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# The Effect of Jersey in Norwegian Dairy Production

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# Føreord

Alt har si tid. det er ei tid for alt som hender under himmelen : ei tid for å studera, ei tid for å slutta. Denne oppgåva vart skriven våren 2022 ved Institutt for husdyr- og akvakulturvitskap, ved Noregs miljø og biovitskaplege universitet. Oppgåva markerer avslutning på tida som student, som innbyggjar i Ås og markerar starten på arbeidslivet.

Åra på Ås har resultert i auka kunnskap og interesse innan fagområder som ernæring, avl, økonomi, fôrteknologi og realfag generelt. Trass i hovudtyngde av fag og interesse innan fôring og ernæring av drøvtyggjarar vart det ei oppgåve innanfor avl, buskapsdynamikk og metan. Oppgåva har ført til aukt interesse også for denne tematikken.

Skriveprosessen byrja med eit flott besøk til Folum og Universitetet i Aarhus for å koma i gang med SimHerd programmet. Der fekk eg god hjelp og oppfylging av blant anna rettleiarane Julie Brastrup Clasen og Morten Kargo. I tillegg har hovudrettleiar Harald Volden vore til stor hjelp med faglige diskusjonar både om ting i oppgåva og utanom. I tillegg vil eg takka Laget på Ås, gode vener og folket på lesesalen på Husdyrfagbygget. Til slutt vil eg også takka Sven Emil Hinderaker, Henrik Siqveland og Vegard Greibrok Ovastrøm for korrekturlesing av oppgåva.

Institutt for husdyr og akvakulturvitskap, NMBU

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Ådne Haugstad

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## Abbreviations

| | |
|---|---|
| **BS** | Beef semen |
| **$CH_4$** | Methane |
| **CM** | Contribution margin |
| **$CO_2$** | Carbon dioxide |
| **CS** | Conventional semen |
| **DIM** | Days in milk |
| **DMI** | Dry matter intake |
| **DJ** | Danish Jersey |
| **DKK** | Danish kroner |
| **DNS** | De novo fat synthesis |
| **DR** | Danish red |
| **ECM** | Energy corrected milk |
| **GHG** | Greenhouse gas |
| **H** | Holstein |
| **J** | Jersey |
| **LSD** | Lease square difference |
| **NDF** | Neutral detergent fibre |
| **NEL** | Net energy lactation |
| **NHRS** | Norwegian herd recording system |
| **NOK** | Norwegian kroner |
| **NR** | Norwegian Red |
| **NTM** | Nordic total merit index |
| **SS** | Sexed semen |
| **TMR** | Total mixed ration |

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# Abstract

Alterations in customer demands has the latest years increased the aggregate demand for milk fat from Norwegian dairy production. To encourage farmers to produce more milk fat, the premium for fat has been increased to 0.09 NOK per 0.1 above 4%. In addition, Norway has farm milk quotas regulated in litres. Danish Jersey differs from Norwegian Red by producing less meat and litres of milk but higher concentrations of milk fat and protein. The aim of the assignment was to investigate how Danish Jersey impacts herd dynamics, production, and contribution margin, and if it could balance the dairy market. To compare Norwegian Red to Danish Jersey, simulations were done in the Danish herd simulation model, SimHerd. Four scenarios within each breed using different combinations of conventional, sexed and beef semen were compared to investigate effect of breed, strategy for breeding management, and the combination. Due to lack of data on Danish Jersey in Norway, it was transposed to Norwegian production conditions to maintain a fair comparison. Maintaining the same milk yield, 100 Norwegian Red cows was compared to 130 Jersey cows. Scenarios with Jersey showed higher contribution margin both per animal and in total. Incomes on NR derived from milk and meat primarily, while J attained the incomes from sale of springing heifers and milk. Jersey had higher disease frequencies but lower methane emissions in the milk production part. In the meat production part the methane per kg BW varied between scenarios and were not distinguished between breeds. Sensitivity analysis showed milk and feed prices to be the most decisive variables for the contribution margin, while meat price and heifer price also were important. A survey with Jersey farmers indicated that Jersey farmers in Norway delivered higher production results than the average Norwegian dairy farmers. The Jersey farmers claimed raise of calves and heifers to be more demanding compared to Norwegian Red. It was crucial to get the correct input values in SimHerd for proper comparison with the surveyed farms. A slightly underestimation of Jersey might have made Jerseys profitability less than in reality. Nevertheless, breeding Jersey deviates from breeding Norwegian Red. The current payment and regulating system favours Jersey, but might not endure forever. A transition to Jersey can reduce emissions of enteric methane, increase contribution margin compared to Norwegian Red production but might increase labour requirement for Norwegian Dairy farmers.

# Samandrag

Endringar i kundebehov har dei siste årene auka det samla etterspunaden etter mjølkefeitt i norsk meieriproduksjon. For å stimulera bøndene til å produsera meir mjølkefeitt er ekstrabetalinga for feitt auka til 0,09 NOK per 0,1 over 4%. I tillegg har Noreg mjølkekvotar regulert i liter. Dansk Jersey skil seg frå Norsk Raudt Fe at dei ved å produsera mindre kjøt og liter mjølk, men meir feitt og protein i mjølka. Målet med oppgåva var å undersøkje korleis Dansk Jersey påverkar dynamikken i buskapen, produksjon og dekningsbidrag, og om det kan balansera meierimarknaden i Noreg. For å samanlikna Norsk Raudt Fe med Dansk Jersey vart det gjort simuleringar i den danske simuleringsmodellen, SimHerd. Fire scenario for kvar av de to rasane med ulike kombinasjonar av konvensjonell, kjønnsseparert og kjøttfesæd vart samanlikna for å undersøka effekt av rase, avlsstrategi og kombinasjonen av dei. På grunn av mangel på data på Dansk Jersey i Noreg, vart Dansk Jersey transponert til norske produksjonsforhold for å sørge for ein rettferdig samanlikning. For å oppnå same mjølkemengde vart 100 Norsk Raudt Fe samanlikna med 130 Jersey kyr. Det resulterte i høgare dekningsbidrag både per dyr og totalt for Jersey. Inntekter på Norsk Raudt Fe kjem primært frå mjølk og kjøt, medan Jersey får inntektene frå sal av livkviger og mjølk. Jersey hadde høgare sjukdomsfrekvens, men lågare utslepp av enterisk metan frå mjølkeproduksjonen, medan metan utslepp frå dei kjøtproduserande dyra varierte mellom rasane. Sensitivitetsanalysen viste at mjølk og fôrpris var dei mest avgjerande variablane for dekningsbidraget, medan kjøtpris og kvigepris også var viktige. Ei undersøking med Jersey-bønder indikerte at Jersey bøndene i undersøkinga leverer betre produksjonsresultat enn gjennomsnittet i Noreg, og hevda at oppdrett av kalvar og kviger var meir krevjande samanlikna med Norsk Raudt Fe. Det var avgjerande å få riktige verdiar inn i SimHerd for riktig samanlikning mellom dei ulike produksjonane. Litt undervurdering av Jersey kan ha gjort lønsamheita med å ha Jersey mindre enn i verkelegheita. Det verkar som oppdrett av Jersey i stor grad avviker frå oppdrett av Norsk Raudt Fe. Betalings- og reguleringssystemet i Noreg i dag favoriserer Jersey, men det er uvisst kor lenge systemet vil vera slikt. Overgang til Jersey kan redusera utslepp frå enterisk metan, auke dekningsbidrag samanlikna med Norsk Raudt Fe produksjon, men vil og generera høgare arbeidsbehov for norske mjølkebønder.

# 1. Introduction

In the last 20 years the demand and consumption of drinking milk has decreased in Norway (melk.no, 2022). At the same time, the demand for processed high-fat dairy products have increased. These changes have resulted in an unbalanced use of raw milk, which leads to reduced profitability for the dairy industry and the farmer. To improve the balance, an increased price for milk fat has been introduced to stimulate to higher fat concentration in the milk (Tine SA, 2020a; Tine SA, 2020c).

Higher production of milk fat in a short- and long-term perspective is important to maintain a high milk price to the farmers. Market equilibrium is attained when demand and supply is met, and it is crucial to create a balanced and efficient market. Milk fat concentration can be increased in short term by enhanced management and feeding of the dairy cows (Abrahamse et al., 2009; Oba, 2011; Randby et al., 2012). A long term and permanent solution are genetic improvement of cows, or alternatively change into a breed that yields milk with higher fat concentration. According to Tine, increased milk fat production will be necessary both in long and short term (Tine SA, 2020a).

Norwegian Red (NR) is the dominating dairy cattle breed in Norway and has a prevalence of 91.3% among Norwegian dairy cows. The NR is known as a dual-purpose cow, producing both meat and milk. The average annual milk yield in 2021 was 8570 kg energy corrected milk (ECM), with 4.3 and 3.6% fat and protein, respectively. Jersey (J) is a purebred dairy cow, yielding 8188 kg ECM with 5.9 and 4.2% fat and protein, respectively (Tine SA, 2021). A change from NR to J would increase fat concentration of the milk delivered to the dairies. However, a possible consequence of exchanging NR with J is a reduced meat production from the dairy cows.

Norwegian dairy production deviates from other European countries by having individual farm milk quotas. The quota is defined in litres of raw milk and attempts to regulate and increase the degree of self-sufficiency in Norway. In the last ten years, the price of milk quotas has substantially increased, whilst the premium for producing fat and protein by 0.1% above 4.0% and 3.2% has increased to present 0.09 NOK and 0.06 NOK for fat and protein, respectively. Lower yields in J compared to NR in a milking quota system makes room for multiple animals on farm level. This change is expected to produce more solids in milk, balance the Norwegian milk market while contributing to higher contribution margins (CM).

In a traditional breeding system, using conventional semen (CS) entails an even sex distribution, slightly advantageous for bulls (Vishwanath & Moreno, 2018). An even sex distribution favours dual bred cows, which produce high value offspring independent of sex. Due to low value on J bull calves, producers earlier euthanized them shortly after birth despite severe critique from customers. New breeding tools like sexed semen (SS) and beef semen (BS) enables alteration of sex, depending on milk or meat production value, marketability, and intern need for recruitment animals. Sexed semen is used to increase the chance of getting a heifer. Sexed semen is used on the youngest and superior cows while BS is used on genetically inferior cows enabling production of higher value offspring and minimizes production of low value animals (Ettema et al., 2017). Using more beef semen in dairy production can decrease the climate impact from beef production (Knapp et al., 2014).

Rising production costs and increased emphasis on greenhouse gas (GHG) emissions makes effectiveness in dairy production more important than ever. Governmental regulated incomes (milk quotas + milk price) in contrast to expenses makes the economic situation unfavourable for dairy farmers in Norway. A small and efficient cow producing high solids in milk might therefore lessen problems both regarding economy and GHG emissions. The aim of this master thesis is to investigate if a production system with J, in combination with SS and BS, will improve the economy and GHG emissions on herd level.

The hypothesis is that a transition to J will improve profitability in the herd compared to having NR and reduce GHG emissions. The study is based on a survey on how Norwegian dairy farmers breed J in their production system, simulations in the SimHerd model, a sensitivity analysis and methane calculations. (Østergaard et al., 2010).

# 2. Background

The background covers the different characteristics of dual-purpose NR and the purebred milking cow J together with genetic tools, the dairy market in Norway, the SimHerd Model and enteric methane.

## 2.1. Norwegian Red

Norwegian Red is by far the most predominant dairy breed in Norway, with 91.3% of the total population being registered as NR cattle (Tine SA, 2021). The NR cow is bred to produce both meat and milk. It yields on average 8084 litres of milk, 4.3% fat, and 3.6% protein, corresponding to 8570 kg ECM. Average carcass scores (EUROP) are O, 3- in fat, and 316 kilo slaughter weight on bulls, unfortunately the age at slaughtering is not registered (Tine SA, 2021). The purebred in Norway, and is attractive for crossbreeding in other countries due to good health and fertility traits. (Begley et al., 2009a; Begley et al., 2009b; Geno, 2022a; McClearn et al., 2020; Rinell & Heringstad, 2018).

Norwegian Red cattle is a dual bred cow, which makes both sexes valuable. Heifers are valuable for milk production, and bulls for meat production. In total 93% of the inseminations in NR cows are from NR bulls, and 2.4% of those is SS (Tine SA, 2021).

**Breeding goal for NR**

The breeding goal of NR is a healthy, fertile cow yielding high milk and meat production. As well as a functional udder, strong frame and strong feet, the NR is bred for good temperament. Within the milk production index kg milk is relative weighted -16%, while kg fat is weighted positive 47%, and protein is positive 37%. Percentage increase of fat and protein is not a part of the breeding goal, and induces overall higher fat and protein production (Geno, 2021).

The breeding goal for NR has changed significantly since the genesis of NR breeding in the 1960s (Geno, 2020b). The breeding goal in the early days constituted mainly of milk yield (70%), milk speed, meat, and exterior (Figure 1). Meat production have had a stable emphasis throughout the years, the largest increase was health and fertility traits which were included in 1970s (Figure 1). Geno was among the first in the world to include health and fertility traits in their breeding goals, which were included by substituting emphasis on milk yield traits (Geno, 2020a; Geno, 2020b).

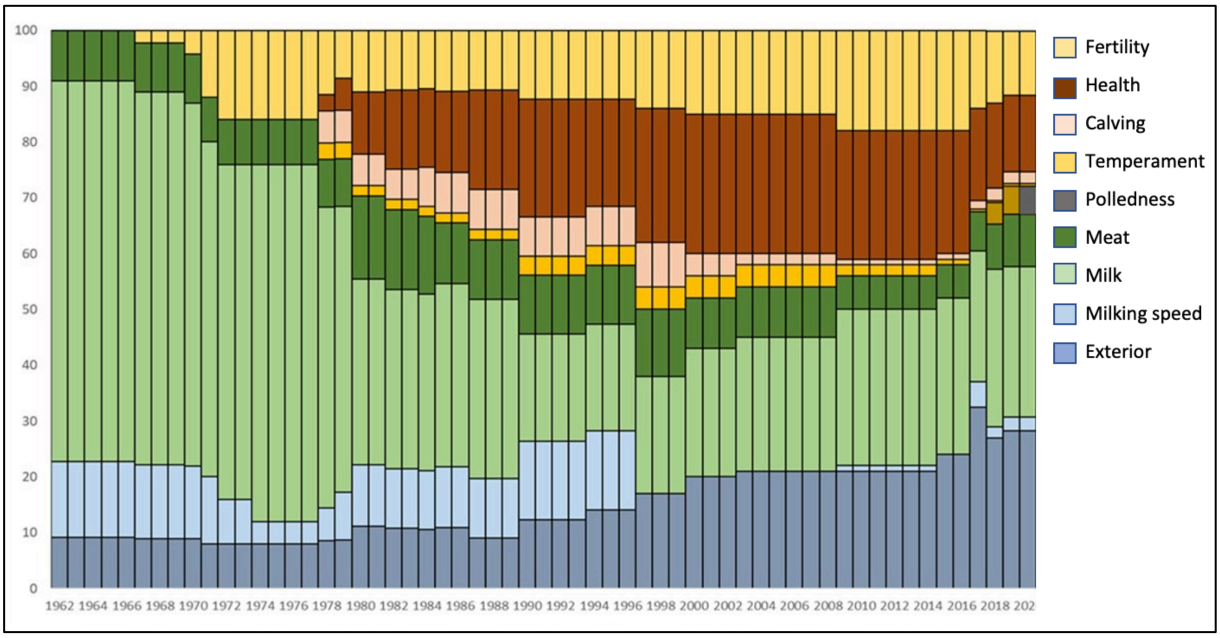


*Figure 1: Development in emphasise in the breeding goal for NR from 1962 to 2020 (Geno, 2020b).*

**The history behind Norwegian Red Cattle**

Until 1935, specific breeds for every valley and area dominated the genetics of milking cows in Norway. This changed on 16th of November 1935, when an official breeding program for a Norwegian dairy cattle was established. The goal was to develop a beefy, high yielding, fast growing, pasture utilizing cow not larger than the Ayrshire. Bulls from Swedish red and white cattle, Red Trønder and Ayrshire were chosen as the most significant breeds (Bækkedal, 1980). Common for the chosen breeds were that they were bred for both milk and meat production. The breeding program eventually advanced and started with pedigrees, progeny examination, artificial inseminations and crossbreeding.

Three main breeds were selected to form the basis of NR, but historical investigations of pedigrees have revealed that 10 - 12 breeds were used in total. Table 1 presents the historical breed distribution examined by Syrstad (n.d.) and Langmoen (1981). They studied the pedigree of 216 bulls that were progeny tested between 1975-1979. The study showed that the two Swedish breeds, Swedish Red and White Cattle and Swedish Lowland Cattle, account for more than half of the genetic origin for NR. Almost 13% of the origin is regarded as unknown because of lack of data on the oldest animals and some animals listed as crossbreds. The rest of the genetic origin of NR derive mainly from Finnish Ayrshire and other Friesians, while old Norwegian breeds are almost negligible (Langmoen, 1981; Syrstad, n.d.).

*Table 1: Different breed contributions from 216 Norwegian Red bulls that were progeny tested in 1975-1979. From (Langmoen, 1981) and (Syrstad, n.d.).*

| ***Breed*** | **%** |
|---|---|
| *Swedish Red and White Cattle* | 45.1 |
| *Other Friesians* | 13.4 |
| *Unknown* | 13.2 |
| *Finnish Ayrshire* | 11.4 |
| *Swedish Lowland Cattle* | 6.9 |
| *Other Ayrshires* | 3.4 |
| *Old Norwegian cattle breeds* | 2.7 |
| *Norwegian Red* | 2.4 |
| *Red Trønder Cattle* | 1.3 |

**Data provided better opportunities for breeding**

Phenotype recordings are important to predict breeding values with high accuracy. The first animal phenotype registration cooperate in Norway can be tracked back to 1898 (Risan, 2015). Already then, simple data was collected to be available for everyone, so that farmers could learn from one another. Since then, the National Herd Recording System (NHRS) in Norway has had great approval from farmers. In 2021 more than 90% of Norwegian dairy cows and 98% of the herds were registered in NHRS (Tine SA, 2021).

Introduction of individual "Healthcards" was important for registering disease frequencies on NR. The intention of the Healthcard was to register and monitor the health situation on individual cows and the entire NR population, simultaneously as the data for breeding was collected. The information became the foundation for calculated heritability when progeny testing the breeding bulls, and a part of NRs success as a healthy cow. (Geno, 2020a). Today many dairy cows is genomic tested and veterinaries register treated diseases in a national animal health database, and the data is published yearly (Tine SA, 2021).

## 2.2. Danish Jersey

Statistics from Tine SA (2021) show that there are 2800 J dairy cows in Norway. Jersey cattle in Norway yields 6301L of milk, 5.9% fat and 4.2% protein on average, corresponding to 8188 kg ECM. Average carcass scores (EUROP) are O- and 2+ in fat, and 210 kg slaughter weight on bulls, unfortunately the age is not registered (Tine SA, 2021). Jersey is prevalent mainly in United States, New Zealand, Denmark, France, Sweden and Finland, sorted roughly from large to small populations (Porter et al., 2016). Jersey is mainly purebred or included in rotary crossings (McClearn et al., 2020; Shetty et al., 2017).

Jersey is a purebred dairy cow and produce high value heifers for replacement and sale, while purebred bull calves are of low value. In 2021, 78.4% of the inseminations on J in Norway were with SS, and 84% of the inseminations were with Jersey semen (Tine SA, 2021).

**Breeding goal for Danish Jersey**

The breeding goal of DJ is a fertile, feed saving cow with good udder health. Youngstock survival, longevity, feet and legs is included in the breeding goal (Nordisk Avlsværdi Vurdering, 2020). The goal for Danish Jersey is to produce 8500 kg milk, 6.12% fat and 4.47% protein within the year 2030.

**History behind Danish Jersey**

In 1896, Jørgen Laursen imported the first J cattle to Denmark from the Jersey island (Lampe & Sharp, 2019). Since then, the number of J cows has increased substantially and there are now 70.000 J cows in Denmark. In the year of 1900, export of Danish agricultural products represented almost half of the total Danish exports. Among these butter was of great significance, the high sale of butter derived from Danish butter being judged as the highest quality at the World's Fair in London in 1879. The grading led to a growing demand for Danish butter in Britain, and higher demand for cows in Denmark yielding high milk fat. Following 1983, protein became important as well, and a change towards increased protein content was needed (Lampe & Sharp, 2019). To meet the demand for more protein in the milk, genetics from United States Jersey bulls were imported. Today J consists of about one third United States J genes (Seges, 2021).

### 2.3. Breeding tools

The use of SS can increase the chance of getting heifer from 50 to 90%, compared to CS (DeJarnette et al., 2009). Conception rates are often lower in SS, and have been found to be 5% lower for Danish Red (DR) and 7% lower for J than in CS (Borchersen & Peacock, 2009). Heifers or cows that do getting pregnant with SS often get serviced with CS after a few attempts with SS. A surplus of reproductive animals allows for sale of heifers, or higher replacement rate. Selective allocation of sex also allows breeders to choose the best animals to be dams for the next generation. Earlier simulations have demonstrated improved profitability and reproductive performance by combining beef and sexed semen (Ettema et al., 2017; Olynk & Wolf, 2007).

Beef semen is used to produce animals with good growth potential of high value offspring. Beef x dairy offspring have carcasses of higher value than purebred dairy calves (Ettema et al., 2017; Wolfová et al., 2007). Sexing of semen makes sorting for bull semen possible, it is called Y-Sexed beef semen, and has equivalent chance for getting bull as X-sexed semen (heifer favouring) has for getting a heifer.

Combining SS and BS allows for a genetic improvement at herd level and higher profit from slaughter calves. Sexed semen provides heifers from the genetically best animals increased the genetic improvement, while BS used on the genetically worst cows increase the growth potential slaughter calves. Hence a higher CM is expected per animal despite higher insemination costs (Ettema et al., 2017; Wolfová et al., 2007).

### 2.4. Milk production in Norway

Norway has a strong governmental regulated agriculture production. Milk production is among those which is highly regulated with farm specific milk quotas. The basic milk price is set annually. To achieve a higher milk price one have exploit the premium payment opportunities. One way of increasing income within milking quota is increased concentration of milk and fat in the milk. Norwegian milk production is primarily for the domestic market

Milking quotas exist as an attempt to regulate milk production, avoiding shortage or surplus milk. The prices of the quotas have increased substantially the last years (Figure 2). Milking quotas are bought, regulated, and paid for per litre.

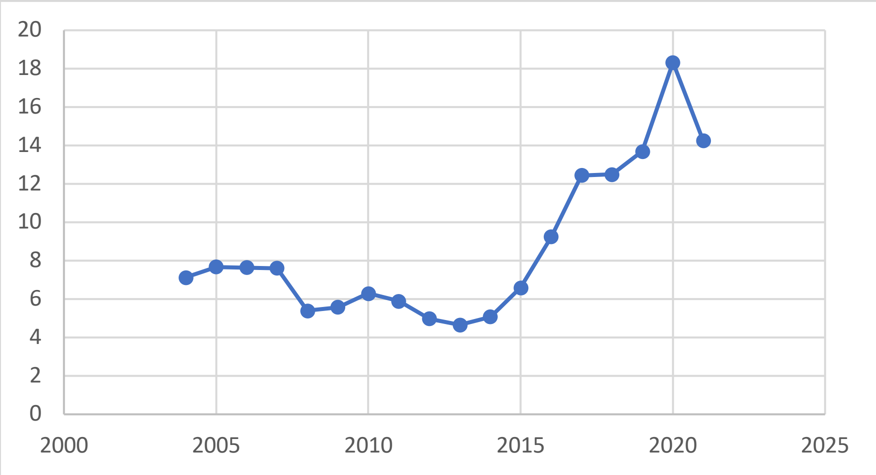


*Figure 2: Development in price of milking quotas from 2004 to 2021, given in NOK/litre (Melkekvoter.no, 2022).*

Milk is bought according to the regulated basis price, plus some quality additions. One litre of standard milk valued 4.40 NOK and is defined as 1l with 4.0% and 3.2% fat and protein. Dry matter premium is added or deducted by 0.09 NOK and 0.06 NOK per 0.1 deviating for standard milk for fat and protein respectively. In addition, there is premium for quality, ecological, delivering summer milk and also based on geography (Tine SA, 2022).

Premium for additional content of solids makes room for extra incomes on the same milking quota. The dairy market in Norway desire increased fat and protein concentration in milk , and is not interested in increasing the quotas (Tine SA, 2020a). By increasing the fat content, one would get a higher income on the same milking quota and ensure a balance between kg fat and kg milk in the dairy industry in Norway (Tine SA, 2020a; Tine SA, 2020c).

## 2.5. Methane emission

Production of methane in the rumen is a loss of energy and it is of great interest in rendering it, both for the animal and the environment (Kristensen & Ingvartsen, 2003). Degradation of carbohydrates in the rumen produces a hydrogen surplus which must be removed. Methane ($CH_4$) is produced in the rumen when free hydrogen and carbon dioxide ($CO_2$) is converted to methane and water (Sjaastad et al., 2016). Feed ration composition affects the methane production within animals, and the number of animals affects total production. High ratio between time in production and dry period and high utilization of nutrients minimizes the methane emission per unit produced (Lehmann et al., 2019).

## 2.6. The SimHerd model

SimHerd is a simulation model developed to help dairy farmers explore the impact of management, breed, disease, and market prices on the CM. The SimHerd model is based on dynamic, stochastic and mechanistic principles. SimHerd is used for research purposes and advisory services giving farm specific decision support. SimHerd was developed in 1992 at Aarhus University and has been used in multiple herd management studies (Clasen et al., 2020; Lehmann et al., 2019; Nielsen et al., 2006; Østergaard et al., 2010).

SimHerd simulates herd dynamics in the dairy production both at animal and herd level. Input parameters related to dairy cow biology and dairy production are inputs for the model which thereafter stochastically simulate the herd dynamics. For example, a reduction of mastitis or increase in milk yield can be compared to a base scenario, and a change in herd dynamics and economy can be estimated. SimHerd have also been used to document and defend bank investments regarding management improvements (SimHerd, 2022).

Economical calculations in SimHerd are calculated as CM. Contribution margins equals the difference between total incomes minus variable costs. Regular expenses not varying with production such as buildings, manpower, depreciation, and interests on loans related to property and other non-varying costs has to be paid for by the CM. After the CM has paid the regular costs what is left is the profit, that can be used for investments to improve the dairy herd.

# 3. Materials and Methods

## 3.1. Survey

A survey containing 42 questions regarding production, feeding, breeding and fertility were given to nine dairy farmers breeding J in Norway. Four out of nine were visited in person, and the five others were contacted digitally. The farmers were divided in two groups. The first group consisted of experienced farmers that had bred J for more than five years, the second group consisted of farmers new to J, that had introduced J in their herd during the last five years. Group one farmers had close to purebred J cows, while farmers in Group two had a mix of NR and J. The goal of the survey was to get an impression on how J cattle are managed in Norway. Perspectives about why they bred J, and how it deviates from the NR was also evaluated.

## 3.2. SimHerd

Simulations were done with the Danish dairy herd model SimHerd (Østergaard et al., 2010). The state of an animal is determined by variables including age, parity, lactation stage, a permanent component of milk yield potential, actual milk yield, body weight, culling status, reproductive status, somatic cell count and disease status. SimHerd simulates values in a 10yr period and print average numbers for the different factors.

**SimHerd scenarios**

The simulation study evaluated the effect of different breed characteristics and breeding management. Here, different combinations using SS and BS in different combinations were evaluated. Comparison of the scenarios was attained by calculating CMs and GHG emissions.

Seven scenarios were compared to NR with no use of SS and BS (NR--) as the base scenario (Table 2). Danish Jersey in Norway lacked data, so the J inputs equals DJ in Norwegian production properties. The parameters transposed was disease frequency, production traits, fertility traits and mortality. Milk quota was regarded the first limiting factor in all scenarios, which decided the number of lactating cows. The simulated herd size was set to 100 annual cows for NR, and 130 for J to maintain same annual milk production in litres.

*Table 2: The simulated scenarios in SimHerd. Eight different breeding strategies for Norwegian Red (NR) and Jersey (J) with sexed semen (SS) and beef semen (BS).*

| ***Strategy*** | **Description** |
|---|---|
| *NR--* | no SS, nor BS |
| *NR-+* | no SS, 25% BS on cows first parity, and 35% BS on second and later parities |
| *NR+-* | 100% SS on heifers, no BS |
| *NR++* | 100% SS on heifers, 70% SS on parity 1 cows, BS on the remaining cows |
| *J--* | no SS, nor BS |
| *J-+* | no SS, 25% BS on cows first parity, and 35% BS on second and later parities |
| *J+-* | 100% SS on heifers, no BS |
| *J++* | 100% SS on heifers, 70% SS on parity 1 cows, BS on the remaining cows |

**SimHerd parameter values**

Data and information on disease, mortality, health, fertility, and production in NR were provided from the NHRS (Tine SA, 2021). Some of the data from the NHRS were prescribed in deviant units and were adjusted to equivalent units for comparison.

Danish Jersey (DJ) was transposed into Norwegian production properties by adjusting for Norwegian management and production properties, in addition to genetic level according to Nielsen et al. (2021). Danish Jersey levers were transposed by assuming the same production ratios between DR and DJ in Denmark, as NR and J in Norway. The difference between DR and NR was accounted for by adjusting genetic levels on the traits yield, female fertility and udder health, while diseases were assumed equal relating to impact of management.

## 3.3. Calibration of SimHerd

SimHerd has a set of default values that are valid for Danish dairy production. The most important variables were changed to reflect Norwegian production and management situations.

**Milk production, breeding, and reproduction**

The SimHerd model uses daily milk yield expressed as ECM and the lactation curve is calculated according to Wilmink (1987). Lactation curves were assumed equal on NR and J. On conception and heat observation rate average national values were used for both breeds on (Østergaard et al., 2005; Tine SA, 2021). The chance of conception using SS was set to 0.90 relative to CS (DeJarnette et al., 2009). The parameter values for milk production and reproduction are presented in Table 3. Number of surplus heifers in NR-+ and SS+BS+ scenarios were simulated equal to make the scenarios economically comparable. All inseminations with BS are Y-sexed beef semen, and sex distribution was set to 90/10 for bulls and heifers according to DeJarnette et al. (2009).

**Disease and mortality**

For NR, the disease risks were set to average numbers of registered treatments per 100 annual cows in Norway (Tine SA, 2020b). For J, numbers were based on the transposed J which is based on Danish data adjusted for Norwegian production properties (Sørensen et al., 2018). Parameter values of disease incidences are presented in Table 4.

**Labour requirement**

SimHerd uses input parameters on time consumption (hours per work task) related to calving, milking, feeding and disease treatment. Due to shortage of Norwegian data, data from the Danish national advisory service (Seges, 2015) was used. It was assumed that the cows were milked twice a day in a milking stall. Inclusion of labour requirement reveals changes in demand for work and includes a dimension as number of youngstock and milking cows may differ. Costs related to work hours is not included in the model, and must be paid by the CM.

**Culling Decisions**

In the simulations, the herd size is maintained over time. Cows were culled involuntary due to disease or voluntary due to infertility or low milk yield. Cows on the culling list were replaced with a calving-ready replacement heifer. If there were no cows ready for culling, the surplus of replacement heifers was sold as springing heifers. When herd size deviate to much from the set value and there was no heifer ready to replace a culled cow, the model would purchase a springing heifer for the same prices as selling heifers. The rate of voluntary culling was set to 20.5% for NR and 10% for J (Table3).

**Feeding and feed efficiency**

The feed requirements in SimHerd are based on specific factors related to the animals, and is based on Danish feeding standards (Strudsholm et al., 1999). Dry matter intake capacity is predicted using exponential functions from Strudsholm et al. (1999) which to a certain extent have the same shape as a Wilmink lactation curve (Wilmink, 1987). Both breeds were assumed fed a total mixed ration (TMR) indoor the entire year. The feed intake capacity is affected by days in milk, daily milk yield and breed. SimHerd does not model fattening of bulls and crossbred calves for beef production, these are instead assumed to be sold at 14 days of age. However, the GHG emissions from the sold animals were calculated separately since they originate from the herd. SimHerd uses a variety of feed conversion factor (ratio between milk production and feed intake) as an indicator for feed efficiency. Value for NR and J were calculated in NorFor and set to 1.42 and 1.55 respectively (Volden, 2011).

## 3.4. Input variables in SimHerd

Table 3 and 4 present key input variables in the SimHerd simulations for production variables and disease variables, respectively.

*Table 3: Input parameters for milk production, still birth, reproduction and, calf mortality, cow mortality for Norwegian Red (NR) and Jersey (J) assumed per year.*

| ***Variables*** | **Unit** | **NR** | **J** |
|---|---|---|---|
| *Peak Yield, first parity* | Kg ECM /day | 26.5 | 24.4 |
| *Peak Yield, second parity* | Kg ECM /day | 30.4 | 28.0 |
| *Peak Yield, older cows* | Kg ECM /day | 32.1 | 29.5 |
| *Stillbirth risk* | % | 3.6 | 5.2 |
| *Calf mortality after birth* | % | 4 | 9.9 |
| *Cow Mortality* | % | 5.0 | 6.9 |
| *Voluntary culling* | % | 20.5 | 10 |
| *Start breeding heifers* | Months | 16.2 | 13.4 |
| *Heat observation rate heifers* | % | 55 | 43 |
| *Conception rate heifers* | % | 79 | 62 |
| *Insemination rate cows* | % | 42 | 44 |
| *Heat observation rate cows* | % | 59 | 57 |

**Disease input**

*Table 4: Presents estimated frequencies for production related diseases for NR and J. Values for Norwegian (NR) based on data from (Tine SA, 2020b), and Jersey (J) calculated (Sørensen et al., 2018).*

| ***Variables*** | **Unit** | **NR** | **J** |
|---|---|---|---|
| *Milk fever* | Incidence per 100- cow-year | 5.0 | 11.0 |
| *Dystocia* | Incidence per 100- cow-year | 9.0 | 5.6 |
| *Retained placenta* | Incidence per 100- cow-year | 1.6 | 0.9 |
| *Metritis* | Incidence per 100- cow-year | 1.5 | 3.0 |
| *Displaced abomasum* | Incidence per 100- cow-year | 0.3 | 0.1 |
| *Ketosis* | Incidence per 100- cow-year | 1.6 | 2.9 |
| *Mastitis* | Incidence per 100- cow-year | 13.8 | 22.6 |
| *Digital Dermatitis* | Incidence per 100- cow-year | 3.4 | 5.5 |
| *Foul in the foot* | Incidence per 100- cow-year | 5.0 | 2.8 |
| *Claw and leg problems* | Incidence per 100- cow-year | 7.2 | 7.2 |
| *Somatic Cell count* | cells per ml (x 1000) | 114 | 130 |

## 3.5. Price inputs

The CMs of the different scenarios were calculated based on income and costs related to milk production, feed, disease treatments, reproduction, culling and sale of animals.

Prices used in the simulations were all equal apart from the prices listed in Table 5. Jersey were assumed to have a higher feed cost than NR. For disease costs, the standard Danish values in SimHerd were used. Feed prices were collected from the Norwegian Grovfôr 2020 project and include harvest costs and machinery costs. Other key prices were gathered from websites and tables (Biosirk Norge, 2022; NorFor, 2021; Nortura, 2022a; Nortura, 2022b; Steinshamn et al., 2020; Tine SA, 2022). All prices given originally in Danish kroner (DKK) was converted to Norske Kroner (NOK), and 1 NOK were set to 0.75 DKK according to the current currency value in January 2022. The prices used in the assignment was gathered early 2022, before the global increase in prices.

*Table 5: Prices for key variables in the model for Norwegian Red (NR) and Jersey (J). Prices is given in NOK.*

| ***Variables*** | **Unit** | **NR** | **J** |
|---|---|---|---|
| *Milk* | per kg ECM | 4.5 | 4.99 |
| *Culling of cows*[1] | per kg | 25.70 | 18.20 |
| *Dead cow* | per animal | - 1 450 | - 1 333 |
| *Springing heifer* | per heifer | 20 000 | 25 000 |
| *Non-pregnant heifer*[2] | per heifer | 14 113 | 6 708 |
| *Bull calf* | per calf | 1 925 | 300 |
| *Cross-bred heifer calf* | per calf | 2 085 | 800 |
| *Cross-bred bull calf* | per calf | 4 170 | 1 925 |
| *TMR for lactating cows* | per kg dry matter | 4.0 | 4.2 |
| *TMR for dry cows* | per feed unit[3] | 3.8 | 4.0 |
| *TMR for cows in summer* | per feeding unit | 3.8 | 4.0 |
| *Milk replacer* | per kg powder | 40 | 42 |
| *Concentrates heifers* | per feed unit | 4.3 | 4.5 |
| *Roughage heifers* | per feed unit | 3.8 | 4.0 |

[1] Price for slaughtering a cow, adjusted for slaughter weight.
[2] Slaughter value on heifer not getting pregnant.
[3] One feed unit equivalent to 1.1kg Dry matter, and to 6.7 MJ net energy lactation. (MJ NEL)

## 3.6. Sensitivity analyses

In all scenarios effects on CM, expressed per cow and year, were investigated by changing prices in milk, meat, heifers, feed, and the parameters on heat observation rate (heifers + cows), conception rate (heifers + cows), milk fever and mastitis, separately. The sensitivity analysis was calculated due to the relative change in response variable relative to the change in the parameter value, and its effect on the CM (Volden, 2011). The parameter values were adjusted by 20% below and above the base value, and the values are listed in Table 6 and 7 for NR and J, respectively. Sensitivity was calculated both on total CM, and CM per cow-year but did not differ. This method of sensitivity analysis makes vertical and horizontal comparisons possible.

$$Sensitivity = \left[ \frac{\left( \frac{rmin - rmax}{rbasal} \right)}{\left( \frac{pmin - p2max}{pbasal} \right)} \right]$$

Where sensitivity is calculated in %, $r_{min}$ and $r_{max}$ are the minimum and maximum response values, $r_{basal}$ is the basal response value. $p_{min}$ and $p_{max}$ are the minimum and maximum parameter values, and $p_{basal}$ is the basal parameter value (Volden, 2011).

*Table 6: Parameter inputs in sensitivity analysis for Norwegian Red.*

| | Unit | Min | Base | Max |
|---|---|---|---|---|
| *Milk price* | NOK | 3.6 | 4.5 | 5.4 |
| *Meat price* | NOK | 20.6 | 25.7 | 30.8 |
| *Heifer price* | NOK | 16000 | 20000 | 24000 |
| *Feed price* | NOK | 3.1 | 3.9 | 4.7 |
| *Heat observation rate* | % | 38.8 | 48.5 | 58.2 |
| *Conception rate* | % | 55.2 | 69.0 | 82.8 |
| *Milk fever* | Incidence per 100- cow-year | 4.0 | 5.0 | 6.0 |
| *Mastitis* | Incidence per 100- cow-year | 11.0 | 13.8 | 16.6 |

*Table 7: Parameter inputs in sensitivity analysis for Jersey.*

| | Unit | Min | Basis | Max |
|---|---|---|---|---|
| *Milk price* | NOK | 4.0 | 5.0 | 6.0 |
| *Meat price* | NOK | 14.6 | 18.2 | 21.8 |
| *Heifer price* | NOK | 20000 | 25000 | 30000 |
| *Feed price* | NOK | 3.3 | 4.1 | 4.9 |
| *Heat observation rate* | % | 34.8 | 43.5 | 52.2 |
| *Conception rate* | % | 47.6 | 59.5 | 71.4 |
| *Milk fever* | Incidence per 100- cow-year | 8.8 | 11.0 | 13.2 |
| *Mastitis* | Incidence per 100- cow-year | 18.1 | 22.6 | 27.1 |

## 3.7. Methane emissions

Methane from enteric fermentation was calculated based on Nielsen et al. (2013) for milk production in SimHerd, and according to Nes (2007) for youngstock sold out of the herd. The enteric methane emission in SimHerd were calculated in gram methane per kg ECM and included enteric methane emissions from recruitment heifers, milking cows and heifers for sale. The SimHerd output of purebred bulls and crossbreds sold model, were used as input in the calculations of enteric methane produced from the youngstock sold from the herds. The enteric methane emissions were calculated in kg $CH_4$ per kg body weight. Age and slaughter weights of bulls used in the calculations are presented in Table 8. All crossbred animals were assumed to be bulls both on NR and J.

*Table 8: Values used when calculated methane production on meat producing animals on Norwegian Red (NR) and Jersey (J).*

| ***Animal*** | **Slaughter age** | **Weight at slaughtering** |
|---|---|---|
| | Months | kg |
| *Purebred Bull NR* | 16 | 300 |
| *Purebred Bull J* | 24 | 250 |
| *Crossbred bull NR* | 16 | 350 |
| *Crossbred bull J* | 19 | 300 |

# 4. Results

## 4.1. Survey

All the nine dairy farmers answered all 42 questions in the survey. The proportion of J cattle in their herd ranged from 15% to 97% averaging 88.4% and 42.4% for experienced and new, respectively (Table 9). The average milk fat and protein content among the experienced J farmers ranged from 6.1 - 6.7 % and 4.1 - 4.3%, respectively. In the new J farmers herds, the fat and protein content ranged from 4.1 - 5.6 % and 3.5 - 4.1%, respectively, and corresponded with share of J in their population.

The high concentration of solids in milk was mentioned as an important reason for having J by all the J farmers. In addition, the farmers included economy, feed efficiency, favourable animal size and good temperament as important factors for breeding J. The J farmers highlighted that the J cow was flexible to changes in feed composition and suitable for grazing. All the farmers stated that the J breed was intentionally chosen.

Several of the experienced J farmers were selling cows and heifers. The selling price ranged from 16 000 NOK to 35 000 NOK, with an average value of 28 000 NOK. The farmers predicted the future heifer market differently, the opinion ranged from much lower prices than today, to a market with equivalent prices as currently. The farmers highlighted earlier inseminations, more vulnerable calf raising, lower fertility and challenges with body temperature after calving when asked how J calves deviate from NR calves.

Most of the J farmers in the survey used BS in their strategy for breeding management. The most frequently used beef breeds were Aberdeen Angus, Charolais, and Limousin. Sexed semen was also frequently used, and insemination of heifers started from 10 to 14 months. Insemination after calving ranged from 42 to 90 days on average, hence the lactations ranged from 310 to 360 days in milk (DIM) in the survey. Results from the survey is listed in Table 9.

*Table 9: Key production information about Jersey (J) farmers. Divided in experienced and new to J group, included standard deviations. All data is about the J production unless other is specified.*

| | **Unit** | **Experienced J** | **SD[2]** | **New J** | **SD** |
|---|---|---|---|---|---|
| *Milking quota* | Litres (x1000) | 442 | 171 | 381 | 198 |
| *Milk yield[1]* | kg ECM | 9064 | 300 | 8749 | 293 |
| *Fat[1]* | % | 6.3 | 0.3 | 4.9 | 0.5 |
| *Protein[1]* | % | 4.2 | 0.1 | 3.7 | 0.3 |
| *Herd size* | Cow-year | 64.6 | 21.2 | 50.8 | 30.4 |
| *Jersey proportion* | % Of herd | 88.4 | 10.8 | 42.4 | 25.7 |
| *Age at first insemination* | Months | 11.6 | 1.5 | 13.0 | 2.6 |
| *Insemination after calving* | days | 59.4 | 12.2 | 64.0 | 24.2 |
| *Slaughter weight* | kg | 198.5 | 27.2 | 197.5 | 3.5 |
| *Slaughter class* | EUROP | P+ | | P+ | |
| *Fat score* | EUROP | 2+ | | 2+ | |
| *Heifers sold per year* | Animals | 25.8 | 10.1 | 0.7 | 1.2 |

[1] Milk production is from both NR and J.
[2] Standard deviation

Both groups of farmers had high focus of forage production, feed quality, and feeding management (Figure 3 and 4). On average, the experienced and new J farmers deviated little in their emphasis on feeding (Figure 3). New J farmers emphasised energy value, and neutral detergent fibre (NDF) higher than the experienced. Correct concentrates and milk yield were comparatively of higher priority among the experienced farmers. Both the experienced and new group had broad focus in their feed production.

The J farmers claimed to have multiple traits in their emphasise on breeding. Emphasis in breeding among the farmers in the survey is illustrated in Figure 4. Milk yield, cow exterior and meat were equally emphasised in the breeding among the two groups. The New J farmers weighted temperament and hoof and leg health higher than the experienced. Both groups had a broad focus in their feeding and bred for multiple traits.

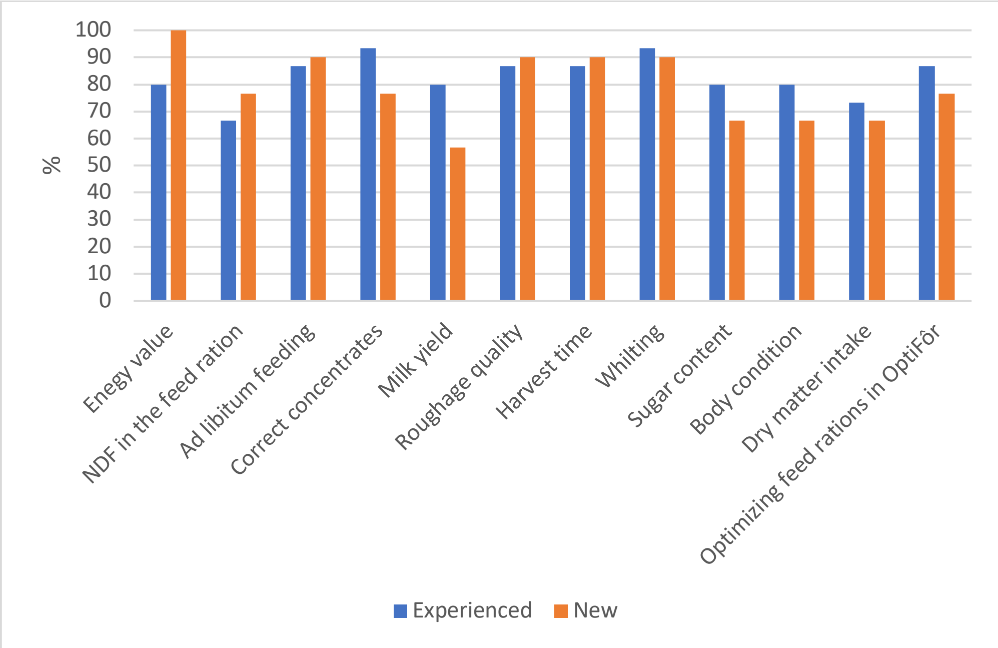


*Figure 3: Illustrates how Jersey farmers emphasise their focus on feeding. Percentage of farmers in experienced group and new group focusing on the different factors. Y-axes indicate what % of the farmers that took the applicable factors on the x-axis into consideration in the feeding and feed planning.*

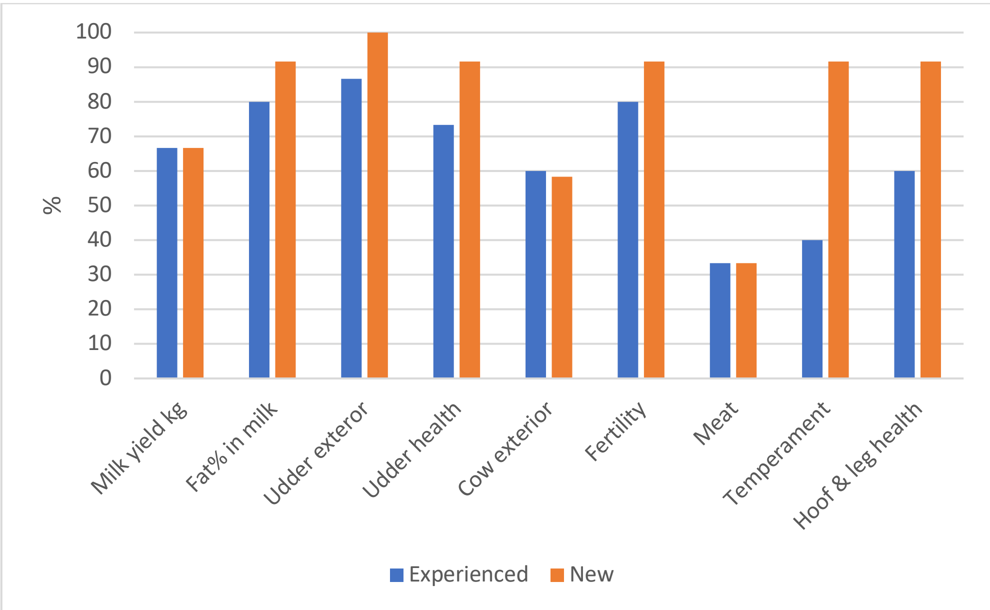


*Figure 4: Illustrates how experienced and new Jersey farmers emphasise traits in their breeding.*

## 4.2. SimHerd simulations

**Herd dynamics**

In the simulations the aim was to fill the farm quota. This resulted in different number of lactating cows for NR and J due to different milk yield on 808 ton for NR and 630 ton for J when keeping 100 cows of both breeds. Number of J cows were increased by 30 cows to maintain equivalent milk yield as 100 NR cows. Different number of dairy cows also increased number of youngstock and impacted the herd dynamics (Table 10). The labour requirement increased when number of cows increased.

Reduced replacement rates on J increased the proportion of third and older parity cows and the sale of youngstock (Table 10). The replacement rate ranged from 31% to 46% and were on average 42% on NR and 34% on J and were affected of voluntary culling. Scenarios having high replacement rates had lower number of sold heifers and higher amounts of heifers in the herd. The NR+- and J+- scenarios have the highest numbers of heifers sold and the NR++ and J++ have the highest numbers of crossbred bulls sold. Use of beef semen moved slaughtered bulls to slaughtered crossbred bulls. The 305-day yield in ECM differed 7-9% between the two breeds.

*Table 10: Simulated herd dynamics using different strategies for breeding management using (+) or not using (-) sexed semen (SS) or beef semen (BS). Norwegian Red (NR) and Jersey (J) with four breeding scenarios are all presented. Number of animals is adjusted to 100 and 130 cow years.*

| | **NR--** | **NR-+** | **NR+-** | **NR++** | **J--** | **J-+** | **J+-** | **J++** |
|---|---|---|---|---|---|---|---|---|
| *Cows (no.)* | 100 | 100 | 100 | 100 | 130 | 130 | 130 | 130 |
| *First parity cows* | 36 | 36 | 40 | 38 | 41 | 42 | 46 | 45 |
| *Second parity cows* | 23 | 24 | 25 | 24 | 29 | 29 | 31 | 31 |
| *Third and older parity cows* | 39 | 40 | 35 | 36 | 58 | 59 | 52 | 55 |
| *Calves < 6 months* | 28 | 23 | 51 | 27 | 33 | 26 | 58 | 29 |
| *Calves 6 - 12 months* | 26 | 21 | 50 | 25 | 30 | 23 | 58 | 26 |
| *Heifers > 1 year* | 60 | 47 | 118 | 60 | 62 | 49 | 124 | 57 |
| *Young stock* | 113 | 90 | 219 | 113 | 126 | 98 | 240 | 113 |
| *Surplus heifers sold* | 4 | 0 | 41 | 2 | 8 | 1 | 50 | 2 |
| *Purebred bull calves sold* | 56 | 43 | 11 | 6 | 68 | 24 | 13 | 7 |
| *Crossbred calves sold* | 0 | 19 | 0 | 46 | 0 | 24 | 0 | 64 |
| *Replacement rate (%)* | 41 | 38 | 46 | 41 | 34 | 31 | 38 | 34 |
| *305d ECM yield (kg)* | 8517 | 8457 | 8586 | 8497 | 7805 | 7746 | 7853 | 7768 |
| *Labour requirement (hours per week)* | 67 | 62 | 83 | 66 | 84 | 78 | 100 | 81 |

**Disease frequencies**

The total number for disease treatments per 100 cows was 45 and 62 for NR and J respectively (Table 11). The most prevalent diseases were milk fever, mastitis, dystocia and hoof and leg diseases. Treatments of ketosis and hoof and leg diseases were similar between the breeds two breeds. Jersey had higher cow and calf mortality than NR. Most of the variation in disease frequency derive from breed, as there is little variation between scenarios.

*Table 11: Simulated disease frequencies and mortality on Norwegian Red (NR) and Jersey (J).*

| | **NR--** | **NR-+** | **NR+-** | **NR++** | **J--** | **J-+** | **J+-** | **J++** |
|---|---|---|---|---|---|---|---|---|
| *Milk fever treatments per 100 cow-year* | 5 | 5 | 5 | 5 | 14 | 14 | 13 | 12 |
| *Mastitis treatments per 100 cow-year* | 10 | 10 | 10 | 10 | 20 | 19 | 19 | 18 |
| *Hoof and leg disease treatments per 100 cow-year* | 8 | 8 | 8 | 8 | 9 | 8 | 8 | 8 |
| *Ketosis treatments per 100 cow year* | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| *Dystocia per 100 cow year* | 10 | 10 | 8 | 10 | 7 | 7 | 5 | 7 |
| *Total disease treatments simulated per 100 cow year*[1] | 45 | 45 | 43 | 45 | 62 | 62 | 59 | 64 |
| *Stillbirth (%)* | 6.8 | 5.8 | 5.8 | 6.8 | 8.2 | 8.5 | 7.0 | 8.4 |
| *Cow mortality (no.)* | 6.8 | 6.8 | 6.7 | 6.8 | 10 | 9.9 | 9.8 | 9.7 |
| *Calf mortality (no.)* | 4.0 | 4.0 | 4.0 | 4.0 | 9.4 | 9.4 | 9.4 | 9.4 |

[1]Milk fever, dystocia, retained placenta, metritis, displaced abomasum, ketosis, mastitis, digital dermatitis, foul in the foot, claw and leg problems.

**Economic calculations**

Incomes and costs from dairy production on two distinct breeds and four different strategies for different breeding management are presented in Table 12. Difference between incomes and expenses corresponds to CM and is given both in total CM and CM per cow-year. The main incomes derive from milk incomes in all scenarios. Norwegian Red-+ is and NR++ is the only scenarios attaining lower CM than NR--. Jersey+- have 673 000 NOK higher CM than NR-- and have the highest CM in the simulation study. Jersey has lower incomes from sale of meat despite 30% more cows. Norwegian Red seems to have lower impact of strategy for breeding management than DJ.

The NR+- and J+- scenarios base their production on sale of heifers and have the highest costs in the simulation study. Production of heifers increase the herd size, workload, costs to insemination and other costs. Feed costs constituted for 88% and 87% of the total costs on NR and Jersey, respectively. Jersey has higher number of animals and higher costs all over. Treatment costs is substantially higher on J than on NR. Least square difference (LSD) of 6000 NOK on total CM and 62 NOK per cow-year indicate significant difference from other scenarios. Except for NR-+ on CM per cow-year all the scenarios in both total and per cow-year differs significantly from each other, thus changes due to breed and strategy for breeding management has significant impact on the CM.

*Table 12: Incomes, expenses and CM per year in 1000 NOK if not specified. In a herd with a milk quota of 808.000l of milk. The results are given in deviation from first column (NR--), which is assumed as basis production. Simulated for scenarios on Norwegian Red (NR) and Jersey (J).*

| | NR-- | NR-+ | NR+- | NR++ | J-- | J-+ | J+- | J++ |
|---|---|---|---|---|---|---|---|---|
| *Milk* | 3661 | -78 | 69 | -23 | 1194 | 1110 | 1248 | 1132 |
| *Culling of cows* | 514 | -46 | 89 | -10 | -308 | -327 | -262 | -298 |
| *Calves* | 105 | 39 | -84 | 66 | -85 | -52 | -101 | 11 |
| *Heifers* | 166 | -98 | 840 | -39 | 88 | -110 | 1235 | -78 |
| *Total income* | **4446** | **-183** | **914** | **-4** | **890** | **621** | **2120** | **777** |
| *Feed cows* | 2423 | -48 | 42 | -14 | 319 | 274 | 347 | 289 |
| *Feed young stock* | 660 | -160 | 670 | -40 | 94 | -100 | 838 | 10 |
| *Treatments* | 54 | -2 | -5 | -2 | 37 | 35 | 29 | 35 |
| *Inseminations* | 68 | -9 | 102 | 21 | 49 | 13 | 120 | 40 |
| *Other costs* | 242 | 54 | 50 | 10 | 49 | 99 | 113 | 71 |
| *Costs in total* | **3448** | **-165** | **850** | **-25** | **549** | **322** | **1448** | **453** |
| *CM per year* | 998[a] | -18[b] | 56[c] | 20[d] | 341[e] | 299[f] | 673[g] | 324[h] |
| *CM per cow-year*[1] | 10114[a] | -40[a] | 450[b] | 244[c] | 379[d] | 154[e] | 2884[f] | 299[g] |

[1]Given in NOK not given in 1000 NOK.
LSD for CM per year is 6000 NOK.
LSD for CM per cow-year is 62NOK.
Letters in superscript defines significant differences between scenarios. Values with the same superscript are not significantly different.

## 4.3. Sensitivity analysis

The sensitivity analysis is based on the results from SimHerd, where the effect of breed and strategy for breeding management was tested. Simulated CMs with min and max values adjusted 20% below and above average value is presented in Table 6 and 7 for NR and J, respectively. The different impacts of the selected variables effect on the CM ranged from 2.3% to 379% between variables and indicate that some prices are crucial and sensitive to the overall CM. Milk and feed price is the most sensitive variables and a 20% change in price impacts the CM with 303-382% and 246-331% for NR and J respectively. Calculated sensitivities also vary between breeds, meat production on NR has an average sensitivity of 52% compared to 17% on J. Feed price sensitivity also differ between breeds and J is less sensitive to feed price changes than NR. J has higher sensitivity for heat observation and conception rate than NR.

Norwegian Red+- and J+- scenarios attain high incomes from sale of heifers and thus have significantly higher sensitivity for heifer prices, compared to NR-+ and J-+ scenarios where CM has a negative sensitivity for change in heifer price. For milk fever and mastitis both have negative impact on the CM, and is more sensitive in J than in NR especially for J. Negative values on sensitivity indicate a negative impact on the CM.

*Table 13: Results of the sensitivity analysis on Norwegian Red (NR) and Jersey (J) in SimHerd to changes in prices to the CM.*

| ***Variable*** | **NR --** | **NR-+** | **NR+-** | **NR++** | **J--** | **J -+** | **J+-** | **J++** |
|---|---|---|---|---|---|---|---|---|
| *Milk price* | 367 | 366 | 352 | 358 | 379 | 382 | 303 | 373 |
| *Meat price* | 52 | 49 | 57 | 51 | 17 | 16 | 17 | 18 |
| *Heifer price* | 8.3 | -8.3 | 81 | 2.2 | 15.5 | -4.1 | 81 | 1.8 |
| *Feed price* | -295 | -283 | -331 | -286 | -262 | -252 | -246 | -252 |
| *Heat observation rate* | 13 | 14 | 24 | 13 | 28 | 25 | 47 | 26 |
| *Conception rate* | 20 | 19 | 38 | 24 | 45 | 39 | 62 | 39 |
| *Milk fever* | -3.7 | -4.0 | -2.3 | -3.4 | -8.9 | -8.3 | -5.9 | -6.9 |
| *Mastitis* | -3.4 | -3.8 | -2.4 | -3.7 | -8.9 | -8.0 | -5.4 | -6.2 |

## 4.4. Methane emissions

Calculated enteric $CH_4$ emission seems to be affected both by breed and strategy for breeding management (Table 14). In the dairy production J on average have 7.5% lower $CH_4$ emissions than NR which corresponds to 1.4g $CH_4$ per kg ECM (Table 14). The NR+- and J+- scenarios have the highest production of $CH_4$ per kg ECM in the dairy production. Within breed, the NR-- and J-+ scenarios have the highest $CH_4$ emission in g per kg ECM in the dairy production. The enteric $CH_4$ from the dairy production seems inversely proportional with enteric $CH_4$ from meat production.

Purebred bulls and crossbred sold from the dairy production were used as input for the calculation of enteric $CH_4$ emissions from meat production. The scenarios having large enteric $CH_4$ emissions in the dairy production have proportional lower emissions in the meat production (Table 14). The NR+- and J+- with the highest emissions in dairy production have lowest in the meat production. The J+- scenario have the highest value for $CH_4$ produced per kg BW. On average, meat production of NR has 20g lower $CH_4$ per kg BW than J in the calculations. Overall production of $CH_4$ is lowest in J+-, and highest in the NR-- scenario.

*Table 14: Calculation of methane emissions for Norwegian Red (NR) and Jersey (J) calves and heifers that is to be used in milk production. Calculated in SimHerd and given in gram methane per kg ECM.*

| | **NR--** | **NR-+** | **NR+-** | **NR++** | **J--** | **J-+** | **J+-** | **J++** |
|---|---|---|---|---|---|---|---|---|
| *Gram $CH_4$ per kg ECM* | 19.6 | 19.0 | 22.9 | 17.0 | 17.8 | 17.1 | 20.7 | 17.4 |
| *Percentage of total $CH_4$ from dairy production* | 80 | 77 | 96 | 79 | 78 | 73 | 96 | 72 |
| *Gram $CH_4$ per kg BW in meat production* | 130 | 126 | 111 | 108 | 116 | 120 | 193 | 126 |
| *Percentage of total $CH_4$ from meat production* | 20 | 23 | 4 | 21 | 22 | 27 | 4 | 28 |
| *Total $CH_4$ emissions on both productions in kg* | 21007 | 20802 | 20527 | 18363 | 17734 | 18803 | 17040 | 18768 |

# 5. Discussion

The goal of the study was to investigate if a production system with J, in combination with SS and BS, will improve the economy and GHG emissions on herd level. Norwegian dairies have in the previous years had a shortage on milk fat and has therefore increased the premium for producing milk with high fat content. In combination with this, Norwegian milk production is unique by having farm specific milk quotas regulated in litres. Jersey produce milk with higher fat and protein concentrations in its milk compared to NR and makes changing breed interesting. To investigate the topic, eight scenarios were evaluated in the SimHerd model, comparing two breeds with four different breeding scenarios, including 130 J and 100 NR to maintain the same milk production. A risk when increasing number of animals is the increased costs and GHG emissions. Jersey breeders are frequent users of SS and BS. To achieve a proper comparison, multiple strategies for breeding management were simulated. A survey among J farmers in Norway were included to bring in positive and negative factors of breeding J in Norway. The results are discussed below.

## 5.1. Survey

The survey with J farmers were done to get an impression of how J are held in Norway. Nine farmers, all suggested by the leader of the Norwegian Jersey association, contributed by sharing their perspectives about breeding J in Norway. Multiple farmers could have been included to make the survey less dependent on few farmers. According to breed statistics in Norway there is 2792 J cows out of total 190 000 milking cows of J, (Tine SA, 2021). The 9 herds in total accounted for a notably share of these.

Production results from J farmers in both NHRS and in the survey were assumed to deviate from average Norwegian dairy production. Considering the results in the survey and the share of Norwegian dairy farmers breeding J (1.5%) compared to NR (91.3%), it was assumed that the few farmers breeding J had higher interest and management level than average. A high interest and management must be separated from breed characteristics to compare breeds and not management level. J farmers probably deviate from the Norwegian average by achieving better results independent of dairy breed.

The validity and credibility of farmers presenting their own production results and achievements were not used as inputs in the simulations. As overestimation of own results might be tempting, so their submitted data were primarily used for comparison. A significant proportion of the data the J farmers was objective data from NHRS. Information from the survey were evaluated and included for further comparing and discussion.

Not all the input values used in SimHerd were in compliance with the survey among the J breeders in Norway. The survey uncovered that J farmers in Norway had higher milk yields, fat and protein contents than both the calculated input values and than NHRS values on J (Tine SA, 2021). They start the insemination of heifers earlier than used as input for SimHerd (Table 3 and 9). This indicates that the farmers in the survey deliver better results than average Norwegian J farmers. Variables such as disease frequencies and slaughter weights were not compared as many of the J farmers did not have all the data available at the time. Higher values for J farmers in Norway is in accordance with earlier assumptions regarding a high management level.

## 5.2. SimHerd

**Simulations in SimHerd**

SimHerd has earlier been recognized as an appropriate method to study simulated executive changes in herds (Clasen et al., 2020; Ettema et al., 2011; Ettema et al., 2017; Lehmann et al., 2019; Nielsen et al., 2006). Distinguishing breed traits from management level is a challenge, but crucial to maintain a proper comparison of breeds. Lembeye et al. (2015) found that the relative yield of cows increased with increased production level, and were in accordance with Bryant et al. (2007), that found evidence for environment affected the expressed level of genetics and heterosis. Proper distinguishing between breed and environments is therefore crucial.

The Norwegian herd recording system collects data from Norwegian dairy farmers. In 2021, 91,3% of the cows in Norway were registered as NR, while 1.5% were registered as J (Tine SA, 2021). Based on a considerably higher interest in farming, breeding and production the data from the J farmers in Norway were regarded to not reflect average Norwegian dairy production. The risk of comparing breeds based on entirely different basis, the J data in NHRS were not used. Instead, J were transposed into Norwegian production properties according to Interbull to compare breeds and not management level.

Denmark have higher milk yields and disease frequencies than Norway, and make the comparison of Danish and Norwegian production results unsuitable as inputs in SimHerd (Sørensen et al., 2018; Tine SA, 2021). Therefore, DJ were adjusted from DJ under Danish conditions to fit Norwegian conditions, by comparing Interbull breeding values from Red breeds (Nielsen et al., 2021). Overall, calculation of J from average Danish production to Norwegian were regarded superior to using Danish data or NHRS data. Adjustment according to Interbull is recognized, and earlier implied by Ettema et al. (2011).

**Feed efficiency and metabolism**

Dry matter intake is rarely registered and the feed conversion factor is therefore usually not attainable. Thus the ratio was calculated using the NorFor system (Volden, 2011). NorFor suggested 33% and 39% of concentrates for NR and J, respectively. This corresponds to 23 and 25 kg of concentrates per 100 kg ECM. The higher energy density was accounted for in the feed prices (Table 6), and the lower feed requirement on the same ECM yield was accounted for by adjusting feed efficiency to be 15% higher for J, resulting in a ECM/DMI value of 1.41 and 1.55 for NR and J respectively (Volden, 2011). The feed efficiency values calculated from NorFor is in compliance with a study by Shetty et al. (2017), which observed lower DMI in J compared to Holstein (H). Jersey and Holstein differ more than 150 kg in BW. Corresponding DMI registrations in NR and J were not found, but the weight difference between the breeds is close to similar. Body weight have earlier been documented to be isometric with rumen-reticulum size in other ruminants (Weckerly et al., 2003), and may explain the lower DMI on Jersey cows. The low DMI and elevated feed costs due to higher energy density on J, compared to H have earlier been recognized by Cunha et al. (2010).

A higher feed efficiency and feed conversion rate is found in J compared to larger breeds in multiple studies. A pasture-based experiment investigating stocking densities, found that J produced more fat and protein per hectare compared to Holstein (Edwards et al., 2019). Shetty et al. (2017) found ECM/DMI ratios of 1.72 and 1.62 for J and H, respectively. Mackle et al. (1996) investigated DMI/solids-corrected milk ratios throughout the grazing season and found values of 1.63 versus 1.49 on J and H. The input value used in SimHerd for J (1.55) might therefore be slightly underestimated.

Jersey cattle have earlier documented higher fat and protein production for the same diet compared to other breeds (Edwards et al., 2019). A study from 1981, found J to have higher uptake of acetate in the udder, which is one of the most important substrates for milk production. Acetate is both used as a energy source and for synthesis of milk fat in the de novo fat synthesis (DNS). This aligns with a higher proportion of milk fat in J milk to derive from DNS (Strudsholm & Sejersen, 2003). Milk fat production in Jersey seems to differ from other breeds, due to deviating metabolism.

**Income and payment system**

In this simulation study J contributed to a higher CMs compared to NR for both CM per cow-year and in total, and when the number of animals was increased to sustain the same total milk yield. Previous studies have compared J and H with adjusted number of animal according to bulk feed (Cunha et al., 2010). This applicable study considered the milking quota more limiting, and therefore adjusted number of animals to quota and not bulk feed. Higher CM on J compared to NR aligns with previous studies comparing profitability on J compared to H, under premium pay for fat and protein in milk (Cunha et al., 2010). The study showed that valuation of fat and protein was necessary for J to compete with profitability in H. Lopez-Villalobos et al. (2000) found chemical composition of J milk to be the most profitable breed when producing cheese. Considering the alteration from drinking milk towards products richer in fat, this might be applicable for Norway as well (Tine SA, 2020a). Edwards et al. (2019) investigated different pasture stocking rates, and concluded that in a high stocking rate where feed was restricted, J was more profitable than H. Edwards et al. (2019) encouraged farmers to consider medium- to long-term outlook for milk fat price when choosing dairy breed for their production.

The Norwegian extra pay for solids in milk might not endure forever. Milk in the European Union (EU) is paid for in ECM. Currently the Norwegian system pays artificial high premium for solids in milk, as a consequence of shortage of fat in milk (Tine SA, 2020a). How long the premium pay will endure is unpredictable and might shorten correspondingly with increasing amount of J cows in Norway. Plotting the current payment for milk in Norway with increasing solids in milk against a possible payment for ECM system reveals a large difference between the two systems which favours milk rich in solids. An increase in J cows in the future might balance the dairy market, brace removal of the artificial high milk fat price and the favouring of milk rich in solids.

Milking quotas in Norway regulates production of milk, but pay farmers plentiful for producing high fat and protein concentrations. The regulation is on something else than what is paid for, and make an opportunity to have high incomes on the same milking quota. The European Union removed their milking quotas on the 1st of April 2015, which had prolonged for 30 years. How long the milking quota will endure in Norway, or how it will be regulated in the future remains uncertain.

The NR+- and J+- are the scenarios with the highest CM in this simulation study. The J+- is the scenario containing the highest number of heifers for sale, and generate 1 401 000 NOK from sale of heifers annually, using a conservative price estimate of 25 000 NOK. The sensitivity analysis showed that CM in NR+- and J+- was highly sensitive for heifer prices. Jersey heifers are registered sold for 40% higher price in the survey, and a higher price would favour CM on J further. Jersey heifers are assumed to have low raising costs compared to other breeds as they have high feed efficiency, low BW, and early inseminations. Apart from that, most costs are similar for the two breeds. A value lower than in the survey was set under the assumption that an increase in farmers breeding J will entail better availability of heifers and thus lower the prices.

The NR in contrast to J struggle to get paid for the production potential. Calculations done by Tine in 2019 suggests costs of 18 002 NOK and a price of 27 000 NOK on a good NR heifer (Skartveit & Nesheim, 2019). Even though the normal market price of a NR heifer is closer to 20 000 NOK. Low prices on surplus heifers should investigate if BS is equivalent profitable, although NR+- seems to be more profitable than NR-+. Norwegian red seems to have comparatively lower effect of strategy for breeding management, and might be affected of the more extreme prices on J. Prices are rarely published so there are few references for comparison (Biosirk Norge, 2022; NorFor, 2021; Nortura, 2022a; Nortura, 2022b; Steinshamn et al., 2020; Tine SA, 2022).

The different simulated scenarios does not fit in the same production properties concerning feed, building space, and farm characteristics. Larger amount of milking cows in J combined with J+- strategy and raising of all heifers seize larger indoor and outdoor area than J++ which keep a minimum and sell the rest at 14 days. Comparing multiple J to larger dairy breeds has earlier showed a increase in the energy density in feed, from higher use and cost of concentrates (Cunha et al., 2010), but also have a higher income from selling animals. In Norway you can have maximum one dairy cattle per 0.4 hectare of cultivated land when it comes to production of manure. Other countries like Denmark distinguish between breeds and allow a 15% higher density of Jersey compared to large breeds (Forskrift om Husdyrgjødsel, 2014; Skjold, 2014). Equivalent system for distinguishing between breeds in Norway would most likely increase interest for Jersey in dense areas of domestic animals.

Replacement rate in the simulations ranged within normal variation (Clasen et al., 2020; Nielsen et al., 2006). Replacement rate indicates how large proportion of the dairy cows are replaced annually in percentage. The high replacement rates in NR+- and J+- are explained by the high amount of heifers in the scenario. The lowest replacement rates are found in NR-+ and J-+ where heifer availability is so low that heifers might be bought. Average replacement rate in Norwegian Red and J is 41.5% and 34% and the difference is due to voluntary culling input (Table 3). For NR the voluntary culling inputs were set double as high as Jersey, this was done to reflect average replacement values for the two breeds (Sørensen et al., 2018; Tine SA, 2021). The high voluntary culling rate on NR might derive from breed specific strategy or from lower longevity on NR cows. Higher replacement on NR might also derive from higher share of income from meat compared to J. Low replacement is beneficial due to low requirement of replacement heifers and higher sale of youngstock. A review of optimal productive lifespan in H, a purebred dairy breed, were suggested to 5 years, which corresponds to 20% replacement rate (De Vries, 2020).

Jersey cattle seems to require a higher management level to succeed in production. A Jersey cow would probably yield less than an average J in a NR system. Breeds have specific management requirements and might affect the total production results. A J cow in a NR system would most likely have higher replacement, lower feed energy density and higher disease frequency and mortality in calves than if breeding J in a J herd. Management impacts production and profitability (Hjortø et al., 2015; Olynk & Wolf, 2007).

**Disease frequency**

Jersey has a higher simulated disease frequency compared to NR for all diseases (Table 11). Higher frequencies seems to align with NHRS and the NTM report which record disease frequency on NR and J respectively (Sørensen et al., 2018; Tine SA, 2021). What is registrated as a disease may differ between countries and breeds, and may affect the disease frequency when comparing two countries and two systems. Knapp et al. (2014) documented increased $CH_4$ due to higher disease frequency and involuntary culling.

**Limitations in the simulations**

Simulated values from SimHerd have several limitations and suits when comparing scenarios. Production data and prices make up the foundations for a simulation study and can easily be deviating on either or both breeds. Thus, a sensitivity approach is important when evaluating the results. Norwegian Red had the best availability of data, while J had to be predicted and calculated. Regarding the prior discussion J input data seems rather underestimated than exaggerated, and NR show low effect on CM of different strategy for breeding management. The SimHerd model is based on cows fed TMR, in a milking parlour system and in larger herds than Norwegian. The simulations are based on average values and display an average farm, the results will not align perfectly with individual farms in Norway but gives an estimated picture of the changes. Hence using a recognized model is the best attainable.

## 5.3. Sensitivity analysis

Performing a sensitivity analysis makes selection of relevant variables decisive for the result. Therefore, the same variables were chosen for both breeds, as well as the expected highest costs and incomes for both breeds. Milk, meat, and feed are quantitatively important, and therefore most sensitive. Sensitivities differ in between variables and between breed and strategy for breeding management. Milk price and feed price and the interaction have earlier been found to impact the profitability largely (Cunha et al., 2010; Edwards et al., 2019; Lopez-Villalobos et al., 2000).

Milk price is a quantitatively important variable highly sensitive to changes. In practical agriculture milk income minus feed cost is often the factor that decides if one will succeed or not. Clasen et al. (2020) investigated the relations between feed and milk price and found, increased milk price favoured the high yielding breeds, whilst increase in feed price favoured lower yielding breed. Increased milk price in our scenario would give the highest increase in CM in Jersey production, as J has the highest sensitivity for milk price. Contrasting if feed price were reduced it would favour NR.

Sensitivity of mastitis and milk fever is higher for J and is explained by higher simulated values for J than NR. Multiple treatments on J induce higher sensitivity on the CM, as the costs related to treatments is a higher proportion of the total costs. Equally on heifers, sale of heifers is more sensitive in scenarios relying highly of incomes from sale of heifers. Fertility traits is also sensitive and is notably sensitive in the scenario selling heifers (NR+- and J+-). Low fertility inhibits production of high value heifers, and thereafter the CM.

## 5.4. Methane emissions

The $CH_4$ emissions from enteric fermentation in dairy and meat production is shown in Table 11. Overall enteric methane production from both dairy and meat production was on average 11.5% higher in NR. Lower GHG production in J compared to large breeds is earlier found in Uddin et al. (2021). The study investigated carbon footprint from animals from cradle-to-farmgate. They found 4.4% higher carbon footprint in milk production, increasing to 10% when accounting for differences in fertility and replacement rate. The simulations showed that J produced less $CH_4$ on a herd level despite having 130 animals compared to 100 NR. Similar results are found by Capper og Cady (2012). The study showed decline in total body mass, water and population energy when using J instead of H. The total emission of $CO_2$ equivalents was reduced by 20% when using J instead of H while maintaining the same production of cheese. The lower $CH_4$ in J than NR despite difference in herd size might derive from lower BW, higher feed efficiency and lower energy demand on J compared to NR.

Riva et al. (2014) found lower $CO_2$-equivalents/kg ECM in J than in H. They stated that lower milk yield, lower DMI, better fertility and lower replacements rate explained lower GHG emission from J cattle. They also reported higher feed efficiency in J compared to in H, which is comparable to the values in the present study based on NorFor calculations. Fertility probably differs less between NR and J than H and J. However, the high GHG emissions in NR+- and J+- keeping high numbers of youngstock have comparable higher $CH_4$ production corresponding with (Riva et al., 2014).

Sex distribution on crossbreds were assumed to be 100% bulls in the simulations. This was set despite the documented sex distribution on 90% bulls and 10% heifers (DeJarnette et al., 2009). The assumption of 100% bulls was set only in methane calculations as slaughter data and feed requirements were unknown. To avoid miscalculations crossbred heifers were assumed crossbred bulls on both NR and J.

## 5.5. General discussion

Danish Jersey was considered to be the most suitable breed for Norwegian farmers regarding the dairy market and dairy quota conditions in Norway. Considering the premium for fat in milk and the milking quota the DJ was chosen to best fit the qualifications. Danish Jersey have the highest fat index and the lowest 305d milk yield index, in addition to high indexes on udder health, longevity, female fertility, milking speed and NTM value compared to other genetic lines (Nielsen et al., 2021). Alteration of premium system or regulations can induce change to another genetic line.

The dual purpose NR have traditionally used CS to service their cows in Norway (Geno, 2022b; Tine SA, 2021). Jersey on the other side has close to 80% SS in their breeding (Tine SA, 2021). Conventional semen on J is almost not obtainable in Norway and is therefore not an alternative. The scenarios using CS in the simulated J scenarios have therefore low practical implication, as it is not possible to implement. The four scenarios were simulated deliberately for proper comparison of the two breeds.

Strategy for breeding management differ on NR and J due to different breeding program and breed traits. Norwegian Red produce high value offspring for both sexes and use NR semen on 93% of animals, and 2.4% SS. Norwegian Red (--) using conventional semen is probably the most common strategy for breeding management for NR farmers. Jersey on the other hand produce high value heifers but low value bulls. Regarding the availability of CS on J, J farmers can only maintain J+- and J++. Comparing the present NR-- to J+- and J++ makes potential for increased CM. A higher work load for 130 J compared 100 NR has to be accounted for. Estimated labour requirement is simulated in the model and assumes milking twice a day. Only 10% of Norwegian dairy cows is milked in milking parlours, bu the estimate also illustrate increase in labour requirement for the 35% of milking cows milked in milking robot systems (Tine SA, 2021).

The beef breed used in dairy crossbreeding affects the profitability, growth potential and dystocia frequency for dairy cattle. Using a larger breed has a expected higher EUROP score and daily weight compared to smaller breeds (Animalia, 2011). A large breed equivalent to Charolais or Limousine was used in the simulations. Despite using large breed in SimHerd, any mentionable increased dystocia frequency is not registered in Table 11. The survey revealed Aberdeen Angus to be the most frequent breed used in crossbreeding. The most frequent breeds used in dairy crossbreeding for J in Denmark is Danish Blue, Angus and Charolais. In Norway, semen from Danish Blue is not obtainable and therefore not relevant for Norwegian dairy farmers (VikingGenetics, 2021). Some slaughterhouses in Norway pay additional for Aberdeen Angus and makes it relevant for dairy crossbreds. To avoid different price calculation systems on large breed compared to Aberdeen Angus that was not included. Breed affects the meat production but does not seem to induce higher dystocia frequency.

Prolonging of the current payment system most likely depend on the Norwegian dairy market and the relation between fat and litres produced by farmers. A continuation of the current situation where consumers eat more fat rich products than before and farmers do not change their production, the favourable system for J can endure (melk.no, 2022). However if the system changes the J will loose its large benefit. As both the milk pricing system and the milk quota system is favourable for J, a change will be a perceptible for the profitability on J. Alteration of paying systems might challenge prevalence of Jersey in Norway, but the documented high feed efficiency would make J an efficient and environmental friendly cow anyhow. Wolf (2010) investigated the milk-to-feed price ratio as proxy for dairy farm profitability and as J have comparatively higher feed efficiency than other breeds it will in the future be a strong candidate among the most profitable dairy cows.

# 6. Conclusion and further perspectives

In summary the simulation study estimates a transition to Jersey will improve profitability and reduce GHG emissions on a herd level. To maintain the same milk production, 100 NR cows were compared to 130 Jersey cows. The contribution margins were higher for Jersey than Norwegian Red both before and after increasing number of Jersey cows. Sexed semen and beef semen both impacted the contribution margin significantly, in all combinations but one. The benefits of breeding Jersey derive from short time effects as high heifer prices, long time effects due to high feed efficiency, in addition to the current payment system in Norway. The Norwegian system favour Jersey by allowing higher incomes by producing higher fat and protein concentrations within the same litre quota.

Sensitivity analysis uncovered milk and feed price to be the most decisive variables to maintain a high contribution margin. Meat price was sensitive for Norwegian Red, while heifer price was important for Jersey.

Enteric methane production output from SimHerd indicate lower methane emissions in Jersey compared to Norwegian Red divided on energy corrected milk. Enteric methane on meat animals were calculated separately, and the highest emissions varied between scenarios. In total meat and dairy production combined J have the lowest methane production. Furthermore, implication of SimHerd in Norwegian advisory services could simulate results to strengthen decisions for individual farmers to achieve better economical and productional results.

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## Appendix - supplementary tables

Appendix 1: Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red--. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 10113 | 2694 | 17533 | 366.8 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 10113 | 9068 | 11159 | 51.7 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 10113 | 9945 | 10281 | 8.3 |
| Fôrpris | NOK | 3.916 | 3.1328 | 4.6992 | 10113 | 16082 | 4144 | -295.1 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 10118 | 9797 | 10340 | 13.4 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 10118 | 9626 | 10420 | 19.6 |
| Milk fever | NOK | 5 | 4 | 6 | 10113 | 10200 | 10051 | -3.7 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 10113 | 10197 | 10058 | -3.4 |

Appendix 2 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red--. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 998797 | 266032 | 1731561 | 366.8 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 998797 | 895548 | 1102046 | 51.7 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 998797 | 982197 | 1015397 | 8.3 |
| Feedprices | NOK | 3.92 | 3.136 | 4.704 | 998797 | 1588276 | 409317 | -295.1 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 998875 | 964101 | 1021627 | 14.4 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 998875 | 947484 | 1029314 | 20.5 |
| Milk fever | NOK | 5 | 4 | 6 | 998797 | 1007328 | 992429 | -3.7 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 998797 | 1006939 | 992659 | -3.6 |

Appendix 3 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red-+. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 10063 | 2695 | 17432 | 366.1 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 10063 | 9077 | 11049 | 49.0 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 10063 | 10230 | 9897 | -8.3 |
| Feed price | NOK | 3.916 | 3.1328 | 4.6992 | 10063 | 15758 | 4368 | -283.0 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 10063 | 9698 | 10266 | 14.1 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 10063 | 9571 | 10331 | 18.9 |
| Milk fever | NOK | 5 | 4 | 6 | 10063 | 10124 | 9965 | -4.0 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 10063 | 10125 | 9973 | -3.8 |

Appendix 4 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red-+. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 979023 | 262174 | 1695872 | 366.1 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 979023 | 883102 | 1074944 | 49.0 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 979023 | 995215 | 962831 | -8.3 |
| Feedprices | NOK | 3.92 | 3.136 | 4.704 | 979023 | 1533076 | 424971 | -283.0 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 979023 | 937965 | 1001538 | 16.2 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 979023 | 925800 | 1006794 | 20.7 |
| Milk fever | NOK | 5 | 4 | 6 | 979023 | 984685 | 969000 | -4.0 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 979023 | 984311 | 969892 | -3.7 |

Appendix 5 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red+-. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 10618 | 3141 | 18094 | 352.1 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 10618 | 9399 | 11837 | 57.4 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 10618 | 8890 | 12345 | 81.3 |
| Feed price | NOK | 3.916 | 3.1328 | 4.6992 | 10618 | 17638 | 3597 | -330.6 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 10618 | 10026 | 11030 | 23.6 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 10618 | 9660 | 11262 | 37.7 |
| Milk fever | NOK | 5 | 4 | 6 | 10618 | 10684 | 10587 | -2.3 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 10618 | 10662 | 10559 | -2.4 |

Appendix 6 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red+-. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 1059587 | 313478 | 1805696 | 352.1 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 1059587 | 937956 | 1181218 | 57.4 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 1059587 | 887217 | 1231957 | 81.3 |
| Feedprices | NOK | 3.92 | 3.136 | 4.704 | 1059587 | 1760205 | 358969 | -330.6 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 1059587 | 999441 | 1101404 | 24.1 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 1059587 | 963104 | 1124406 | 38.1 |
| Milk fever | NOK | 5 | 4 | 6 | 1059587 | 1066205 | 1056422 | -2.3 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 1059587 | 1064087 | 1053608 | -2.5 |

Appendix 7 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red++. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 10324 | 2927 | 17722 | 358.3 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 10324 | 9280 | 11369 | 50.6 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 10324 | 10279 | 10370 | 2.2 |
| Feed price | NOK | 3.916 | 3.1328 | 4.6992 | 10324 | 16220 | 4429 | -285.5 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 10324 | 10005 | 10554 | 13.3 |
| Conceptionrate heifers+cows | NOK | 69 | 55.2 | 82.8 | 10324 | 9742 | 10727 | 23.9 |
| Milk fever | NOK | 5 | 4 | 6 | 10324 | 10424 | 10284 | -3.4 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 10324 | 10367 | 10214 | -3.7 |

Appendix 8 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Norwegian Red++. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.5 | 3.6 | 5.4 | 1014758 | 287652 | 1741864 | 358.3 |
| Meat price | NOK | 25.7 | 20.56 | 30.84 | 1014758 | 912105 | 1117412 | 50.6 |
| Heifer price | NOK | 20000 | 16000 | 24000 | 1014758 | 1010269 | 1019249 | 2.2 |
| Feed price | NOK | 3.92 | 3.136 | 4.704 | 1014758 | 1594184 | 435333 | -285.5 |
| Heat observation rate heifers+cows | NOK | 48.5 | 38.8 | 58.2 | 1014758 | 983247 | 1036465 | 13.1 |
| Conception rate heifers+cows | NOK | 69 | 55.2 | 82.8 | 1014758 | 957505 | 1053310 | 23.6 |
| Milk fever | NOK | 5 | 4 | 6 | 1014758 | 1024992 | 1011365 | -3.4 |
| Mastitis | NOK | 13.8 | 11.04 | 16.56 | 1014758 | 1018575 | 1004260 | -3.5 |

Appendix 9 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey--. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 9930 | 2407 | 17452 | 378.8 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 9930 | 9583 | 10276 | 17.4 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 9930 | 9621 | 10238 | 15.5 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 9930 | 15124 | 4735 | -261.6 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 9930 | 9335 | 10442 | 27.9 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 9930 | 8921 | 10693 | 44.6 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 9930 | 10142 | 9787 | -8.9 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 9930 | 10105 | 9752 | -8.9 |

Appendix 10 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey--. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 1282297 | 310874 | 2253721 | 378.8 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 1282297 | 1237556 | 1327039 | 17.4 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 1282297 | 1242497 | 1322097 | 15.5 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 1282297 | 1953081 | 611514 | -261.6 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 1282297 | 1204635 | 1349871 | 28.3 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 1282297 | 1150425 | 1382082 | 45.2 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 1282297 | 1310574 | 1263801 | -9.1 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 1282297 | 1305867 | 1259230 | -9.1 |

Appendix 11 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey-+. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 9777 | 2311 | 17244 | 381.8 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 9777 | 9462 | 10093 | 16.1 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 9777 | 9857 | 9698 | -4.1 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 9777 | 14705 | 4850 | -252.0 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 9777 | 9190 | 10161 | 24.8 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 9777 | 8819 | 10340 | 38.9 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 9777 | 9912 | 9586 | -8.3 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 9777 | 9876 | 9564 | -8.0 |

Appendix 12 Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey-+. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 1250186 | 295539 | 2204833 | 381.8 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 1250186 | 1209890 | 1290482 | 16.1 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 1250186 | 1260326 | 1240046 | -4.1 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 1250186 | 1880177 | 620195 | -252.0 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 1250186 | 1169147 | 1303003 | 26.8 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 1250186 | 1120343 | 1325914 | 41.1 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 1250186 | 1267182 | 1225396 | -8.4 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 1250186 | 1263279 | 1221925 | -8.3 |

Appendix 13 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey+-. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 12475 | 4904 | 20045 | 303.4 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 12475 | 12062 | 12887 | 16.5 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 12475 | 10436 | 14513 | 81.7 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 12475 | 18600 | 6349 | -245.5 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 12475 | 11061 | 13428 | 47.4 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 12475 | 10648 | 13758 | 62.3 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 12475 | 12650 | 12356 | -5.9 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 12475 | 12576 | 12308 | -5.4 |

Appendix 14 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey+-. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 1619549 | 636712 | 2602385 | 303.4 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 1619549 | 1566006 | 1673092 | 16.5 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 1619549 | 1354894 | 1884204 | 81.7 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 1619549 | 2414813 | 824285 | -245.5 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 1619549 | 1434583 | 1744431 | 47.8 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 1619549 | 1381072 | 1787417 | 62.7 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 1619549 | 1642554 | 1600405 | -6.5 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 1619549 | 1632826 | 1597654 | -5.4 |

Appendix 15 : Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey++. Response value given in NOK per cow-year.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 10046 | 2557 | 17534 | 372.7 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 10046 | 9687 | 10404 | 17.8 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 10046 | 10009 | 10082 | 1.8 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 10082 | 15145 | 5003 | -251.5 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 10082 | 9382 | 10412 | 25.5 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 10082 | 9115 | 10670 | 38.6 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 10082 | 10149 | 9871 | -6.9 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 10082 | 10137 | 9885 | -6.2 |

Appendix 16 Sensitivity analysis. Effect of 20% decrease and increase on contribution margin in Jersey++. Given in NOK in parameter value and 1000NOK in response value.

| | | Parameter values | | | Response values | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Unit | Basis | min | max | Basis | min | max | Sensitivity % |
| Milk price | NOK | 4.99 | 3.992 | 5.988 | 1291494 | 328775 | 2254213 | 372.7 |
| Meat price | NOK | 18.2 | 14.56 | 21.84 | 1291494 | 1245410 | 1337578 | 17.8 |
| Heifer price | NOK | 25000 | 20000 | 30000 | 1291494 | 1286849 | 1296139 | 1.8 |
| Feed price | NOK | 4.12 | 3.296 | 4.944 | 1296139 | 1947110 | 643245 | -251.5 |
| Heat observation rate heifers+cows | NOK | 43.5 | 34.8 | 52.2 | 1296139 | 1204194 | 1337384 | 25.7 |
| Conceptionrate heifers+cows | NOK | 59.5 | 47.6 | 71.4 | 1296139 | 1170671 | 1370018 | 38.5 |
| Milk fever | NOK | 11 | 8.8 | 13.2 | 1296139 | 1303577 | 1267780 | -6.9 |
| Mastitis | NOK | 22.6 | 18.08 | 27.12 | 1296139 | 1301673 | 1269807 | -6.1 |

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