Norwegian University of Life Sciences
Faculty of Biosciences
Department of Animal and Aquacultural Sciences

Philosophiae Doctor (PhD)
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Alternative systems for Norwegian sheep production: extending fresh meat season and meeting niche market demands

Alternative system for norsk saueproduksjon: Utviding av fersk-kjøt-sesongen og fylling av marknadsnisjer

Muhammad Azher Bhatti

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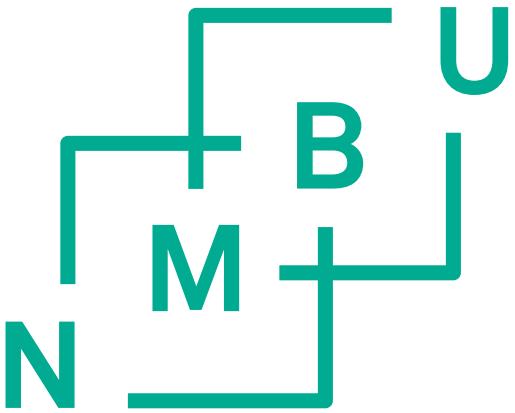
Ås (2020)



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Ås, October 2020

Muhammad Azher Bhatti

Dedication

This thesis is dedicated to my parents – Muhammad Akram Bhatti & Zahida Parveen. Without their support and motivation, it would have been difficult for me to reach up to this level.

Abbreviations

BW	Body weight
MMF	Muslim meat festival / Muslim festival (also called *Eid al-Adha*)
NWS	Norwegian White Sheep breed
NS	Norwegian Spæl breed
GM	Gross margin
HM	Halal meat
HB	Hierarchical Bayesian
EBF	Educated Big Families (1st generation immigrants)
ESF	Educated Small Families (1st generation immigrants)
DYR	Dedicated Young Residents (2nd generation, born in Norway)
BRF	Big Resident Families (2nd generation, born in Norway)
DBF	Dedicated Big Families (1st generation immigrants)
LP	Linear programming

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Summary

Bhatti, M. A. 2020. ***Alternative systems for Norwegian sheep production: extending fresh meat season and meeting niche market demands.*** Norwegian University of Life Sciences, Philosophiae Doctor Thesis, 2020: 49, ISSN: 1894-6402, ISBN: 978-82-575-1715-1.

Norway has the largest sheep population (>1 million winterfed ewes) in Scandinavia. Sheep farming is taken as a part-time activity by most farmers. The focus of this PhD study has been on increasing year-round fresh meat availability, exploring the new niche meat (halal) markets (such as Muslim festivals), and to increase the sustainability of sheep farming (economic analysis) and the meat industry (meat sensory and consumer analysis) in Norway. In paper 1, an overview of the whole Norwegian sheep farming and new niche market is provided. The sheep farming system is adapted to produce most of the lamb crop (slaughtered) over a three- to four-month period from September to December with a peak in September-November. The concentrated slaughtering season has reduced the availability of slaughter animals for rest of the year, thereby limiting year-round fresh meat availability. Additionally, a large quantity of frozen meat (lamb and sheep) has exerted huge pressure on the storage facilities and disturbed the market supply and demand balance. This led to overall lower meat prices and has affected the meat consumers' appeal to and consumption of lamb/sheep meat. To overcome the limited out of season meat supply, a better understanding of the Norwegian sheep farming system as a whole, and some critical factors, is vital for the creation of sustainable sheep meat production. Summer range grazing (90-100 days), winter indoor feeding, and meat market price, are the critical factors to be considered when suggesting any changes in the current practices. In paper 2, based on the Norwegian White sheep breed, linear optimisation was used to compare farm profitability (gross margin) of baseline practices with four different scenarios. The alternative scenarios were delayed lambing, hogget production, 1st lambing when two years old, and ewe longevity increased to 5.3 years with first lambing at two years of age. Hogget meat market price and availability of autumn pasture were the critical factors affecting gross margin for "hogget production" and "delayed lambing" scenarios respectively. Better market prices for the hogget meat

would make it the most profitable production system. Increasing production life for Norwegian white sheep ewes to more than 5.3 years has the potential to produce more lamb meat per live weight of ewes. The calculated amount of concentrate feed used to produce one kg of meat was lower in the case of hogget production since hoggets mostly grazed and were not pregnant. In paper 3, the baseline sheep farming practices and four alternatives were the same as in paper 2, but the farm gross-margin of the two main breeds (Norwegian White sheep and Norwegian Spæl sheep) were now compared. Highest gross margin was calculated for the 4th alternative scenario (ewe production life increased to 5.3 years). The very low input meat prices for the hogget led to a lower gross margin for that alternative. Comparatively the Norwegian Spæl breed produced a higher gross margin compared with the Norwegian White sheep breed. The amount of concentrates used to produce one kilogram of meat was lower for two scenarios: hogget production and production life increased to 5.3 years. In paper 4, meat sensory profile of hogget and lamb meat was investigated with a trained sensory panel using quantitative descriptive analysis evaluated on an unstructured line scale from 1 (lowest intensity) to 9 (highest intensity). In total, 23 sensory attributes were analysed using the meat samples from 50 carcasses of lamb (5-month-old) and hogget (17 months old) of Norwegian White sheep and Norwegian Spæl sheep breeds. An effect ($P<0.05$) of animal age was found for the odour (fried roasted, sheep, and intensity), flavour (fried roasted, gamey, sheep, rancid, and liver), hardness, tenderness, fatness, and coarse fibre structural unit. Some of the flavour, juiciness, and tenderness scores were higher for lambs compared with hogget meat. Compared with Norwegian Spæl, the Norwegian White sheep breed obtained higher scores ($P<0.05$) for sheep odour, hardness and coarse fibre intensity. For the sensory attribute tenderness, Norwegian Spæl lamb, Norwegian Spæl hogget and Norwegian White sheep lamb scored similar while Norwegian White sheep hogget scored lower. Animal age and breed interaction ($P<0.05$) was found only for the fried roasted and gamey odour characteristics. Conclusively, it seems that Norwegian Spæl breed is less affected (in terms of meat sensory quality) by age compared with Norwegian White sheep breed. In paper 5, the purchasing intention for halal meat among Muslim meat consumers in Oslo was investigated by a Choice-Based Conjoint survey using the Sawtooth software. A latent class analysis was used to create consumer segments. The market share of some specific product concepts was re-estimated using a hierarchical

Bayesian approach. The survey results showed that the majority of the meat consumers prefer to buy from halal butchers. In contrast, 2nd generation Norwegian born consumers gave 2nd preference to purchase halal meat from national supermarket chains. Trust is an important aspect when purchasing halal meat, and the market share would increase if the national supermarket chains had a wider range of halal meat products. An integration of halal butcher and national supermarket chains may have the potential to increase the trust and halal meat consumption among Norwegian Muslims.

In conclusion, the Norwegian Spæl breed can be used for hogget production to fulfil the demand for fresh meat and religious festivals, while Norwegian White sheep farming to produce lambs rather than hogget is more profitable if ewe production life is increased to more than five years. The superior meat-eating quality of the Norwegian Spæl hogget should be advertised as a marketing strategy to get a better market price for hogget meat. To gain market share for halal meat, the national supermarket chains in Norway need to adjust their marketing strategy to include some of the services of the traditional halal butchers.

Samandrag

Bhatti, M. A. 2020. ***Alternative system for norsk saueproduksjon: Utviding av fersk-kjøt-sesongen og fylling av marknadsnisjer.*** Noregs miljø og biovitskaplege universitet, Philosophiae Doctor Thesis, 2020: 49, ISSN: 1894-6402, ISBN: 978-82-575-1715-1.

Noreg har den største sauepopulasjonen (>1 million vinterfôra søyer) i Skandinavia. Sauehald er oftast ein deltidsjobb for bønder. Fokus i denne PhD-studien har vore på å auka tilgangen på ferskt sau- og lamme-kjøt gjennom heile året, ved å utnytta nye nisjer i (halal-) kjøtmarknaden (som den muslimske kjøtfestivalen), og å auka bærekrafta til sauehaldet på garden (økonomiske analysar) og til kjøtomsetninga (kjøtkvalitet og marknadsanalyse) i Noreg. I artikkel 1 blir det gitt eit oversyn over heile sauehaldet i Noreg og den nye nisjemarknaden. Til nå har det vore vanleg å slakta dei fleste lamma i ein 3-4 månadars periode frå september til desember, med ein topp i september-november. At slaktesesongen har vore så konsentrert har avgrensa tilgangen på ferskt kjøt gjennom heile året. Dessutan har store mengder frose kjøt (av lam og sau) ført til press på lagerkapasitet og forstyrra balansen mellom marknadstilbod og etterspørsel. Dette har ført til lågare generelle kjøtprisar og redusert konsumentane sin lyst på og bruk av lam og sauekjøt. For å bøta på mangelen på kjøt utanom sesong trengst det ei god forståing av det norske sauehaldssystemet i det heile og av nokre kritiske faktorar, før ein kan foreslå bærekraftige endringar i den nåverande kjøtproduksjonspraksisen. Sommarbeiting i utmark (i 90-100 dagar), innefôring om vinteren, og kjøtmarknadsprisar, er kritiske faktorar ein må ta med i vurderinga når ein foreslår endringar i det nåverande sauehaldet i Noreg. I artikkel 2 brukte ein lineær optimering for norsk kvit sau-rasen for å samanlikna vanleg sauehald med fire alternative driftsformer for økonomien på karakteristiske gardsbruk (med dekningsbidrag). Dei fire alternativa var: utsett lemming, slakting av halvtannaårs søyer (fjorlam), første lemming to år gamle, og første lemming to år gamle, men søyealder auka til 5,3 år. Prisen på fjorlam og tilgang på haustbeite var kritiske faktorar for fjorlam- og utsett lemming-alternativa. Betre pris på fjorlam kunne gjera det til det mest lønsame alternativet. Ved å la norsk kvit-søyene leva til over 5,3 år kan ein produsera meir lammeslakt per vaksenvekt av søyer. Utrekna

mengd kraftfôr per kilo kjøt var lågare for fjorlam fordi dei gjekk på beite og ikkje var drektige. I artikkel 3 brukte ein dei same fem driftsformene som i artikkel 2 for å finna dekningsbidrag på garden og samanlikna begge rasane (norsk kvit sau og spælsau). Det høgaste dekningsbidraget fann ein for den fjerde alternative driftsforma (søyealder auka til 5,3 år). Fordi fjorlamsprisane til garden var svært låge fekk ein lågare dekningsbidrag for det alternativet. Samanlikna med norsk kvit ga spæl høgare dekningsbidrag. Mengd kraftfôr per kilo produsert kjøt var lågare for to alternativ: fjorlam og søyealder auka til 5,3 år. I artikkel 4 evaluerte eit trena sensorisk panel kjøtkvaliteten til fjorlam og vanlege lam etter slakting med kvantitativ deskriptiv analyse på ein ustrukturert lineær skala frå 1 (lågast intensitet) til 9 (høgast intensitet). I alt 23 eigenskapar blei bedømt på kjøtprøver av 50 lammeslakt (5 månadar gamle) og fjorlam (17 månadar gamle) av norsk kvit sau og spælsau. Ein fann effekt ($P<0,05$) av dyra sin alder når det gjaldt lukt (steikt, sau, intensitet), smak (steikt, vilt, sau, harsk, lever), hardheit, mørheit, feitt og fiberstruktur. Nokre skårar for smak, saftigheit og mørheit var høgare for lam enn for fjorlam. Samanlikna med spæl hadde norsk kvit høgare skår ($P<0,05$) for sauelukt, hardheit og fiberstruktur. For mørheit skåra spæl-lam, spæl-fjorlam og norsk kvit-lam tilnærma likt, medan norsk kvit-fjorlam skåra lågare. Samspel mellom alder og rase ($P<0,05$) fann ein bare for steikelukt og viltlukt. For å konkludera ser det ut som om spæl-rasen er mindre påverka (når det gjeld kjøtkvalitet) av alder samanlikna med norsk kvit sau. I artikkel 5 undersøkte ein kva slag halal kjøt muslimar i Oslo hadde til hensikt å kjøpa med ei Choice-Based Conjoint spørjeundersøking der ein brukte Sawtooth programvare. Latent klasse-analyse blei brukt for å etablera forbrukarsegment. Marknadsandelen til nokre spesifiserte produktkonsept blei reestimert med ein hierarkisk Bayes-metode. Undersøkinga viste at dei fleste forbrukarane som var spurde helst ville kjøpa kjøt frå halalslaktarar, medan andregenerasjons norskfødte kjøparar ga andre prioritet til å kjøpa halalkjøt frå matkjedebutikkar. Tillit er viktig når ein handlar halalprodukt. Dersom matkjedebutikkane hadde hatt eit vidare tilbod av halalprodukt kunne dei nok ha fått ein større del av marknaden. Med ein halalslaktar i matkjedebutikken skulle ein kunna vinna tillit og auka halalsalet.

Til konklusjon kan ein seia at spæsau-rasen kan nyttast til å produsera fjorlam som kan tilfredsstilla fersk-kjøt-marknaden og til religiøse festivalar, medan norsk kvit sau-søyer som lemmer første gong ved to års alder med forlenga levetid til over 5 år heller

kan produsera lammekjøt. Kjøtkvaliteten til fjorlam av spæl-rase burde nyttast i marknadsføringa for å få betre pris. For å auka marknadsandelen av halalkjøt treng matkjedebutikkane å ta i bruk noko av det som den tradisjonelle halalslaktaren kan tilby.

List of papers

1. Bhatti, M. A., Williams, T., Hopkins, D. L., Asheim, L. J., Steinheim, G., Campbell, M., Eik, L. O., Wynn, P., Ådnøy, T. (2019). **Adapting Seasonal Sheep Production to Year-Round Fresh Meat and Halal Market in Norway.** *Sustainability*, 11(6), 1554. DOI:10.3390/su11061554

2. Bhatti, M. A., Eik, L. O., Steinheim, G., Ådnøy, T., Horneland, R., Wynn, P. C., Hopkins, D. L., & Asheim, L. J. (2020). **Rangeland grazing strategies to lower the dependency on imported concentrates in Norwegian sheep meat production.** Sustainability, 12(13), 5340. DOI: 10.3390/su12135340

3. Bhatti, M. A., Eik, L. O., Steinheim, G., Ådnøy, T., Hopkins, D. L., & Asheim, L. J. (2020). **Management Strategies to Improve the Economics of Sheep Farms in Norwegian Coastal and Fjord Areas—The Effect of Animal Size and Capacities for Rangeland Utilisation.** Sustainability, 12(9), 3713. DOI:10.3390/su12093713

4. Bhatti, M. A., Øvrum Gaarder, M., Steinheim, G., Hopkins, D. L., Horneland, R., Eik, L. O., & Ådnøy, T. (2020). **Lamb or hogget meat – A different sensory profile? Extending the fresh meat season in Norway.** Small Ruminant Research, 185, 106086. DOI:10.1016/j.smallrumres.2020.106086

5. Bhatti, M. A., Godfery, S., Ryan H. L. Ip., Øvrum Gaarder, M., Aslam, S., Steinheim, G., Wynn, P., Hopkins, D. L., Eik, L. O., & Ådnøy, T. (2020). **An exploratory study of Muslim consumers' halal meat purchasing intentions in Norway.** Manuscript. Accepted revision submitted: Acta Agriculture Scandinavica, Section A – Animal Science

1 Aims and outline of thesis

In Norway, the current seasonal surplus of mutton and lamb meat has led to lower meat price for sheep farmers, thereby making the enterprise less profitable. A profitable sheep farming system, through increased meat consumption by exploring the niche markets, will benefit both sheep farmers and the meat industry. To investigate and address these issues, a parent project "*Fjorlam, eit supplement til tradisjonelle haustlam for Fatlandskonsernet?*" (in English: *Could Fjorlam be a supplement to traditional autumn lambs for the Fatland Group*?) was initiated by researchers at the Norwegian University of Life Sciences and the meat industry enterprise Fatland Ølen AS. To further strengthen the ties between the meat industry and research institutions, an industrial PhD project was started with the below aim and goals.

The main aim of this industrial PhD, from which this thesis originates, was to contribute towards increased sheep industry profitability through comparing sheep feeding systems with a special focus on halal meat value chain development and efficient utilisation of sheep meat products in Norway. The following project goals were set:

- To evaluate different feeding systems in terms of slaughter weight and meat sensory quality
- To undertake economic modelling of different feeding systems with special focus on comparing grass- and concentrate- based systems
- To understand halal meat consumers' meat purchase intentions in Oslo

The goals were investigated through four studies. First, an overview of the Norwegian sheep farming system, slaughtering and meat consumption was produced, with a particular focus on year-round fresh meat availability and niche halal meat market. Second, a sheep farm economic analysis was conducted using linear programming models for the breeds Norwegian White Sheep (NWS) and Norwegian Spæl (NS) to check farm gross margin for current sheep farming practices and four alternative scenarios. Third, the meat sensory quality of lamb and hogget of NWS and NS was checked using a trained sensory panel. Lastly, the halal meat consumers' meat purchasing intentions were investigated by conducting a meat consumer survey in Oslo.

2 Introduction

2.1 Background information

The farming industry, both in Norway and internationally, is facing the challenge of providing enough food for the growing population. In 2015, there were more than 800 million undernourished people (FAO, 2015). About 18% of calories and 25% of proteins consumed globally are from animal-based food sources with high-quality protein and a variety of micro-nutrients (Mottet et al., 2017). Wilkinson (2011), Gerber et al. (2015) and Mottet et al. (2017) have described the following positive and negative impacts of livestock on human food security. Provision of high-quality animal proteins for human food, increasing agricultural productivity by providing manure and draught power, and income from livestock production, provide the positive impacts. Adverse impacts include: use of animal feed formulation based on ingredients that could be used as human food, the use of large land areas for growing animal feed/fodder that may be used to cultivate other directly edible field crops, the low efficiency by which animals, and especially ruminants, convert feed into human-edible protein, and methane production causing global warming. The negative impacts of livestock may be minimised by practising grazing based production systems since non-arable rangeland will not produce other edible crops, and permanent pastures may have beneficial effects on carbon sequestration (Garnett et al., 2017). Moreover, recalculating the efficiencies of energy and protein production, based on human-edible food produced per unit of human-edible feed consumed, gave higher efficiencies for ruminants than for monogastric animals (Gill et al., 2010; Wilkinson, 2011).

Small ruminants for multipurpose use (meat, fibre and browsing) have been introduced in livestock production systems in Norway. Substantial work was undertaken to determine the energy-use in different farming systems (Breirem & T. Homb, 1976; Breirem & A. Ekern, 1979; Breirem et al., 1980; Nedkvitne, 1980; Breirem et al., 1983; Eik, 1991; Ertl et al., 2015). Some general conclusions may be drawn from this work. Firstly, a plant-based diet may sustain more people than a diet rich in animal products. Secondly, compared with ruminants, mono-gastric animals like poultry and pigs are more efficient meat producers for a given amount of digestible nutrients. Still, they compete with man for the same feed resources. Thirdly, ruminants production is efficient, compared to pigs, poultry, when considering the use of alternative resources (that cannot be used as human food) in production systems.

According to Benoit & Laignel (2011), the economic and environmental performance of sheep farms is mostly based on ewe productivity and the level of concentrate feed consumption. Thus, the profitability of production system will increase with decreased consumption of costly feed. Another benefit of a grazing based production system is that the modern affluent consumer prefers meat being produced in an environmental and animal-friendly way (Bernués et al., 2003).

Globally, the trend towards more intensive livestock production systems is likely to increase fossil fuel demand because more outside inputs are required (Sainz, 2003). More intensive production systems may decrease methane emissions per unit of the product since fewer animals are needed. Still, total carbon emissions are likely to increase since more of the inputs will be purchased outside the farm (Sainz, 2003). Based on different livestock production systems, Zervas & Tsiplakou (2012) report 29.4%, 65.2% and 5.3% methane emission (from enteric fermentation and manure management) and 24.3%, 68.1% and 7.6% nitrous oxide emission from grazing, livestock crop complex, and intensive systems, respectively. The detail of methane and nitrous oxide emissions from different livestock species and production system is shown in Table 1.

Table 1. Estimated annual global emissions of methane (CH_4) and nitrous oxide (N_2O) modified form of FAO (2006) and Zervas & Tsiplakou (2012) data as published

	Enteric CH_4 (%)	**Manure CH_4 (%)**	**Total CH_4 (%)**	**N_2O (%)**
Animal species				
Cattle and buffaloes	87.68	44.70	80.38	60.00
Sheep and goats	11.02	1.94	9.48	18.38
Camels	—	—	—	—
Horses	—	5.53	0.94	—
Pigs	1.30	47.83	9.20	11.89
Poultry	—	—	—	9.73
Livestock production system				
Grazing	34.55	4.40	29.42	24.32
Mixed	64.25	70.00	65.24	68.11
Industrial	1.20	25.60	5.34	7.57

Total methane emission by grazing system was lower than mixed livestock production system (29.4% vs 65.2%). However, intensive/industrial livestock production system produced the least amount of methane (enteric and manure) and nitrous oxide (Table 1). It is interesting to note (Table 1) that industrial livestock production system had higher methane from manure

compared with grazing production system (4.4% vs 25.6%). It can be concluded from Table 1 that Green House Gas (GHG) emissions were lower for an intensive production system, but such a system competes for human-edible protein sources.

The importance of the forest as a carbon sink is well known, but more recent studies suggest that grasslands maintained by livestock grazing may also have great potential as a carbon sink (Conant et al., 2001; Retallack, 2013). Also, livestock farming systems play a central role in the management and conservation of high-nature-value farmland, mostly located in less-favoured areas such as mountainous regions in Europe (EEA, 2004). Sustainable livestock farming practises based on livestock grazing have the potential for maintenance of landscapes and biodiversity (Metera et al., 2010).

2.2 Sheep husbandry practices in Nordic countries

Sheep husbandry has been important for the survival of man even before the introduction of agriculture in the Nordic countries (Sweden, Norway, Finland, Denmark and Iceland) especially in Norway (Dýrmundsson, 2006; Agerskov, 2007). Sheep grazing is important for maintaining landscapes and biodiversity worldwide (Milchunas & Lauenroth, 1993). In the North-Atlantic region (defined as the Faroe Island, Greenland, Iceland, Norway and Scotland), the economic importance of livestock grazing has decreased significantly, and sheep husbandry is maintained by state subsidies (Hester et al., 2005). From the early 20th century, traditional sheep production practices changed, influenced by market demands, and meat has become the main product replacing wool and milk.

Failure or success of Norse societies was linked with livestock management strategies (Diamond, 2011) and defining sustainable grazing regimes remains a major challenge due to different opinions about grazing in the Nordic region (Thompson et al., 1995; Mysterud, 2006). Sheep graze in alpine and northern boreal vegetation with a long and harsh winter season with limited pasture available (for 5-6 months) in the whole North-Atlantic region. However, feeding resources are available on some outlying lands during the winter season on Faroe Island and the coastal parts of Iceland and Norway. The sheep number in the entire North-Atlantic region countries vary, and until the 18th century, ancient Norse breeds were dominant in the region. Over the last century, the breeding goals were set for heavier and more productive animals that prefer higher quality and larger quantity of fodder.

The native breeds in the North-Atlantic region are still more similar to the ancient Norse breeds, being lighter in body weight, with low maintenance requirements and may be grazed

on low-quality fodder (Austrheim et al., 2008). Based on the characteristics mentioned above, native breeds may be more sustainable and efficient grazers in the rangelands and are also preferred due to their surviving ability on naturally produced feed resources, thereby maintaining the natural landscapes. The characteristics of the sheep population in Norway, Sweden, Denmark and Finland are presented in Table 2.

Table 2. Characteristics of the sheep population in Nordic countries, a modified form of Vatn (2009) data as published.

	Norway	**Sweden**	**Denmark**	**Finland**
Number of flocks	15000	10000	9200	960
Number of breeding ewes	1000000	220000	113000	57000
Average flock size	67	30	12	60
Main lambing season	April-May	April	March-May	March-April
Prevailing breeds	Norwegian White Sheep, Spæl, Dala, Steigar, Cheviot, Rygja, Pelt sheep	Gotland Pelt, Rya, Swedish Finnish	Texel, Shropshire, Dorset, Oxford Down, Suffolk, Spel	Finnsheep, Kainuuis Gray, Ålands får, Texel, Oxford Down, Dorset, Rygja

Norwegian sheep production system

Norway has the largest sheep population and the highest mutton and lamb meat production in Scandinavia with more than 1 million winter-fed ewes and producing a total of 24403 tons (annual) of lamb and mutton (Åby et al., 2014). About 55% of Norway is mountainous areas (Nersten et al., 1999). Only 3.7% of the total area is arable land in Norway, and 30% of that is used for grains and vegetable production, while the rest of the area can only be used for grass production (Statistics Norway, 2020).

Sheep farming in Norway is not only important for food production, but also for maintaining ecosystem services (Austrheim et al., 2008). The vast landscape grazing resources can accommodate more than double the current sheep population (Nationen, 2012), but Norwegians are eating less red meat, with an average per capita sheep meat consumption of only 5.4 kg (Åby et al., 2014). Norwegian sheep farms vary in flock size from very small flocks (<10 ewes) to large ones (>150 ewes); 36.7% of sheep are found in the >150 ewes flocks, while 48% of the sheep are in medium size (50-149 sheep) flocks (Statistics Norway, 2017).

Sheep farming is usually a part-time activity in Norway, and it must operate within strict environmental restrictions, especially climatic ones. Husbandry practices vary substantially between the seasons: spring, summer/rangeland, autumn, and winter/indoor periods. The majority of lambs including ram lambs (due to welfare reasons, castration of ram lambs is prohibited in Norway) are slaughtered at the age of 4-5 months. Older male animals are kept for breeding purpose only. Thus, in Norwegian sheep husbandry, hoggets are almost exclusively 1-2 year old ewes (Mushi et al., 2008a).

Lambing usually takes place in late April, followed by a short-time indoor feeding and on-farm fenced spring pasture grazing until May/June (Figure 1). Rangeland grazing on unfenced natural pastures is practiced from June until September (approximately 90-100 days) during which most ewes and lambs graze on high-quality mountain rangelands at relatively low stocking rates where 40-50% of the total annual feed is consumed (Asheim & Mysterud, 1999). The slaughtering season starting from August and peak from September until late November.

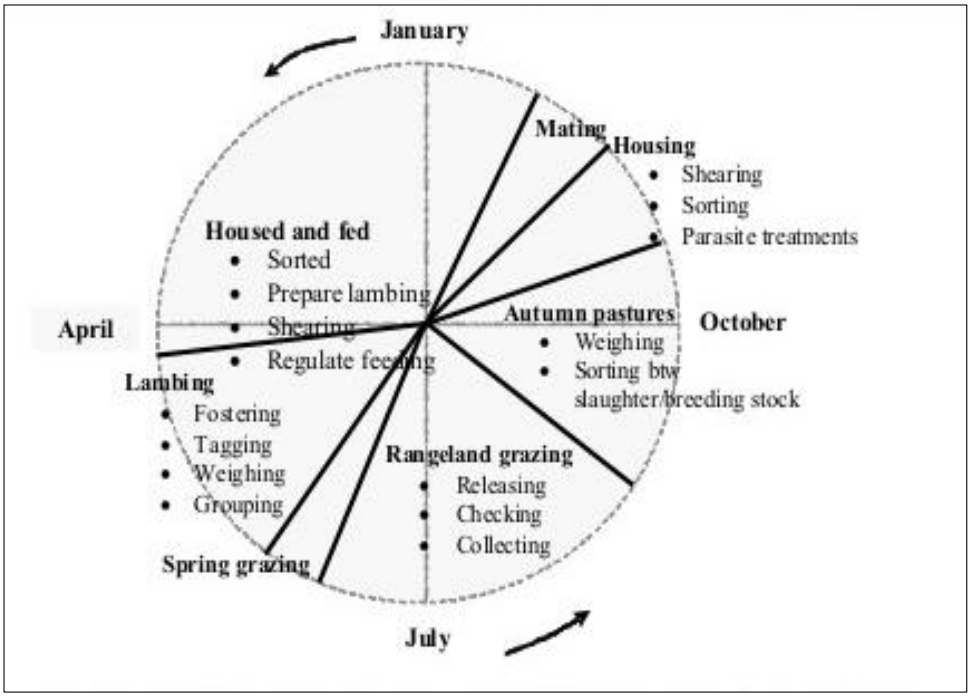

Figure 1. Sheep farm yearly cycle (Hellebergshaugen & Maurtvedt, 1998; Austrheim et al., 2008)

Norwegian Sheep breeds

There are two main sheep breeds in Norway: the Norwegian White Sheep (NWS) and Norwegian Spæl (NS) sheep (Figure 2). The NWS, a composite, prolific dual-purpose breed with adult ewes weighing >85 kg (Lillehammer, 2004), constitutes 70% of the recorded sheep population (Animalia, 2018). The nordic-type, short-tailed sheep "Spæl" is the second most common breed in Norway and makes up 21.5% of the recorded population. Three sub-types (white, coloured, and old Norwegian) may be specified within the Spæl breed. The dual-purpose White Spæl (9.6%) is the most common. Its ewe adult body weight is around 72 kg (Lillehammer, 2004).

Compared with NWS, previous studies indicate that NS stay together in larger flocks (Drabløs, 1997) and cover longer distances on the rangeland pastures (Jørgensen et al., 2016). NS chooses more woody plants in their diet than NWS (Steinheim et al., 2003; Steinheim et al., 2005), potentially making this breed more suitable for managing grazing-affected landscapes, including traditional flowering meadows.

Figure 2. Norwegian Spæl sheep (left) and Norwegian White sheep (right) on farm pasture.
(Photo: Siv Kathrine Holte)

2.2.1 Year-round supply of quality-meat from small ruminants

The Norwegian meat industry has improved and optimised their slaughtering processes in several ways, including electrical stimulation of carcasses, shearing after killing the animal, slow carcass chilling and modified vacuum packaging for long term storage of meat cuts. However, these actions have limitations in terms of capacities at the slaughtering plants. Reducing the supply of slaughter animals in the peak season is likely to give improved meat quality due to less pressure at the chilling facilities both at the slaughterhouse and along the whole value-chain (Hildrum et al., 2000). By facilitating a more even distribution of animals for slaughter throughout the year, the cost of slaughtering will be lower because labour, space and equipment at the slaughterhouses will be better utilised.

The Norwegian mountain sheep-farmers operate within strict environmental boundaries. Animals must be fed in-doors from mid-October to mid-May. Availability of home-grown feeds for the winter is limited due to small farm sizes and a short growing season. High-quality pastures, however, are freely available during the summer months. Therefore farmers seek to optimise the number of lambs per ewe to use rangeland resources and have more lambs ready for slaughter in the fall (Asheim & Mysterud, 1999).

Norwegian inland farmers are facing several constraints that limit their flexibility to expand or diversify compared with farmers along the coast who have more options available. Coastal farmers may graze their sheep in high-mountains during summer, lower-mountains during fall and finally along the fjords during the wintertime. Still, such an adaptation is not common. Like inland farmers, coastal-farmers slaughter the lambs in September, resulting in pressure on slaughtering-facilities and shortage of fresh lamb-meat in the off-season. In the UK, the system is different due to stiff competition from frozen meat imports from New Zealand lamb, "British Lamb" is normally sold fresh. Also, to facilitate the supply of fresh lamb meat, a system of late lambing followed by over-wintering and slaughtering the following spring has a long tradition in the UK. It is contended that for the coastal areas of Norway, well-managed older lambs consuming homegrown feeds can offer an opportunity for the farming industry in terms of cash flow and the sustained supply of quality meat throughout the year. A properly planned hogget production system with perhaps an extended grazing season plus appropriate supplements may improve feed utilisation, profit margins and the environment (Croston & Pollott., 1985; Keady et al., 2007; Chaudhry, 2008).

Norwegian small ruminant farmers receive governmental subsidies for the preservation of natural landscapes and food production based on natural resources. Special price support is

also granted for meat produced in rural areas (Thorvaldsen, 2014). To maintain support for agriculture, it is also important that the processing industry is cost-efficient and provides high-quality products. Consumers' preference for lamb meat will probably increase if it can be documented that it is produced in an environmentally friendly way (Bernués et al., 2003).

Critical challenges for the industry are low demand for sheep meat, surplus sheep meat (frozen) in storage units, the high proportion of concentrate feed required for sheep production systems, criticism of increased emission of greenhouse gases from livestock farming, a short slaughtering season and the management of flocks during winter and the lambing season. The meat production and consumption imbalance through the year create surplus frozen sheep meat. Based on the meat sensory characteristics, fresh meat is preferred over frozen meat (Lagerstedt et al., 2008; Coombs et al., 2017), and a reduced year-round supply of fresh meat has negatively affected the meat consumers' appeal and consumption. The Norwegian halal market has the potential to increase sheep meat consumption and provide an example of alignment of religious authorities and industry by bringing together religious and commercial interests for mutual benefits (Lever & Miele, 2012).

2.3 Muslim consumers, meat festivals and fresh meat availability

Globally, there are 1.6 billion Muslims, accounting for a quarter of the world's population (Grim & Hsu, 2011) and Islam is the second-fastest-growing religion in the world. The Pew Research Centre (2015) estimated that the Muslim population would increase by 73% to reach 2.8 billion by 2050. Grim & Karim (2011) also reported an increasing Muslim population across Europe due to an increase in immigration from the Middle East (Bergeaud-Blackler, 2004; Bonne & Verbeke, 2008). The Muslim proportion of the population is 7.5% in France, 5.8% in Germany, 4.6% in Sweden, 4.2% in Norway (Bolsgård, 2016a), and 4.1% in Denmark (Hackett, 2017).

In Norway, Muslims are the second-largest religious community, after Christians, (Bolsgård, 2016a). The majority of Norwegian Muslims originate from Pakistan (Lever & Miele, 2012), even with the recent influx of Somali refugees (Bolsgård, 2016b). Muslims are expected to constitute 6.1% of the Norwegian population by 2030 (Brunborg & Texmon, 2011), which should increase the demand for halal meat and create a potential for marketing halal food products (Ali, 1996). Norwegian livestock farmers and the meat industry are in a position to utilise this potential, as Norwegian consumers in general, have trust in food items produced locally following the Norwegian food safety laws (Hersleth et al., 2012).

Muslims eat halal meat as a part of their regular diet in addition to the special social occasions (Bonne et al., 2007; Bonne et al., 2008). Halal animal slaughtering differs from non-halal slaughtering with some strict basic requirements that must be fulfilled during the slaughter process.

What is 'halal'?

Halal is an Arabic word that means "permissible" or "allowed" (Wilson & Liu, 2010). According to Islam, all food items are permissible (halal) for the Muslims unless prohibited by "the Quran & Hadith". Permitted food items are called "halal" while those forbidden to eat are "haram". The forbidden foods are mentioned in "the Holy Quran" as:

"He has forbidden you only carrion, and blood, and swine flesh, and that which has been immolated to (the name of) any other than Allah…"

Chapter II, Verse 173

Meat is highly regulated compared to other halal food items. The slaughterer must preferably be a Muslim, or else another follower of a religion of the Book (such as Christians and Jews), of sound mind and age (Riaz & Chaudry, 2003). A prayer ("*Tasmiyyah*") must be recited before cutting the throat of the animal. The prayer consists of saying "*Bismillah*" – (*in the name of Allah*, in Arabic) or "*Bismillah Allahu Akbar*" (*in the name of Allah, Allah is Great*) before cutting the throat of the animal. The knife incision should cut all the neck blood vessels and the trachea and oesophagus, minimising pain experienced by the animal. The spinal cord must not be cut. The knife must be very sharp to induce rapid and complete bleeding leading to death (Riaz & Chaudry, 2003). In most European countries, stunning is performed before slaughtering. Low voltage stunning is recommended because it does not kill the animal (Nakyinsige et al., 2013): death must be caused by blood loss. In Norway, slaughterhouses producing halal meat follow these regulations with help from local Muslim organizations. Meat from sheep and goats is a favourite during festive occasions, at weddings and at the "*Aqiqat*" (celebration of the birth of a baby) (Al-Qaradawi, 1999).

Muslim religious festivals

The meat-eating (lamb) preferences of the Norwegian population, in general, have been investigated (Helgesen et al., 1997; Kubberød, Ueland, Rødbotten, et al., 2002; Kubberød, Ueland, Tronstad, et al., 2002; Hersleth et al., 2012). However, no previous research has focused on meat-eating preferences of the Norwegian Muslim minority.

Muslims across the globe celebrate two main religious festivals, *Eid al-Fitr* and *Eid al-Adha*, each year. These festivals are celebrated by all Muslims irrespective of social status.

The *Eid al-Adha* festival is celebrated to commemorate the faith of the Prophet Ibrahim (Abraham). This festival begins with the slaughtering of animals on the 10th of *Dhu'l-Hijja*, the last month in the Islamic calendar, and lasts for four days. Every Muslim who can afford it must purchase one animal (fresh carcass, animal slaughtered within four days of festival celebrations) for *Eid al-Adha*, preferably a ruminant such as a sheep or a goat (minimum one-year-old), cattle, or camel. The external physical traits of the animal (e.g. colour, beauty) contribute to the market price (Brooke, 1987). In Muslim countries, people routinely purchase animals 1–2 months before the actual slaughter date. A system producing sheep slaughtered at >1 year of age is needed to fulfil the requirements for this festival.

The *Eid al-Fitr* festival is celebrated at the end of the holy month of "*Ramadan*". This festival is celebrated seventy days (two months and ten days, following the Islamic lunar calendar) before the *Eid al-Adha*. This celebration is in thankfulness to God for the self-discipline practised during the fast. This festival includes social gatherings with families and friends and serving traditional meat-based dishes is of prime importance.

Currently, very few Norwegian Muslims are getting halal animal carcasses on the eve of the Muslim festival (*Eid al-Adha*) in Norway for the following reasons:

- Less trust: Poor monitoring of the halal procedure at slaughter leading towards reduced demand
- Short supply: Reduced supply of sacrificial animals in Norway due to summer grazing practices
- Logistic issues: Failure in the management of meat logistics for the sacrificial animal and its delivery within the prescribed four days of *Eid al-Adha*

The majority of the Norwegian Muslim population has adopted a modified strategy to celebrate the Muslim festival: the slaughtering of sacrificial animals is done in their home country while they are in Norway. This is considered a poor substitute for purchasing the carcass locally. In some cases, people send money, equivalent to the price of a sacrificial animal to charity organizations operating in their home country. These practices undermine the halal meat demand and the benefits associated with increased production and sale of Norwegian sheep and goat meat. There is a business opportunity in serving the needs of the Muslim population better on the eve of the *Eid al-Adha*. An increase in the year-round demand for halal meat products is also envisaged.

Particularly for religious festivals, halal meat authenticity is essential. In Muslim countries, there is a trustworthy supply of halal meat, and meat markets enjoy peak sales. However, trustworthy supply of halal meat is not always present in non-Muslim countries. Consumer scepticism about the authenticity of the halal meat supply chain often leads to abstinence from some of these festivals. There is a scope for improvements in meeting the growing market demand of Norwegian Muslims. Today, the fresh meat supply for the Muslim festivals is minimal since the main slaughtering season is from September until end of November.

2.4 Meat quality

Meat quality is defined as "compositional quality (lean to fat ratio) and the palatability traits such as visual appearance, smell, firmness, juiciness, tenderness and flavour" (FAO, 2014). Purslow (2017) has defined meat quality as "a set of properties that together identify what we appreciate about meat when we purchase it, eat it, or select it for use as a raw material for processing into meat products".

Consumer acceptance of cooked meat is usually determined by the meat tenderness, flavour and juiciness. In the case of adult sheep meat quality, the flavour is regarded as more important than tenderness and juiciness (Young et al., 1997; Pethick, 2006). Purslow (2017) has presented the consumer perceptions of meat quality as a "triangle of needs" (Figure 3). In this representation, the bottom level (basic needs or desired quantity) needs to be satisfied before the higher-level attributes. In the first half of the 20th century, the focus was on the availability of meat and preservation of meat wholesomeness, including the intrinsic quality

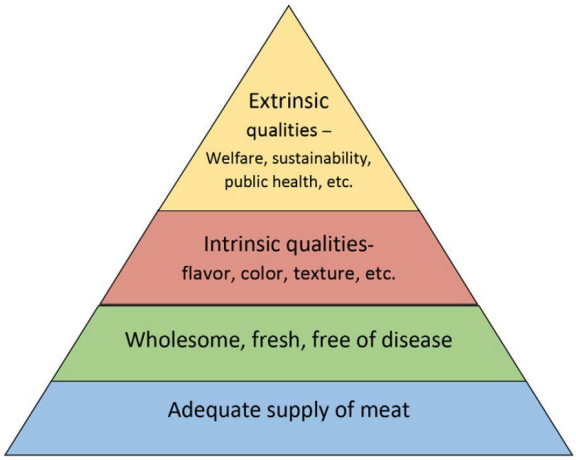

Figure 3. Consumer perceptions of meat quality represented as a "triangle of needs" Purslow (2017).

of meat. However, today extrinsic factors associated with meat, such as animal welfare, sustainability, and public health receive increasing attention.

2.4.1 Factors affecting the meat quality

Several factors affect meat quality, including nutrient physiology parameters, hygiene and toxicology parameters, processing parameters and sensory parameters (Purslow, 2017). These parameters are further divided into the following:

- Nutrient physiology parameters
    - Protein content
    - Fatty acids composition
    - Mineral content
- Hygiene and toxicology parameters
    - Microbiological status
    - Pharmaceutical residues
    - Heavy metal content
- Processing parameters
    - Shear force value
    - Blood Spots
    - pH value
    - Drip loss
    - Fat content
    - Connective tissue content
    - Specific water content
- Sensory parameters
    - Texture
    - Colour
    - Juiciness
    - Odour/flavour
    - Taste
    - Marbling
    - Structure

Since the topic of meat quality and its parameters is diverse, this thesis section will be limited to the flavour of the meat with a focus on factors affecting it (*mainly effect of breed, diet, animal age and body weight)*. These factors are divided into pre- and post-harvest factors.

Meat flavour

Meat flavour is an important sensory attribute that plays a vital role in consumer acceptance of meat and hence better value of meat in the market. Flavour is regarded as a unique sensory signature in the human brain that is created by the interaction of flavour with texture, visual and some other sensory cues (Watkins et al., 2013). Flavour development occurs by interaction of volatile and non-volatile compounds present in raw meat. Multiple factors affect flavour development during the cooking process. The non-volatile compounds such as amino acids, peptides, reducing sugars, fats, vitamins and nucleotides, interact during cooking and formulate the volatile compounds. These volatile compounds undergo a series of chemical reactions and create the specific meat aroma depending upon factors such as time, duration and fat content during the cooking process.

The characterisation of cooked meat flavour is challenging because the flavour of cooked meat not only influences the taste but also affects the olfactory organs. A series of chemical reactions occur during cooking. Basically, meat flavour is dependent on the chemical composition of raw meat that produces a particular meat flavour during the thermal process.

Factors affecting sheep/lamb meat flavour

Pre-harvest factors:

1. Animal nutrition
2. Feed
3. Sex of animal
4. Breed of animal
5. Genetic makeup
6. Age of animal
7. Stress

Post-harvest factors:

1. Fats and fatty acids composition
2. Proteins
3. Marbling

4. Temperature
5. pH
6. Irradiation
7. Processing (temperature)

Effect of age, breed and nutrition

The flavour intensity increases with increasing animal age, as in the case of sheep, it is termed as “mutton” flavour (Watkins et al., 2013). The changes in meat flavour with age are due to the changes in the concentration of the flavour precursor compounds in meat. Since the fat percentage also increases with the age of the animal, the fat-soluble flavour precursors are responsible for higher flavour intensity of meat from older animals. The biochemical difference in different muscle produce different flavour when cooked, such as bovine *longissimus dorsi* has strong flavour than *semitendinosus* (Calkins & Hodgen, 2007). The animal weight increases with increasing age until the animal does not suffer severe feed restriction or any other weight loss disease. Thus, increasing carcass weight will increase the body fat, and the influence of slaughter weight and animal age on fatty acid composition is controversial (de Lima Júnior et al., 2016). Dıaz et al. (2003) found an effect of slaughter weight on the fatty acid composition. However, in another study, Wood et al. (2008) found an increase in the proportion of mono-unsaturated fatty acids with increasing age of the animal. More specifically, the proportion of saturated fatty acids falls, linoleic acids level remain constant and conjugated linoleic acids (CLA) in fat increased with increase in age (Wood et al., 2008).

The breed can influence meat flavour. In one study, Elmore et al. (2004) found a difference in the level of pyrazines in two breeds of sheep (Soay and Suffolk lambs). Duckett & Kuber (2001) have reported the effect of genetics and nutrition on lamb meat flavour. This study showed that water-soluble fraction of meat is responsible for the meat flavour and lipid-soluble fraction of meat is responsible for the species-specific flavour. In another study (Pearson et al., 1973), the panellists were not able to detect any species difference in lamb and beef water extracts until the fat was also added. The composition of fatty acids affects the flavour of meat more in lambs than in beef. Polyunsaturated fatty acids (PUFA) are more susceptible to oxidation during cooking. However, the lipid oxidation products do not appear to influence the flavour characterisation instead contribute to the off-flavour and other flavours development (Duckett & Kuber, 2001). The branched chain fatty acids (BCFA) seem to influence the flavour characteristics of the lamb meat. In lamb and goat meat, there is a

higher concentration of BCFA. Young et al. (1997) found that BCFAs were major lamb meat flavour contributors. Ba et al. (2013) concluded that physicochemical meat quality, sensory characteristics, and the content of volatile flavour compounds are affected by the animal breed.

The feeding system and the feed itself affect the meat flavour directly or indirectly. The content of carbohydrates, glucosinolates and crude protein is different in different pastures depending upon various factors such as the quality of pasture, time of the season, the weather condition in that season, age of the plants, application of fertilisers and soil condition etc. In different grass verities, the content of crude protein is variable such as 17-30 % (*Trifolium subterranean*) and 5-19 % (*Lolium perenne*). Since the weather (summer/winter) is also important in terms of total nitrogen concentrates in the grass. In New Zealand, the content of total nitrogen concentration in grass was higher in colder months compared to lower nitrogen contents in the summer months (Metson & Saunders, 1978). This variation in the composition of pasture is ultimately going to affect the composition and concentration of carbohydrates and fats in ruminant muscles, hence variability in meat flavour. The development of intramuscular fats is very important since it is highly appreciated by meat consumers in terms of meat flavour. However, all these effects due to different feeding system conditions can be minimised by feeding animals on a neutral feed for 1-2 weeks before slaughtering (Watkins et al., 2013).

In the same study, Watkins et al. (2013) reported that the specific mutton like odour is due to the 4-ethyloctanoic acid, and this volatile compound is absent in beef. The intensity of odour is increased by the degradation of tyrosine (in pasture) and formation of 4-methyl phenol. Moreover, the previous exposure and traditional preferences drive the consumer's preferences for a specific meat flavour. For example: Spanish consumer prefer higher n-6 PUFA (in concentrates), and British consumers prefer stronger flavour due to n-3 PUFA (in the grass) (Sañudo et al., 2000).

It is generally believed that grass-fed animals have higher n-3 PUFA (alpha-linolenic acid) and lower lipid oxidation due to the presence of vitamin E in the grass; grain feeding animals have higher n-6 PUFA (linoleic acid is the most common n-6). The grass-fed animal meat with lower lipid oxidation is beneficial in terms of low oxidation (Wood et al., 2004). However, the higher content of intramuscular fat is taken as a sign of good meat quality, and its flavour is perceived as pleasant by consumers (Hopkins et al., 2006).

2.4.2 Meat sensory evaluation

Stone & Sidel (2004) defined meat sensory evaluation as "a scientific method used to evoke, measure, analyse and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing". Product sensory evaluation involves all four principles mentioned in the definition. A trained panel of experts performing the sensory evaluation under controlled conditions minimise the biasing factors. It is based on quantitative science where quantitative data is collected, and a relationship is established between product characteristics and human perceptions. There are three classes of test methods used in sensory evaluation of the products: discriminative, descriptive, and affective testing (Table 3).

Table 3. Classification of test methods used in sensory evolution (Lawless & Heymann, 2013)

Class	Question of interest	Test type	Panellist characteristics
Discrimination	Are products' perceptibility different in any way	"Analytic"	Screened for sensory acuity, oriented to test method, sometimes trained
Descriptive	How do products differ in specific sensory characteristics	"Analytic"	Screened for sensory acuity and motivation, trained or highly trained
Affective	How well are products liked or which products are preferred	"Hedonic"	Screened for products, untrained/consumers

The descriptive analysis provides detailed information on all the sensory properties of the product and is regarded as the most comprehensive protocol in sensory science (Murray et al., 2001). There are international and national standards that are dedicated to sensory evaluations, consisting of basic standards. These include:

- ISO 6658:2017, Sensory analysis - Methodology - General guidance (ISO - International Organization for Standardization)
- ISO 5492:2008, Sensory analysis - Vocabulary (ISO - International Organization for Standardization)
- ISO 8586:2012, Sensory analysis - General guidance for the selection, training, and monitoring of selected and expert assessors (ISO - International Organization for Standardization)
- ISO 8589:2007, Sensory analysis - General guidance for the design of test rooms (ISO International Organization for Standardization)

- ISO 11037:2011, Sensory analysis - Guidelines for sensory assessment of the colour of products (ISO - International Organization for Standardization)
- IEC 60050-845 CIE 17:1987, International electro technical vocabulary -Chapter 845: Lighting International lighting vocabulary (IEC - International Electrotechnical Commission).
- Norsk standard NS-ISO 5492. ISO. (1999). Sensory analysis, vocabulary.

Lamb and sheep meat sensory profiling is associated with many different attributes such as odour (fried roasted, gamey, sheep, odour intensity, rancid), flavour (gamey, sheep, fried roasted, rancid, liver, flavour intensity), texture (hardness, tenderness, fatness, juiciness), and coarse fibre structural unit (Lawless H., 2010).

Over a 15-year-period, the Norwegian meat industry has collaborated with research institutes and other partners to improve the quality and availability of lamb meat. Some significant results are summarised below:

- Content of poly-unsaturated fatty acids, which are considered to be healthier, were higher in meat from "mountain-lambs" compared to that of comparable lambs grazing low-land pastures (Ådnøy et al., 2005). In a further study, Lind et al. (2009) compare sensory profile and fatty acid composition in meat from lambs slaughtered directly from unimproved mountain pastures with meat from lambs raised on unimproved mountain pastures and fattened on cultivated pastures for 26, 39 and 42 days before slaughter. The results showed a lower concentration of polyunsaturated fatty acid levels in lambs that were fattened on cultivated pastures.

- Off-flavour in lamb meat due to ram-taint is a serious quality problem due to higher skatole concentration in fat (Schreurs, 2013). To minimise this problem, ram lambs should be slaughtered directly off the pastures, preferably in August or September (Mushi et al., 2008a; Lind et al., 2011).

- Norwegian Muslims originating from Pakistan have a traditional preference for meat from goat and sheep yearlings since it is prohibited in Pakistan to slaughter ''useful'' animals (such as pregnant ewes and animals younger than one year) and yearling meat quality is regarded as better (FAO, 2003; Toplu et al., 2013) depending upon breed and feeding system.

- Smaller native sheep breeds could be promoted for landscaping purposes (Clemetsen & Eik, 2002).

3 Problem statement, hypothesis and research topics

3.1 Problem statement

In Norway as well as in other high-cost countries, small-ruminant farming systems are changing from high utilisation of the local resource-base to higher input/output systems that are more dependent on purchased resources. While improving labour efficiency, these farming systems may have a higher carbon footprint per unit of meat and milk produced and may also be less profitable. Hence the main objective was to study some alternative systems that also could meet and extend niche market demands, and estimate their profitability and concentrate use. It is assumed that improvements may be found using a value-chain-approach, including a comparative economic analysis of the current sheep husbandry practices with alternative practices based on low concentrate use and niche market's meat demands. In affluent societies like Norway, the quality of products is essential for a successful sale. Therefore, the assessment of meat sensory quality will be combined with a study of niche market demands.

3.2 Hypothesis and research topics

The hypothesis in this study was that quality lamb and hogget meat may be produced profitably from alternative production systems for coastal farmers with access to summer mountain grazing. Thereby, it may help to meet year-round fresh meat supply and niche market demands.

4 Brief summary of papers

4.1 Paper 1

Adapting seasonal sheep production to year-round fresh meat and halal market in Norway

Year-round fresh meat availability is important to increase Norwegian meat consumers' demand for red meat and lower the quantity of frozen meat stored for year-round usage. To be able to suggest changes in the existing sheep farming system, a better understanding of the present production systems is vital. Paper 1 provides a review describing the overall Norwegian sheep farming system, including the seasonal slaughtering and aspects of the Muslim meat festival and general halal market.

Seasonal sheep farming, slaughtering and niche market

- Norway is the largest sheep meat producer in Scandinavia. Rogaland county has most sheep and the highest proportion of older (>1 year) sheep compared with lambs (<12 months) slaughtered.
- Sheep production is divided into spring-grazing (April – May), range-grazing (June – September), autumn grazing and feeding (September – November), and indoor-feeding (November – March).
- The majority of lambs (approximately 1.5 million) are slaughtered in a concentrated slaughtering season (August – November). It is hard to consume 1.5 million carcasses from August to November; hence most of the carcasses are frozen for later use.
- Meat market price is much lower for hogget and older sheep carcass, thereby keeping lamb meat the mainstream product. The lower market price for sheep meat and a large stockpile of frozen carcasses (lamb and sheep), pressure the meat industry to empty the frozen units before the next slaughtering season rather than addressing the need for year-round fresh meat availability.
- New niche markets, especially servicing the needs of multicultural meat consumers, can increase the meat (halal) consumption in Norway. However, proper marketing strategies (including highlighting the meat quality of hogget) are essential to encourage meat consumers to pay more for the hogget.

- The *Eid al-Adha* in Arabic, which is an annual religious meat festival. In this Muslim festival, preference is for hogget carcasses.
- Better price for hogget meat and a proper economic analysis of the hogget production system will encourage the sheep farmers to produce more hogget for the eve of Muslim festival.
- A profitable hogget production system will be essential for creating year-round fresh meat availability.

4.2 Paper 2

Rangeland grazing strategies to lower the dependency on imported concentrates in Norwegian sheep meat production

This study aimed to compare economics (gross margin) of Norwegian sheep (Norwegian White Sheep) at current prevailing practices (baseline) to alternative scenarios using a linear programming model. The use of concentrate feed to produce one kg of meat was calculated and compared between baseline practices and alternative scenarios.

Baseline practice: Ewes start lambing at one year with a life span of 3.3 years, and the rate of replacement is 0.30. Ewe lambing occurs on the 14th of April and slaughtering on the 20th of September. The majority of the lambs (except for breeding stock) are slaughtered at the age of approximately 159 days.

Alternative scenarios were:

1. Lambing delayed to the start of grazing season (around 1st of May) with a corresponding 15-day delay in slaughtering until around 5th of October.
2. Hogget production: Production system is the same as Baseline practices, but surplus female lambs (no breeding) are kept during the winter and marketed as hogget in July or August (in the following year).
3. First lambing when two years old: Production system is the same as Baseline practices, but with first lambing when ewes are two years old.
4. Longevity increased to 5.3 years: Production system is the same as Baseline practices, but with first lambing when ewes are two years old, and assuming longer ewe lifespan (5.3 years).

Main results

- Based on the current meat market price, the model's optimal solution calculated higher profitability (gross margin) for the baseline practice and the 4th alternative scenario. Hogget production was not profitable, since the market price per kg of hogget meat was significantly lower (10.28 NOK for hogget meat and 66.10 NOK for lamb meat) leading to a lower gross margin for hogget production.

- The use of concentrate feed to produce one kg of meat was lower for the hogget production system compared with baseline practices (2.85 kg vs 3.87 kg) since the hoggets were not bred and were fed at maintenance level.

Conclusion

The model solutions calculated (with Norwegian White Sheep breed) showed that none of the alternative scenarios was profitable compared with the baseline practice. The profitability of alternative scenarios will be improved for farms where autumn pastures are abundant and with better market prices for the hogget meat. Based on the meat consumer's preferences for a natural food production system, hogget production will be preferable because of less input of concentrates. Moreover, native sheep breeds that are more adapted to grazing rangelands should be investigated.

4.3 Paper 3

Management strategies to improve the economics of sheep farms in Norwegian coastal and fjord areas – the effect of animal size and capacities for rangeland utilisation

Norwegian sheep farming is operated under strict environmental boundaries. Norwegian White Sheep (NWS) is the main breed comprising of about 70% of the sheep population. NWS is a heavy weight composite meat breed. Norwegian (white) Spæl (NS) is a relatively small breed and accounted for approximately 10% of the recorded ewes. NS is relatively light in body weight and considered as more adapted to the local Norwegian environmental condition.

The objective of this study was to calculate farm profitability by using NS breeds and then comparing the farm profitability of NS and NWS breeds.

The baseline practices and alternative scenarios of Paper 2 were used to calculate the gross margin using a linear programming model.

Main results

- The overall profitability of using the NS breed was higher compared with NWS. Hogget production for NS breed was comparatively more profitable: just replacing the NWS with the NS breed would increase farm profitability by 33%. In the case of increasing the longevity (5.3 years), the highest gross margin was calculated, and replacing NWS with NS for this scenario increased profitability by 8%.
- The use of concentrate feed per kg of meat produced was overall lower for the NS breed. Within the NS breed, the hogget production and increased longevity scenarios showed the lowest (3.0 and 3.1 kg) use of concentrate per kg of meat produced.

Conclusion

The coastal and fjord areas have a year-round grazing option in addition to the vast Norwegian rangelands. The NS breed may better serve the purpose of environmentally friendly meat consumers because of the lower use of concentrate and their greater adaptation to natural grazing. Better marketing strategies to promote hogget meat may increase the profitability of hogget production system many folds. NS hogget production can be helpful in

providing the meat supply for the Muslim Meat festival and facilitating year-round fresh meat availability.

4.4 Paper 4

Lamb or hogget meat – a different sensory profile? Extending the fresh meat season in Norway

The main aim of this study was to compare the meat sensory profile of two sheep breeds (Norwegian White Sheep – NWS, and Norwegian Spæl – NS) of two age groups (lambs – 5 months and hoggets – 17 months old). A total of 50 animal carcasses and 23 sensory attributes were assessed by a trained sensory panel using quantitative descriptive analysis.

Main results and Conclusion

- The sensory quality of lamb meat was in general higher than that of hogget. The NS hogget may better fulfil out-of-season fresh meat supply in Norway. The meat from NWS hogget was generally of lower eating quality than from the NS hogget.
- For the attributes fried roasted odour and gamey odour and flavour, a significant age × breed interaction was found, with less difference between age groups in NS. Differences (P<0.05) between samples from hogget and lamb, regardless of breed, were found for several attributes where lamb compared to hogget had lower intensity in both odour (fried roasted, sheep odour, intensity) and flavour attributes (fried roasted, gamey, sheep flavour, rancid, liver flavour). Differences were also observed for the texture attributes, in which lamb was evaluated to be softer and more tender.
- The NS lamb and hogget were lighter in body weight compared with the NWS. The animal age had a lower impact on the eating quality of NS breed than NWS breed.

4.5 Paper 5

Muslim consumer purchase intentions regarding halal lamb meat in Norway

Globally, there is an increasing Muslim population. In Norway, Muslims are the second-largest religious minority after the Christians. Eating halal meat is associated with religious belief. A better understanding of this niche market may play a significant role in increasing the sales and consumption of Norwegian sheep meat. The study aimed for a better understanding of the halal meat consumers' purchasing preferences and associated factors affecting their purchasing decision; a cross-sectional survey was conducted in Oslo using a snowball sampling technique. Without prior knowledge about the market segments, a descriptive post hoc market segmentation was performed using latent class analysis in order to address the heterogeneity of respondents in choice data and to develop market segmentation. Latent class simultaneously detects relatively homogeneous respondent segments and calculates part-worths (i.e. utilities) for those discovered segments. The latent class analysis provides the benefits of aggregate estimation while recognizing market heterogeneity.

Main results and Conclusion

Relatively homogeneous respondent segments were defined by Latent class analysis, and part-worth utilities were calculated. The consumer segments were named according to their characteristics, as shown in Table 4.

Table 4. The consumer segment characteristics identified using latent class analysis

Consumer segments	Characteristics
Educated Big Families (EBF)	1st generation highly educated immigrants living with ≥5 family members and prefer to purchase Norwegian lamb meat in addition to imported lamb meat. Their lamb meat-eating frequency was at least once per week.
Educated Small Families (ESF)	Highly educated small-sized families (average three members) 1st generation immigrants in Norway with greater preference for the Norwegian lamb meat. This segment has a higher number of consumers who eat lamb meat daily.
Dedicated Young Residents (DYR)	Norwegian born (2nd generation) also including young consumers up to 18 years old, prefer to purchase only Norwegian lamb meat. This segment member is independent in terms of marital status since this segment has a higher number of people living as single/divorced/separated/widowed. They also eat lamb meat at least once per week
Big Resident Families (BRF)	Norwegian born (2nd generation) living in a big family (≥5 members). When purchasing lamb meat, they are open to imported meat despite a preference for the local Norwegian lamb meat. They eat lamb meat at least once per week.
Dedicated Big Families (DBF)	These are big families of immigrants (1st generation), who prefer only local Norwegian lamb meat. They eat lamb meat at least once per week.

Table 5. Six different meat product characteristics concerning specific (market-oriented) attribute levels.

Product ID	Place of purchase	Shelf life	Meat cuts	Packaging size	Price (NOK)
BU1	Halal butcher	Fresh	Specific parts	Small (≤ 2 kg)	130
SM1	Supermarket	Frozen	Mixed all parts	Medium (3-5 kg)	110
OL1	Online order	Frozen	Mixed all parts	Large (5-8 kg)	130
BU2	Halal butcher	Frozen	Mixed all parts	Small (≤ 2 kg)	110
SM2	Supermarket	Frozen	Specific parts	Medium (3-5 kg)	130
OL2	Online order	Fresh	Specific parts	Medium (3-5 kg)	130

- Data were simulated to check the product (six hypothetical products, Table 5) market share for each consumer segment. The market share (%) for three and six products together is summarized in Figure 4 and 5.

- It showed that the consumer's meat purchasing preferences are changed if more products with different characteristics are available in the market. However, in case of limited options, most of the meat consumers prefer to purchase from the halal butcher.

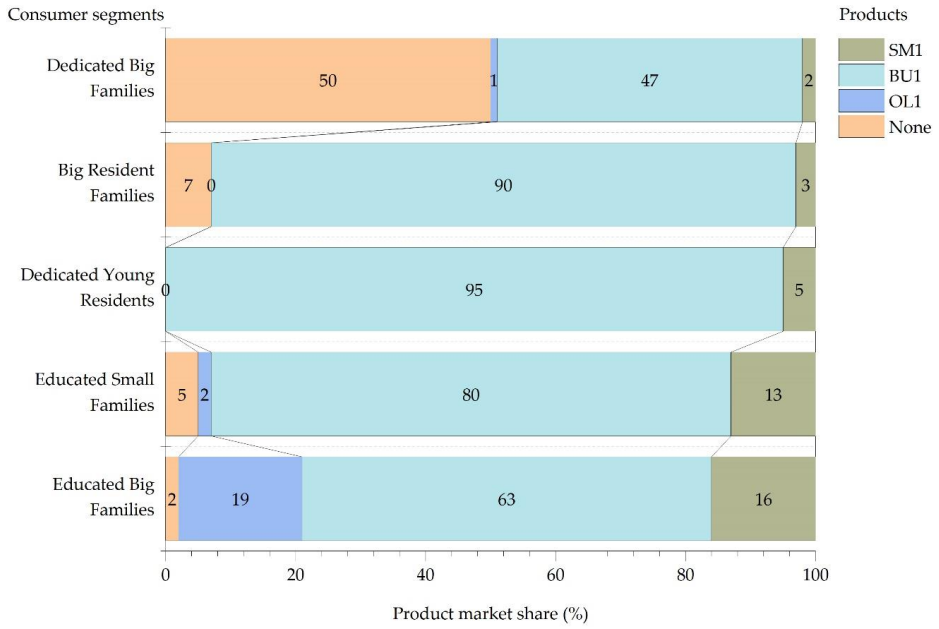

Figure 4. The halal meat consumers' preferences for three products' market share based on simulation of data using Hierarchical Bayesian approach. The description of consumer segments and products is given in table 4 and 5 respectively.

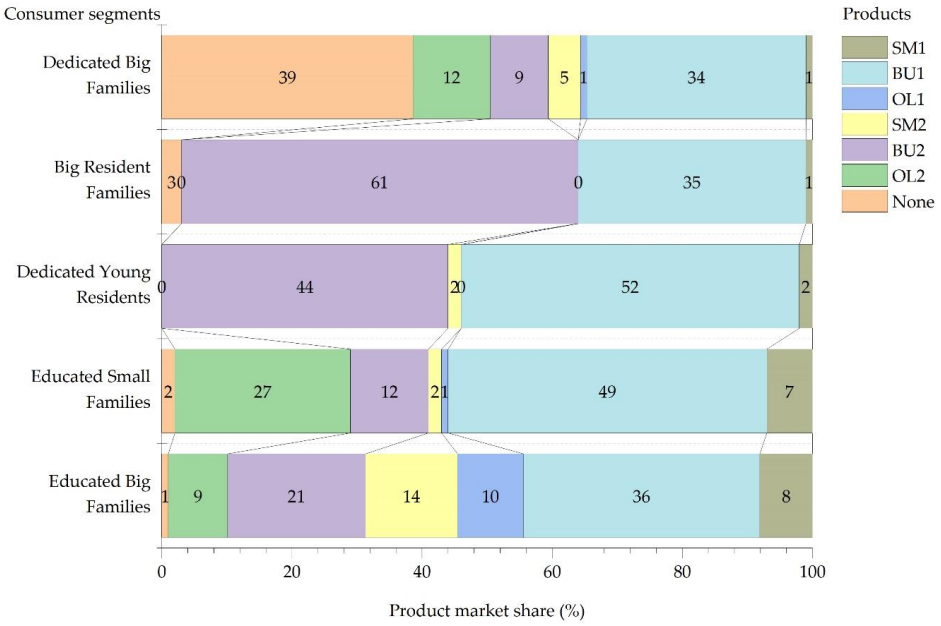

Figure 5. The halal meat consumers' preferences for six products' market share based on simulation of data using Hierarchical Bayesian approach. The description of consumer segments and products is given in table 4 and 5 respectively.

5 General discussion

5.1 Sheep production system and halal niche markets

The current seasonal surplus of meat has negatively affected Norwegian sheep farmers. Exploring niche markets may increase the sale of lamb meat and mutton. Paper 1 demonstrates that halal meat market in general and Muslim festivals in particular represent a niche market that can be utilised by the meat industry to sell a high number of hogget and older sheep carcasses (following age requirements for sacrificial animals) during the short period of the festivals. In Muslim countries, such religious festivals are an excellent marketing opportunity for farmers to sell their animals at higher market prices (Boughalmi et al., 2016). However, in the Norwegian scenario, the time of the leading Muslim festivals (*Eid al-Adha and Eid al-Fitr*) does not coincide with the peak slaughtering season (Figure 6, paper 1). Instead, currently it coincides with the period when a majority of the animals are grazing up in the mountains and are unavailable for slaughter. One option might be that farmers do not slaughter all lambs during the traditional slaughter season (September to November), but instead keep them until spring in the following year. However, this will add an extra cost of feeding and management for a longer duration, which may not be covered by the market price for hogget and older sheep which is at present very low.

The demand for meat is high during these Muslim festivals, especially during *Eid al-Adha*. In addition, there is a strict requirement that sacrificial animals must have been slaughtered during the four days of celebration. For a successful supply-chain development for these Muslim festivals, coordination and management related to slaughtering, carcass processing, delivery to the consumers and meat distribution to the poor (Hidayat & Munshi, 2019) are of critical importance in addition to the production and selection of animals while they are still on the farm. This presents logistical issues in enabling the purchaser to inspect animals before purchase. Online marketing strategies may need to be devised to overcome this obstacle.

The Norwegian meat industry must review the existing production and market supply chains to find ways to better satisfy the needs of this growing niche halal market. To fulfil the year-round fresh meat and supply-demand in general and at the time of key religious festivals in Norway, revision of existing sheep farming practices by farmers and a better understanding of multi-cultural meat consumer preferences is vital.

An economic analysis of different sheep production systems to identify the profitable system may motivate farmers to service the demands of niche market. The hogget production system seems to fulfil the niche halal meat market demands. Therefore, a reasonable increase in market price for hogget (by developing recognised brands and highlighting the hogget meat quality (paper 4)) will increase the profitability of hogget production system. However, without increasing the current market price (especially for hogget), current practices will not change (papers 2, 3). Another solution to reduce the surplus meat production might be by exporting to European countries with high Muslim population. Improving overall lamb and hogget meat quality and adopting better marketing strategies for traditional halal meat markets will be helpful to initiate meat export from Norway.

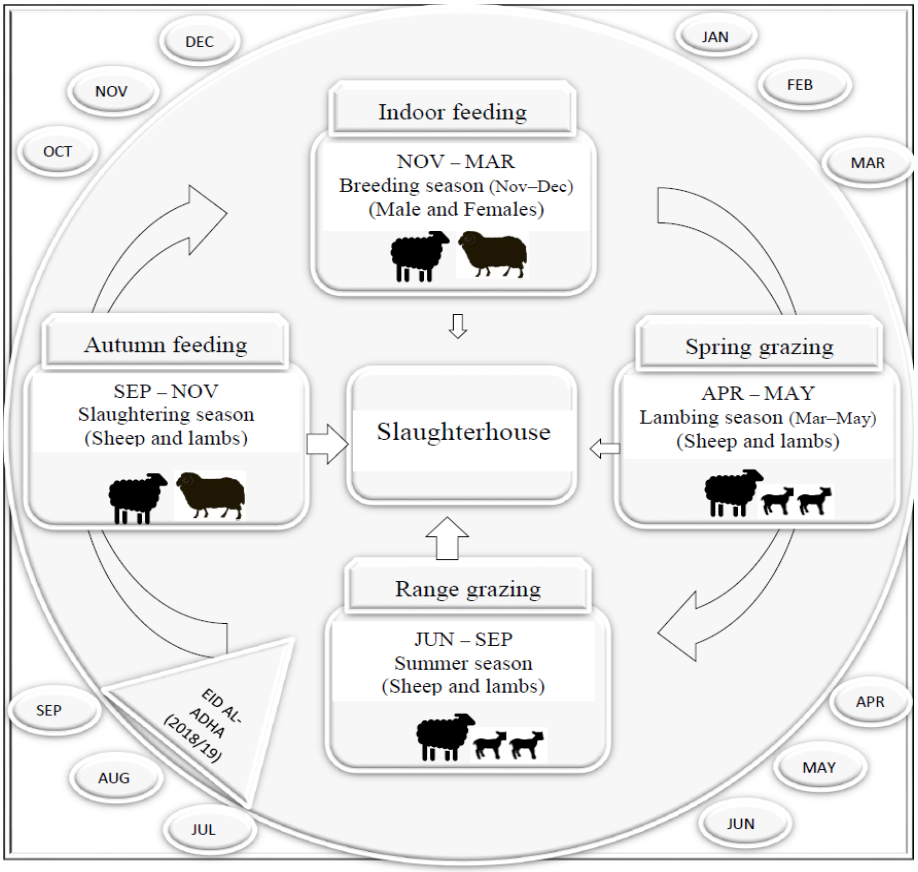

Figure 6. A simplified overview of the Norwegian sheep farming system with integrated meat supply and the Muslim meat festival (*Eid al-Adha*) – paper 1

5.2 Farm economics, breeds and reduced use of concentrates

Farm profitability is vital for a sustainable sheep production system. Meat consumer preferences drive the meat market. Current Norwegian meat consumers are paying a high price for lamb meat and prefer lamb over sheep meat. Thus, sheep husbandry practices are strongly focused on lamb meat production. Marketing campaigns are used in order to increase meat consumption, gain better prices and to introduce new products (Rodríguez-Serrano et al., 2016). A study conducted by Hersleth (Hersleth, 2016a, 2016b) included a consumer test where meatballs from lamb (9 months), young sheep (20 months) and older sheep (5 years) were served. In blind tests, no differences were found, but when the test subjects knew what they were tasting, they preferred meatballs from lamb. The study concluded that mutton is better than its reputation and that this information is important for marketing purposes. Consumers also preferred locally produced food from grazing based systems rather than concentrate-fed products from intensive systems (Bernués et al., 2003; Hersleth et al., 2012). On the other hand, knowledge of other factors such as geographical area, type of pasture, ecosystem services, native breeds and local brand schemes could lead to increased interest and willingness to pay (Bernués et al., 2003; Guerrero et al., 2009; Bernués et al., 2015; Bernués et al., 2016).

The linear programming model (papers 2, 3) calculated a higher gross margin for the baseline practices and for the fourth alternative scenario (when the ewe life span was increased to 5.3 years). However, across the two breeds, comparison of gross margins for baseline practices and all alternative scenarios (paper 3) showed that the gross margin for the NS breed was slightly higher than that for the NWS breed. It might be due to the smaller size of NS that is related to their lower feed maintenance requirements (Steinheim et al., 2003; Steinheim et al., 2005). The results (papers 2, 3) also show that the hogget production system was not profitable when compared with baseline practices. However, it required the least amount of concentrates (Figure 7) because the hoggets were mostly grazing throughout the year and were not pregnant. The price per kg meat for older sheep, hogget and lamb meat used in the model input were 7.18, 10.28, 66.10 Norwegian Kroner (NOK). The big price difference between hogget and lamb meat has resulted in a lower gross margin for the hogget production system (papers 2, 3). A reasonable increase in hogget meat market price will make the hogget production system the profitable scenario.

Although it is believed that the proposed interventions can improve productivity and economic efficiency (papers 2, 3), it is still not likely that the sheep meat sector can compete

on price with cheap lamb meat imports. Therefore, halal meat value-adding activities and understanding and fulfilling niche market demands are of great importance.

The limitation of this study (papers 2, 3) was that it was focused on large sheep farms. Since about half (48%) of the Norwegian sheep flock are of medium size, a revised model run with data from medium size flocks should also be considered.

A study conducted in six European countries showed that consumers had increased confidence in recognised brands (Verbeke et al., 2013). Developing a recognised brand for hogget meat, highlighting its quality might increase its market value since consumers also like brands based on natural, high-quality mountain pastures (Ådnøy et al., 2005).

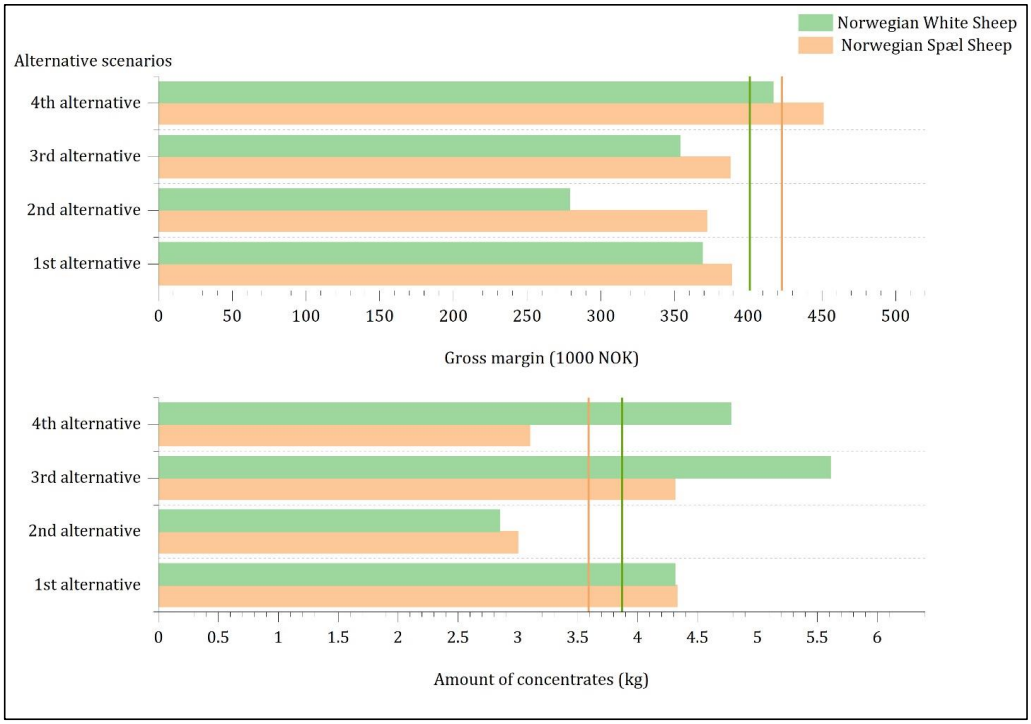

Figure 7. Gross margins and concentrate use (per kg meat produced) calculated in all four alternative scenarios. The reference lines indicate the values for the baseline system. The detailed description of all alternative scenarios is given in papers 2 and 3.

5.3 Profitable quality meat production

In Norway, the sensory quality of lamb and hogget meat had not been investigated before this study (paper 4). However, differences in meat quality (sensory analysis) have been reported when comparing meat from four months old lambs and four years old sheep (Hersleth, 2016a). In paper 4, comparing the sensory characteristics of lamb (five months old) and hogget (17 months old) meat, the overall lamb sensory quality was better, but the quality of NS hogget meat was similar to that of NS lamb.

This result (paper 4) supports the claims made by Pethick, Hopkins, et al. (2005) on lambs (12 months old) and yearlings (22 months old). They compared lambs (finished on self-feeders for 16 weeks on a mixture of oats and barley grain with canola meal added to give a crude protein content of 16%) and yearling sheep (finished on self-feeders for 3.5 weeks on a diet of oat, barley and lupin grain to give a final crude protein content of 16%). The results (Pethick, Hopkins, et al., 2005) showed that yearling sheep meat from *M. longissimus lumborum* has acceptable eating quality attributes compared with lamb. However, eating quality also depends upon the type of meat cut; for example, topside leg muscle will be tougher compared with other parts (Hopkins et al., 2007).

The results of paper 4 are also in accordance with results from the study by Pannier et al. (2019) on Merino wether lambs (11.6 months old) and Merino wether yearlings (22.5 months old) generally maintained under extensive pasture grazing conditions, but fed grain, hay or feedlot pellets when grass supply was limited. No significant sensory difference was reported in meat (*M. longissimus lumborum*) from lambs and yearlings, while Pannier et al. (2019) reported greater sensory difference between lamb and yearlings when meat samples from *M. semimembranosus* were used.

However, the results (paper 4) showed (using *M. longissimus lumborum*) that for the NWS breed, NWS hogget meat was different (higher intensity) from NWS lamb and from both NS lamb and hogget in term of meat sensory attributes such as fried roasted odour, gamey odour, fried roasted flavour, sheep flavour, gamey flavour, hardness, tenderness and coarse fibre. This contradicts the above claims made by Pethick, Hopkins, et al. (2005) and Pannier et al. (2019). This breed difference may stem from the fact that NWS hoggets achieved higher live weights (Table 7, paper 4) and higher subcutaneous fat levels compared to NS lamb and hogget. More subcutaneous fat can slow down the chilling rate and improve the meat eating quality, but could also greatly increase the undesirable sheep flavour associated with fats (Hopkins et al., 2007). The collagen concentration is reported to be a better indicator of

sensory tenderness than collagen solubility as the collagen solubility decreases (due to increased cross-linking) with an increase in animal age (Young & Braggins, 1993). The NS hogget had grown at a slower rate than NWS hogget, and this might affect the concentration of the collagen in the muscle and the tenderness of the meat whereas increased growth rate can also improve the collagen solubility. The slow growth of NS hogget with lower collagen concentration compared to the NWS hogget might be the reason for NS hogget obtaining a lower muscle hardness score. The slower growth of the NS hoggets is at least partly a breed effect, but differences in the imposed feeding regime before the experiment was initiated may also have had an effect. This needs to be confirmed in future studies.

The meat sensory quality results (paper 4) in Table 6 should be verified with a larger data set representing a bigger sample size from both breeds (NS and NWS), both for random samples of animals at the slaughterhouse, and under controlled conditions in terms of feeding. Another limitation of this study (paper 4) was the measurement of sensory meat quality only using the *m. longissimus thoracis et lumborum*. A further study involving consumer acceptance tests as performed by Pethick, Davidson, et al. (2005) should be conducted to verify the results of the sensory quality of hogget meat based on different muscles. The results (paper 4) are novel and may be used to design marketing strategies to attract a better price for NS hogget meat.

Table 6. Least square mean (±SD) for live weight, slaughter weight, EUROP carcass classification conformation score, and fatness score of lamb and hogget of NWS and NS breeds. Different letters ^{a,b} in the same row indicate significant statistical differences (P<0.05, Tukey's test) (Paper 4)

Description	**NWS**		**NS**	
Age-group	**Lamb**	**Hogget**	**Lamb**	**Hogget**
Live weight, kg	$45.2^{a} \pm 6.1$	$74.3^{b} \pm 8.1$	$45.6^{a} \pm 3.1$	$56.6^{c} \pm 6.2$
Carcass weight, kg	$17.8^{a} \pm 3.0$	$30.1^{b} \pm 3.9$	$17.0^{a} \pm 0.9$	$20.0^{a} \pm 2.8$
EUROP conformation*	$7.0^{a} \pm 1.7$	$8.3^{b} \pm 0.9$	$6.9^{a} \pm 1.0$	$6.4^{a} \pm 0.6$
EUROP fatness**	$5.4^{a} \pm 1.6$	$6.8^{ab} \pm 1.4$	$7.1^{b} \pm 0.8$	$6.7^{ab} \pm 1.0$

*Scale 1-15 (15 = best conformation)

**Scale 1-15 (15 = fattest)

5.4 Halal meat consumers' purchasing intentions

Understanding the consumer perception about the product purchase is important for successful product development and marketing. In the case of halal meat also, the consumer trust and product awareness are important factors affecting purchase decisions (Bonne & Verbeke, 2008; Wilson & Liu, 2010; Bashir et al., 2018). The results of this study (paper 5) suggest that first-generation Muslim immigrants trust halal butchers when purchasing halal meat. It is in line with a consumer study (Ahmed, 2008) conducted in the United Kingdom that showed the majority of Muslims trust the halal butcher when purchasing halal meat. They do not trust the big supermarkets. This might be due to the lack of awareness about halal meat availability at the supermarkets. Contrary to Ahmed (2008), our study (paper 5) showed that 2nd generation young Muslims in Oslo preferred to purchase halal meat from national supermarkets. The reasons may be changing attitudes, or it may be a wish for time-efficient shopping. The halal butcher gains trust by communicating with consumers, but younger consumers are less inclined to engage with staff at the halal butcher shop. Muslim consumers are mostly price-sensitive (paper 5). Currently, some grocery stores in Oslo have adopted a new model where a portion of the shop is allotted to a halal butchery with whom consumers can interact directly. A similar model for the national supermarket chains would likely boost their halal meat sales, in particular to the increasing proportion of young Muslim clientele.

The halal meat consumer survey (paper 5) showed that consumers preferred fresh meat, but the price and convenience made larger households to additionally purchase more frozen meat. This is consistent with the findings of Tzimitra-Kalogianni (1996), who showed that a majority of Greek consumers prefer fresh meat over frozen for health or nutritional reasons. In both studies, it is apparent that consumers place a high value on the quality aspects associated with fresh meat. Consumers with big households like fresh meat, but also value availability of frozen meat that they can purchase in bulk and store in a freezer as a time saving and practical option. This study (paper 5) showed that the preferences of the meat consumers changed when a wider variety of halal products was available at the national supermarket. These findings (paper 5) are in line with other studies (Chien-Huang & Wu, 2006; Berger et al., 2007) that reported that a wider choice in products would change consumer preferences and potentially increase the emphasis placed on product quality.

Hersleth et al. (2012) reported that Norwegian meat consumers, in general, had a strong preference for nationally produced lamb. This study (paper 5) results showed that the same is the case for most halal lamb consumers: 2nd generation young immigrants and those from

big households preferred locally produced halal lamb meat. This preference may be related to a wish to support the Norwegian economy but also to a growing appreciation of the quality of product now available from Norwegian sheep producers.

6 General conclusions and future perspectives

- Hogget production has the potential to improve fresh meat supply and to better meet the demands of the halal market especially Muslim Meat festivals.
- We found that the quality of meat (*M longissimus thoracis et lumborum*) from Norwegian Spæl (NS) hoggets was similar to that of lambs; this could be used in marketing to increase consumer demands and willingness to pay for this product. The NS's lower carcass weight could mean less of the undesirable sheep flavours associated with carcass fats (subcutaneous) in heavier carcasses. Smaller cuts are also more in line with the wishes of modern, smaller households.
- For Norwegian White Sheep (NWS) economic modelling of sheep farms showed that today's prevailing production system gives the highest gross margin, except for the increase in the production life span of ewe from 3.3 to 5.3 years. The same was the case for NS, but this breed required less concentrates per kg of meat produced. The profitability of hogget production system could be increased by getting a higher price for hogget meat.
- The current industry practices in Norway favour lamb production from NWS, but the benefits of using the NS for hogget production, either as a substitute, or complementary breed should be investigated further, focusing on the coastal and fjord areas with longer grazing seasons.
- Consumers increasingly prefer food produced on natural resources, and a system based on more NS sheep grazing native pastures while using less concentrates should be easy to promote. Future research should include economic analyses of smaller and medium-size sheep farms and additional native sheep breeds.
- The halal meat niche market has the potential to increase meat consumption in Norway, especially for meat from hogget and older sheep. Muslim meat consumers especially first-generation, trust the halal butcher more than the national supermarket chains.
- Extending the range of halal products and integration of halal butcher (with national supermarket chains) will increase the total consumption for the Norwegian produced halal meat. However, the meat industry needs to carefully evaluate the associated risks and the economic viability of this market. Further studies of Muslim meat consumer

preferences for halal lamb and older sheep meat involving a larger number of consumers will be helpful for the meat industry.

In summary, Muslim consumers represent a niche market not yet well utilised by the Norwegian sheep industry; the demand for hogget meat, in particular, is poorly served. Our findings of similar meat sensory quality of NS hogget compared to NS lambs indicate this breed as well suited for hogget production, with its additional benefit of smaller carcasses better suited to modern small households. A successful marketing strategy of hogget for the halal market, with focus on the NS breed, could increase market prices sufficiently to make such a production system profitable. NS hogget production will use less concentrates and more pasture, making it even more attractive to general Norwegian consumers who are concerned about environmental sustainability as well as product quality.

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Paper 1

Adapting Seasonal Sheep Production to Year-Round Fresh Meat and Halal Market in Norway

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Review

Adapting Seasonal Sheep Production to Year-Round Fresh Meat and Halal Market in Norway

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Abstract: Norway is the largest sheep meat producer among Nordic countries with more than 1.3 million lambs and sheep slaughtered in 2017. The sheep industry is limited by the need for in-house feeding during the winter months. In summer, Norwegian sheep are mainly kept on rangeland pastures, with sufficient feed for almost double the current sheep population. Lambs are slaughtered over a three- to four-month period from September to December with a peak in September–October, providing a surplus of lamb, much of which is subsequently frozen, followed by eight months during which fresh produce is in limited supply. Norwegian consumers eat an average of 5.4 kg of sheep meat per person per year, much of which is purchased as a frozen product. The Muslim (4.2% of the population) preference for year-round halal meat, with an increased demand on the eve of the Muslim meat festival (Eid al-Adha), has the potential to boost demand, particularly in Oslo. This paper provides an overview of the Norwegian sheep farming system, the current market value chains, and the potential to meet the demand for halal meat in Norway (specifically during the Muslim meat festival—Eid al-Adha) to the advantage of both consumers and sheep farmers.

Keywords: halal; meat consumer; meat market; sheep farming; sustainable meat production

1. Introduction

While sheep farming is a part-time endeavour for most of the 14,000 Norwegian sheep flock owners, the industry is still vital for rural employment in Norway [1]. Over the past decade, sheep farming and sheep meat production have increased substantially. Recent figures from Statistics Norway [2] have shown that meat production has risen by 8.4% since 2012, while consumption increased by only 0.5% in the same period [3]. Norwegians consume a yearly average of 77.8 kg of meat per person of which 7% is from sheep [1]. The slaughtering of lambs and sheep is seasonal and so any meat in excess of demand for fresh consumption is frozen and stored for later use. Sheep farms are

supported by government subsidies for production and the maintenance of open, cultural landscapes created through long-term livestock grazing. The sheep industry is investigating opportunities to improve market conditions to make sheep farming more profitable including increased grazing and decreased concentrate-feeding, thereby increasing national food self-sufficiency [4] and helping to maintain the pasture landscapes that are now threatened by woody plant encroachment [5,6].

In Norway, approximately 4% of the population are Muslim. Meat dishes are of prime importance during Muslim festivals, especially Eid. The main festival is Eid al-Adha, the Muslim meat festival (MMF), where animals (preferably sheep) of a specified age (>12 months old) are slaughtered, and meat is shared among the family (1/3), friends/neighbours (1/3), and the poor (1/3) [7]. This meat festival offers a significant marketing opportunity for the industry. However, Norwegian sheep farmers have yet to utilise the commercial opportunity of selling halal meat in general and meet the market demand generated by the Eid festival in particular.

Norwegian sheep farmers have adopted existing production strategies as the demand for sheep meat has varied little during the past few decades. However, a more recent influx of Muslim refugees and immigrants has created a new niche in the domestic market. An export market for halal products may also be a possibility. In this context, it is essential to understand the production practices of Norwegian sheep farmers in both inland and coastal areas, including the current patterns of slaughter, to see how they might meet production targets to service this opportunity. Improved availability of fresh meat throughout the year is also an important objective that would allow the establishment of a regular fresh halal meat supply chain. Adjustments to farming practices to allow the supply of fresh product year-round has the potential to improve the profitability of the industry while maintaining the grazing environment.

Norwegian farmers need to adjust the production system to account for the low price of sheep meat other than lamb in the domestic marketplace. The transportation of animals to and from summer highland grazing environments and the need to overwinter animals indoors, as well as the cost of storage of the frozen product for long periods, have added to the challenges in sustaining profitability. Norwegian rangelands can accommodate a higher number of grazing sheep—almost two times the current sheep population, according to research [8], so there is a potential for the industry to expand. The establishment of a tailor-made halal meat marketing chain may trigger changes that lead to higher profitability.

In this review article, Norwegian sheep farming is discussed as a case study to explore a new niche in meat marketing—the establishment of a sustainable halal meat value chain. This opens the possibility for the more efficient utilisation of meat from older (>1 year) animals. We will briefly describe Norwegian sheep farming practices in the inland and coastal areas and the seasonal factors affecting out-of-season meat production in order to better facilitate sustainable halal meat supply in general and for the Muslim meat festival (MMF) specifically.

2. Sheep Farming in Norway

Of the Nordic countries, Norway has the largest sheep industry in terms of animal population and meat production (Table 1). Norwegian consumption of sheep meat per capita is the second highest of the Nordic countries, surpassed only by Iceland where the small human population and limited availability of grazing areas restrict production [1].

Table 1. Sheep population, mutton and lamb meat production, consumption, and import/export in the Nordic countries in 2011. Adapted from Åby, Kantanen, Aass, and Meuwissen [1].

Country	Sheep (Winter-fed Ewes)	Flocks (of Sheep)	Mutton and Lamb Meat Production (Tonnes) [e]	Import/Export (Tonnes)	Per Capita Consumption (kg)
Denmark	67,421	2380	2000	4630/1050	1.2
Finland	129,100	657 [a]	950	2033 [c]/359[c]	0.7
Iceland	474,759	2435 [b]	9587	23 [d]/2567	18.8
Norway	1,045,495	14,591	24,403	1545/25	5.4

Table 1. *Cont.*

Country	Sheep (Winter-fed Ewes)	Flocks (of Sheep)	Mutton and Lamb Meat Production (Tonnes) [e]	Import/Export (Tonnes)	Per Capita Consumption (kg)
Sweden	296,712	9387	5070	8277 [c]/350 [c]	1.5

[a] year 2012, [b] year 2006, [c] year 2010, [d] year 2008. [e] Lamb and sheep meat are combined, as mutton production in Norway is negligible.

Small, family-owned holdings dominate the Norwegian sheep farming system. There are currently more than 14,000 sheep farms in Norway, with 30% of farms owning 20–49 winter-fed sheep per flock while 13% have more than 150 (Table 2) [9].

Table 2. The structure and winter-fed flock size of Norwegian sheep farms [9].

Flock Size	Farms	Farms (%) per Flock Size	Ewes in Winter	Sheep Number (%) per Flock Size
1–9	761	5.2	4418	0.4
10–19	1504	10.4	21,800	1.9
20–49	4310	29.7	144,698	12.8
50–99	4014	27.6	286,889	25.4
100–149	2107	14.5	257,091	22.8
150–	1827	12.6	414,465	36.7
Total	14,523	100	1,129,361	100

There are two main Norwegian sheep breeds—the Norwegian White Sheep (NWS), a crossbred combined meat-wool type, and the short-tailed, double-fleeced Spel sheep (Spel). The NWS constitutes 71.5% and Spel 19% of the total Norwegian sheep population [10]. These breeds are supported by national breeding programmes with broad breeding goals, including improving lamb growth and ewe fertility [11]. Both breeds are first mated at seven months of age, and most ewes deliver their first litter at one year of age. Ewes are mated in autumn/winter with lambing in spring, maximising the utilisation of the short plant growth season [12] of the rangeland grazing areas to support lamb growth. The duration of the grass growing season varies across the country, ranging from 90 to 150 days.

The weather from coastal to inland areas changes considerably due to the Gulf Stream, which sweeps across the Atlantic Ocean from the Gulf of Mexico and up the Norwegian coast, providing a milder winter climate for Norway than most other countries at the same latitude. The average temperature falls below 0 °C (Figure 1), and most of the country is covered by snow in the winter season. However, in many coastal areas, the warmth of the Gulf Stream leads to intermittent snow cover. The mountain ranges bordering the inland areas block the effects of the Stream which lead to prolonged, relatively dry, and colder winters in the inland areas.

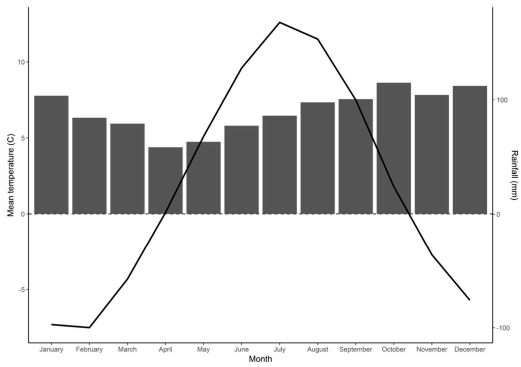

Figure 1. Average monthly temperature (line graph) and rain/snow-fall (bar graph) in Norway (1991–2015). Adapted from The World Bank Group [13].

3. Rural Sheep Management in Norway

Animal welfare concerns and winter season conditions are significant factors affecting sheep management and the livelihood of sheep farmers in Norway. There is little variation in the timing of the production cycle of sheep farms located in different rural areas across the country.

The sheep feeding system in Norway depends on ewes being barn-fed during the winter months. Lambing also usually occurs indoors followed by spring pasture grazing of sheep and suckling lambs on fenced land and summer range grazing mostly on unfenced highland pasture areas (Figure 2). Lambs that meet slaughterhouse specifications are separated from their dams at the end of the summer grazing period and transported to abattoirs, with slaughter peaking in September. As per the Norwegian Ministry of Agriculture and Food [14] directive, the time used to transport animals to a slaughterhouse must not exceed 8 h. Lambs that have not reached an appropriate slaughter weight during summer grazing are transferred to fenced autumn pastures (if available) and may also be supplemented with concentrate feed for 3–4 weeks to reach a commercially acceptable bodyweight, usually deemed to be around 42–45 kg live weight.

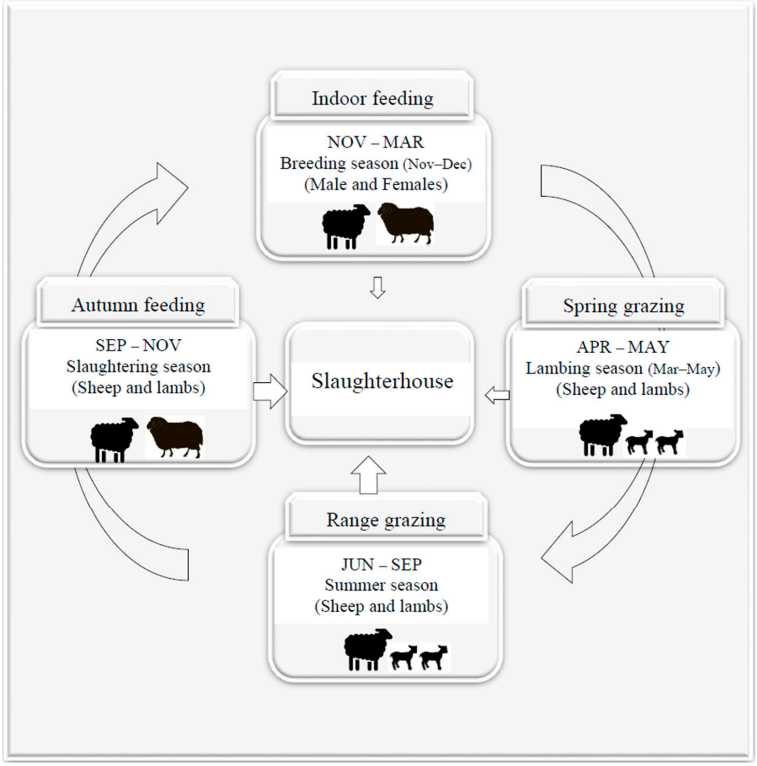

Figure 2. A typical Norwegian sheep production system (simplified layout). The length and placement of solid arrows pointing towards the slaughterhouse indicate the number of animals sent to the slaughterhouse and the time of year from the production cycle.

During the winter season, more than one million sheep are fed indoors. After lambing, the sheep population increases to 2.4 million [1]. Sheep numbers are not uniform throughout the country. Nine of the 19 Norwegian counties produce more than 80% of the lamb carcasses [15] (Figure 3). Rogaland County on the southwest coast is the main sheep meat producing region, supplying more than 27% of

the total lamb carcasses in 2017. During spring and autumn, sheep in Rogaland are maintained on farm pasture at the highest stocking rates in the country (Statistics Norway) [2] (Figure 4). The numbers provided above are based on the registered location of the sheep farm. However, during the summer, rangeland-grazing sheep registered to one county may graze in neighbouring counties.

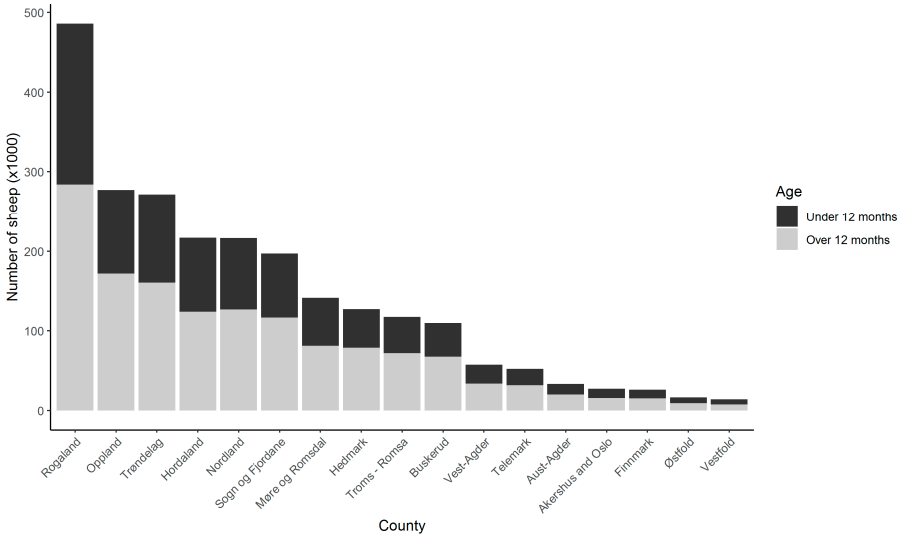

Figure 3. Norwegian sheep population in winter (under/over 12 months of age) in the 19 counties. Nord-Trøndelag and Sør-Trøndelag were merged in 2017 and are now referred to as Trøndelag. Data from Nord-Trøndelag and Sør-Trøndelag have been combined.

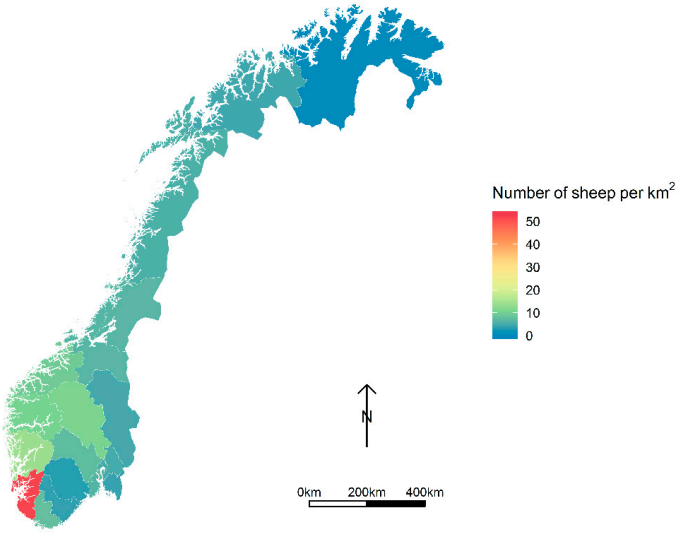

Figure 4. Sheep population density (per square kilometre) in Norwegian counties according to home farm location [10].

3.1. Winter/Indoor Feeding

During the indoor winter season, sheep are mostly fed grass silage or hey supplemented with concentrates and mineral feed. The number of sheep in winter flocks is minimised due to the higher costs associated with feeding, winter housing, and labour required for management [16]. Ewes are often fed according to their reproductive status later in the winter. Lambing takes place at the end of the winter season, mostly indoors with 3–4 weeks' variation in the time of lambing between regions (Figure 2).

Inland vs. Coastal Areas

Inland farmers facing colder winters with temperatures down to −40 °C [17] are limited in their ability to expand their sheep flocks by grazing, while farmers along the western coast have more options available for sheep grazing. They may graze their sheep in high mountains during summer, lower mountains during the autumn, and sometimes along fjords or on islands during winter. Still, the use of this flexibility is not common today.

In some coastal areas, sheep farmers may graze their animals outdoors at all times due to the year-round availability of pasture (of varying quality) and milder temperatures [12]. This practice is mostly found on the west coast of Southern- and Mid-Norway.

3.2. Spring Grazing

After lambing in April–May, ewes and lambs are fed indoors before starting a short period of spring grazing on fenced land. The timing of lambing is synchronised with the typical spring flush of pasture growth in the area. Farmers who do not have adequate spring pastures may send their animals directly to open ranges at higher altitude. In the case of triplets or more lambs born per ewe, lambs are usually fostered ("fosterlam" in Norwegian) to another ewe or hand-reared ("kopplam" in Norwegian). Hand-reared lambs are typically kept in a fenced paddock with access to grass, milk or a commercial milk replacer, and concentrates. Lambs slaughtered by 3–4 months of age are defined as "dielam". Dielam is a rare product that attracts high market prices, since it is a fresh meat product supplied during the summer months that is tender compared to other sheep meat.

3.3. Summer Grazing

During summer, sheep graze on unfenced rangeland for an average 90–100 days. The rangeland pastures are a resource that is essentially free of cost, except for the labour cost of occasional monitoring of the flock for welfare purposes and for bringing the flock back to the farm in autumn. Upon their return from the open ranges, lambs are sorted based on size and conformation to slaughter criteria and are weaned from the dam. Lambs that meet the criteria, typically attaining a live weight of ≈43 kg, are sent to the slaughterhouse, while smaller lambs are grown out on farm pasture or fed indoors [18]. Most rangeland pastures have an excess availability of dry matter during the summer months, though the quality decreases as the grazed plants mature. Lambs grazing high in the mountains have different meat quality characteristics compared to lambs grazed in lowland areas, with an increased content of beneficial polyunsaturated fatty acids [19]. Free-range summer grazing is an essential part of the Norwegian sheep farming system. Rangeland grazing provides an abundant resource capable of supporting a large number of sheep during the entire summer grazing season (Nationen, 2012). Reliance on rangeland grazing, however, leads to an over-supply of fresh lamb meat in autumn followed by nine months of a shortage of the fresh product.

3.4. Autumn Feeding

During autumn, unfinished lambs are fed indoors with silage and concentrate to attain high-quality carcasses with a variable meat flavour [18,20]. Lambs are kept on fenced pasture and concentrate may be offered indoors—animals have free access to pasture grazing and some

indoor feeding. After 3–4 weeks of additional feeding, the majority of the lambs are slaughtered. Only breeding stock and lambs too small to be slaughtered are retained for indoor feeding.

The Fate of Ram Lambs

Pre-pubertal, non-castrated ram lambs are slaughtered during the main slaughter season. The castration of ram lambs has been uncommon and is now illegal in Norway based on welfare grounds. While painless methods using immune-castration technology are under development [21], the early-age slaughtering of ram lambs is currently the only management option for farmers. The maintenance of intact ram lambs above 4–5 months of age introduces the risk of unwanted pregnancies and meat may attain a ram taint [20,22]. The early slaughter of ram lambs reduces carcass yield and dressing percentage compared to yields from more mature female lambs of the same breed. On the other hand, decreasing the duration of grazing for female lambs and mature ewes minimises the utilisation of the upland grazing environment. In this context, the preferences of consumers should be considered and meat from ram lambs is highly favoured in the Punjabi kitchen, due to its traditional preference by Pakistani Muslims.

4. Slaughtering Facilities in Norway

There are 29 slaughterhouses in Norway, of which 14 are owned by the farmers' cooperative (Nortura AS), three by the private meat processor Fatland AS, and the rest by 12 small Norwegian enterprises [10]. During the peak slaughtering season from August to November (Figure 5), the surplus meat is usually stored in central meat chiller storage facilities and marketed by further dividing it among the meat processors within set quota limits for each processor/slaughterhouse. Quota are set according to a mutual understanding between the major meat processors. The price of sorted meat is currently regulated by the main meat processor, Nortura AS. However, the price of premium meat products and out-of-season products (if any) are decided by the meat processors as part of their internal business strategy. Farmers receive a number of government subsidies for sheep production and for the preservation of rural landscapes.

Of the 24,115 tonnes of mutton and lamb meat produced in 2008 [23], only 200 tonnes (0.8% of total mutton and sheep meat produced) was halal [24]. Based on more recent data, Lever and Miele [25] showed that halal meat production had increased substantially, with Nortura alone selling 900 tonnes of halal product in 2012, showing a clear growth in demand for halal meat in Norway.

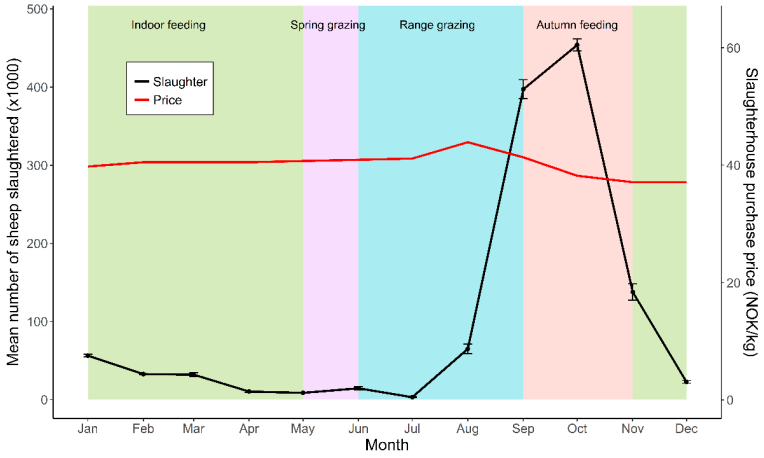

Figure 5. The number of sheep and lambs slaughtered per month and year (2014–2017) and average slaughterhouse purchase price (2017–2018). [15,26].

5. Trends in Sheep Slaughter

Based on age, Norwegian sheep carcasses are categorised into five classes—suckling lamb, lamb, young sheep, adult sheep, and ram. The mean carcass weight of lamb and sheep (pooled) increased from 22 kg in 2003 to 27 kg in 2009–10 (Figure 6). Since then, carcass weights have stabilised at 25–26 kg. If carcasses are categorised into four weight categories (Figure 7), the number of carcasses produced within the 0–16 kg class are at the same level in 2017 as in 1999. However, the 24–40 kg class increased significantly after 2003.

The changes in average weight have resulted from a higher proportion of heavier sheep as farmers adjust their production system to maximise financial returns. Traditionally, breeding sheep have been kept for up to 8 years to maximise their lifetime productivity. However, today, more ewes are being slaughtered after 3–4 years, providing the marketplace with a higher quantity of mutton product (Figure 8).

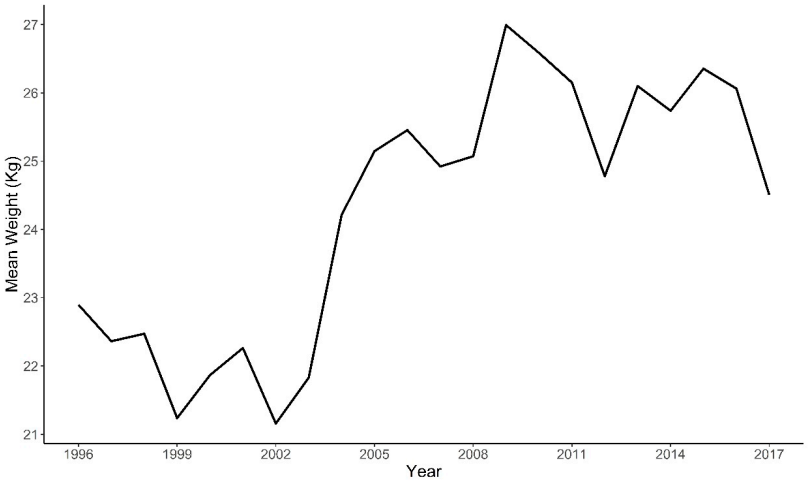

Figure 6. Lamb and sheep mean carcass weight (1995–2017).

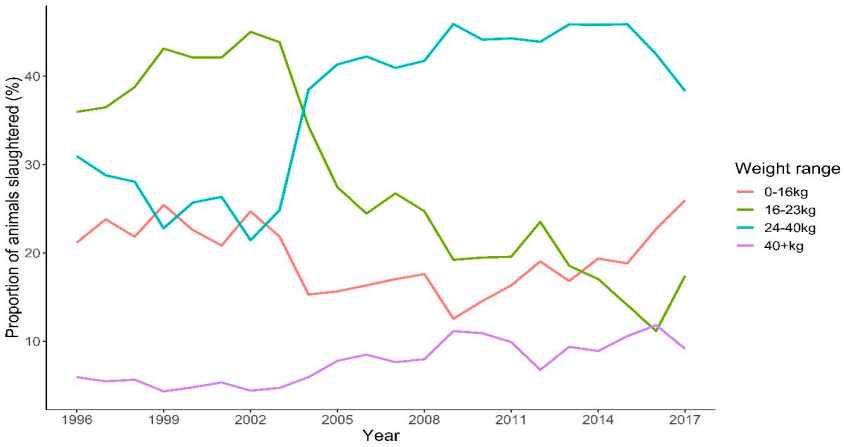

Figure 7. Sheep carcass weight group percentage (1995–2017) [15].

Carcass quality is assessed based on carcass conformation and fat status using the EUROP classification system. The EUROP conformation classification is not directly related to eating quality but is based on a visual inspection of the carcass, as described by Johansen et al. [27]. Carcass quality as classified by EUROP has improved since 2004 (Figure 9). Farmers generally obtain a good EUROP class for larger sheep carcasses; however, consumers often prefer smaller meat cuts based on their family size [28]. Relationships between the EUROP classification and consumer preferences are currently not well understood [29].

The percentage of each Norwegian sheep carcass category is shown in Figure 8. Since 2004, the quantity of suckling lambs and adult females has increased.

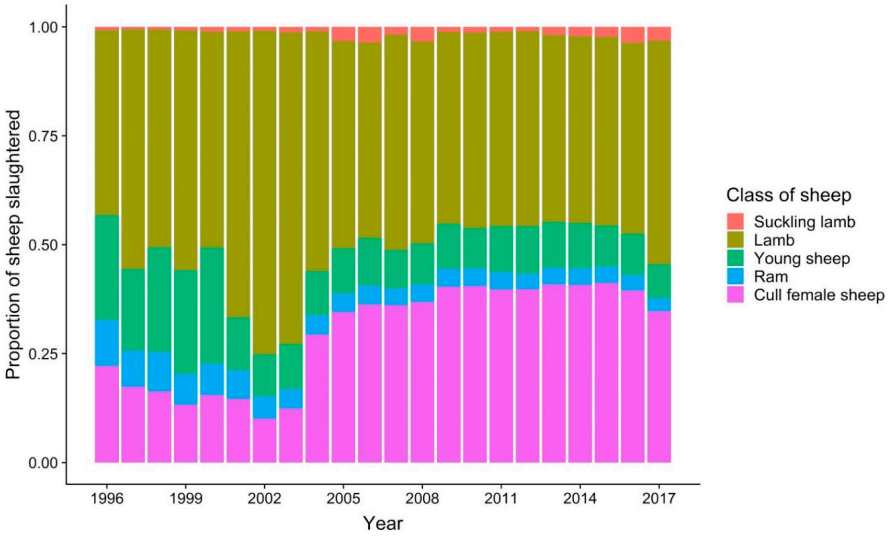

Figure 8. Proportion of types of sheep slaughtered (1995–2017).

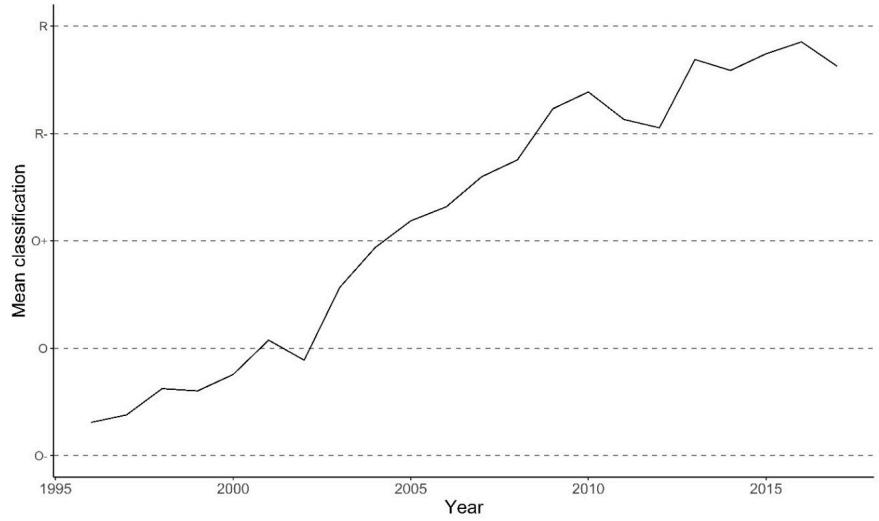

Figure 9. Mean EUROP confirmation classification of Norwegian lamb carcass (1995–2017).

6. Muslim Population and (Halal) Meat Consumption

In Norway, Muslims represent the second largest religious community after Christians [30], with most originating from Pakistan [25]. Muslims are projected to constitute 6.1% of the Norwegian population by 2030 [31]. The demand for halal meat will thus increase, creating a market potential for the sheep industry if it can gain the more than 0.3 million Norwegian Muslim consumers' trust in local (halal) meat produced under the strict Norwegian food safety laws [32].

Islamic dietary laws, followed by most practising Muslims, place prime importance on the halal status of food products, especially for meat and meat products. The meaning of the word "halal" is "things or actions that are permissible under Islamic Sharia Law" [33]. The consumption of halal food meets Islamic religious requirements, while also meeting fundamental nutritional needs [7].

Eid Al-Adha (Muslim Meat Festival—MMF)

MMF is celebrated by Muslims throughout the world to commemorate the faith of Prophet Ibrahim (Abraham). This festival begins with the slaughtering of animals on the 10th of Dhu'l-Hijja, the last month in the Islamic calendar, and lasts for three days. On this occasion, all Muslims who can afford it purchase an animal, such as a sheep or a goat above one year of age, a cow ($\geq$2 years), or a camel, as a sacrificial animal. Keeping in view that the animal is slaughtered (halal) for religious reasons, physical traits, such as the colour and 'beauty' of the animal, are deemed important and determine the economic value of the animal in the halal meat market [34,35].

In addition to the routine slaughtering practices required for the sheep meat to be halal, a Muslim person must bleed the animal in accordance with halal protocol. The process of slaughtering is critical, and halal slaughtering protocols must be followed [34]. The halal process can take place either in a registered slaughterhouse/abattoir (such as in Europe, the USA, or Australia) or at an informal place (government approved slaughterhouse/abattoir) specified by the local government on the eve of this meat festival (such as in most Muslim countries). In Norway, the halal slaughtering protocol (with some additional practices and approved food safety) is usually conducted using existing slaughterhouse practices. Therefore, on the eve of MMF, the slaughter of sheep (>1 year old) occurs and the meat is delivered to the nearest grocery shops and sold alongside the regular array of meat products. After purchasing the halal carcass, the meat is equally divided among family, friends/neighbours, and the poor. In Muslim countries, people routinely purchase year-old sheep at least 1–2 months before the actual slaughter date. A livestock production system producing sheep $\geq$1 year is needed to best fulfil the requirements for the MMF.

7. Barriers for the Current (Halal) Meat Supply and MMF Celebration in Norway

Currently, it is difficult for Norwegian Muslims to obtain halal slaughtered animals of sufficient age, especially during the MMF, for the following reasons:

- The Muslim meat festival does not usually coincide with the time of peak meat supply in Norway. Animals that could service this market are still grazing on rangeland pastures at the time of the festival (Figure 10) [36]. It is not profitable for farmers to bring down free-range grazing animals unless offered an exceptional price. However, the MMF offers a unique market for the slaughter of yearlings in Norway;
- A lack of infrastructure for the choice of animal, management, slaughter, and then delivery of meat often restricts consumer access to the halal product during the MMF.

As an alternative strategy in the provision of animal sacrifice at the MMF, the majority of Norwegian Muslim immigrants have their sacrificial animal selected and slaughtered in their country of origin, while residing in Norway. This is, however, considered a poor substitute for the traditional religious celebration of slaughtering the festival animal in situ. Norwegian Muslims sometimes send money equivalent to the price of a festival animal to charity organisations operating in their "home"

country. The practice of slaughtering animals back in their home country may undermine the potential for halal meat demand and the increased production and sale of sheep and goat meat in Norway.

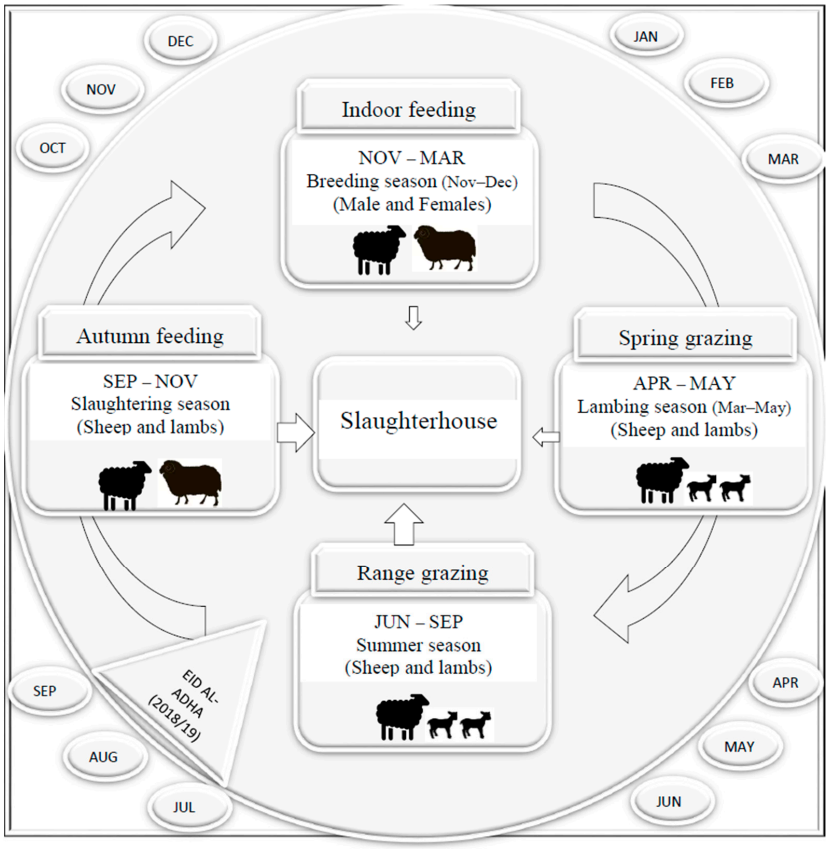

Figure 10. Potential for the integration of meat supply for the Muslim Eid festival into the Norwegian sheep farming system.

8. Sheep Meat Production and Consumption Imbalance

During the slaughter season (September–November) in 2017, more than 1.3 million sheep and lamb carcasses (27,445 tonnes of meat) were approved for human consumption [2]. Despite the higher demand for lamb meat at Christmas, these 1.3 million carcasses cannot be consumed as a chilled fresh product over this 3- to 4-month period. Moreover, it is challenging for slaughtering facilities to handle the concentrated slaughtering season [15]. A large quantity of meat/carcass is frozen for later use.

The need for farmers to reduce their flock size during the winter months, due to higher feeding and housing costs and the very low prices for older animals, restricts the potential to meet the requirements of the Norwegian halal market. Slaughtering during autumn seems the only option to restrict winter-stock numbers and get a good price per kg of lamb meat.

The frozen product does not provide the same sensory experience to consumers as fresh meat [37]. Sensory evaluation, tenderness, and juiciness are deemed superior in chilled meat compared to frozen–thawed meat produced in Norway [38]. Thus, the industry should develop new strategies for lamb production to maximise the availability of chilled products year-round.

Existing Norwegian sheep production systems and slaughtering practices lead to the limited availability of fresh meat in the "off-season" and, in particular, do not meet the requirements of the MMF. Overall, the Norwegian market consumes meat worth USD 2.75 billion annually, including USD 1.5 billion worth of meat that is resold to retailers in the form of frozen meat. Despite occasional overproduction, Norway does not export sheep/lamb meat and actually imports lamb meat for, on average, 2–3% of its requirements [24].

9. Discussion and Conclusions

It is essential that the Norwegian meat industry reviews production and marketing chains to better meet the needs of an evolving consumer population. Norwegian sheep farmers receive government subsidies for the preservation of rural landscapes and food production based on natural resources. To maintain the popular support for agriculture and rural livelihoods, it is essential that the industry provides high-quality products. Consumer preference for meat from small ruminants will likely increase if the Norwegian industry can provide a consistent supply of high-quality fresh product without compromising the environment [39] and the low emission of greenhouse gases [40].

Norwegian sheep farmers operate within strict environmental boundaries. The availability of home-grown feeds for the winter is limited due to farm sizes and the short growing season. High-quality summer pastures are, on the other hand, abundant and freely available during the short summer months. Most of the summer grazing areas are found in mountainous areas, but forest grazing is also important during the summer and autumn seasons.

Like the Norwegian sheep meat industry, the British lamb industry has had to deal with similar challenges, but in their case, the frozen product was imported from New Zealand. In the United Kingdom, the import of sheep meat is declining continuously [41]. This is perhaps because British farmers changed from the traditional system of late lambing to a sustainable production system by adopting more than one lambing season per year. By doing this, they can utilise their home-grown lamb meat as a year-round fresh meat product and maintain better prices for farmers. This shows that it is possible to adjust production strategies to meet consumer needs that are beneficial for farmers—something that Norway might consider.

In general, a well-planned sheep farming system based on rangeland grazing will extend the use of natural feeding resources and, in addition to the strategic use of feed supplements, may improve economic and environmental sustainability [42–44]. A future diversification of Norwegian sheep production systems, producing either 5- to 6-month-old lambs (regular meat supply) or yearling animals (MMF supply) may lead to a more regular supply cycle, thereby reducing seasonal pressure on slaughter facilities while satisfying the MMF market. Further research including economic comparisons is required. Such work should focus on the natural and economic production constraints, and the nature of government subsidies provided for alternative production systems should also be considered.

One possible solution for the availability of off-season fresh meat is to focus more on a yearling production system using the Norwegian Spel breed. The yearlings can be better utilised for the MMF, and older lambs (born in May and slaughtered in February the next year) can provide fresh out-of-season meat. The price difference in lamb and sheep meat, a lower price offered for sheep meat, has resulted in more lamb meat production than sheep meat. More than 40% of the meat comes from sheep (Figure 8), which has resulted in a lower income due to the lower price offered per kg of sheep meat. The production of sheep meat can be reduced by slaughtering the animals at eight years thus increasing the lamb to sheep meat ratio.

In order to benefit from the growing halal meat market potential, Norwegian farmers need to rethink their production strategies to be able to meet the year-round demand for halal meat but with a particular emphasis on maintaining the supply for the peak demand around the time of key religious festivals.

Increased production of the meat of animals that have reached one year of age, to cover the requirements for the MMF together with Easter and Christmas celebrations, should be a priority for the industry. Ewes are counted after the spring lambing season for calculating the government subsidy for production. Keeping ewes after lambing will assist in servicing the requirements of religious festivals, and farmers will be rewarded financially for keeping their sheep longer. It is also anticipated that more extensive early and late rangeland grazing of sheep in spring and autumn (where possible) will add to the national feedbase, with beneficial effects on the grazing environment. The maintenance of the rangeland environments should not be forgotten; it is vital for the rural landscape and the tourism industry, as well as the long-term livelihood of farmers.

A possible way to alleviate the imbalance during the concentrated slaughter season (August–October) is for coastal farmers, with access to a more extended plant-growing season, to adjust their breeding and lambing seasons to extend the slaughter season and therefore the period during which fresh lamb products are available to the consumer. Clear economic signals would need to be provided to facilitate changes in traditional farming practices.

In conclusion, modifications to the traditional sheep-rearing system including the production of yearlings for slaughter, has the potential to increase the sustainability of fresh off-season meat in the general Norwegian meat market and thus increase consumption. In addition, an improved fulfilment of Muslim meat demands will increase the Norwegian per capita meat consumption, thereby providing greater financial potential for sheep farmers. Further research focused on the economic analysis of yearling production systems and Muslim consumer meat-eating preferences is required. Cost-benefit economic analyses of traditional and yearling sheep-farming systems should help farmers to understand the current potential for a year-round increase in cash flow.

In order to make Norwegian sheep production economically sustainable [45], economic modelling of sheep-farming systems, with more focus on a sustainable year-round supply of sheep meat and supplying the halal market, will be required. To better understand the Norwegian Muslim meat consumers' perceptions and demands, a survey focusing on their meat purchase preferences, consumption, and trust in the meat industry will be conducted (by the present authors). This will play an important role in forming the best strategies for a sustainable Norwegian sheep industry.

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Conflicts of Interest: The authors declare that they have no conflict of interest.

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Paper 2

Rangeland Grazing Strategies to Lower the Dependency on Imported Concentrates in Norwegian Sheep Meat Production

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Rangeland Grazing Strategies to Lower the Dependency on Imported Concentrates in Norwegian Sheep Meat Production

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Abstract: Norway has vast rangeland resources (292,361 km^2) with an estimated carrying capacity of nearly four million sheep and lambs, twice the current number. However, the intensive production system currently applied has led to more concentrate dependency, resulting in heavier animals in addition to poorer utilization of rangelands and homegrown feed. Intensive feeding systems indirectly influence the sustainability of ecosystems by promoting intensive cropping that can deplete soil fertility and threaten landscape preservation and biodiversity. By contrast, extensive grazing systems can produce environmentally and animal-friendly food products and contribute to regulating soil health, water and nutrient cycling, soil carbon sequestration, and recreational environments. In this paper, the economics of current sheep feeding practices in Norway, using a linear programming model, were compared with more extensive systems which allow for higher usage of on-farm feed resources. Changes in current sheep farming practices have the potential to increase lamb meat production relative to mutton production, in addition to improving the year-round supply of fresh meat. The investigated alternatives, using the Norwegian White Sheep (NWS) breed, suggest that delayed lambing is useful only on farms with abundant pastures available for autumn feeding. Lambs achieve a better market price than hoggets and mature sheep. Therefore, based on the current Norwegian meat market and price offered per kilogram of meat for lamb, an increase in NWS lamb production improves farm profits. On the other hand, when the aim is on greater use of homegrown feed and rangelands, this can be achieved through hogget production, and the quantity of concentrates required can be reduced substantially.

Keywords: gross margin; concentrate feed; rangeland; production systems

1. Introduction

Sheep farming is important for Norway with two million sheep and lambs producing ca. 25 thousand tonnes of meat, thereby ranking Norway as the largest Scandinavian sheep meat producer [1].

Only 3.7% of the total area is arable land in Norway, and 30% of that is used for grains and vegetable production, while the rest of the area can only be used for grass production [2]. In addition, sheep graze in the mountains in the summer season. Sheep farming based on non-cultivated rangeland grazing has the potential to double sheep production [3].

Sheep farming is a part-time activity for most Norwegian farmers that keep sheep, and their primary source of income is from off-farm activities. Most (72% in the National Sheep Control Records [4]) of sheep are Norwegian White Sheep (NWS), which is a crossbred meat-wool breed. The sheep are fed indoors during the winter season (November to March) and during lambing in April, while farm pasture and rangeland grazing (common resource) are practiced in the summer months from June until September [3].

Extensive sheep farming is widely accepted by the Norwegian society on the basis of animal welfare considerations and the view that it represents a natural way of food production since it is practiced on farmlands, fenced farm pastures, and through rangeland grazing [3]. However, the intensive farming systems in Norway also rely on concentrate-feeding in addition to the use of local feed resources. Arguments against red meat production rest on the assumption that if grazing ruminants are removed and the meat required is provided through intensive livestock systems (non-red meat), greenhouse gas (GHG) emissions will be reduced. However, the current paradigm for mitigating the effects of climate change by promoting intensive meat production from monogastric animals may be misleading [5]. In fact, in the absence of grazing by farmed ruminants, rangeland habitats may be dominated by other methane-producing herbivores including roe deer, elk, and reindeer. Moreover, grazing may be applied as a management strategy to keep the land open and to lower the risk of wildfires [6]. For small ruminant production to be environmentally and societally legitimate, a greater emphasis on pasture and lower use of concentrate feed in the ration is vital. An extensive grazing system may allow for environmentally sustainable food products and services that also contribute to regulating and improving soil health, water and nutrient cycling, soil carbon sequestration, and recreational environment. It should be noted that sheep farming is subsidized in Norway both for meat production and for maintenance of the farming and grazing landscape [7].

The objective of this study was therefore to examine the economics of typical Norwegian sheep farms and how they are affected under different scenarios through adapting or changing the farming system to allow for increased and more efficient utilization of rangelands and homegrown winter feed while the use of concentrates is minimized. The study focuses on sheep farms in the Hardanger fjord area and surrounding coastal and fjord areas in Agder, Rogaland, and Sogn because of the high sheep numbers and meat production found in this area [3] compared to the other regions in Norway.

2. Materials and Methods

2.1. The Model

In this study, the NWS breed was used for the economic modelling. The potential gross margin (GM) of the current semi-intensive (in spring) and intensive (in winter) sheep feeding practices were compared with more extensive feeding practices using a linear programming (LP) model. The model was parameterized with the averaged data from 18 sheep farms (for 2014–2016) in the Western Norway and Agder regions [8]. Many farms in the area have lower numbers of sheep, but less information was available. The LP technique uses constrained optimization to identify the composition of non-negative activities resulting in the maximum objective function within the constraints. The mathematical formula [9] used in the LP model is given below:

$$\text{Max } Z = c'x \text{ subject to } Ax \leq b,\ x \geq 0.$$

Here, Z is the farmer's objective function or gross margin (GM), i.e., total yearly returns from livestock and governmental payments, minus variable costs. Since the fixed costs were not affected in any of the solutions examined, a range of alternatives according to the GM would be similar to a range

according to farm profit. Moreover, x is a vector of activity levels and c' the vector of marginal net returns for the activities. A is the matrix of technical coefficients showing resource requirements by the activities; b is the vector of right-hand side values of resources such as farmland and semi-cultivated farm pastures, farm workforce, and constraints due to, e.g., area and feeding requirements.

The area constraints encompassed arable and pasture-able farmlands as well as constraints relating to crop rotation, use of manure, and area and cultural landscape (ACL) payments. The feeding requirements were developed based on Madsen, Hvelplund [10] and encompassed energy for milk production measured in feeding units (FEm), roughage dry matter (DM), and amino acids absorbed in the small intestine (AAT), each relating to specific constraints. 1 FEm = 6.9 Mega Joule or approximately the amount of energy in one kg of barley. AAT refers to amino acids absorbed in the small intestine. Its composition relates to all amino acids (AAs) needed for growth and does take into account special needs for, e.g., the Sulphur containing AAs cysteine and methionine for growth of wool. The amount of AAT was measured in proportion to the amount of energy in different feeds (g AAT/FEm) and in the amount needed on a daily basis by animals (g AAT/day). Constraints also accounted for indoor production of manure, used in the sward establishment activities, and flock replacement. The work constraints encompassed one for the grazing season and one for the whole year, assuming farmers would be willing to work longer days in shorter peak periods of work within these periods, as long as the total work requirement in the whole period was not exceeded. The model was defined under assumed certainty. The model detail is provided below.

2.2. *Land, Feed Provision, and Animal Activities*

The farm area used was 18.4 ha of arable land and 6.2 ha of arable pasture land for sheep, making a total area of 24.6 ha. While arable land can alternate between harvesting and grazing, mechanical harvesting cannot take place on the pasture-able farmland area, and a separate process for grazing on pasture designated farmland area was developed in the model. The governmental ACL payments for arable land and pasture-arable farmlands were added in a separate process to the model with lower rates for pasture-arable farmland handled directly in the model matrix.

The cropping activities on arable land matched the feed demand in the indoor and pasture periods through the supply of silage and pasture. The yields were set reflecting minimum agronomic sward establishment requirements for meadow restoration, which were set to 6% of the arable area in the model, while data in farm accounts [11] constituted the basis for fixing the farm pasture yields, considered sustainable in a long-run perspective without a restoration. The land activities consisted of grass leys with two cuts of silage (baled) or one cut plus pasturing the first growth or the re-growth. Moreover, there was one activity for grazing arable land during spring and autumn with a small cut in between in the model. In each period, except for the summer pasture period, it was possible to purchase concentrate feed to supplement pasture or indoor feed. Crop and pasture yield parameters were standard net energy, protein, and DM, measured as net uptake by the animals, which were considerably lower than the produced amounts due to harvesting and feeding losses. The net yields for the different processes in FEm, kg roughage DM, and kg of AAT per 0.1 ha are given together with amounts of manure and mineral fertilizers.

In situations with less work time available for agriculture, farmers may lower the intensity of the farming system, i.e., by choosing types of agriculture with lower levels of input and output per unit of agricultural land area. A low yield intensity level, represented with 30% lower yields, 37.5% lower use of fertilizers, and 4% sward establishment, based on the results in field trials conducted at Bioforsk Vest Fureneset [12], was defined for the model. The optimum yields were approximated linearly between the low and the high levels. It is well known that harvested farm yields can be considerably lower than yields in experimental plots [13]. All yields in the sheep model were lowered by 15% in a calibration run based on account results for the sample of sheep farms [7].

Parameters for feed intake, work time requirements, amount of manure, mineral fertilizers and other inputs for different plant and animal processes were collected from the Farm Management

Handbook [14] supported with farm account data and expert opinions. These were the feeding requirements in the model: Energy springtime (FEm), Protein (AAT) spring kg, Summer energy (FEm), Energy fall (FEm), Energy winter (FEm), Protein (AAT) winter kg, Max dry matter winter kg, Min dry matter winter kg, concentrate feed (MIN FORMEL SHEEP kg, MIN FORMEL FAVØR kg). The energy requirement of Norwegian White Sheep was calculated using the following equation in NILF [14].

$$ERS_i = ERWMain_i + ERGrow_i + ERFetu_i + ERWMLamb_i + ERGrowLamb_i,$$

where:

- ERS_i = Energy requirement per sheep in period i
- $ERWMain_i$ = Energy requirement for wool and maintenance of sheep in period i
- $ERGrow_i$ = Energy requirement for growth of yearling and 2 years old ewes in period i
- $ERFetu_i$ = Energy requirement for growth of fetus in period i
- $ERWMLamb_i$ = Energy requirement wool and maintenance of lambs in period i
- $ERGrowLamb_i$ = Energy requirement for growth of lamb in period i, and i = feeding period; 1 = indoors, 2 = spring pasture, 3 = summer pasture, and 4 = autumn pasture.

In the current version of the model, the input prices (Table 1) were updated to the price level in 2018, based on Hovland [15]. The agricultural subsidies system for the 2019–2020 season was applied. The sale price of lamb was 66.10 NOK per kg, while mutton and hogget (1–2 years old) were 7.18 and 10.18 NOK per kg, respectively (Table 1). Additionally, basic and rural price support, amounting to NOK 9.06 per kg, was included for all meat (from lambs, hogget and sheep). It should be noted, however, that the high price of lamb declines throughout the slaughter season from September to December, and while the lambs also get heavier, the cost of feeding them for a longer period increases.

Table 1. Farmgate product prices, input prices, and support premiums used in the model, in Norwegian kroner (NOK).

Description	NOK
Livestock product price per kg	
Sheep meat	7.18
Hogget meat	10.28
Lamb meat	66.10
Wool per kg	53.8
Input prices	
Concentrate feed lamb, (92, 11) * per kg	3.69
Concentrate feed fiber, (86, 11) * per kg	3.72
Concentrate feed sheep, (96, 12) * per kg	4.21
Diesel, per L	11.52
Mineral fertilizer (22% Nitrogen, 2% Phosphorus, 12% Potassium), per kg	3.72
Shearing costs, per kg of meat	0.52
Support premiums	
Basic support meat, per kg	3.81
Relief support, per sheep	485
Grazing farmland, per animal	50
Grazing rangeland, per animal	205
Support per sheep (from 1 to 150 sheep)	883
Support per sheep (more than 150 sheep)	194
Lamb support, grade O (in EUROP classification), per carcass	450
Lamb support, grade <O (in EUROP classification), per carcass	41

* FEm per 100 kg and gram AAT per FEm.

The annual maintenance costs for meadows and pastures included fertilizer and lime, seed, pesticide, and machinery. The machinery costs were computed as work time for different operations multiplied by an hourly rate depending on the type of machinery. The hourly rate included the tractor's

diesel consumption, at 8.5 L per hour, a standard amendment for lubricating with oil and grease, and cost of maintenance of machinery computed as a fraction in relation to type and price for the acquisition of new machinery. Equipment for compression and packing of bales, containing 135 FEm (1 FEm = 6.9 MJ net energy), was rented for 184 NOK per bale of feed. The model did not allow for the purchase of bales or other roughages for the farm; only concentrate feed could be bought. The farm gate prices for the various concentrate feedstuffs are displayed in Table 1, including the transportation costs (bags). National import tariffs to keep a high price of concentrate feedstuffs were applied.

The model was run on an average of data collected through the 18 farms. The optimal solution showed that a flock of 172 sheep (including lambs and hoggets) and hiring 570 h of worktime was promoted. Thus selected as the current or baseline practice. This compared with 165 sheep (including lambs and hoggets) and 463 h of hired work in the average of the records from the 18 sheep farms in the area. The yield (FEm/ha) for the optimal solution was 2711 FEm/ha while for the recorded 18 farms it was 2530 FEm/ha. The hired labor cost was found to be lower in the farm data compared to the optimal solution (69,706 NOK and 85,732 NOK, respectively).

2.3. Baseline Practices

Under the baseline practice, ewe-lambs were assumed to give birth at one year of age and ewes to have a lifespan of 3.3 years with a replacement rate of 0.30. Lambing occurred on 14 April, and the expected average lifetime for the lambs that were slaughtered in the fall was 159 days with slaughtering stipulated on 20 September.

The net number of lambs per adult ewe in the fall was set to 1.33 based on the average in the 18 farm records representing sheep farms in the area. Moreover, the live weight of adult sheep was set at 74.5 kg and 43.3 kg for lambs, and the carcass weight was stipulated to be 45% of the live weight for both sheep and lambs. There was no information of breed in the farm records, however, according to the National Breed Recording scheme [4], 70% of the ewes belonged to the NWS crossbred type of sheep in 2018. The average number of lambs per ewe of the NWS breed at the end of grazing (in September) was 1.89 in the National Breed Recording scheme. Moreover, average live body weight (BW) of lambs in the fall was 43.7 kg, and an average BW of ewes (up to 5 years) was 100 kg [16]. The National Breed Recording scheme (43.4% of herds and 55.4% of sheep are recorded) was assumed to represent farms with well above average production results, while the farm records were assumed to be more representative for the results in the area.

2.4. Alternative Scenarios

The following alternative practices were investigated: delayed lambing, hogget production, 1st lambing when 2 years old, and longevity increased to 5.3 years (Table 2).

The aim of the first alternative scenario, delayed lambing, was to avoid extensive grazing of arable farmland (early in the spring) and instead send the lambs to summer rangeland grazing after only a short period on intensive farmland pastures. In addition, the aim was to reduce the use of concentrates in the barn-feeding period after lambing.

In the second alternative scenario, hogget production, female hoggets were assumed to graze more on the farmland pastures during the second summer when the rest of the flock were grazing in the mountains. These hoggets were marketed in the summer with slaughter date set to 12 August to make way for the regular flock of ewes with lambs grazing the same pastures from 5 September. The hoggets were slaughtered at around 15 months of age and required little management input for feeding and none for mating since they were not lambing. It is noted that the ram lambs were slaughtered at around 6 months of age to avoid the ram-taint flavor of the meat. For welfare reasons, routine castration of lambs is not permitted in Norway, hence only females may be kept as hoggets.

In the third alternative scenario, lambing 2nd year, ewe lambs to be bred were kept with the regular flock and grazed in the mountains (rangeland grazing), but mating was postponed until the

second year. Since they were older when mated, it was not necessary to boost body condition with strategic concentrate-feeding in addition to grazing.

Table 2. Description of baseline farming system and alternative management scenarios.

Alternative Scenarios	Description
Baseline practices	Ewes start lambing at 1 year with a life span of 3.3 years, and the rate of replacement is 0.30. Ewe lambing occurs on 14 April and slaughtering 20 September. Majority of the lambs (except for breeding) are slaughtered at the age of approximately 159 days.
Alternative scenarios	
1. Delayed lambing	Compared with Baseline practices, ewes lamb 16 days later at that is the start of grazing season (around 1 May) and a corresponding 15 days delay in slaughtering until around 5 October.
2. Hogget production	Production system is the same as Baseline practices, but surplus female lambs (no breeding) are overwintered and marketed as hoggets in July or August (next year).
3. 1st Lambing when 2 years old	Production system is the same as Baseline practices, but with first lambing when ewes are 2 years old.
4. Longevity increased to 5.3 years	Production system is the same as Baseline practices, but with first lambing when ewes are 2 years old, and assuming longer ewe lifespan (5.3 years).

In the fourth alternative scenario, longevity, the ewe lifespan was increased to 5.3 years in addition to the first lambing at the age of two years. The ewes were then maintained in the breeding flock for five or more years compared to 3 years when mated as 7–8 months old lambs (baseline practice).

The minimum amount of concentrates used in the different systems is displayed in Table 3. A considerable quantity of concentrates will be saved by not mating ewes in the first year.

Table 3. Daily amounts of concentrate offered by age categories of sheep and mated and unmated lambs.

Concentrate Type and Season	Ewes, Years		Lambs, 0.5–1 Year	
	>2	1–2	Mated	Unmated
Standard concentrate mixture, winter (kg/head)	0.2	0.3	0.5	0.15
Standard concentrate mixture after lambing (kg/head)	0.5	0.5	0.5	-

The studied systems allowed for higher utilization of on-farm-produced feed resources and less dependency on concentrates. They have the potential to increase lamb meat production relative to mutton while at the same time improving the year-round supply of fresh meat by the marketing of meat from female hoggets. The quantity of concentrates used to support the growth of hoggets was lowered by postponing the initial lambing until the second year since the non-mated first year ewes have a lower feed requirement compared to pregnant ones. For ewes with late lambing, the normal practice of spring grazing on arable land combined with concentrates can be switched to un-supplemented pasturing on the farm, while rangeland pasturing in the summer would be as before.

3. Results and Discussion

The model, with the baseline practices, used lambing on 14 April, slaughtering on the 20 September, and first lambing at the age of one year with a lifespan of 3.3 years. The results for this are displayed in Tables 4 and 5, together with the alternative scenarios 1–4.

Table 4. Gross margins (GMs), flock size, and hours of hired labor for the baseline farm and the alternative scenarios.

	GM, 1000 NOK	Breeding Sheep	Hoggets for Meat	Lambs in Stock *	Total Flock Size	Hired Work, Hours
Baseline practice, lifespan 3.3 years	401	119	0	53	172	570
Alternative scenarios						
1. Delayed lambing	369	116	0	52	168	510
2. Hogget production	279	99	52	44	195	593
3. 1st Lambing when 2 years old	354	157	0	70	227	693
4. Longevity increased to 5.3 years	417	163	0	38	201	612

* Less than 1 year.

Table 5. The use of concentrate feed and roughages (per year) per sheep in terms of energy (FEm), as well as grazing offtake per ha and use of concentrates per kg of meat for different scenarios studied for the Norwegian White Sheep (NWS).

	Concentrates EnergyFEm*/Sheep	Roughages FEm*/Sheep	Grass Yield FEm*/ha	Concentrate Used FEm*/kg Meat
Baseline practice, lifespan 3.3 years	115	387	2711	3.87
Alternative scenarios [a]				
1. Delayed lambing	127	380	2588	4.31
2. Hogget production	113	476	2714	2.85
3. 1st Lambing when 2 years old	115	296	2735	5.61
4. Longevity increased to 5.3 years	114	331	2705	4.78

* 1 FEm = 6.9 MJ net energy. [a] Detailed description of alternative scenarios is in Table 2.

For the baseline practice, the model optimal solution showed a gross margin of 401 thousand NOK, with a flock of 172 sheep (including lambs), and hiring 570 h of work time; which compares with an average flock of 165 sheep (including lambs) and 463 h of hired work in the records from the sampled 18 sheep farms in the area.

For the 1st alternative scenario, with delayed lambing and slaughtering, the optimal solution showed a lower gross margin by 32 thousand NOK, thereby making this scenario less profitable compared with the baseline practices. The reason for the lower gross margin in this case was the limited availability of autumn pasture. The lambs were born (16 days) later in the year and needed to spend more time on autumn pastures or needed more supplementary feeding with concentrates in the fall. However, at smaller sheep farms with easily available autumn pasture, improved economic performance for this alternative scenario might be possible.

For the 2nd alternative scenario, marketing surplus female hoggets in the second grazing season, the gross margin was the lowest (279 thousand NOK vs. 401 thousand NOK for baseline). The main reason was the low market price for hogget meat. The farmers obtain a high price (66.10 NOK/kg) for meat from 5–6 months old lambs, while for hoggets (10.28 NOK/kg) and older sheep (7.18 NOK/kg) they get very low prices (Table 1). This may be surprising since the sensory quality of the meat from Norwegian lambs and hogget was similar when assessed by a trained sensory panel [17]. If the consumer price is corrected based on the knowledge of sensory meat quality, and a higher price attracted for hogget meat, it will make the second alternative more profitable. The appropriate marketing and branding of the hogget meat is estimated of having the capacity to increase the price fivefolds, which then makes the results very different. However, under the current price for hogget meat, GM (compared with baseline practice) was 122 thousand NOK lower. The hogget numbers would depend on the prolificacy of the breeding flock and the number of breeding replacement ewes required to meet production objectives. Using a lambing rate of 1.33 and 50% of lambs being females with a replacement rate of 0.3, the expected number of surplus females per breeding ewe is 0.37. The consumption of lamb in Norway has traditionally been seasonal with the bulk of the production

and demand in the fall from September to December. To fill the more recent seasonal market demand for fresh lamb meat, especially when the Muslim meat festival is in the summer months, we suggest that the use of surplus females (non-pregnant) would be sufficient for the foreseeable future. The costs of feeding in the secondary season need to be calculated carefully. We assumed feeding requirements were lowered by using mainly winter pasture since the lambs would grow more slowly over the winter months. However, the gross margin fell substantially due to the cost of supplementary concentrate and other feeds required to meet market specifications.

The 3rd alternative scenario examined was to delay initial lambing until the second year. The model optimal solution showed a gross margin of 354 thousand NOK that was 47 thousand NOK lower than the baseline practices. This would require feeding non-mated ewe lambs for another winter, but that will require a substantially lower feed level compared to feeding pregnant ewe lambs. We hypothesize that slower-growing hoggets fed at just above maintenance energy requirements would take longer to attain live weights sufficient for joining and would make better use of winter pasture in the first year. Analysis of the feeding value of such pasture would be needed to predict when saleable live weights are reached.

The fourth alternative scenario showed that extending the lifespan to 5.3 years would increase profitability measured as aggregate GM by 16 thousand NOK (compared with the baseline practice). While the calculations over a lifespan of 3.3 years for the breeding stock yielded a negative result with delayed initial lambing age compared to the prevailing practice, profit margins improve when animals are grown out to 5.3 years due to lower cost of replacement and feeding before first lambing. This assumes the prevailing substantial price premium for producing lamb meat relative to mutton. The break-even seems to be around two more years of lifetime for the NWS breed. Table 5 shows the resource use per kg of meat produced in the baseline and alternative scenarios.

The quantity of concentrates used to produce one kg of meat was lowest in the scenario with hogget production. The use of concentrates/kg meat can be considerably reduced when marketing hoggets, instead of using the baseline practices. However, it should be noted that the 2nd alternative was least profitable—the main reason being the low price/kg for hogget meat compared with lamb meat. In the case of delayed lambing, the quantity of concentrates required was higher because of the scarcity of farm pastures in autumn. The NWS, being a heavyweight composite breed producing more triplets, is prone to some reproductive difficulties, and mastitis is common. This can lead to increased labor costs on the farm. The option of artificial rearing of NWS lambs also needs to be carefully evaluated. It is likely that the ewes will last longer if first lambing occurs at the age of two years rather than one, thus lowering the costs of ewe replacement. The effectiveness of this measure should become an area for future research. The shadow price calculation showed that for a unit (0.1 ha) increase in the cultivated farm area, the GM will increase by 385 NOK. Moreover, the total farm labor was calculated as 1585 h per year, while the shadow price calculations showed an increase of 150 NOK in GM for one extra hour of labor at the farm. The sheep farming system with increased longevity (4th alternative scenario) will better utilise Norwegian rangeland resources by more grazing and will lower the risk of wildfires [6].

Since NWS are heavyweight sheep, it is interesting to know the possible effects of animal size on the farm gross margins. Bhatti, Williams [3] argue that by using lighter sheep and goat breeds rather than the dominant heavy Norwegian White Sheep (NWS), a larger share of the mountainous grazing-based ecosystem could be utilized. Later, these hoggets can also be used to fulfil the out-of-season fresh meat supply at relatively better market price. Based on the current situation (after the worldwide COVID-19 pandemic), the preference for locally produced food may increase, and many countries will strive for self-sufficiency in food. Based on Norwegian land topography and vast rangeland resources, Norway can be not only self-sufficient in sheep meat production but might export sheep meat to neighboring countries.

By focusing on smaller rangeland-grazing-adapted breeds, farmers may play an important role in the eyes of the Norwegian populace in maintaining sustainable grass and rangeland agroecosystems

which improve the amenity of the agricultural landscape, biodiversity, soil fertility, animal welfare, and the quality of animal products [18]. The meat consumer's preference for good quality meat from grazing-based animal-friendly production systems and animal welfare aspects will positively impact the meat industry.

Grazing lands (grasslands, rangelands, and pasture lands) cover 30–40% of the total global land-use area, or 70% of the total land used for agriculture [19,20]. Management strategies are required to balance livestock production (for human nutritional demands) and the environmental impact on sustainable grazing lands [21]. Countries with extensive rangeland resources available for grazing (such as mountainous regions in Pakistan and China) could use the LP model with the local input of resources and constraints and might also minimize the use of concentrates by adopting efficient and sustainable grazing practices. Efficient use of natural pastures can decrease concentrate-feeding depending on the nutritional value of the pasture. However, a failure to attain commercial carcass specifications at the right age because of utilizing upland native pastures without resorting to the use of feed concentrates may in effect be more costly for the lamb producer. Prices achieved for lambs and hoggets and prices of concentrates will yield different optimal solutions for GM.

4. Conclusions

Using data generated with the NWS breed, we found that neither postponing lambing nor delaying slaughter until 1–1.5-year-old sheep (hoggets) would increase profitability for the Norwegian sheep farmers studied, compared to the baseline practice. Delaying lambing may work on farms with access to abundant high-quality autumn mountain or farm pasture resources. The main problem with meat production on over-wintered lambs was the substantial decline in the price for hoggets compared to regular 5–6-month-old lambs. Better marketing strategies and brand development may increase the price per kilogram for the hogget meat and hence profitability. To use less concentrates, sheep farmers could then be recommended to adopt the 2nd alternative scenario (hogget production), but not under the current prices. However, farmers should also consider moderating the feeding of replacement lambs combined with delaying first lambing until two years of age. If the breeding life of NWS ewes can increase from 3.3 to 5.3 years by this change, profitability may be slightly improved. The break-even seems to be around five years of replacement age for this breed. The importance of decreasing the cost of feeding lambs to be bred on ewe endurance should be investigated and compared with other measures to extend the ewe life span. Moreover, further research on other native sheep breeds should be conducted with the aim of producing lambs and sheep from grazing pastures, given their lighter mature weights and subsequent lower maintenance requirements. Under the current circumstances, the baseline scenario for the NWS seems to give the highest gross margin, unless ewes can be kept for an extra two years, and reducing the concentrate consumption is not an interesting economic alternative.

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Paper 3

Management Strategies to Improve the Economics of Sheep Farms in Norwegian Coastal and Fjord Areas — The Effect of Animal Size and Capacities for Rangeland Utilisation

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Management Strategies to Improve the Economics of Sheep Farms in Norwegian Coastal and Fjord Areas—The Effect of Animal Size and Capacities for Rangeland Utilisation

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Abstract: The morphological and productive aspects of Norwegian sheep have developed over time and adapted to the diverse environment of the country. Before 1900, native Norwegian sheep were crossed with UK breeds to attain higher body weight and reproductive efficiency. Subsequent selection programs eventually led to the creation of the heavier (adults often >90 kg) Norwegian White Sheep (NWS), today constituting 70% of the recorded ewes. The modern Norwegian (White) Spæl (NS) sheep, mostly <75 kg and accounting for 10% of the recorded ewe population, originated from the native short-tailed breeds that are smaller and are believed to prefer grazing at higher altitudes than NWS. Other registered breeds of the short-tailed spæl type account for another 12% of the recorded sheep. Rugged Norwegian terrain with rich summer pastures makes the NS a complementary breed to the NWS. Increasing demand for year-round fresh meat requires changes at the farm level. Efficient use of local feed resources by extensive feeding of smaller size ewes is an opportunity for attaining economic gains and for year-round fresh meat production. The NS has a lighter bodyweight, requiring less housing space, is efficient in grazing rangeland and local pastures, and is better suited to outdoor winter grazing in coastal and fjord areas. In this paper, we compare the farm profitability (gross margin) of two Norwegian sheep breeds (NS and NWS) using a linear programming model designed for the coastal and fjord areas. The impact of ewe body weight, housing capacity, and meat produced per unit of concentrate are discussed.

Keywords: ewe size; grazing; concentrates; Spæl sheep

1. Introduction

Norwegian sheep farmers operate within strict environmental and climatic boundaries, and the timing of production is strongly linked to the natural seasonal variation in plant growth. The farmers adapt to the winter season, mostly by feeding their flock in-doors from October to May, but some by feeding concentrates and silage outdoor. The availability of homegrown winter feed, mainly grass-silage is, however, limited due to the short growing season and often insufficient amounts of

cultivated meadows suited for baling. In the prevailing production system, sheep take up more than half (60%) of their annual feed consumption by grazing farm pasture in April and May, followed by high-quality rangeland pastures during the summer months from June to August, and farm pasture in September and October [1,2]. Farmers seek a maximum lamb crop in the autumn because of the considerably better price per kg of lamb than for hogget and sheep; this also coincides with rangeland plant production coming to a halt. The Age of the first lambing is 1 year, and triplets are common. It is often labour intensive to have more than two lambs per ewe during the summer: most young (1 year old) ewes will be unable to support more than one or two lambs, and even prime-age ewes should only be tasked with rearing triplets on good quality rangeland pastures [3].

The Norwegian (White) Spæl (NS) is the second most common breed in Norway, after the Norwegian White Sheep (NWS) breed, with approximately 10% of the recorded (43.4% of herds, and 55.4% of sheep are in the national recording system in 2019, [4]) sheep population. Other registered breeds of the short-tailed spæl type account for another 12% of the recorded sheep. The NS is, like the NWS, a dual-purpose breed kept for meat and wool. The average number of lambs per adult NS ewe at weaning/the start of slaughtering in September was 1.77, compared to 1.89 for the NWS. The mean live body weight (BW) of NS lambs in the fall was recorded as 41.8 kg, and the mature BW of ewes (5 years) was recorded as 80 kg [4]. In the Norwegian National Sheep Recording Scheme, one productivity index is the number of lambs per ewe per year, leading to an advantage for the heavier NWS. However, based on the lamb crop in the fall per 100 kg of ewe BW, the performance of NWS and NS was 83 and 100 kg [4]. NS thus produces more lamb meat per 100 kg of ewe body weight [5]. NS is also known as an efficient grazer of the rugged Norwegian rangelands [2,6]. The hoggets of NS were, according to the European Union EUROP classification, leaner than NWS [4], making hoggets from NS suitable for modern meat consumer preferences. The smaller size cuts also add value for modern, smaller families [7]. NS carcasses do, however, score lower on the EUROP carcass conformation scale, resulting in lower prices for farmers.

On free-range summer pastures, the NS, compared with NWS, stay together in larger flocks, cover longer distances on the range [6], are more robust towards environmental variation [8], and choose a diet containing more woody plant species [2]. The Norwegian terrain is rugged with rich pastures in-between, making the lighter NS suited as a complementary breed to the NWS for optimal rangeland pasture utilisation. Since the NS sheep chooses more woody plant in its diet than the NWS, it may also be more suitable for maintaining traditional flowering meadows and other vegetation communities threatened by woody plant encroachment [2,9].

The large price difference between lamb meat and mutton make systems producing more lambs and less older animals more profitable. A recent study, based on sensory characteristics of meat from the NS and NWS breeds, indicated little difference in the meat quality between hoggets (17 months old female ewes) and lambs for the NS, while the difference was substantial for the NWS [10]. The meat from hogget and lamb from the NS breed were similar in terms of meat tenderness in that study.

Coastal and fjord farmers, due to the mild winter climate, may graze their sheep in high-mountains during summer, lower-mountains during the spring and fall (Figure 1) and along the fjords in the winter. Both inland and coastal farmers routinely sell the main crop of lambs for slaughter in September–October, resulting in the pressure of slaughtering facilities and a shortage of fresh lamb meat in the off-season. Due to the huge price difference between meat from lambs and hoggets/older sheep, farmers prefer to raise lambs for slaughtering in the fall before indoor winter feeding.

Figure 1. View of typical Norwegian farm pasture on the west coast, with some arable land (green near river) for silage. Photo: Torstein Lund Eik.

In Norwegian coastal and fjord areas, a less intensive production system with less use of concentrates and more winter grazing could be a viable alternative. A well-managed hogget production system based on locally grown feeds and pastures can offer an opportunity for the farming industry to increase the availability of fresh meat and improve the regularity of cash flow throughout the year. It could make sheep farming more sustainable in terms of better economic performance, being more environmentally friendly, and being more efficient in terms of resource utilisation. Increasing demand for fresh meat year-round may favour production changes. Such extensive production systems will allow for more lambs and hoggets to be slaughtered in the winter and following spring.

This study examines the farm profitability by using the NS breed and compares the two breeds (NS vs. NWS) in an extensive system in the Norwegian coastal and fjord areas with four alternative practices to the current: delayed season, hogget production, first lambing at two years and longer lifespan.

2. Materials and Methods

Linear programming was used to compare farm economics, measured as the gross margin (GM) of alternative scenarios, with the model details described by Asheim, Thorvaldsen [11]. The prices in the model reflect the level in 2018 (Table 1) and the model was parameterised with data from 18 sheep farms in the Vestland and Agder counties. Agricultural subsidy payments for the 2019–2020 season were applied.

The LP (Linear Programming) technique uses constrained optimization to identify the composition of non-negative activities resulting in the maximum objective function within the constraints. The mathematical model of an LP problem is as follows [12]:

$$\text{Max } Z = c'x \text{ subject to } Ax \leq b, x \geq 0 \quad (1)$$

Here, Z is the farmer's objective function or gross margin (GM), i.e., total yearly returns from livestock and governmental payments, minus variable costs. Since the fixed costs were not affected in any of the solutions examined, a ranging of alternatives according to GM would be similar to a ranging according to farm profit. Moreover, x is a vector of activity levels and c' the vector of marginal net

returns. A is the matrix of technical coefficients showing resource requirements by the activities; b is the vector of right-hand side values of resources such as farmland and semi-cultivated farm pastures, farm workforce, and constraints due to, e.g., area and feeding requirements.

The area constraints encompassed arable and pasture able farmlands as well as constraints relating to crop rotation, the use of manure and area and cultural landscape (ACL) payments. The feeding requirements were developed based on Madsen, Hvelplund [13] and encompassed energy for milk production measured in feeding units (FEm), roughage dry matter (DM), and amino acids absorbed in the small intestine (AAT), each relating to specific constraints. 1 FEm = 6900 Mega Joule or approximately the amount of energy in one kg of barley. AAT refers to Amino acids Absorbed in the small intestine. Its composition relates to all AAs needed for growth and do take into account special need for, e.g., the Sulphur containing AAs cysteine and methionine for growth of wool. The amount of AAT was measured in proportion to the amount of energy in different feeds (g AAT/FEm) and in the amount needed on a daily basis by animals (g AAT/day). Constraints also accounted for the production of manure, used by the land activities, and herd replacement. The work constraints encompassed one constraint for the grazing season and one for the whole year, assuming farmers would be willing to work longer days in shorter peak periods of work within these periods as long as the total work requirement in the whole period were not exceeded.

Table 1. Farmgate meat prices, input prices and support premiums, Norwegian kroner (NOK), 2019.

Description	NOK	Description	NOK
Basic price cull ewe meat, per kg	7.18	Support per sheep, 1–150	883
Basic price hogget, per kg	10.28	Support per sheep, >150	194
Basic price lamb, per kg	66.10	Lamb support, grade O, per carcass	450
Basic support meat, per kg	3.81	Lamb support, grade <O, per carcass	41
Shearing costs, per kg of meat	0.52	Concentrate Lamb, (92, 11) * per kg	3.69
Wool, per kg	53.8	Concentrate Fibre, (86, 11) * per kg	3.72
Relief support, per sheep	458	Concentrate Sheep, (96, 12) * per kg	4.21
Grazing farmland, per animal	50	Diesel, per Liter	11.52
Grazing rangeland, per animal	205	Mineral fertiliser, 22-2-12, per kg	3.72

* FEm per 100 kg and gram AAT per FEm. Feeding unit (Fôreining mjølk-FEm) = 6.9 MJ [14].

The net number of lambs per adult ewe in the fall was set to 1.33, like the number for the NWS breed, similar to the average in these 18 farm records representing sheep farms in the study area. We assumed weights and growth rates of NS to be 75% of those for the NWS breed. The daily feeding requirements for maintenance feed, as well as the minimum amounts of concentrates, were lowered by 25% compared to the rates for the NWS breed.

In the current practice, we assumed the age of first lambing to be one year, a lifespan of ewes to be 3.3 years, that lambing took place around 15 April, and that the slaughtering of lambs was on 20 September.

The alternative, more extensive systems of rearing NS sheep included four practices (Table 2):

Alternative 1—Delayed season: Delaying lambing for 16 days until the start of grazing (around 1 May) and a corresponding 15 days delay in slaughtering until around 5 October.
Alternative 2—Hogget production: Overwintering of female lambs and marketing them as hogget in July or August.
Alternative 3—As with Alternative 2, and with first lambing when 2 years old
Alternative 4—As with Alternative 3, but assuming longer ewe lifespan. The first lambing at two years of age, and, in addition, increasing the ewe life span to five (5.3) years.

Table 2. Description of the investigated alternative scenarios.

Alternative Scenarios	Description
1. Delayed season	Delayed lambing for 16 days until the start of grazing (around 1 May) and a corresponding 15 days delay in slaughtering until around 5 October.
2. Hogget production	Overwintering of surplus female lambs and marketing them as hogget in July or August.
3. First lambing when 2 years old	As with Alternative 2, but with first lambing when ewe is 2 years old.
4. Longevity increased to 5.3 years	As with Alternative 3, but assuming longer ewe lifespan (5.3 years).

The comparison between NS and NWS was made by running the same methodology as NWS while changing the weights and growth rates of NS to 75% of those for the NWS breed. In case of NS, the feeding requirements for maintenance feed, as well as the minimum amounts of concentrates, were lowered by 25% compared to the rates for the NWS breed. The EUROP carcass classification was same for both breeds (NS and NWS).

3. Results and Discussion

The farm-level economics of rearing NWS in an extensive pasture-based system with four alternative practices using a Linear Programming (LP) model shown in Table 3. Since NS is smaller and lighter, the ewe number increased within each farm given the existing resources used in the model. The same daily work input was assumed per sheep irrespective of breed in the modelling. The solution of the model for the NS is presented in Tables 4 and 5, and the difference compared to the NWS breed in Table 6. Since the NS breed is smaller and requires less space; the model allows for 1–25 more NS sheep than NWS on a farm, and the model solution was with a slightly lower (0.4–3%) yield of roughages when keeping NS. Profitability, measured as farm GM, was higher for NS compared to NWS. However, the difference (NS–NWS) in the amount of hired work was 184, 253, -10, -100 and 106 h for current practice, delayed season, hogget production, first lambing when 2 years old, and Longevity increased to 5.3 years respectively (Tables 3 and 4).

One reason for the overall improved profitability for NS sheep was that the Norwegian lump-sum subsidy payments per animal favour lighter sheep. While the general lump-sum subsidy payment per sheep is lowered when the number of breeding sheep is 150 or more, this is not the case for the payment for lambs that get a lump-sum payment based on certain carcass traits (EUROP). Moreover, subsidises meant to promote grazing are based on the number of grazing animals.

Table 3. Gross margins (GM), hours of hired work, as well as the number of breeding sheep and hogget of Norwegian White Sheep (NWS) for the baseline and the alternative scenarios studied.

	Gross Margin, 1000 NOK	Breeding Sheep	Hoggets for Meat	Lambs (0–1 years)	Hired Work, (hours)
Current practice, lifespan 3.3 years	401	119	0	53	570
Alternative scenarios [a]					
1. Delayed season	369	116	0	52	510
2. Hogget production	279	99	52	44	593
3. First lambing when 2 years old	354	157	0	70	693
4. Longevity increased to 5.3 years	417	163	0	38	612

[a] Detailed description of alternative scenarios is given in Table 2.

Table 4. Farm GM, the hours of hired work, the number of breeding sheep and hoggets per farm of the Norwegian Spæl (NS) breed for the Current baseline and the Alternative scenarios.

	Gross Margin, 1000 NOK	Breeding Sheep	Hoggets for Meat	Lambs (0–1 years)	Hired Work (hours)
Current practice, lifespan 3.3 years	423	132	0	59	754
Alternative scenarios [a]					
1. Delayed season	389	134	0	59	763
2. Hogget production	372	112	59	50	583
3. First lambing when 2 years old	388	160	0	72	593
4. Longevity increased to 5.3 years	451	163	0	38	718

[a] Detailed description of alternative scenarios is given in Table 2.

Table 5. Use of concentrate feed and roughage per sheep in terms of energy (FEm), as well as grazing offtake per ha, and use of concentrate per kg of meat for the different scenarios studied for Norwegian Spæl (NS) breed.

	Concentrates FEm */Sheep	Roughage FEm */Sheep	Yield FEm */ha	Concentrates FEm */kg Meat (overall)
Current practice, lifetime 3.3 years	98	348	2699	3.59
Alternative scenarios [a]				
1. Delayed season	117	325	2550	4.33
2. Hogget production	105	409	2700	3.00
3. First lambing when 2 years old	81	285	2694	4.31
4. Longevity increased to 5.3 years	68	330	2701	3.10

* 1 FEm = 6.9 MJ net energy [a] Detailed description of alternative scenarios is given in Table 2.

Table 6. Calculated difference (NS–NWS) between the Norwegian Spæl (NS) and the Norwegian White Sheep (NWS) breeds in gross margins, numbers of breeding sheep per farm, the use of roughages and the use of concentrates per kg of meat.

	Gross Margin, 1000 NOK	Breeding Sheep	Roughage FEm */Sheep	Concentrates FEm */kg Meat
Current practice, lifetime 3.3 years	22	13	−39	−0.28
Alternative scenarios [a]				
1. Delayed season	20	17	−55	−0.02
2. Hogget production	94	13	−58	0.15
3. First ambing when 2 years old	34	3	−11	−1.30
4. Longevity increased to 5.3 years	33	0	−1	−1.68

* 1 FEm = 6.9 MJ net energy [a] The detailed description of alternative scenarios is given in Table 2.

The yield (Table 5) is lower in Alternative 1 (Delayed season) and the concentrates per sheep is higher compared to current practice because of more pasturing of farmland in the fall that gives lower pasture yields than silage production. More supplement concentrates were used for the ewes grazing on pasture due to the lack of silage. The amount of concentrates used was higher for Alternative 3 (first lambing when 2 years old) compared with Alternative 4 (Longevity increased to 5.3 years). Since the lifespan of the ewe was increased to 5.3 years, it requires 3.10 kg of concentrates to produce one kg meat in Alternative 4.

In all investigated scenarios, the difference in profitability from wool is trivial and hence not included in this study.

Under the "current practice", the overall GM was 5.5% higher for NS compared to NWS. The NS lambs are lighter in BW than the NWS lambs. The later are favoured by the EUROP classification system, which is based on body conformation [10]. This price difference per kg was not accounted for in the modelling. Getting a poorer EUROP carcass conformation grade, and thus a lower price, for NS

lambs, may lead to the GM difference being reduced to a level where it is insufficient for choosing the NS breed under the "current practice".

The first alternative scenario, delaying lambing for 16 days, was less profitable than the current scenario since the amount of autumn pasture became a critical factor. However, the autumn pasture might not be an important issue in all cases of small sheep farms along fjords and in coastal areas. Given the abundant pasture available in the fall, either as near-farm outfields or fenced farm pastures, later lambing may prove more profitable for both breeds. Moreover, the NS sheep may extend the time in more remote pastures (in coastal and fjord area) compared to the larger NWS breed, thus not needing so much autumn pasture at the farm.

For the Hogget production (Alternative 2), NS is more profitable than NWS, with a GM of NOK 372,000 compared to NOK 279,000, or an increase by 25%. In addition, NWS hoggets may not serve the demand for fresh meat supply adequately because of negative changes in the meat sensory quality from lamb to hogget [10] and due to heavier carcass weights and more subcutaneous fat compared to the NS. In the alternatives investigated in this study, lambs were supplemented with concentrates due to a shortage of grazing areas in the fall. Increased grazing on cultivated pastures will result in a lower production of silage for winter feed. The amounts of concentrate needed to produce one kg of meat under the scenarios are shown in Figure 2.

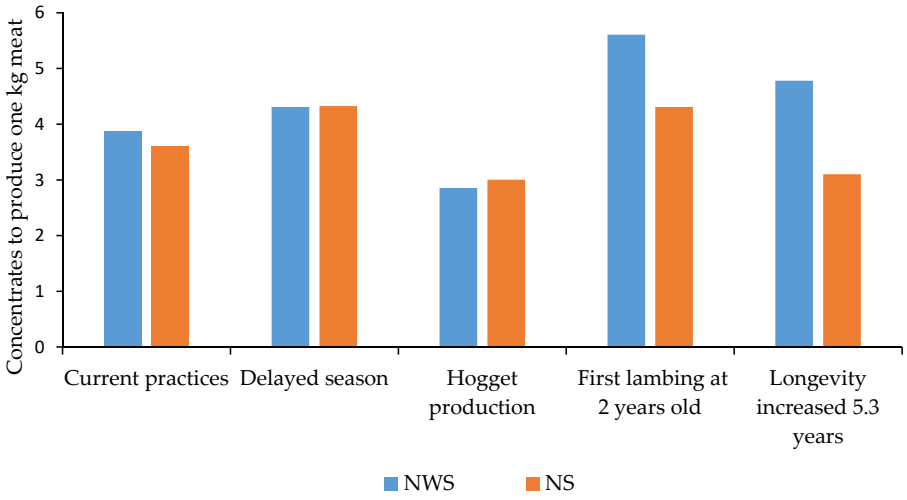

Figure 2. Estimated amount of concentrates required per kg of meat produced for the scenario practices and the two breeds studied.

NS also maintains the "lamb's meat characteristic" better for overwintered hoggets, thereby making it a suitable complementary breed for an extended fresh-meat season [10]. During the winter season, ewe-lambs reared for marketing as hogget will graze, but with the available winter pasture only sufficient for maintenance level feed intake, an additional supplementary feeding of 0.15 kg concentrates is offered per animal per day.

The NS are smaller in size and believed by farmers to prefer to graze higher up in the terrain than NWS and also sustain for longer periods under rangeland grazing compared to the NWS. For the first alternative scenario, NS will exert less pressure on the farm pasture during autumn and require less supplementary feeding of concentrates compared to the NWS sheep. However, the modelling could not take into account any impacts over season upon the rangeland grazing, nor any impacts of that rangeland upon sheep performance.

The higher meat prices in June–July (when lower national lamb slaughterings) and similar meat quality of NS hogget with NS lamb [10] would increase the GM of the second alternative by getting

better market price for the hogget meat. Another option is grazing half of the winter-flock outside while the rest remains indoors and is fed concentrates and silage (or hay), thereby increasing the shed's carrying capacity.

Given the huge price difference between mutton (meat from hogget and sheep) and lamb meat, the offtake of sheep meat needs to be as low as possible. This is aided by a longer productive life of ewes.

The production of NS hogget was most profitable (34% higher GM for NS compared to NWS). The high GM for NS hogget makes it suitable for increasing the year-round fresh meat availability. Regarding the use of concentrates to produce one kg of meat, both breeds (NS and NWS) were similar in the case of the first alternative (delayed season). For the second alternative (hogget production), the NS gives the highest GM, but also uses 5% more concentrates per kg of meat compared to the NWS. As compared to NWS, the NS uses 7%, 23% and 35% less concentrates per kg meat for current practice, the third scenario (first lambing when 2 year old), and the fourth scenario (longevity increased to 5.3 year), respectively.

In the current practice (with lifetime 3.3 years), and delayed lambing (16 days), the model was solved with more hired work (32% and 50% more hired work, respectively) in the case of the NS breed compared to NWS. GM was higher (5% for both the current and first scenarios) for NS—keep in mind that there were more NS breeding sheep (11% and 15%, respectively) than NWS breeding sheep per farm unit. The overall more suitable NS will improve the efficiency and sustainability of the production system [15,16].

4. Conclusions

The dominating practice of the Norwegian sheep industry is to produce lamb meat from the heavy NWS breed. Increased use of the NS or similar breeds, either as a substitute, or complementary, to the NWS might be a way forward, particularly in the coastal and fjord areas of the country. This study shows that the overwintering of NS ewe lambs will benefit the maintenance of open landscapes and biodiversity in addition to higher profitability. Consumers must also be made aware of the hoggets' (NS) meat eating quality as a marketing tool for the hogget sale. Moreover, whenever possible, the breeding life of ewes should be prolonged to increase the offtake of lamb or hogget meat per ewe to keep the cost of recruitment to a minimum. In a situation with an overall declining meat consumption in the country, a transfer to a system based on more NS sheep grazing with less use of concentrates and greater adoption of a grass-fed production system may be a sustainable and consumer-appreciated way forward. It will help reduce the use of concentrates, thus shifting the sheep forage use towards more human non-edible feed.

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Paper 4

Lamb or Hogget Meat – A Different Sensory Profile? Extending the Fresh Meat Season in Norway

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Lamb or hogget meat – A different sensory profile? Extending the fresh meat season in Norway

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ABSTRACT

This study compared the meat sensory profile of lambs (5 months old) and hoggets (17 months old) from two sheep breeds, Norwegian White Sheep (NWS) and Norwegian Spel (NS). The loin (left and right) samples (*M longissimus thoracis et lumborum*) from 50 carcasses were analysed for 23 sensory attributes by a trained sensory panel using quantitative descriptive analysis evaluated on an unstructured line scale from 1 (lowest intensity) to 9 (highest intensity). There was an effect ($P < 0.05$) of animal age on the attributes: odour (fried roasted, sheep and intensity), flavour (fried roasted, gamey, sheep, rancid and liver), hardness, tenderness, fatness, and coarse fibre structural unit. The loin muscles of lambs were scored significantly lower compared to that from the hoggets in all the sensory attributes except rancid odour, flavour, and juiciness. Sheep odour, hardness, and coarse fibre intensity differed between breeds ($P < 0.05$) – the NWS breed obtained a higher score than the NS breed. Meat from lambs of both breeds and the hogget NS breed was similar in tenderness while that from the NWS hoggets was scored lower by the panel. For the attribute hardness, lambs and hoggets were similar within each breed, except the NS hoggets were similar to NWS lambs. There was an interaction between animal age and breed ($P < 0.05$) for the fried roasted and gamey odour. The results indicate that animal age has a lower impact on eating quality for the NS breed than for the NWS breed. In the Norwegian scenario, the NS hoggets appear more suitable for supplying fresh out-of-season meat. Results should be confirmed with a larger sample size of both breeds.

1. Introduction

Norwegian sheep are bred in late autumn with lambing in the spring season, followed by summer range grazing and slaughter in autumn. This strong seasonality has resulted in a short period (in autumn) in which fresh lamb meat is available for the consumer (Bhatti et al., 2019). Consequently, large quantities of lamb carcasses are frozen, with an associated reduction in eating quality of the meat (Muela et al., 2016). Increasing the availability of fresh meat out-of-season may increase the overall annual consumption and reduce the need for storage facilities and extra workforce during the peak slaughtering season. Any modification in the sheep farming system needs to account for the feeding requirements during intensive winter feeding and extensive summer grazing. One way to increase the out-of-season fresh meat supply is to retain lambs until they reach hogget (12 months or more of age) in the spring. Another option is to hold chilled vacuum-packed meat for up to 10 weeks to supply fresh meat during the December to January period. Therefore, there is still a lack of fresh meat from February-July which needs to be filled.

It has been shown that for a number of different "genotypes" sheep meat quality is affected by animal age (Purchas, 2007; Hopkins and Mortimer, 2014). This is manifested as increased toughness, particularly in the hind leg cuts and darker meat (Hopkins et al., 2007). With increasing age of the animal, the muscle collagen becomes less soluble due to increased cross-linkages between collagen molecules resulting in an increased shear force (Young et al., 1993). Wiese et al. (2005) reported that the sensory quality of hogget is similar to that of lamb meat and suggested the possibility of including of a new "yearling" sheep

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category in the Australian meat classification system, with particular focus on the loin cuts. The increase in intramuscular fat found in older animals (Wiese et al., 2005; Hopkins et al., 2006) may compensate for any increased toughness in hoggets.

There are two distinct sheep breeds in Norway: a composite crossbred sheep, the Norwegian White Sheep (NWS), and the Norwegian Spel (NS) - a smaller breed, that anecdotally prefers grazing on high areas and is more adapted to local conditions (Steinheim et al., 2008; Bhatti et al., 2019). The NS breed seems more adapted to the natural environment compared to the NWS due to a smaller body stature and lower weight and is possibly more suited to grazing the higher mountain pastures producing a leaner carcass with comparatively less subcutaneous fat.

Generally, Norwegian sheep carcasses are classified into lamb (< 1-year-old), hogget (1–2.5 years old) and sheep (> 2.5-year-old) based on animal age at slaughter. Lamb meat is sold at a much higher market price than meat from hoggets and older sheep (Norway Today, 2017). The need to feed hoggets and older sheep for longer periods makes it uneconomical for farmers to raise them as a mainstream product. Meat consumers prefer lamb meat over sheep meat due to its recognised better quality in terms of tenderness and colour (Fogarty et al., 1995; Hopkins and Mortimer, 2014), which affects the market value for older sheep meat. Scientific evidence demonstrating selected portions of hogget meat to be equal to lamb meat in terms of sensory traits, could be used in a marketing strategy to raise the profile of this product and increase sales to justify the retention of animals to yearlings to increase out of season fresh meat supply in Norway.

In order to promote NS hogget as an option for out-of-season fresh meat production, it is vital to know the sensory meat quality. To our knowledge, no research has been conducted to establish and compare the meat sensory profile of hogget with the lamb meat of the NS breed. The aim of this experiment was, therefore, to test the effect of sheep age on meat sensory traits and further compare the sensory profile of meat from lambs (5 months old) and hogget (17 months old) of the two main Norwegian sheep breeds, the crossbred NWS and modern NS breed.

2. Materials and methods

2.1. Study animals experimental design and slaughter

Fifty animals were reared at the experimental sheep farm of Baroniet Rosendal (59° 59′ 22.74″ N, 6° 1′ 44.94″ E) located in Kvinnherad in Hordaland county, Norway. One NWS ram and 3 NS rams sired the 50 animals used in the study. These study animals were selected based on age (5 and 17 months for lambs and hoggets respectively) and breed (NWS and NS). The animals (n = 50) were divided into four groups: NWS hogget (n = 16) and NWS lambs (n = 9); NS hogget (n = 16) and NS lambs (n = 9).

During summer months, all animals had free access to unimproved mountain pastures in south-western Norway ranging from 50 to 900 m above sea level with the NS-breed preferring higher and steeper pastures. Before slaughter, the animals grazed on the same cultivated pasture for four weeks before being transported to a commercial abattoir (80 km away). At arrival, the animals were held in lairage overnight with free access to water and slaughtered as one group using a head-only stunning method as a routine procedure at the abattoir in a randomised order.

Due to the high biodiversity on the natural pastures sampling and estimation of rangeland feed quality was not feasible. The cultivated pasture harvested as silage for winter feed had an average dry matter content (DM) of 20.7 %, crude protein (CP) 11.8 %, neutral detergent fibre (NDF) 50.6 % and the organic matter digestibility (OMD) was 72 %.

2.2. Carcass sampling

The carcasses were processed at a commercial abattoir without using electrical stimulation. The hot carcasses were placed on separate hooks, weighed and graded for body conformation and external fat classification using a 15-point scale of the European Union EUROP classification system (Johansen et al., 2006). The carcasses were chilled (3–4 °C) overnight, and the 24 h post-mortem temperature (average temperature ± 4.2 °C) of 10 carcasses selected randomly was recorded by inserting a temperature probe into the 9th rib region of the *longissimus thoracis* (LT) muscle (Okeudo and Moss, 2005).

After overnight chilling, the *m. longissimus thoracis et lumborum* (LL) from both sides of the carcass were removed between the $12^{th}/13^{th}$ ribs. The left loin and right loin muscles (n = 100) were wrapped and vacuum-packed as per routine procedures of vacuum packaging at the slaughterhouse and transported to Nofima AS (Ås, Norway). At Nofima, the samples were stored at 4 °C for seven days, and the pH (average 5.6) of the left and right LL was measured using a meat pH meter (meat electrode Mettler and Microprocessor pH Meter, Portamess® 752, SOLIDS, Switzerland) prior to the sensory assessment. The pH meter was calibrated as per manufacturer recommendations before use.

2.3. Sensory analysis

To objectively describe the perception of the meat samples, a trained panel of 11 sensory assessors performed a Quantitative Descriptive Analysis QDA, ISO 13,299:2016 E of the samples Lawless and Heymann, 2010). Assessors were selected and trained following recommendations in ISO 8586-1:2012(E). In the present experiment, assessors were trained and calibrated on two samples from each breed and age category, for the purpose of agreeing on the variation in different sensory attribute intensities. A standard serving procedure, as described by Lawless and Heymann (2010), was used. Water was served between each test for rinsing the palate. The left loin (L) and right loin (R) muscles were randomised and cut into pieces of 1.5 cm each, heated at 70 °C in a combi-oven (Electrolux Air-o-steam, Model AOS061EANQ) for 30 min and served from a hot plate at 65 °C to the sensory panel. A continuous, non-structural scale from 1 (lowest intensity) to 9 (highest intensity) was used for evaluation following NS-ISO 5492:1999 (ISO, 1992). Four sensory modalities (odour, flavour, taste, texture) were evaluated including 23 sensory attributes (Table 1).

The samples within the experimental categories: NWS hogget, NWS lamb, NS hogget and NS lamb, were served randomly to each assessor. The samples were coded with three-digit numbers and served to the assessors in blind trials randomised according to sample, assessor and replicate in a total of 13 sessions conducted over three days. The left

Table 1
The sensory modalities evaluated and the sensory attributes tested by the sensory panel.

Sensory modalities	Attributes
Odour attribute	Fried roasted, intensity of odour, sour, wet wool, sheep, gamey, rancid and liver
Flavour attribute	Fried roasted, intensity of flavour, wet wool, sheep, gamey, rancid and liver
Taste attribute	Sour, sweet and bitter
Texture attribute	Hardness*, juiciness, tenderness, fatness and coarse fibre structural unit

* Hardness: the force required to bite completely through the sample when placed between molar teeth (Lawless and Heymann, 2010).

and right loin muscles were evaluated indistinctly by the assessors. Each assessor evaluated the samples at their own leisure on a computerised system for the direct recording of data (EyeQuestion® web application software, version 4.11.33 (Build 1123), Netherlands).

2.4. Statistical analysis

Based on the 11 (10 on day 2) assessors' scores, data were analysed one trait at a time using the fixed general linear model:

$$y = mean + age + breed + age \times breed + e$$

where y is one of the traits assessed (averaged over the assessors) for each carcass, *age* is either lamb or hogget, *breed* is either NWS or NS, and *age* × *breed* is the interaction of the two, all taken as fixed effects, and e is the residual.

The panel used to assess the samples were trained in such assessments. Data were analysed with the R-package lm(), significance levels of the fixed effects found (with anova() function), and model-based means (using lsmean() package in R) for the fixed effects estimated with standard errors, based on the above model.

The data were also analysed with lmer() using a mixed model, with the random terms *individual carcass* and *assessors* added to the model; this yielded similar results.

A multivariate analysis was conducted with Principal Component Analysis using RStudio package PCA() for averages over the assessors, to show the main correlations of traits, to be able to relate them to individual carcasses, and to the effects of the model. The Tukey method was used for comparing the four sensory modalities (odour, flavour, taste, texture) of 23 sensory attributes. The $P < 0.05$ was considered to be significant in the statistical analyses.

3. Results

The NS lambs and hoggets were lighter at slaughter yielding lower hot carcass weights (Table 2). The live weight and hot carcass weight difference between hoggets and lambs of the NS breed was 11.0 kg and 3.0 kg respectively, and for the NWS breed was 29.1 kg and 12.3 kg respectively (Table 2). The average fatness score of NWS hoggets was higher than the NWS lambs; however, it was slightly lower for NS hoggets compared with NS lambs. In comparison, the NS lambs were fatter than NSW lambs.

3.1. Sensory analysis

Results from the QDA showed that component 1 and 2 from the PCA plot explained 59 % of the total variability of the data (Fig. 1). PCA components 1, 2, and 3 altogether explained 70 % of the variability in the data. The data points representing lambs (NWS/NS breed in turquoise/lavender colour) are situated in the lower left side, and data points representing hoggets (NWS/NS breed in green/salmon colour) tend to be in the upper right side (Fig. 1). Moreover, the NS lambs (lavender data points) are closer to the hogget NS (salmon data points) compared to the hogget NWS (green data points). Generally, the data points representing hogget NS exhibit more spread but are closer to the data points of NS lambs. The distribution of the attributes is presented as a variables factor map of the sensory attributes in Fig. 2. The fried roasted odour and flavour are correlated while the sheep flavour, sheep odour, gamey odour and hardness are related and appear in the same dimension in the two first dimensions of the PCA.

Table 2
Least square mean (SD) live weight, slaughter weight, European Union EUROP carcass classification conformation score and fatness score of lamb and hogget of NWS and NS breeds. Different letters [a,b] in the same row indicate significant statistical differences ($P < 0.05$, Tukey's test).

	NWS		NS	
Age-group	Lamb	Hogget	Lamb	Hogget
Live weight, kg	45.2[a] ± 6.1	74.3[b] ± 8.1	45.6[a] ± 3.1	56.6[c] ± 6.2
Carcass weight, kg	17.8[a] ± 3.0	30.1[b] ± 3.9	17.0[a] ± 0.9	20.0[a] ± 2.8
EUROP conformation[a]	7.0[a] ± 1.7	8.3[b] ± 0.9	6.9[a] ± 1.0	6.4[a] ± 0.6
EUROP fatness[b]	5.4[a] ± 1.6	6.8[ab] ± 1.4	7.1[b] ± 0.8	6.7[ab] ± 1.0

[a] Scale 1–15 (15 = best conformation).
[b] Scale 1–15 (15 = fattest).

3.1.1. Age (lamb/hogget), breed (NWS/NS) and age × breed interaction effects

Significant interactions for age × breed were found for odour attributes fried roasted and gamey, and for flavour gamey (Table 3). There appeared to be less variability in meat sensory attribute scores for the NS breed relative to the NWS breed. Differences ($P < 0.05$) between samples from hogget and lamb, regardless of breed, were found for several attributes (Table 4) where lamb compared to hogget had lower intensity in both odour (fried roasted, sheep odour, intensity) and flavour attributes (fried roasted, gamey, sheep flavour, rancid, liver flavour). Differences were also observed for the texture attributes, in which lamb was evaluated to be softer and more tender.

For the breeds (NWS and NS), differences ($P < 0.05$) were found for the sensory attributes: sheep odour, hardness and coarse fibre structural unit, where NWS recorded significantly higher scores than the NS breed. Fried roasted odour changed significantly for NWS, while for the NS breed age did not cause any significant change (Table 4). Sheep odour scores were affected by both breed and age. Furthermore, hardness and coarse structural fibre unit scores were also significantly influenced by breed.

4. Discussion

In the current study, the sensory evaluation of the meat samples was undertaken using a well-trained sensory panel based on Quantitative Descriptive Analysis (QDA). Trained sensory panels are used in order to get accurate and repeatable objective data due to the panellists' uniqueness in sensitivity, interest, motivation and ability to judge the sensory differences in the given product (Lawless and Heymann, 2010; Liu and Zhang, 2020).

The sensory analysis showed that sensory profile of NS lamb meat was similar to NS hogget meat in our experiment while the sensory profile of NWS lamb meat was not similar to NWS hogget meat. This breed difference may stem from the fact that NWS hoggets achieved higher liveweights and higher subcutaneous fat levels compared to NS lambs and hoggets. The NS-breed was less influenced by animal age than the NWS-breed (Table 3). The sensory profile and carcass weight of lambs and hoggets of the NS breed were closer to each other compared to the lambs and hoggets of the NWS breed. The collagen concentration is reported to be a better indicator of sensory tenderness than collagen solubility as the solubility of collagen decreases with increase in animal age (Young and Braggins, 1993). The NS hogget had grown at a slower rate than NWS hogget, and this might affect the concentration of the collagen in the muscle and the tenderness of the meat. The slow growth of NS hoggets with lower collagen concentration compared to the NWS hoggets might be the reason for NS hoggets obtaining a lower hardness score from the panel compared with the NWS hogget. The slower growth of the NS hoggets may be due to the breed or the treatment before this experiment was initiated.

Since consumer demand for specific meat cuts is shifting to smaller sized animals because of smaller household sizes (Fowler et al., 2018), the smaller carcass weight of the NS appears to make this breed more suitable for targeting a hogget product for the winter period. The findings of this study indicate that consumer liking will not be affected since there was no major difference in flavour attributes, especially for the NS-breed. Meat from NS-hoggetsis more likely to be accepted by

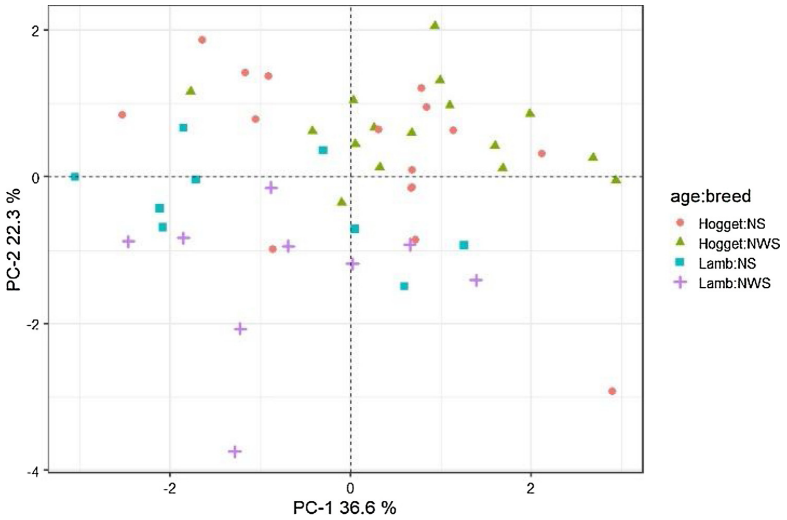

Fig. 1. Principal Component Analysis (PCA) averages per individual for the significant sensory attributes (PC-1 and PC-2).

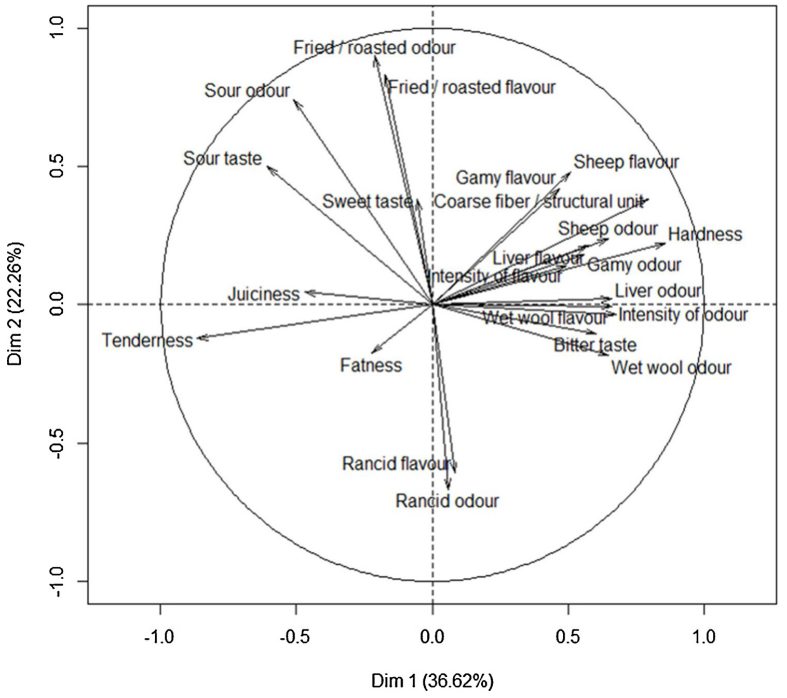

Fig. 2. Biplot for the significant sensory attributes showing the sensory dimensions (Dim) 1 & 2 from the Principal Component Analysis (PCA).

consumers than meat from NWS hoggets due to less increase in undesirable flavours. The findings of this study are also similar to the results of Wiese et al. (2005). They concluded that increasing animal age did not affect the liking of flavour by consumers. In their study the meat cuts used were stripped carefully of subcutaneous and intermuscular fat. This is likely to lessen differences since the fat component is the one that contributes in a major way to the development of flavours.

Current industry practice promotes the production of lamb meat rather than hogget and older sheep of any breed by paying farmers a higher price/kg for lamb meat. The results of the current study can be used to support a marketing strategy for NS hoggets on the basis of providing an equivalent eating experience to lamb, but at a lower price. However, we found significant differences in lamb and hogget meat

Table 3
The significance (P values) of effects of age, breed, and age × breed on the odour, flavour, and texture attributes based on the analysis of the average scores from the trained sensory panel tested samples from m. longissimus thoracis et lumborum (LL). Only traits with some significant effects ($P < 0.05$) included.

	Age	Breed	Age × Breed
Odour			
Fried roasted	0.001	0.06	0.01
Gamey	0.057	0.73	0.01
Sheep	< 0.001	0.009	0.79
Intensity	0.03	0.06	0.13
Rancid	0.07	0.60	0.33
Flavour			
Fried roasted	0.002	0.11	0.30
Gamey	< 0.001	0.60	0.05
Sheep	< 0.001	0.16	0.35
Intensity	0.06	0.31	0.31
Rancid	0.006	0.88	0.83
Liver	0.01	0.81	0.55
Texture			
Hardness	< 0.001	0.01	0.28
Tenderness	< 0.001	0.18	0.68
Fatness	0.037	0.16	0.94
Juiciness	0.098	0.67	0.58
Coarse fibre structural unit	< 0.001	0.03	0.36

Table 4
The effects of breed (NWS vs NS) and age (lamb vs hogget) on sensory attribute scores (odour, flavour, and texture) (lsmean and SE) describing the quality of meat obtained by a trained taste panel offered meat samples from *m. longissimus thoracis et lumborum* (LL). A score of 1 indicates low/no intensity and 9 indicates high intensity for each parameter following NS-ISO 5492:1999 (ISO, 1992). Different letters ^{a,b,c} in the same row indicate significant statistical differences ($P < 0.05$, Tukey's test).

	NWS				NS			
	Lamb	Hogget			Lamb		Hogget	
Attribute	Mean	S.E	Mean	S.E	Mean	S.E	Mean	S.E
Odour								
Fried roasted	2.76^{b}	0.24	4.02^{a}	0.18	3.83^{a}	0.24	4.01^{a}	0.18
Gamey	2.57^{b}	0.15	3.15^{a}	0.11	3.03^{ab}	0.15	2.96^{ab}	0.11
Sheep	3.86^{ab}	0.13	4.25^{b}	0.10	3.53^{a}	0.13	3.97^{b}	0.10
Intensity	5.20^{b}	0.14	5.66^{ab}	0.10	5.66^{ab}	0.14	5.75^{a}	0.10
Sour	3.20^{a}	0.19	3.50^{a}	0.14	3.39^{a}	0.19	3.42^{a}	0.14
Wet wool	3.60^{a}	0.17	3.57^{a}	0.12	3.37^{a}	0.17	3.50^{a}	0.12
Rancid	1.72^{a}	0.12	1.42^{a}	0.09	1.64^{a}	0.12	1.55^{a}	0.09
Liver	2.54^{a}	0.16	2.79^{a}	0.12	2.65^{a}	0.16	2.61^{a}	0.12
Flavour								
Fried roasted	2.50^{b}	0.15	3.07^{a}	0.11	2.89^{ab}	0.15	3.18^{a}	0.11
Flavor intensity	5.44^{a}	0.09	5.67^{a}	0.07	5.62^{a}	0.09	5.69^{a}	0.07
Wet wool	3.53^{a}	0.18	3.64^{a}	0.13	3.23^{a}	0.18	3.51^{a}	0.13
Sheep	3.79^{a}	0.16	4.53^{b}	0.12	3.77^{a}	0.16	4.23^{ab}	0.12
Gamey	2.58^{b}	0.12	3.16^{a}	0.09	2.90^{ab}	0.12	3.06^{a}	0.09
Rancid	1.82^{a}	0.10	1.55^{a}	0.08	1.79^{a}	0.10	1.55^{a}	0.08
Liver	2.63^{a}	0.17	3.11^{a}	0.13	2.71^{a}	0.17	3.01^{a}	0.13
Texture								
Hardness	4.46^{a}	0.17	5.35^{b}	0.13	4.32^{b}	0.17	4.89^{ab}	0.13
Tenderness	5.22^{a}	0.26	4.22^{b}	0.19	5.39^{a}	0.26	4.58^{ab}	0.19
Juiciness	5.30^{a}	0.17	5.12^{a}	0.13	5.47^{a}	0.17	5.13^{a}	0.13
Coarse fiber	4.62^{a}	0.12	5.37^{b}	0.09	4.53^{a}	0.12	5.07^{b}	0.09
Fatness	3.44^{a}	0.07	3.30^{a}	0.05	3.35^{a}	0.07	3.23^{a}	0.05
Sour taste	3.70^{a}	0.20	3.73^{a}	0.15	3.76^{a}	0.20	3.64^{a}	0.15
Sweet taste	3.42^{a}	0.06	3.52^{a}	0.04	3.47^{a}	0.06	3.44^{a}	0.04
Bitter taste	3.98^{a}	0.07	4.04^{a}	0.06	3.96^{a}	0.07	4.10^{a}	0.06

from the NWS breed (Table 4 and 5) that indicates the NWS lambs should be slaughtered in peak slaughtering season and NWS hogget should be used for breeding rather than meat production. If farmers are offered a better price for hogget meat, it will be a motivation to rear hoggets for supplying fresh meat during the off-season, provided that the additional costs for feeding are reflected in the sales price.

Pethick et al. (2005) reported no difference in the objective measurement of the tenderness and the consumer tenderness on 12 months old lambs and 22 months old yearlings of Merino breeds. Therefore, a further study at large scale and under controlled conditions in terms of feeding, should be conducted. Thus, testing of the NS breed will also be important to understand the production and economic viability of this breed to produce more out-of-season fresh meat. Since this study was limited to the measurement of sensory meat quality of both ages and breeds in the LL muscle; a further study involving consumer acceptance tests to verify the sensory quality of hogget meat based on different muscles would be essential to develop either the NS or NWS breeds for out of season production. Results of the current study could be helpful in marketing meat to consumers in terms of sensory quality from hoggets of the NS breeds.

5. Conclusion

Based on the study results, the sensory profile of loin meat from lamb and hoggets of the NS breed is similar, and this could be used to promote the production of fresh meat from hoggets during the off-season. NS hoggets have a lighter carcass, an additional benefit for selling NS hogget meat to avoid undesirable flavours associated with the higher subcutaneous fats in heavier carcasses. The NS breed may be perceived as a more native breed that is more acclimatised to grazing mountain pastures, and it shows potential as a species for the conservation of the Norwegian rangeland. Our results, however, should be verified with a larger sample of lambs representing a wider genetic base.

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Declaration of Competing Interest

The authors declare that they have no conflict of interest.

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Paper 5

An exploratory study of Muslim consumers' halal meat purchasing intentions in Norway

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An exploratory study of Muslim consumers' halal meat purchasing intentions in Norway

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An exploratory study of Muslim consumers' halal meat purchasing intentions in Norway

Norwegian Muslims constitute 3.3% of total population and are expected to increase to 6% in the next decade. Although Norway is the largest sheep meat producer in Scandinavia, but the local per capita red meat consumption is very low. Investigating the niche halal markets and understanding the Muslim lamb consumers' purchase intentions can help to increase the meat consumption. The meat purchasing preferences of the Norwegian Muslim group have not been investigated and knowledge regarding the Muslim lamb meat consumers' purchase intentions would help stakeholders to understand the niche halal meat market. A choice-based conjoint survey was conducted in which respondents had to complete 17 tasks where they had to choose one option among four choices, including three concepts formed by combining different levels chosen from five attributes plus a "no choice" option. Post-hoc market segmentation was performed using latent class analysis and factors affecting consumers' purchase intentions were studied within each segment formed. Purchasing halal meat from a butcher was the top preference while younger consumers of 2nd generation Pakistanis were also willing to purchase from national supermarkets. In order to benefit from the niche halal meat market, Norwegian supermarkets are recommended to adapt some of the services that halal butchers are offering to their consumers.

Keywords: halal butcher; halal meat; market share; meat consumer; segments; supermarket

Introduction

In Norway, Muslims comprise 3.3% (~175,500 individuals) of the total population and are the second-largest religious group after the Christian denominations. The majority of Norwegian Muslims are of Pakistani origin (Lever and Miele 2012, Statistics Norway 2019). The Pew Research Centre (2015) has reported an increasing Muslim population

(4.9% in 2016) across Europe. It has been predicted that the Norwegian Muslim population will increase to reach 6% (~321,283 individuals) of the Norwegian population by 2030 (Brunborg and Texmon 2011). This will create a market potential for halal food products, especially if produced by local farmers (Pickett-Baker and Ozaki 2008) due to consumers' trust in traceable high-quality local products. Home grown meat products are widely accepted by Norwegian society due to the strict food safety regulations implemented for product quality and animal welfare (Bhatti, Williams et al. 2019).

Muslims eat halal meat as a part of their normal diet. Meat of sacrificial animals is also used at religious festivals such as Eid al-Adha. Halal is an Arabic word that means "permissible" or "allowed" (Wilson and Liu 2010). Halal animal slaughtering differs from non-halal slaughtering with strict basic requirements that must be fulfilled during the slaughter process. According to Islam, all food items are permissible (halal) for the Muslims unless prohibited by "the Quran & Hadith". Permissible food items are called "halal" while those forbidden to eat are "haram". In terms of halal, meat is a highly regulated food item compared to other halal foods.

The food market is consumer-focussed and in the case of halal meat (HM) marketing, the trust of Muslim consumers in the whole production system, including farming and slaughterhouse practices, awareness of the slaughter process and their perceptions of purchase convenience is vital (Bonne and Verbeke 2008, Wilson and Liu 2010, Bashir, Bayat et al. 2018). All halal food items including meat (except pork) are permissible for consumption by Muslims if standard halal slaughtering procedures are followed on the slaughter line (Wilson and Liu 2010). The development of a positive attitude along with consumer satisfaction is vital for developing a successful meat market (Font and Guerrero 2014). Previous studies (Ahmed 2008) have highlighted the

importance of trust while purchasing the HM with a preference for an approved halal butcher.

In Scandinavia, Norway is the largest sheep meat producer with a population of more than one million ewes (Aby, Kantanen et al. 2014). The Norwegian sheep industry has the potential to double the quantity of meat produced with the strategic use of rangeland for grazing (Bhatti, Williams et al. 2019). Thus, increasing the consumers' appeal for Norwegian lamb and sheep meat and finding new market niches is important for sustaining the meat industry and the profitability of sheep farming. The eating preferences for lamb of the general Norwegian population are well-investigated (Helgesen, Solheim et al. 1997, Kubberød, Ueland et al. 2002, Kubberød, Ueland et al. 2002, Hersleth, Næs et al. 2012). However, the meat purchasing preferences of the Norwegian Muslim group have not been investigated. The potential for meat consumption in the Norwegian HM market can be better understood with knowledge of these preferences. This study aimed to understand the Norwegian Muslim consumers' purchase intentions of HM sheep meats and the impact of choice of retail outlet (supermarket or specialist halal butchery) on their purchase decisions.

Materials and methods

Survey sampling

Cross-sectional data were collected from an online survey in Oslo, Norway starting from 1st November 2019 to 28th February 2020. Since Muslims are a minority population in Norway and are difficult to reach, a snowball sampling technique was adopted as recommended by Browne (2005) for a minority group of people. The survey web-link was shared with respondents personally by contacting friends, friends of friends, and family of initial contact persons; and electronically using Facebook (Bonne and Verbeke 2008).

Questionnaire development

A preliminary qualitative study was conducted involving 15 Muslim families living in Oslo, Norway. The selection of these families was also based on the snowball sampling method. A prior time for a home-visit was discussed and set depending upon the ease and availability of the interviewee. Face-to-face interviews were conducted using open-ended questions. A single-visit-multiple-subject survey technique was used to obtain data including personal demography, eating, and cooking patterns and preferences, purchasing habits and intentions to purchase new products in the market. In each interview, the interviewee was allowed to discuss any topic related to halal lamb meat purchase in Norway. All the interviews were audio-recorded. The consent form for their intention to participate in the interview was signed by each interviewee before their interview.

Based on this qualitative data, five attributes were selected (Table 1) and used in the Choice-Based Conjoint (CBC) survey using the Sawtooth software (version 9.8.1, USA). A web link was created and shared with respondents (n = 140). In addition to the demography questions, the respondents had to complete 17 tasks where they had to choose one option among four choices, including three concepts formed by combining different levels chosen from five attributes plus a "no choice" option (Figure 1).

The following three prohibitions were set in Sawtooth software so that, while choosing the CBC concepts, the consumers would not get a combination of those specific attribute levels where prohibitions were applied:

1st prohibition (†): *Meat wholesaler* option could not market a *small (less than 3 kg) package* in the CBC survey. For practical or commercial reasons, the "meat wholesaler" could not offer a package of less than 3 kg, but rather offer meat in larger packaging (more than 8 kg) or whole animal carcasses to restaurants and halal butchers.

2nd prohibition (‡): Lower value *mixed meat cuts* obtained from all parts of the carcass could not be combined with premium quality cuts attracting the highest meat *price (150 NOK/kg)* in the CBC survey.

3rd prohibition (¥): *Specific premium meat cuts* cannot be combined with lowest value cuts *(less than110 NOK/kg)* in the CBC survey. The specific meat cuts with better eating quality are usually sold at the higher market price compared to the mixed meat cuts.

Apart from these prohibitions, all other combinations of attribute levels were allowed, yielding a total of 174 allowable combinations from all 16 levels of the 5 attributes used in this study.

Table 1. List of attributes and levels for each attribute used in choice-based survey. The prohibitions set on attribute levels are shown with the symbols.

Attributes	**Levels**
Place of purchase	Halal butcher
	† Meat wholesaler
	National supermarket
	Online order
Product storage/shelf life	Fresh (slaughtered within last 1 week)
	Recently frozen (slaughtered within last 2-4 weeks)
	Frozen (slaughtered more than a month ago)
Meat cuts	‡ Mixed meat cuts (all parts)
	¥ Specific meat cuts
Packaging	Extra-large (8 kg or more)
	Large (5-8 kg)
	Medium (3-5 kg)
	† Small (less than 3 kg)
Meat price / kg	¥ 110
(Norwegian Kroner)	130
	‡ 150

† - First prohibition

‡ - Second prohibition

¥ - Third prohibition

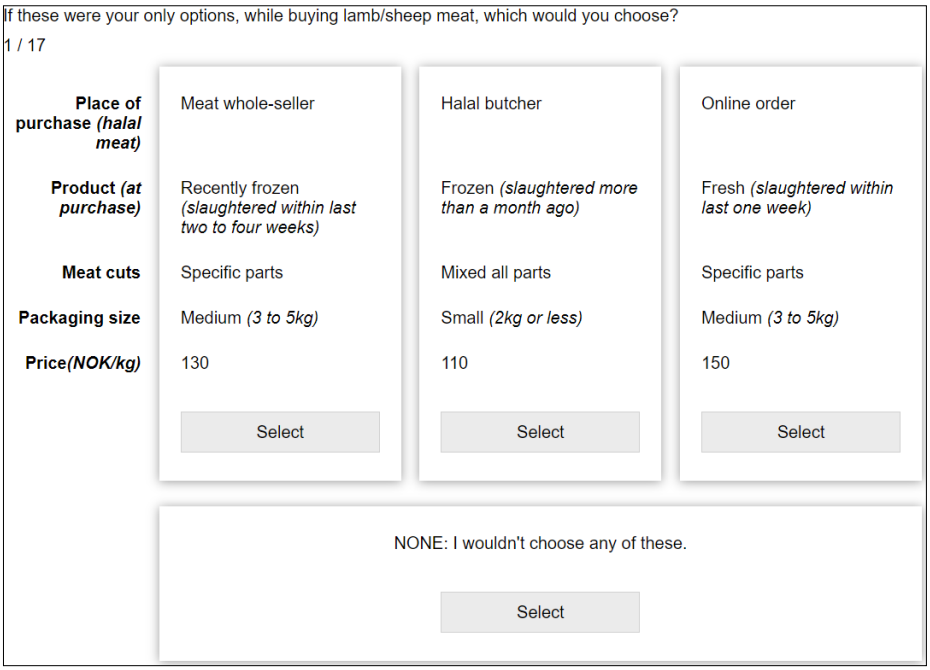

Figure 1. An example of a choice set used in the online choice-based conjoint survey

The product concepts were carefully selected by the Sawtooth software using the balanced overlap method (Sawtooth 2019). Specifically, the software kept track of the co-occurrences of all pairs of attribute levels (or levels) and showed each attribute levels as few times as possible in a single task, and each level for an attribute appeared roughly the same number of times throughout the whole survey. In a single task, no duplicate concepts were allowed. This facilitated an efficient design to estimate the effects of the different attribute levels.

Consumer segmentation

Without prior knowledge about the market segments, a descriptive post hoc market segmentation (Wedel and Kamakura 2012) was performed using latent class analysis (DeSarbo, Ramaswamy et al. 1995) in order to address the heterogeneity of respondents in choice data and to develop market segmentation. Latent class simultaneously detects relatively homogeneous respondent segments and calculates

part-worths (i.e., utilities) for those discovered segments. Latent class analysis provides the benefits of aggregate estimation while recognizing market heterogeneity (Orme 2014, Orme and Chrzan 2017, Sawtooth 2019). The minimum and maximum number of segments were specified as 2 and 10 respectively, and the optimal number of consumer segments were determined using the consistent Akaike information criterion (CAIC) introduced by Bozdogan (1987). A logistic model was then fitted within each segment to estimate the part-worths and the importance of each attribute. To present the model mathematically, β_{ij} denotes the part-worth of alternative j for attribute i. To ensure parameter identification, the sum of all part-worths within an attribute is always zero, that is, $\sum_{j=1}^{r_i} \beta_{ij}$, where r_i represents the last alternative of an attribute i. In other words, the part-worth of the last alternative of an attribute is the negative sum of the part-worths of the other levels. To incorporate the "none" option, an extra parameter β_6 was added to the model. Altogether, there were 12 parameters for each segment. The estimated probability for an individual choosing a concept can be calculated as the ratio of the antilog of the total utility for that concept to the sum of the antilog of the total utilities.

To obtain the relative importance of each attribute, the part-worths were first rescaled so that the average range of the part-worths within an attribute is 100. The importance of an attribute is calculated as the ratio of the range of the part-worths within that attribute to the sum of the ranges from all attributes, with the part-worth of the "none" option ignored.

To estimate the market shares of some specific concepts, the part-worths of each attribute alternative for each respondent were re-estimated using the hierarchical Bayesian (HB) approach (Sawtooth 2019). It was assumed that the part-worths of an individual follow a multivariate normal distribution and the probability of choosing a

particular concept follows a multinomial logit model. Non-informative priors were used, and the final estimates were obtained using the Metropolis-Hastings algorithm.

Market shares of preference for six different meat product combinations by five consumer segments were determined by a simulation method using the HB approach. The product characteristics are described in Table 2.

Table 2. The definition of six different meat product classes based on place of purchase, shelf life, meat cut, packaging size and price

Product ID	Place of purchase	Shelf life	Meat cuts	Packaging size	Price/kg (NOK)
BU1	Halal butcher (BU)	Fresh	Specific parts	Small (2kg or less)	130
SM1	National supermarket (SM)	Frozen	Mixed all parts	Medium (3 to 5kg)	110
OL1	Online order (OL)	Frozen	Mixed all parts	Large (5 to 8kg)	130
BU2	Halal butcher (BU)	Frozen	Mixed all parts	Small (2kg or less)	110
SM2	National supermarket (SM)	Frozen	Specific parts	Medium (3 to 5kg)	130
OL2	Online order (OL)	Fresh	Specific parts	Medium (3 to 5kg)	130

In the end, an open-ended question requesting the general feedback from the consumer formed part of this choice-based conjoint (CBC) study. The study has been notified to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data, and approval was obtained (No. 58377 FJORLAM). A consent to voluntarily participate in the research was attained from each respondent as a part of the introductory text screen.

Results

The average age of male and female respondents (n = 140 in total) was 37 and 32 years respectively while the average household size was 3.8. More than half of the respondents were first generation immigrants. Regarding education, most respondents had at least a high school level education. Around two-third of the respondents were married. More details about the characteristics of the respondents can be found in Table 3.

205 Table 3. Socio-demographic characteristics of the study sample (%, n=140)

Gender	Male	76
	Female	24
Age	15-17	1
	18-26	17
	27-30	19
	31-40	36
	41-50	19
	>50	8
Immigrants' generation.	1st generation	52
	2nd and 3rd generation	44
	Other	4
Education	Primary school	9
	High school	26
	Bachelor	26
	University education	39
	No education/Do not answer	0
Marital status	Single/Divorced/Separated/Widowed	33
	Married/Partnership	66
	Others	1
Annual income (NOK)	< 250.000	19
	250.000−500.000	26
	500.001−750.000	21

	750.001−1000.000	11
	1000.001−1.5 million	5
	> 1.5 million	2
	I do not know	9
	Do not want to answer	7

Consumer segments characteristics, importance of attributes and their preferred levels

Based on the demographical characteristics, five consumer segments were identified: Educated-Big-Families (EBF, segment-1, 29%), Educated-Small-Families (ESF, segment-2. 19%), Dedicated-Young-Residents (DYR, segment-3, 28%), Big-Resident-Families (BRF, segment-4, 17%) and Dedicated-Big-Families (DBF, segment-5, 7%). The detailed description of each segment is given in Table 4.

The importance of attributes by consumer segments based on the latent class analysis and ranking (first, second and third) for the attributes and their levels are shown in Table 5.

Segment 1 (Educated Big Families) gave 1st priority to the *place of purchase* (halal butcher) when purchasing HM and 2nd priority was given to *meat cuts (specific cuts).* These consumers preferred to purchase the premium meat cuts from the local halal butcher. Product *shelf life* (fresh/frozen) and meat *packaging size* were not considered important.

Segment 2 (Educated Small Families) gave 1st priority for the *product shelf life (fresh)* while 2nd and 3rd priorities were given to *price (110 NOK/kg)* and *packaging size (medium)* attributes respectively. These were also price-sensitive consumers and preferred to purchase medium size (3-5kg) packaging of fresh HM. Compared to other

segments, these consumers constituted a higher proportion of daily lamb HM eating consumers. *Meat cuts* were the least important.

Segment 3 (Dedicated Young Residents) have prioritized the *place of purchase* (halal butcher) while other attributes were not considered important. In addition to selecting a halal butcher, members of this segment placed a relatively higher trust in the supermarket. Comparatively these consumers are living independently (without partner) and were daily meat eaters who allocated a higher importance for the national supermarket as place of HM purchase.

Segment 4 (Big Resident Families) gave their 1st priority to the *place of purchase* (halal butcher) as in Segment 3, although packaging size and meat cuts were also of relatively higher importance. This segment preferred to purchase *medium size* (3-5 kg) packaging of meat from halal butchers with a preference for a lower purchase price (110 NOK/kg).

Segment 5 (Dedicated Big Families) emphasized the importance of all five attributes in the study, with 1st priority given to *packaging size (small)* while the 2nd and 3rd most important attributes were choice of *meat cuts (specific cuts)* and *product shelf life (fresh).* These meat consumers preferred *small size* (less than 3 kg) meat packaging of *specific fresh meat cuts.* These consumers were dedicated to Norwegian origin meat and they gave the lowest importance to the place of purchase and were not price-sensitive in their preferences.

246 Table 4. Consumer segment characteristics identified using latent class analysis

Consumer segments	**Characteristics**
Educated Big Families (EBF)	1st generation highly educated immigrants living with up to 5 family members with a preference to purchase local Norwegian lamb meat in addition to imported product. Their lamb meat eating frequency was at least once per week.
Educated Small Families (ESF)	Highly educated small sized families (average 3 members) 1st generation immigrants in Norway with a greater preference for Norwegian lamb meat in addition to the imported meat. The majority of these families ate lamb meat daily.
Dedicated Young Residents (DYR)	Norwegian born (2nd generation) including the young consumers (18 years old), preferred to purchase only Norwegian lamb meat. This segment consisted of a higher number of single/divorced/separated/widowed individuals. They chose lamb meat at least once per week
Big Resident Families (BRF)	Norwegian born (2nd generation) living in a big family (≥5 members). When purchasing lamb meat, they were equally satisfied with the purchase of either imported or Norwegian grown product. They ate lamb meat at least once per week.
Dedicated Big Families (DBF)	These were big families of immigrants (1st generation), preferring only local Norwegian lamb meat. They ate lamb meat at least once per week.

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Table 5. The relative importance (in terms of part-worth utilities) of five attributes (top) and their levels (with SE). The * means p-value < 0.05 for significantly different from zero. The description of consumer segments abbreviations is given in Table 4.

Consumer segments		**EBF**	**ESF**	**DYR**	**BRF**	**DBF**
Place of purchase		51.16	13.54	91.14	73.70	11.08
Product shelf life		2.30	41.69	1.85	3.46	19.37
Meat cuts		25.60	5.03	0.10	6.83	21.73
Packaging size		8.17	14.05	3.26	9.46	33.81
Price (NOK/kg)		12.76	25.70	3.64	6.55	14.02
Attributes	**Levels**	**EBF**	**ESF**	**DYR**	**BRF**	**DBF**
Place of purchase	Halal butcher	0.53 (0.07)*	0.34 (0.11)*	5.22 (0.44)*	3.68 (0.22)*	0.16 (0.24)
	Meat wholesaler	-0.16 (0.09)	0.11 s(0.12)	-4.43 (0.65)*	-0.94 (0.26)*	0.23 (0.29)
	N. Supermarket	-0.11 (0.08)	-0.12 (0.11)	3.33 (0.43)*	-0.87 (0.26)*	-0.15 (0.27)
	Online order	-0.25 (0.08)*	-0.34 (0.12)*	-4.13 (0.56)*	-1.88 (0.35)*	-0.24 (0.27)
Shelf life	Fresh	-0.02 (0.06)	1.11 (0.09)*	0.13 (0.13)	-0.14 (0.16)	0.46 (0.19)*
	Frozen (< 4 weeks)	0.01 (0.06)	-0.13 (0.09)	-0.06 (0.13)	0.12 (0.16)	-0.08 (0.22)
	Frozen (> 4 weeks)	0.01 (0.06)	-0.98 (0.11)*	-0.07 (0.12)	0.01 (0.16)	-0.37 (0.23)

Meat cuts	Mixed all parts	-0.19 (0.08)*	-0.13 (0.11)	0.01 (0.16)	0.26 (0.20)	-0.47 (0.24)
	Specific parts	0.19 (0.08)*	0.13 (0.11)	-0.01 (0.16)	-0.26 (0.20)	0.47 (0.24)
Package size	Extra-large (≥ 8kg)	-0.07 (0.08)	-0.23 (0.11)*	0.07 (0.17)	-0.03 (0.20)	0.36 (0.25)
	Large (5−8kg)	0.05 (0.08)	-0.27 (0.12)*	0.04 (0.16)	0.11 (0.20)	-0.74 (0.34)*
	Medium (3−5kg)	-0.05 (0.08)	0.44 (0.11)*	-0.22 (0.16)	0.31 (0.20)	-0.34 (0.29)
	Small (≤ 2kg)	0.06 (0.08)	0.06 (0.12)	0.12 (0.15)	-0.4 (0.20)*	0.71 (0.26)*
Price (NOK)/kg	110	0.03 (0.10)	0.73 (0.15)*	0.13 (0.21)	0.31 (0.25)	0.20 (0.36)
	130	0.08 (0.06)	-0.18 (0.09)*	0.12 (0.12)	-0.13 (0.16)	0.20 (0.21)
	150	-0.11 (0.09)	-0.55 (0.15)*	-0.25 (0.21)	-0.18 (0.26)	-0.40 (0.30)

Market share of preferences by different consumer segments

The consumer segments have indicated their preferences for meat attributes from which market shares of each attribute was calculated using the HB method. The six meat products were designed in such a way that each “place of purchase” had two

257 products with different characteristics (Table 2). The market share (%) for these six
258 products for each consumer segment is described shown in Figure 2 and 3.

259 (1) Segment 1 (Educated Big Families - EBF): When considered for three products
260 (SM1, BU1 and OL1), the highest market share (63%) was attained for the halal
261 butcher, while 16% and 19% of the market share was attributed to national
262 supermarkets and online purchases, respectively. The consumers' preferences
263 for these three products was changed when they get more options to choose from
264 six products (SM1, BU1, OL1, SM2, BU2 and OL2) such that the market share
265 for the halal butcher (BU1+BU2) declined to 57% while the overall national
266 supermarket (SM1+SM2) share increased to 22% with the total market share for
267 online products (OL1+OL2) remained the same.
268 (2) Segment 2 (Educated Small Families- ESF): The highest market share (80%)
269 was attributed to the halal butcher, with only 13% purchased from national
270 supermarket and 2% online. With all six products (SM, BU1, OL1, SM2, BU2
271 and OL2), the halal butcher (BU1+BU2) and national supermarket (SM1+SM2)
272 market shares were reduced to 61% and 9% respectively, with online purchases
273 increasing to 28%. These consumers were price sensitive and placed a higher
274 importance on a low price for meat compared with other segments.
275 (3) Segment 3 (Dedicated Young Residents-DYR): The preference for Dedicated
276 Young Residents was biased in favour of the halal butcher (BU1) attracting 95%
277 of the trade with only 5% being purchased from national supermarkets. Similar
278 trends were found when all six products were combined (Figure 3). Online
279 products did not attract this consumer segment.
280 (4) *Segment 4 (Big Resident Families-BRF):* Again, the highest market share (90%)
281 was also for the halal butcher, with national supermarkets-attracting only 3% of

the trade. These consumers also did not shop online. When considered over all six products (SM1, BU1, OL1, SM2, BU2 and OL2), the market share for halal butcher (BU1+BU2) was highest (96%) with only 1% of the trade being attracted by national supermarkets.

(5) *Segment 5 (Dedicated Big Families-DBF):* The highest market share for this consumer segment (47%) was also for the "halal butcher", with only 2% provided by national supermarkets and 1% by online sources.

With all six products (SM1, BU1, OL1, SM2, BU2 and OL2), the market share for the halal butcher (BU1+BU2) was reduced to 43% and the national supermarket (SM1+SM2) increased to 6%. However, in this case online (OL1+OL2) purchases were more popular attracting 13% of custom.

Overall, for the three products (BU1, SM1, OL1) for all the consumer sectors, the halal butcher attracted the most trade. The Educated Big Families were the most attracted segment to online (19%) and national supermarket (16%) outlets. For the six products considered together (SM1, BU1, OL1, SM2, BU2 and OL2), the halal butcher was the most favoured outlet overall consumer segments. Online purchases (28%) were most favoured by Educated Small Families.

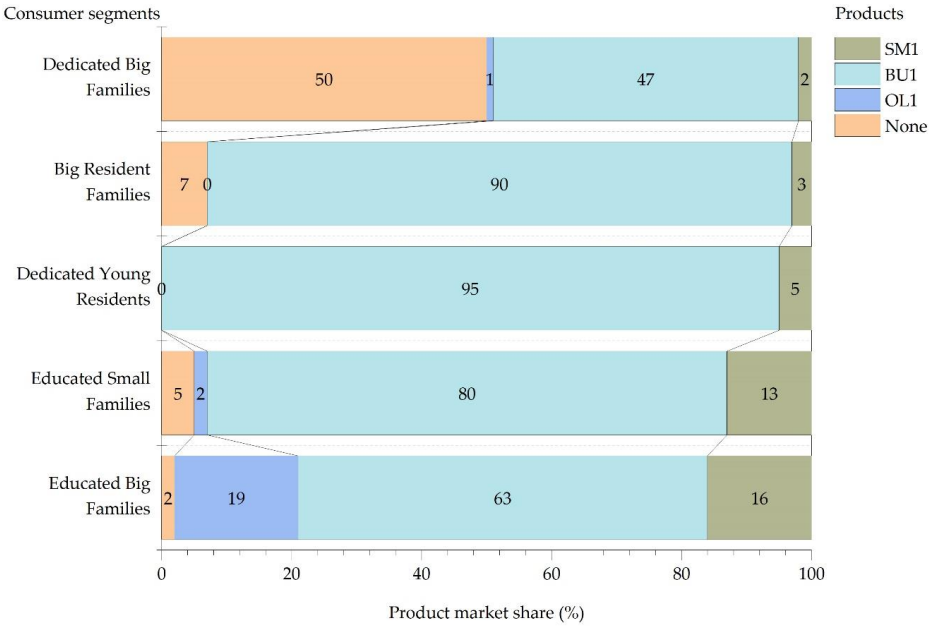

Figure 2. The halal meat consumers' preferences for three products' market share based on simulation of data using Hierarchical Bayesian approach. The description of products is given in table 2.

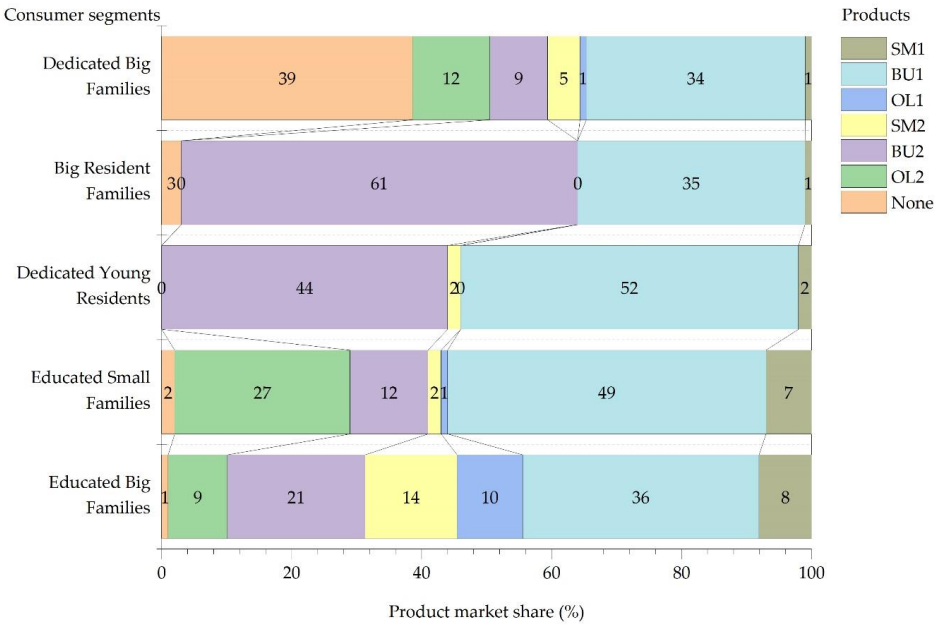

Figure 3. The halal meat consumers' preferences for six products' market share based on simulation of data using Hierarchical Bayesian approach. The description of products is given in table 2.

Discussion

Halal meat (HM) consumers' preferred attributes

The HM purchase is based on the HM consumers' trust in the halal authenticity of meat (Ahmed 2008). This trust provides the basis for the decision of consumers to purchase from a halal butcher, national supermarket, or online shopping outlet. When a halal butcher communicates directly ("word of mouth") with the meat consumers, he is providing assurances based on the consumers wishes and price preferences articulated in the conversation (Ahmed 2008). The halal butcher relies very much on local and regular patrons. Familiarity with them builds consumer trust for purchasing HM.

Besides, there is a greater choice of meat cuts and meat-based products at a halal butcher outlet, which are developed to meet the needs of traditional meat-based dishes. On the other hand, at the supermarket, storekeepers do not have the same opportunities to communicate with HM consumers and therefore understand their preferences for the preparation of traditional meat dishes (Wilson and Liu 2010, Wilson and Liu 2011). However, if regulatory authorities controlling halal product authenticity can gain the confidence of the consumer then purchases from national supermarkets are likely to improve (Caswell 1992, Issanchou 1996).

Importance of attributes by part-worth utilities

In this study, the meat consumers categorized as EBF, DYR and BRF (Table 5) gave their highest priority to "place of purchase". However, the ESF and DBF consumers were attracted more to "product shelf life" and "packaging size", as important marketing attributes. These consumer segments exhibited no preference for place of purchase, while the ESF segment was accustomed to seeking knowledge of "product shelf life" and meat freshness. This might be related to their small family and a preference for small packaging of fresh meat. The preferences for packaging size in larger families (DBF) varied from small to extra-large. The smaller packaging may be easier to shop for while the large packaging are best purchased from a meat wholesaler. Since meat wholesalers usually sell in bulk with an option of free home-delivery, that may attract consumers with big family size i.e. DBF.

Younger consumers (DYR), showed a preference for purchasing meat from "national supermarkets" in smaller packaging sizes. This consumer segment is comprised of second-generation Muslims, born in Norway, who over time have been influenced by the local cultural preference for "national supermarkets" for their halal meat supply. It is possible that these younger consumers are restricted in shopping time

and so prefer not to engage with staff at the halal butchery and also prefer to purchase *"mixed meat cuts".*

In assessing overall preferences, the halal butcher provided the most popular outlet for all except the younger consumers who also preferred to purchase from the national supermarket. Fresh products were most preferred by Educated Small Families (ESF) while the freezing of meat was a practical option for larger families. It is interesting to note that both large families (DBF) and younger consumers (DYR) preferred locally produced (Norwegian) product. This preference may be related to their more nationalistic outlook to support the Norwegian economy. Based on this preference these consumer segments are likely to be major targets for Norwegian lamb products (Table 5).

The number of respondents in this study was limited by the lack of access to the minority Muslim community across Norway. The number of segments formed was purely statistically motivated and the interpretations of the segments were based on the demographic variables collected. Based on the results reported, a larger scale a-priori study which accounts for theoretical, behavioural and/or cultural insights could be conducted to verify our results.

Market share for the specific products

The preferences of lamb meat consumers were changed when a larger variety of products was available at the national supermarkets. For ESF, the market share for the products (Table 5) follows the same pattern as EBF segment. However, the market share for the fresh medium price (130 NOK/kg) range was higher for HM (27%) compared to the frozen meat (3%). For BDF, highest market share was calculated for the "*fresh HM"* products available online. For DYR and BRF, highest market share was calculated for the HM available at the halal butcher. These consumers prefer locally

produced meat but have less trust in the *"national supermarket".* It might indicate their confidence in the Norwegian products overall but less faith in the halal slaughtering protocols in Norway (Bhatti, Williams et al. 2019). The meat industry can attain their trust by showing more clarity with respect to the halal slaughtering practices exercised at their slaughterhouses. In addition, product branding and better communication of "national supermarket" staff with HM consumer can increase the market share for "national supermarket" based products. Since the Muslim consumers are price conscious as the results of current study showed (Table 5), national supermarkets are recommended to carefully price the meat since meat consumers are not willing to pay extra for halal meat. Halal meat consumers, however, were willing to pay a higher price for certified halal meat to halal butchers as they are considered to be more trust-worthy (Verbeke, Rutsaert et al. 2013).

Norway is the largest Scandinavian sheep meat producer, but lamb consumption is declining. Increases in the size of the Muslim community clearly provides a growing market for halal meat with this study providing some guidelines on how this growing niche market can be supplied. A future study focused on the opportunities and constraints relating to marketing and brand development for "halal butchers" may provide more insight about the consumers' trust with their "halal butcher". Moreover, the acceptance of a uniform halal-logo among butchers is difficult for launching their own brand in market due to their associations with various representative Muslim organisations. Integrating the "halal butcher" outlets within the "national supermarket" will not only increase the market share of the HM for the Norwegian national supermarket, but will also increase the HM consumption with a greater variety of high quality meat products available that the consumer can trust. Under medium level migration, the Muslim population in Europe overall, and more specifically in France,

and Germany is predicted to be 11.2%, 17.4%, and 10.8% respectively of total their population in 2050 (Pew Research Centre 2017). It will create halal meat export opportunities for Norwegian halal meat across the European Muslim population. However, it is important to be mindful of the different dynamics of and similarities between each halal niche market.

Conclusions

First-generation halal meat consumers clearly prefer to purchase their meat from a halal butcher in whom they place their trust for authenticity. In contrast younger second generation consumers are also willing to trust the supply from "national supermarkets". Most of the consumers prefer traditional meat cuts for specific dishes which are readily available from the "halal butcher" who is aware of traditional halal cooking methods. To gain market share for halal meat, the "national supermarkets" in Norway need to adjust their marketing strategy to incorporate some of the services that the traditional halal butcher is able to provide on a larger scale. If they succeed however, the viability of the traditional butcher may be threatened since economies of scale will dictate that they offer the same services at a cheaper price. The industry needs to evaluate these risks carefully before proceeding to grow the halal lamb trade.

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