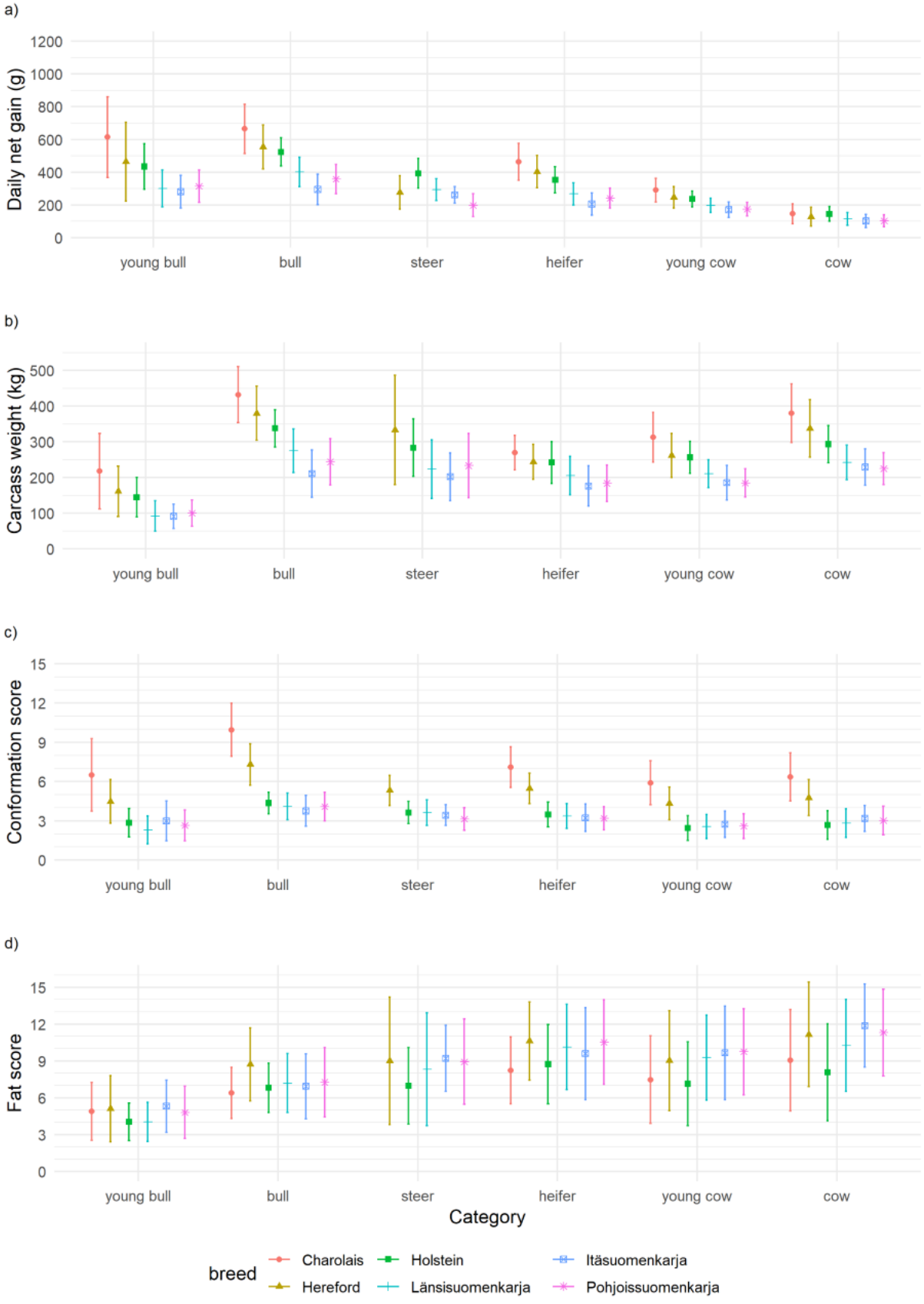

Figure 2. Daily net gain (a), carcass weight (b), conformation score (c) and fatness score (d) in six animal categories of three reference (Charolais, Hereford, Holstein) and three native (Länsisuomenkarja, Itäsuomenkarja, Pohjoissuomenkarja) breeds of Finnish cattle, where the dots are means and bars are standard deviations.

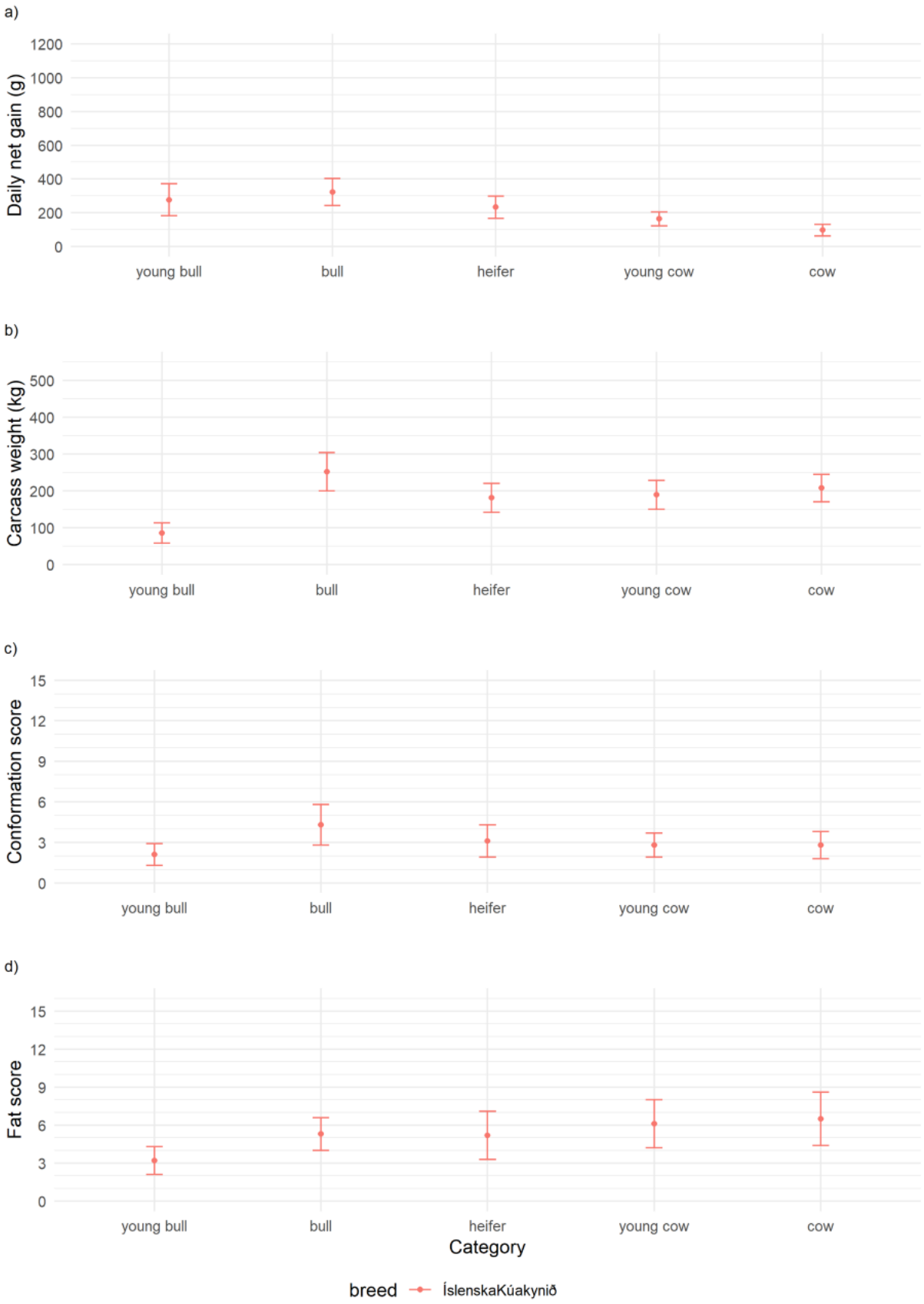

Figure 3. Daily net gain (a), carcass weight (b), conformation score (c) and fatness score (d) in five animal categories of the native (Íslenska kúakynið) Icelandic cattle breed, where the dots are means and bars are standard deviations. There is no steer production in Iceland.

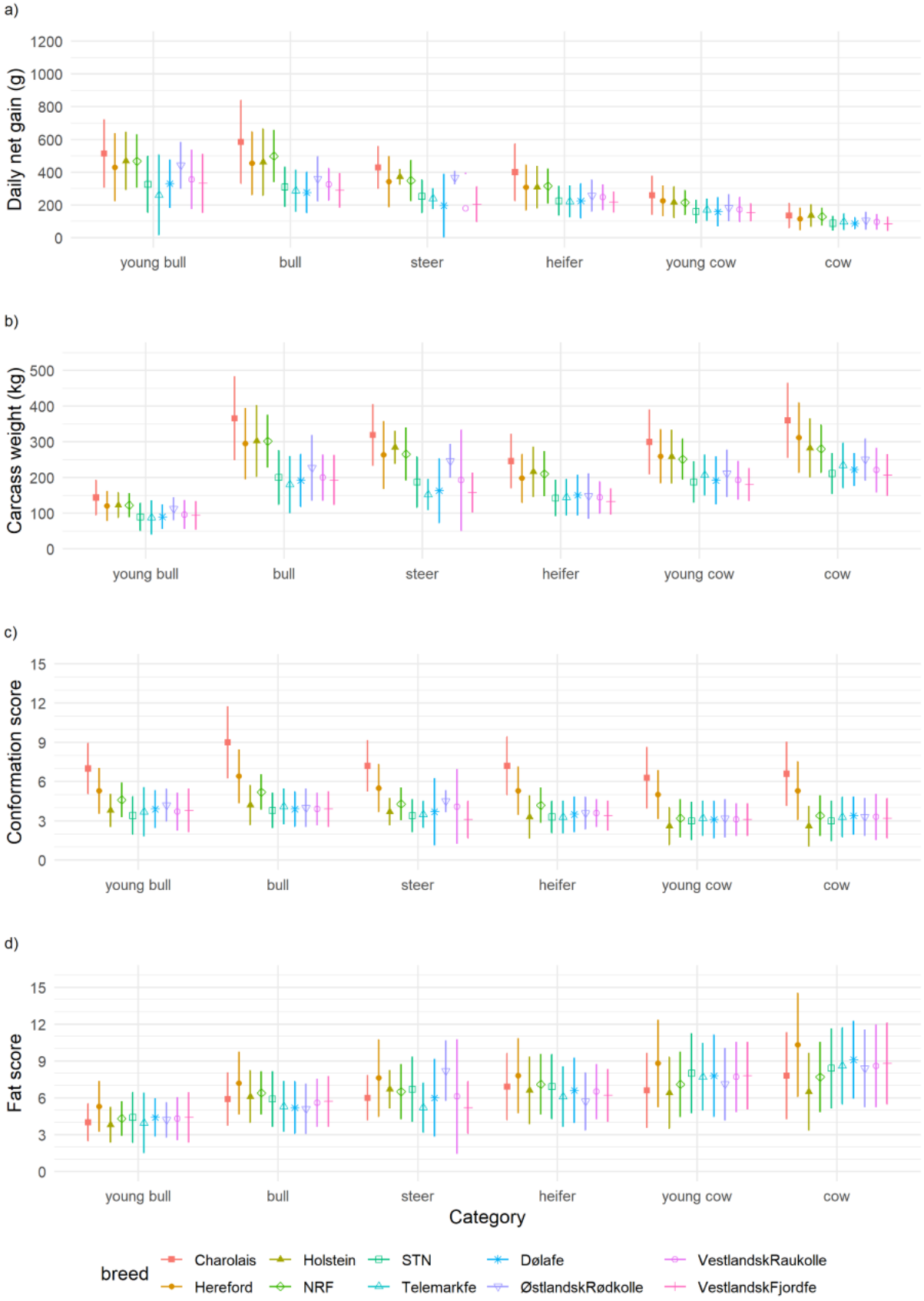

Figure 4. Daily net gain (a), carcass weight (b), conformation score (c) and fatness score (d) in six animal categories of four reference (Charolais, Hereford, Holstein, NRF) and six native (STN, Telemarksfe, Dølafe, Østlandsk Rødkolle, Vestlandsk Raukolle, Vestlandsk Fjordfe) breeds of Norwegian cattle, where the dots are means and bars are standard deviations.

females having higher carcass fatness than males and also showing a higher within-breed variation.

It should be noted that the numbers of Väneko, Ringamålako and Bohuskulla animals were low with fewer than 10 heads per breed x category for 9 out of 14 groups (Supplemental Table 6).

Comparison between countries

The adjusted carcass weights of the beef bulls showed a similar pattern for Charolais and Hereford, as both were highest in Finland and lowest in Norway, with a difference of 33kg and 46kg for Charolais and Hereford, respectively (Figure 6). For Holstein bulls, it was a bit different, as the Danish Holstein bull turned out as being the heaviest. However, the average age of the Danish Holstein bulls was only 14.4 months, thus using the daily net gain at that age to linearly predict the carcass weight at 21.5 months would probably overestimate the carcass weight at the adjusted 21.5 months used for the comparison. The weight of Holstein bulls from Finland, Norway and Sweden is more realistic, as they did not differ more than one to two months from the adjusted age of 21.5 months. Among those, the Finnish bulls were the heaviest and the Norwegian the lightest, with a difference of 20kg. For the young cows of the reference breeds, the Norwegian Charolais, Hereford and Holstein were always the lightest relative to Danish (+64, +44 and +23kg, respectively), Swedish (+46, +62 and +25kg, respectively) and Finnish cows (+26, +20 and +10kg, respectively) (Figure 7).

The adjusted carcass weights of the native breeds were close to 250kg for one group of bulls (Danish Jysk kvæg and RDM-1970, Finnish Länsisuomenkarja and Pohjoissuomenkarja, Norwegian Østlandsk Rødkolle, and Swedish Rödkulla, Väneko, Bohuskulla and Ringamålako) and closer to 200kg for a group of smaller native breeds (Finnish Itäsuomenkarja, Icelandic Íslenska kúakynið, Norwegian STN, Telemarkfe, Dølafe, Vestlandsk Raukolle, and Vestlands Fjordfe, and Swedish Fjällko) (Figure 6). The carcass weights of bulls were lowest for all native breeds, followed by Hereford and dairy breeds, whereas Charolais from all countries had the highest carcass weights.

For young cows from native breeds, the two Danish native breeds and the Swedish Väneko had the highest carcass weights, whereas the lowest carcass weights were seen among the Finnish Itäsuomenkarja and Pohjoissuomenkarja, Icelandic Íslenska kúakynið, the six Norwegian breeds and the Swedish Fjällko (Figure 7). The adjusted carcass weights of young cows showed a similar pattern as bulls, with the heaviest carcass weights being the Charolais from Denmark, Finland and Sweden, followed by Charolais from Norway and Hereford from Denmark, Finland and Sweden. The dairy breeds from all countries were similar to the Norwegian Hereford as well as the two Danish native breeds and Väneko from Sweden.

The adjusted carcass weights of bulls of the native breeds ranged across countries from 196 to 275kg with an average of 233kg, corresponding to 57, 71 and 67% of the average carcass weight of Charolais, Hereford and Holstein, respectively. The adjusted carcass weight of young cows of the native breeds across the countries was 172–253kg, with an average of 203kg, corresponding to 62, 72 and 78% of the average carcass weight of Charolais, Hereford and Holstein, respectively.

Regarding carcass conformation, bulls of the Danish breeds Jysk Kvæg and RDM-1970 and Swedish breeds Rödkulla, Väneko and Ringamålako scored 5 or more, similar to the red reference dairy breeds NRF and SRB. Bulls of the remaining native breeds had carcass conformation around 4, similar to the reference dairy breed Holstein. In addition, young cows of the native breeds Jysk Kvæg, Rödkulla and Väneko had numerically higher carcass conformation (4) compared to the other native breeds, which had about 3 in carcass conformation. Generally, young cows of native breeds were in the same range as the dairy breeds (2.5–4.5).

Carcass fatness for bulls within country differed by less than one unit for all native breeds, dairy breeds and Charolais. The Icelandic Íslenska kúakynið and Norwegian Telemark, Dølafe and Østlandsk Rødkolle were the numerically leanest breeds with a carcass fatness close to 5 followed by Charolais, dairy breeds and the other native breeds with a carcass fatness close to 6. Hereford was numerically the fattest breed in all countries. For young cows, the variation in carcass fatness between breeds within country was larger than for bulls. The young cows of Danish Jysk Kvæg, the three Finnish native breeds and the Swedish Väneko were similar in carcass fatness to Hereford, whereas the other native breeds were numerically fatter or similar to Charolais and dairy breeds, but leaner than Hereford.

Discussion

Preservation of native breeds

Preserving native breeds can occur in two main directions: preserving by conservation or preserving by development (FAO, 2007). Preserving by conservation implies aiming at keeping the characteristics and their variation within the population as they were at the start of the conservation work. Preserving by development means selecting specific characteristics within the population, such as higher milk yield or more developed muscle conformation (Statistics Iceland, 2022). Different stakeholders can have different opinions on which of these two directions is desirable, and this is the case for the Nordic native cattle breeds. These breeds are preserved in different ways aiming at either conservation or development for specific production traits, or something in between. The way of preserving a specific breed impacts what means are available to influence traits, e.g. carcass characteristics. For breeds being developed, genetic selection is a measure to improve this trait, whereas only environmental factors, such as production systems

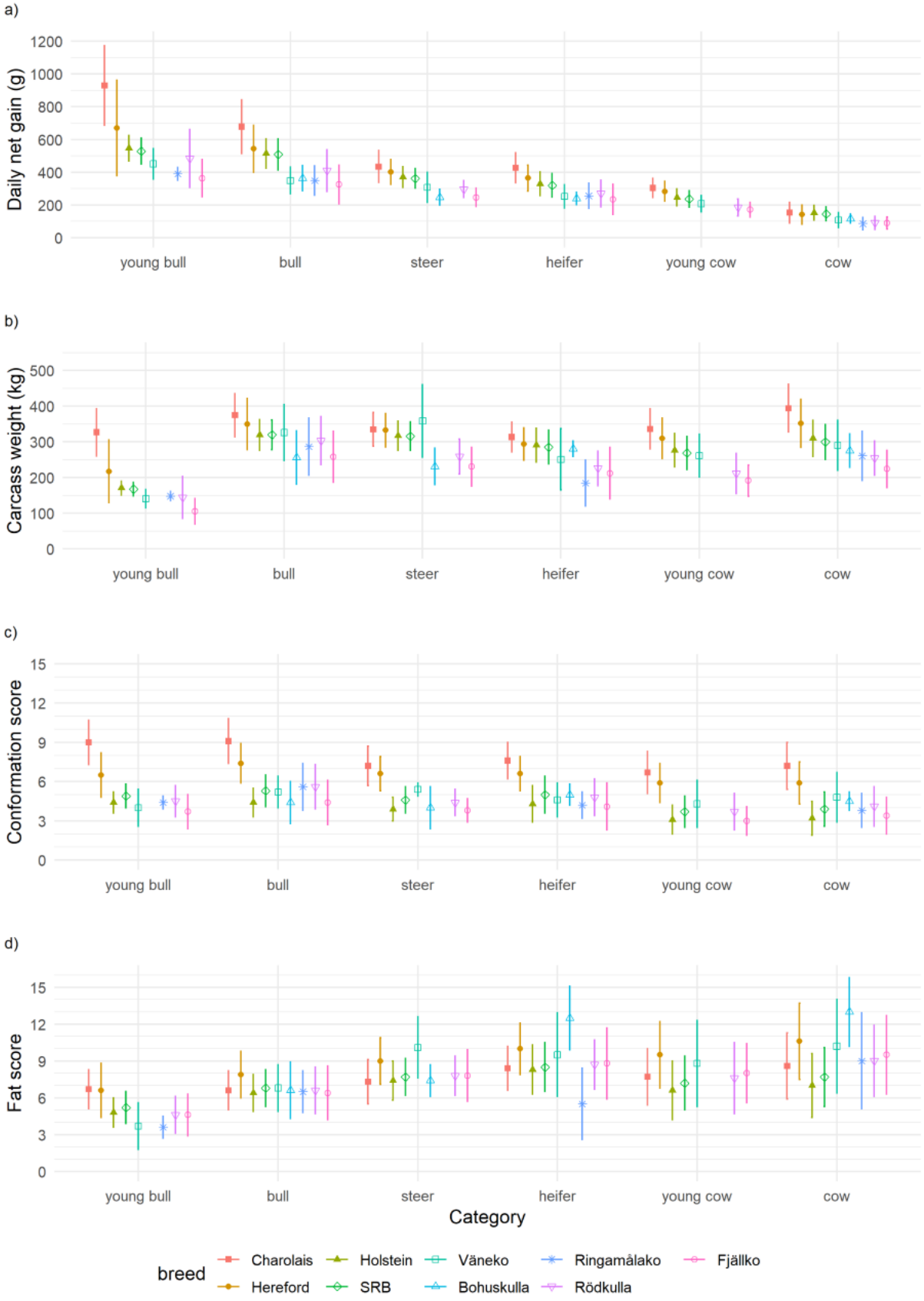

Figure 5. Daily net gain (a), carcass weight (b), conformation score (c) and fatness score (d) in six animal categories of four reference (Charolais, Hereford, Holstein, SRB) and five native (Väneko, Bohuskulla, Ringamålako, Rödkulla, Fjällko) breeds of Swedish cattle, where the dots are means and bars are standard deviations.

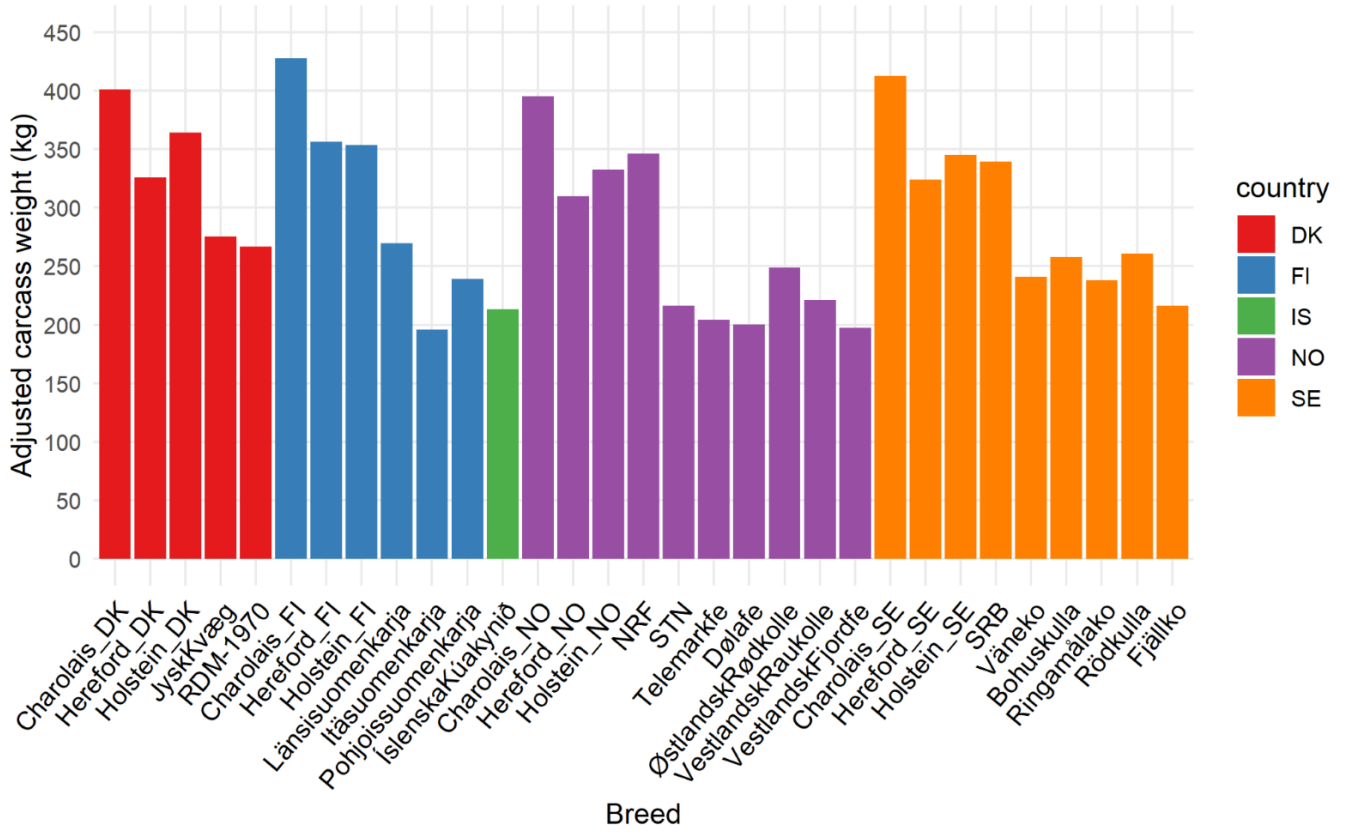

Figure 6. Adjusted carcass weights of bulls of reference (Charolais, Hereford, Holstein, NRF, SRB) and native breeds in Denmark (DK) (Jysk Kvæg, RDM-1970), Finland (FI) (Länsisuomenkarja, Itäsuomenkarja, Pohjoissuomenkarja), Iceland (IS) (Íslenska kúakynið), Norway (NO) (STN, Telemarksfe, Dølafe, Østlandsk Rødkolle, Vestlandsk Raukolle, Vestlandsk Fjordfe) and Sweden (SE) (Väneko, Bohuskulla, Ringamålako, Rödkulla, Fjällko), where slaughter age was adjusted to 21.5 months, which was the average age of Charolais and Hereford across countries.

and market opportunities, can be used to exploit the characteristics of conservation breeds.

The most obvious example of preserving by development in the present study is the Icelandic Íslenska kúakynið, which is a native but commercial dairy breed considered large enough for active breeding purposes, without severe risks of inbreeding (Gautason *et al*, 2020). The Íslenska kúakynið is one of the few native cattle breeds remaining in northern Europe that still comprises a large population size and a well-defined purpose (Ásbjarnardóttir *et al*, 2010). Icelandic agriculture is now in the dilemma of maintaining the breed to preserve biodiversity by development or relying on more efficient imported continental and British meat breeds to compete with imported meat and other food products on the market. Today, the market share of meat from Íslenska kúakynið, crossbred bulls and imported meat is about 70%, 15% and 15%, respectively (Statistics Iceland, 2022).

Like the Íslenska kúakynið, there is an ongoing, albeit weak, genetic selection in the Swedish Fjällko focused on milk production, having today, despite its small body size, an average milk yield of 60% of the dominating commercial breeds Holstein and SRB (Växa Sverige, 2021). However, there is a subgroup of Fjällko focused on conservation (Föreningen Äldre Boskap, 2022). In Finnish Länsisuomenkarja, an improvement in milk yield was undertaken between 1950 and 1970 by crossbreeding it with Friesian (currently Holstein) before the actual conservation work started with the purebred animals (Luke, 2015). The yield is today 68 to 74% of the commercial breeds of Holstein and Ayrshire used in Finland, respectively (Nokka, 2021). Breeding for increased milk production has also led to a rise in body size. The change in height varies from 7 to 14% in all Finncattle breeds. Correspondingly, the alteration in live weight is on average 18%. This is partly explained by improved conservation status, but more likely due to pleiotropic effects of genes controlling both milk production and body size (Viitala *et al*, 2006; Xiang *et al*, 2017).

Preserving by conservation is the most common direction for a majority of the Nordic native breeds. It is applied to the Danish breeds Jysk Kvæg and RDM-1970, Finnish breeds Itäsuomenkarja, Pohjoissuomenkarja and Länsisuomenkarja since the beginning of 1980s, Norwegian breeds Dølafe, Telemarkfe, Vestlandsk Raudkolle and Vestlandsk Fjordfe, and Swedish breeds Rödkulla, Väneko, Bohuskulla and Ringamålako. There are, however, some breeds where the stakeholders are aiming at simultaneously conserving and developing the breed,

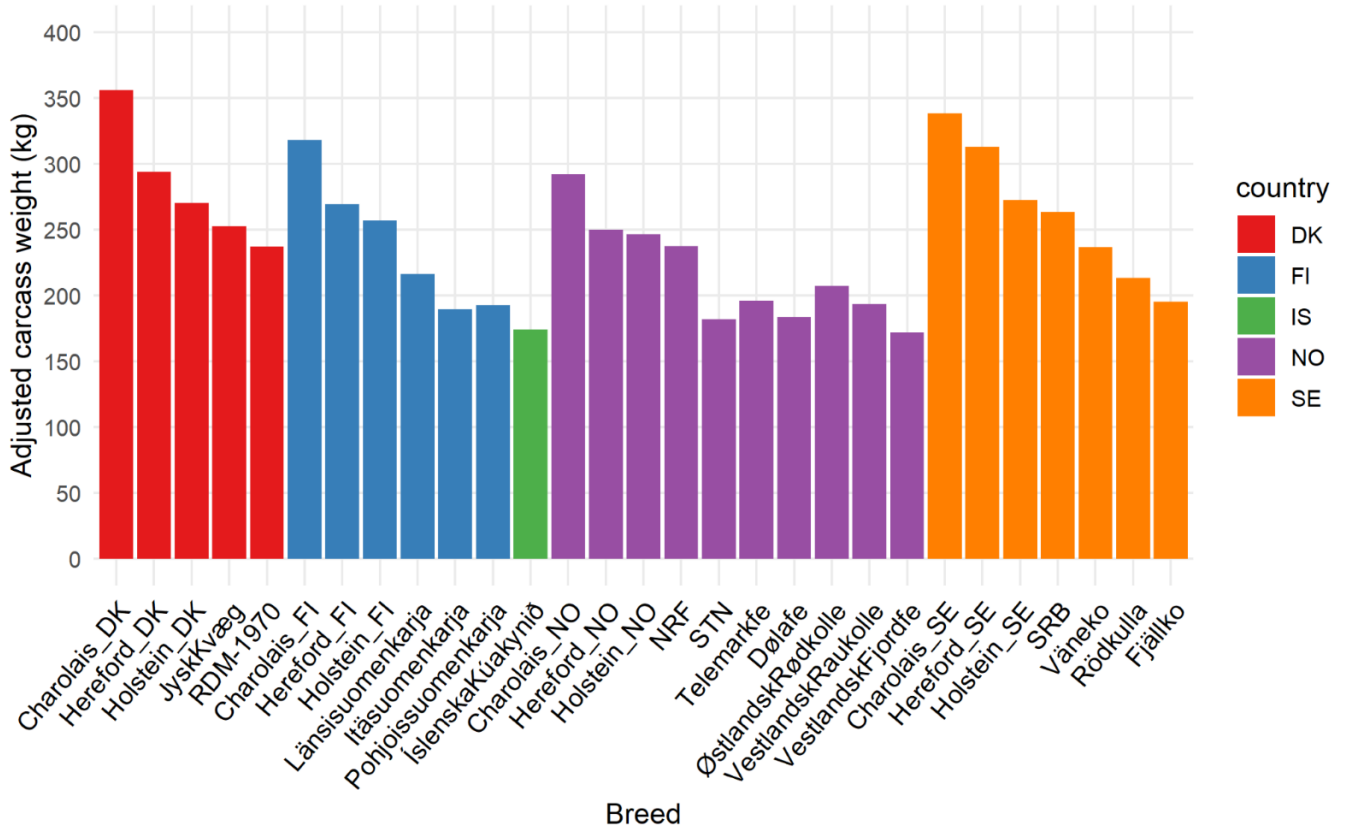

Figure 7. Adjusted carcass weights of young cows of reference breeds (Charolais, Hereford, Holstein, NRF, SRB) and native breeds in Denmark (DK) (Jysk Kvæg, RDM-1970), Finland (FI) (Länsisuomenkarja, Itäsuomenkarja, Pohjoissuomenkarja), Iceland (IS) (Íslenska kúakynið), Norway (NO) (STN, Telemarksfe, Dølafe, Østlandsk Rødkolle, Vestlandsk Raukolle, Vestlandsk Fjordfe) and Sweden (SE) (Väneko, Rödkulla, Fjällko), where the slaughter age was adjusted to 34.3 months, which was the average age of Charolais and Hereford across countries.

namely, the Finnish breed Länsiuomenkarja, and the Norwegian breed Sidet Trønderfe og Nordlandsfe (STN).

Variation between breeds

The differences in carcass characteristics among the native breeds could be either due to genetics, developed in varying historical production systems or due to various environmental factors such as general feeding levels and national market preferences. The two Danish native breeds Jysk Kvæg and RDM-1970 had a higher net gain, carcass weight and carcass conformation than the reference dairy breed, although the reference beef breeds had even higher values. Contrary, all Finnish and most of the Norwegian and Swedish native breeds had lower net gain and carcass weights than the dairy breeds in the same category and country, but with similar carcass conformation and carcass fatness. The net gain of the bulls of the native breeds from these countries was at the same level as the heifers of beef breeds. There were no reference breeds in Iceland, but previous studies have found bulls of pure native breeds to be inferior to native x beef crossbred bulls in weight gain and carcass weight (Rikhardsson *et al*, 1996; Hilmarsson *et al*, 2000).

Breed means of carcass characteristics indicate that there is a range of native breeds where one end in the spectrum contains small-sized breeds of distinctive milk type with low net gain, carcass weights and carcass conformation, and the other end consists of big-sized dual-purpose breeds with high net gains, carcass weights and carcass conformation. The comparison between breeds and specifically the Nordic native breeds compared with the reference breeds, show that it is the carcass weight that deviates most from the reference breeds, whereas the conformation and the fatness of the Nordic native breeds are close to the Holstein and the red dairy breeds bulls and young cows. Bigger-sized breeds such as Danish Jysk Kvæg and RDM-1970, the four southern-most Swedish breeds Rödkulla, Väneko, Bohuskulla and Ringamålako originate from regions with both lusher conditions and a higher influence of foreign genetics. Finnish Länsisuomenkarja originates also from more lush conditions than the other two Finnish native breeds. However, at the time of establishing the herd book, the true representatives of each Finnish native breed were thought to be found in the small, isolated villages where cattle most likely suffered from lack of feed. Therefore, the breeds of Finnish Itäsuomenkarja and Pohjoissuomenkarja were considered smaller than Finnish Länsisuomenkarja (Juvani,

2014). Smaller-sized breeds, such as the six Norwegian breeds, especially Telemarksfe, and the Swedish Fjällko originate from harsher environments. The small-sized Íslenska kúakynið from Iceland has not been influenced by foreign genetics, whereas the biggest-sized Norwegian native breed Østlandsk Rødkolle historically has been crossed with NRF and has previously shown high weight gains (Rundlöf, 2014).

All Nordic native breeds were originally kept mainly for milk production, but today a majority of all the Norwegian and Swedish native breeds, except Fjällko, are kept as suckler cows (Hessle, 2009; Belin, 2017; Holene and Sæther, 2021; Sæther *et al*, 2021). However, according to the data analyzed here, more Finnish native breeds are still kept for milk production (45, 26 and 36% for Länsisuomenkarja, Itäsuomenkarja and Pohjoissuomenkarja, respectively). Weight gain is most likely promoted by the suckling system, especially for breeds with high milk-producing potential such as Länsisuomenkarja, Østlandsk Rødkolle and Rödkulla. Thus, comparing net gain in suckling vs. manually fed calves can be biased. The variation in net gain within the heifer, young bull and bull categories of the Swedish Rödkulla and Fjällko might be an effect of mixed groups with both manually milk-fed and suckling calves. Also, comparison among countries might be biased as the introduction of native breeds in suckling systems did not start simultaneously in all Nordic countries. This might be a further explanation for the higher net gains for growing cattle in the Danish and four southern-most Swedish breeds compared to the other native Nordic breeds. On the other hand, even if the native breeds are kept as dairy cows, the practice may also vary between breeds and countries – in Denmark the native cows would typically be part of a conventional system, which then challenges the native breeds on fatness and health, due to the high-quality diet offered to the cows (Munk *et al*, 2020).

Comparisons over time

In small populations, there is a significant risk of genetic drift, also in the Nordic native cattle breeds (Upadhyay *et al*, 2019). Such unintended changes in the breed are not desirable in conservation.

The net gain of the Danish native breeds RDM-1970 and Jysk Kvæg in the present study was only 5% lower than the net gain seen under the current commercial praxis of slaughter calves (Myhlendorph-Jarlfoft, 2022). Furthermore, it was only slightly lower than the level obtained for young bulls of RDM and Sortbroget Dansk Malkekvæg, in studies from the 1970s (Andersen, 1975; Andersen *et al*, 1977). Also, the growth potential, as evaluated using net gain, of the Danish reference dairy breed Holstein seems to be only marginally improved during 40 years of selection for primarily milk yield, illustrated by the stable genetic level for growth traits in the last 20 year in all the Nordic dairy breeds (https://nordic.mloy.fi/NAVTrends). However, the lower carcass conformation of Holstein in the present study, compared to that of Jysk Kvæg and RDM-1970 breeds, suggests a lower dressing percentage in the former, which in turn may have led to a smaller increase in average daily live weight gain for the Holstein. In accordance with studies from the 1970s (Andersen, 1975; Andersen *et al*, 1977), the Jysk Kvæg in the present study had 11% higher carcass weight compared with RDM in the 1970s.

While Holstein has developed from a dual-purpose type to a milk type with low carcass conformation during the last decades, the two Danish native breeds in the present study had similar carcass conformation as in the studies from the 1970s (Andersen *et al*, 1977). Then as now, Jysk Kvæg had a considerable higher carcass conformation than RDM-1970 (Andersen *et al*, 1977). Carcass fatness had not changed much for any of the Danish breeds.

Fulfilling market's demand for carcass characteristics

Carcass weight, carcass conformation and carcass fatness aim at giving an estimate of the relative value of the carcass for the industry. Lower prices paid to the farmer for small-sized cattle with less developed muscle conformation, compared to mainstream carcasses, are due to a similar cost of processing but obtaining less saleable meat. The highest prices for a specific weight range are also due to the end-consumer expecting specific retail cuts to be of the same size and shape. Mainstream selection in beef production is towards bigger carcasses (Pesonen, 2020), leaving the small populations of conserved native breeds behind.

Along with increasing live weight, growing cattle deposit a lower proportion of muscles and an increasing proportion of fat. For small-sized and early maturing breeds, such as the native breeds, the challenge is to plan for a time of slaughter when the body has become heavy enough but not too fat. Consumers' desire for fatness varies among markets. Therefore, the beef market differs among the studied countries, and thus affects the carcass composition. In Norway, lean bovine carcasses with carcass fatness of 3–6 are preferred (Nortura SA, 2021), whereas fatter carcasses are asked for in Denmark (7–12, Danish Crown, 2022), Finland (9, Kiviranta, 2022a,b), Iceland (6–8, SS Meat Company Iceland, 2022) and Sweden (6–9, HkScan Agri, 2021). Hence, in the present study, the average carcass fatness and carcass weights were lower in Norway than in the other countries. National individuality in the rosé veal market affects the results of the heifer and young bull categories, with varying target weights and proportions of cattle within the groups reared for rosé veal versus beef.

The heavier native breeds, i.e. Danish Jysk Kvæg and RDM-1970, the Finnish Länsisuomenkarja, the Norwegian Østlandsk Rødkolle and the Swedish Väneko and Rödkulla, had carcass characteristics best fitting into the present market preferences, with moderately high carcass weight and net gain. The other native breeds, i.e. the Finnish Itäsuomenkarja and Pohjoissuomenkarja,

the Icelandic Íslenska kúakynið, the Norwegian STN, Telemarkfe, Dølafe, Vestlandsk Raudkolle and Vestlandsk Fjordfe, and the Swedish Fjällko, Bohuskulla and Ringamålako, had carcasses which could be more problematic to fit into the mainstream market.

Recommendations for future beef production on the endangered native breeds

As stated above, there is a risk for cattle of native breeds and other small-sized breeds to become too fat before the lower limit of optimal carcass weight range has been reached. The best way to avoid excessive fat deposition at too low live weights is an extensive forage-based production system with only moderate weight gain (Robelin and Daenicke, 1980; Webster, 1989).

In the present study, the rearing generally seems to have been less intensive for the native breeds than for the beef breeds, also when the difference in mature live weights is considered. The carcass weights of the native breeds were about 71% of the beef breeds, whereas their net gain was only 65% of the beef breeds' net gain. Despite this low feeding intensity, a vast majority of the male cattle of the native breeds were raised as intact bulls (70–100%), which generally are more suited to intensive feeding. It is known that the growth potential of, for example, the Icelandic Íslenska kúakynið is not fully exploited (Sveinsson, 2017). In accordance with previous research (Sveinsson, 2016), the present study confirmed a 25-month slaughter age for indoor bulls of this breed, which, together with the Swedish native breeds, was the oldest at slaughter. The long rearing time for the Íslenska kúakynið bulls has a negative economic impact on the production output of facilities, feed and labour (Sveinsson, 2017). Previous studies have shown that at least under Swedish conditions, male calves for the highest profitability should either be reared very intensively as indoor bulls or very extensively as grazing steers, whereas semi-intensive rearing results in a poor economy (Hessle and Kumm, 2011).

Castrating a higher proportion of the males of the native breeds, and rearing them as steers, would be a means to keep them in even more extensive production systems where their carcass characteristics would be less deficient compared to commercial breeds. An increasing proportion of cattle of the Nordic native breeds are kept in suckler-based beef production systems, often in small integrated herds, where castration would enable a rational common keeping of males and females (Hessle, 2009; Claesson and Ekberg, 2015; Belin, 2017; Holene and Sæther, 2021; Sæther *et al*, 2021).

Animals' growth potential and carcass characteristics influence the economy on the farm. Other factors than carcass revenues, such as agri-environmental payment and support and costs for winter housing, influenced the profitability more than genotype, especially in extensive pasture-based systems where the higher genetic growth potential in the crossbreds could not be fully expressed (Holmström *et al*, 2021). The differences between the genotypes in the most extensive system studied by Holmström *et al* (2021) was 50kg in carcass weight and 2.6 in carcass conformation, which is in the same range as breed differences for steers, heifers and young cows in the present study. Hence, although production conditions vary among the Nordic countries, the economical drawback of not fully market-oriented carcasses in the native breeds, compared to commercial breeds, should not be exaggerated, especially not in extensive production systems. Hence, the results of this study support the multi-use potential of Nordic indigenous cattle as beef production in extensive production systems on marginal grasslands, forests and mountains, while providing ecosystem services for the revitalization of traditional biotopes. The Finnish native breed Itäsuomenkarja is an example of a breed that has found its role in providing ecosystem services grazing traditional landscapes (Lilja *et al*, 2009). Dairy farmers in Iceland have chosen development over conservation of the native Íslenska kúakynið. The farmer will continue to use it as the main production breed in the country, despite economic arguments against it. The multicoloured breed is what makes cattle farming in Iceland unique. It is considered the best way to meet the growing competition for dairy and meat products (Agrogen Is, 2021). Most of the Icelandic population supports it for traditional and cultural reasons. Growing tourism also plays a role. One reason for Iceland´s popularity as a destination is its unique landscape and scenery (Ferðamálastofa-Icelandic Tourist Board, 2016). Maintenance of the native grazing livestock both perpetuates the scenery and constitutes a part of the uniqueness. Changing or replacing native livestock with commercial breeds would most likely decrease the attractiveness of Iceland as a tourist destination.

The eating quality of meat is not estimated in the EUROP carcass classification system (Guzek *et al*, 2016; Bonny *et al*, 2016). Meat traits in Nordic native breeds have previously been compared with meat from commercial breeds with varying results. Their meat has been found to have more intramuscular fat with a healthier fatty acid composition and to be tastier, juicier and more tender than meat from commercial breeds (Aass and Fristedt, 2003; Suleimenova, 2016) and is appreciated by chefs in restaurants (Exceptionell Råvara, 2022; Soini *et al*, 2019). On the other hand, other studies show bulls of purebred native breeds being inferior to native x beef breed bulls in juiciness, tenderness and overall sensory quality (Rikhardsson *et al*, 1996; Hilmarsson *et al*, 2000). The divergence in results of these studies is most likely due to varying experimental designs. However, the present favouring of increased carcass weight and carcass conformation in the price setting does not support a focus on valuable meat quality traits, which could be used to increase the market share of native beef products. In addition to eating quality traits, there might be other characteristics

of the meat from native breeds, similar to specific traits of their milk, which could be used as benefits when selling the product. The specific milk protein composition giving a high cheese yield in the Swedish Fjällko has been known for a long time (Hallander, 1989). Likewise, a recent milk oligosaccharide profiling study (Sunds *et al*, 2021) demonstrated that milk of Finnish Länsisuomenkarja has a suitable quality for special food ingredients such as infant formula or healthy ingredients. To support similar development for meat from native breeds, the characterization of meat quality traits and composition is required.

Possible shortcomings of the study

Sample sizes was the smallest for the Swedish breeds Väneko, Bohuskulla and Ringamålako with 22–80 animals, indicating results from these breeds are more uncertain than the others. Across countries, the number of samples in the steer category was relatively low for all native breeds, especially in some Norwegian and Swedish breeds, indicating results from the steer category should be interpreted with reservation. Besides the small populations, the low number of animals of native breeds could be due to absent carcass data from some small abattoirs. Finally, a source of error in the used data could be incorrectly reported breed codes in the databases.

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Author contributions

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Declaration of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplemental Data

- Native and reference breeds description
- Supplemental Table 1. Reference cattle in Denmark, Finland, Norway, and Sweden: breeds, categories, numbers and age
- Supplemental Table 2. Danish native cattle: breeds, categories, numbers and age
- Supplemental Table 3. Finnish native cattle: breed, categories, numbers and age
- Supplemental Table 4. Icelandic native cattle: breed, categories, numbers and age
- Supplemental Table 5. Norwegian native cattle: breed, categories, numbers and age
- Supplemental Table 6. Swedish native cattle: breed, categories, numbers and age

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