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Intake of grass of Norwegian White Sheep and Old Norwegian Spæl – Are there breed differences in feed intake in a zero-grazing system?

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Forord

Ved denne masteroppgaven avsluttes fem år som student ved Norges miljø- og biovitenksapelige universitet. De siste fem årene har gått fort og sakte på samme tid, med alt fra tradisjonell til heldigital undervisning. Det har vært en tid jeg ikke kunne vært foruten.

Fra jeg startet i 2018 har jeg vært sikker på at denne utdanningen har vært det rette valget for meg. Gleden av fagene vokste raskt utover bøkenes teorier og i dag sitter jeg ikke bare med en kompetanse fra Ås, men også en egen besetning av Norsk Kvit Sau og Farget Spæl.

Denne oppgaven omhandler noe av det jeg synes er det viktigste innen drøvtygger ernæring. Kunnskap om grovfôr og kvalitetens innvirkning og påvirkning for dyrenes opptak og helse er grunnleggende for å kunne drive en god grovfôrbasert produksjon. Å nytte av et produkt ingen andre enn herbivore kan er viktig inn i en fremtid med økt matbehov og begrensninger av arealer.

Først og fremst vil jeg rette en stor takk til de flotte professorene jeg har samarbeidet med, som til enhver tid sørger for å gi svar og refleksjoner på små og store spørsmål. Særlig vil jeg trekke frem Geir Steinheim og Bente Aspeholen Åby, som begge har vært til uvurderlig hjelp som veiledere for denne oppgaven. Jeg vil også rette en stor takk til min mor og far, og min samboer, som har gitt meg muligheten til å gjøre det jeg elsker, både akademisk og hjemme på gården.

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Lier, 12.05.2023

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1. Abstract

In Norway, sheep farmers use pastures in the spring, summer and fall period, and harvested roughage in the winter period. Knowledge of feed intake and factors affecting it is important to ensure sustainable production and healthy animals. The aim of this thesis was to investigate if there were any effect of breed and phenological development of regrowth grass, simulating an autumn pasture, on feed intake.

This thesis analyses how daily dry matter intake is affected by continuously growing grass, with a method called zero-grazing (freshly cut grass fed directly indoors), where the quality of the grass herbage is defined by the weekly analysis. The trial was conducted in August/September 2021 and lasted 6 weeks. There were two different breeds of sheep; the Old Norwegian Spæl (ONS) a short-tailed breed and the Norwegian White Sheep (NWS) a long-tailed breed called. There were 20 adult ewes of each breed, and they were stalled in individual pens indoors with two main feedings daily. Feed intake was recorded continually by using a system from BioControl.

In the grass herbage, there was a change in the concentration of crude protein (CP) and water-soluble carbohydrates (WSC), and the concentration of neutral detergent fiber (NDF) fluctuated throughout the trial. There was no significant change in dry matter intake (DMI) as the quality of the grass herbage changed (P=0.96). The number of trough visits increased insignificantly from the 2nd to the 3rd week and decreased significantly in the last 3 weeks of the trial. The results showed a significant difference in dry matter intake between the breeds (P<.0001), where the mean intake was 1,743 g and 2,558 g for ONS and NWS, respectively. There were no significant differences in the number of trough visits between the breeds (P=0.69). All animals gained weight trough the trial. The eating pattern was the same for both breeds, with two spikes after each main feeding.

The results suggest that the NDF concentration is the main factor determining the DMI, and that a 3rd harvest has fluctuating development of NDF as the grass matures. This caused no significant change in DMI throughout this trial. As expected, due to the difference in bodyweight and anatomy of the digestive tract there were significant breed differences, however the eating pattern was the same for both breeds.

Sammendrag

I Norge går sauen på beite om våren, sommeren og høsten, og i vinterperioden står de inne og blir fôret høstet grovfôr. Kunnskap om fôropptaket og faktorer som påvirker det er viktig for å sikre en bærekraftig produksjon og friske dyr. Målet med denne gradsoppgaven er å se om det er effekt av rase og økende fenologisk utvikling av gjenvekst gras, som simulerer høstbeite, på fôropptak.

Denne oppgaven analyserer hvordan det daglige tørrstoffopptaket blir påvirket av kontinuerlig voksende gras gjennom en metode kalt null-beiting (ferskkuttet gras fôret direkte innendørs), hvor kvaliteten av graset defineres gjennom ukentlige grasanalyser. Forsøket ble gjennomført i august/september 2021 og varte i 6 uker. Det ble brukt to ulike saueraser; Gammalnorsk Spæl (GNS) som er en korthalet rase, og Norsk Kvit Sau (NKS) som er en langhalet rase. Det var 20 voksne søyer av hver rase, og alle var individuelt oppstallet innendørs med to utfôringer daglig. Fôropptaket ble registrert kontinuerlig av et system fra BioControl.

Grasanalysene viste at det var en endring i konsentrasjon for råprotein (CP) og vannløselige karbohydrater (WSC), og konsentrasjonen av nøytralt løselige fibre (NDF) varierte litt gjennom forsøket. Det var ikke signifikant forskjell i tørrstoffopptak (DMI) når kvaliteten av graset endret seg (P=0.96). Antall fôrkar-besøk økte ikke-signifikant fra uke 2 til uke 3, og ble signifikant redusert de siste 3 ukene av forsøket. Resultatene viste en signifikant forskjell i tørrstoffopptak mellom rasene (P<.0001), hvor det gjennomsnittlige opptaket var 1743 g og 2558 g for henholdsvis GNS og NKS. Det var ingen signifikant forskjell i antall fôrkar-besøk mellom rasene (P=0.96). Alle søyene gikk opp i vekt i løpet av forsøket. Spisemønsteret var det samme for begge rasene med to topper etter hver fôring.

Resultatene foreslår at det er konsentrasjonen av NDF som er hovedfaktoren ved regulering av DMI, og at en 3.slått har en beskjeden utvikling av NDF ved aldringen av graset. Dette medfører at det ikke er funnet noen signifikante endringer i DMI gjennom de 6 ukene. Som forventet, grunnet forskjell i levendevekt og fordøyelsessystemets anatomi, var det en signifikant forskjell mellom rasene. Samtidig var spisemønsteret likt for begge rasene.

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2. Introduction and Background

The GrassToGas project aims to investigate the effects of grass quality and sheep breed on feed intake and enteric methane emissions. Two experiments have been conducted in the project where grass of different development stages has been cut and fed to adult ewes of two different breeds; Norwegian White Sheep (NWS) and Old Norwegian Spæl (ONS). In the first experiment, early and normally harvested grass silage according to cutting data was compared (Eidet, 2021), and in the second experiment increasing development stage of regrowth grass was studied using a zero-grazing system, simulating an autumn pasture. Individual daily dry matter intake, body weight and enteric methane emission were measured in both experiments. The methane measurements from the Portable Accumulation Chamber (PAC) will not be included in this thesis.

Forage ingestibility is defined as the maximum quantity of the feed that can be eaten by the animal when this is supplied *ad libitum* as the sole feed. When given indoors, ingestibility of forage depend mainly on its nutritive value, fill effects and on its sensory properties (Baumont et al., 2000). Ruminal fill is mainly determined by the cell-wall concentration and the rate of passage through the rumen (Jung & Allen, 1995). Cell-wall, or fibers, constitutes a large fraction of the ewe's diet (Allen & Mertens, 1988) and therefore the increasing phenological stage of the grass which increases the content of fibers will decrease the rate of passage and affect the fill value of the feed possibly causing a lower feed intake.

Feed intake is regulated by physiological, physical, and psychological factors (Eik, 2017). E.g., if the feed has such a low digestibility that the ewe does not consume enough nutrients to meet its needs, the feed intake is limited by the physical capacity of the rumen. In other words, the breakdown of dry matter (DM)-particles in the rumen affects the clearance of digesta from the rumen, and hence voluntary feed intake (Domingue et.al, 1991). The two processes that affect the breakdown of DM-particles are initial chewing during eating and further chewing during rumination. The density, size and digestibility of the particles determine how long it is retained in the rumen. Hey and other fibrous feeds are repetitively ruminated before becoming small enough to pass (Sjaastad et.al. 2016). Both the physical and physiological regulation can be disturbed by psychological factors, such as human handling, issues with hierarchy within the herd, and other stressors.

Zero-grazing is when the grass is harvested and transported directly and fed fresh to the animals, which means the grass will continue to grow between the harvests, causing further phenological development. The stage of phenological development of the grass has long been used as a criterium for harvest time for silage due to the high correlation between the development and feed quality (Bakken et.al, 2005). The correlation is not absolute and may vary due to circumstances which directly or indirectly affect the feed quality and due to inaccuracy when determining the phenological state of the grass. A 1991 study conducted my Moore et.al set out to develop a comprehensive system for describing and quantifying the morphological development of perennial forage and range grasses. The study's intention was to develop a system thorough enough for scientific purposes that could be applied routinely in the field. The system is based on the growth cycle of the grass and is divided into 5 primary growth stages (1) germination, (2) vegetative, (3) elongation, (4) reproductive and (5) seed ripening (Moore et.al, 1991).

This system of determining the phenological status of the grass is important because as the forage grass ages the balance between the concentration of cell-content and cell-wall changes. Younger grasses are richer in cell-content which contains crude protein, vitamins, soluble carbohydrates and more. As the grass ages the concentration of cell-content decreases and the structural components, the cell-wall, increases, which contains Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and other fibers (Barnes et al. 2003; Jung & Allen, 1995; Kohler, 1944). The shift in concentration also means that younger grasses have a higher digestibility and energy concentration than older grasses (Arzani et.al, 2004).

NWS is a long-tailed breed comprising 65.3% of all registered sheep in Norway, making it the most popular breed in Norway (Animalia, 2022). Adding to its popularity is the breed’s fast growth and high slaughter weight averaging at 20.5 kg at 153 days for the lambs. The NWS was defined as a breed in 2000/20001 (Norsk Sau og Geit[a], n.d.) and is a crossbreed based on the Norwegian breeds with British background such as Steigar, Dala, Sjeviot and Rygja (Blix & Vangen, 2023).

NWS is one of four breeds in Norway which has a national breeding scheme with defined breeding objectives. The main objective of the breeding scheme is to strengthen the economy in the sheep production (Norsk Sau og Geit[b], n.d.). All the 4 breeds, (NWS, Fur, Spæl and Sevjot) include the same breeding goal traits but with different weighing of the traits. The traits are, among others, birth weight, slaughter weight and lambing number (Norsk Sau og Geit[c], n.d.).

Old Norwegian Spæl (ONS) is a short-tailed landrace and was defined as an own breed in 2002. Presumably, this type of sheep was the sole breed in Norway till 1600-1700 when new breeds were imported from Great Britain (Landslaget for Gammalnorsk Spælsau[a], n.d.). At the beginning of the year 2000 ONS was almost extinct, with approximately 500 ewes in Norway, and this started the targeted breeding work to preserve the breed (Norsk Sau og Geit[a], n.d.). In 2022 6 % of the registered sheep in Norway was ONS, and it had an average slaughter weight at 14.5 kg at 168 days of age (Animalia, 2022).

The main objective of the breeding plan for ONS is 1) to preserve the distinctiveness and diversity of the breed described in the breed standard, 2) to breed new animals with the properties described in the breed standard, and 3) to breed a healthy and functional sheep in accordance with good animal welfare (Landslaget for Gammalnorsk Spælsau[b], n.d.).

There may be breed differences in the digestive tract anatomy, that can have an effect on feed intake. A study done by Steinheim et.al (2003) showed that Dala (related to NWS) has a longer small intestine and a heavier rumen, hereby larger rumen capacity, relative to body mass than Spæl (related to ONS). Dala is a composite breed closely related to many other long-tailed breeds and may indicate that there is a general difference in anatomical and possibly physiological characteristics between long-tailed and short-tailed breeds, e.g., between NWS and ONS. Body size and the size of the digestive tract are limiting factors for feed intake and feed utilization (Van Soest, 1994), and due to the limited retention time in the digestive tract, the smaller animals are expected to have a lesser capacity for digestion feed with lower quality. Smaller animals also ruminate more per gram of feed, which will cause the time of rumination to compete with eating time (Van Soest, 1994).

The aim of this thesis is to analyze data from the second experiment in the GrassToGas-project to study differences between NWS and ONS in feed intake in a zero-grazing system with continuous increasing phenological development of the grass. We hypothesize that 1) DMI decreases with increased development stage of the grass for both breeds, 2) ONS will have more trough visits and lower DMI consumption than NWS.

3. Materials and Methods

3.1 Experimental Design

The trial was conducted at The Livestock Production Research Center (SHF) at NMBU in Ås in August/September 2021. The trial started in week 32 and lasted for 6 weeks. The weeks are numbered 1 to 6, where week 1 was an adaptation week where the animals got used to the new feed and surroundings.

3.2 Grass Herbage

The harvested field was 103 daa and was established in the start of September 2018 with Spire Surfôr Beite Pluss 10 (Felleskjøpet, 2023) containing 45% Timothy (Liljeros), 20% Meadow Fescue (Vestar), 15% Smooth-Meadow Grass (Knut), 10% Perennial Ryegrass (Figgjo) and 10% White Clover (Edith). In addition to the sown seeds, it was also observed Dandelion and Northern Dock.

Weather data (Figure 3.1) from the trial was collected from yr.no and measured at the weather station id SN17850, Ås. The maximum temperature was 26°C, and the lowest temperature was 4.4°C. The weather was dry and sunny throughout most of the trial, except for some rainfall at the start, and mostly at the end, of the trial.

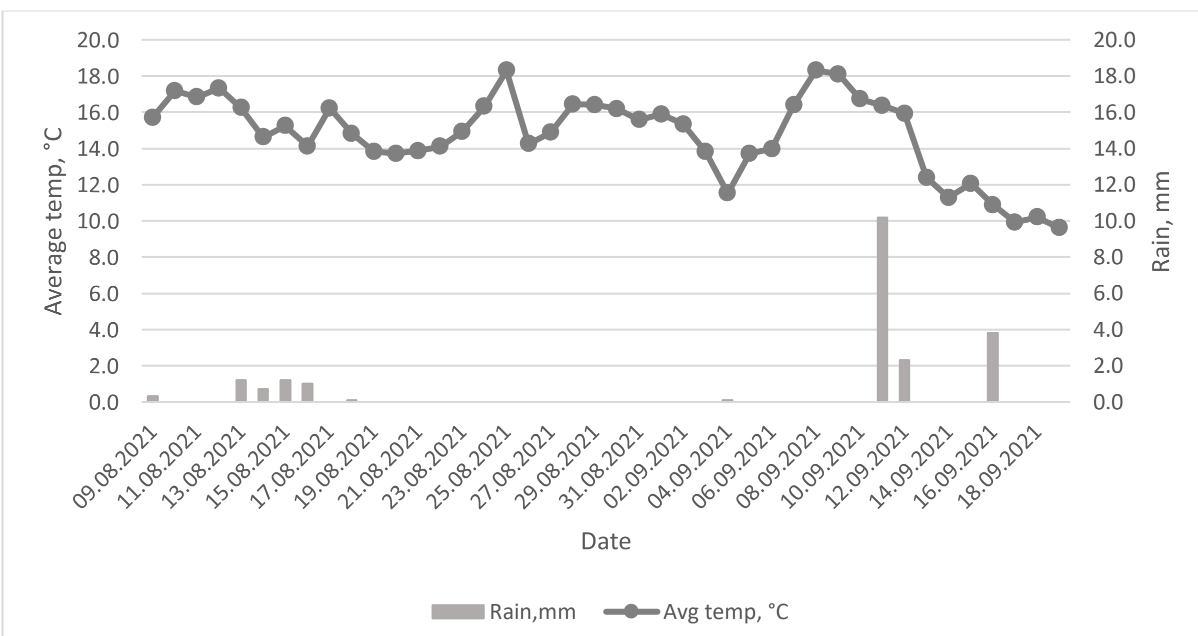

Figure 3.1 Average daily temperature in °C and daily precipitation in mm from 09.08.2021 to 19.09.2021.

The grass was harvested daily using a Serigstad forage harvester. The harvest was done in circles, around the field, starting from the outer edge of the field, going inward, to ensure that the grass was harvested from different areas of the field. The area that was harvested was dependent on the weight of the crop, i.e., in the beginning of the trial, the tractor drove less than one round per harvest, and as the trial continued and the circle got smaller the tractor drove more than one round per harvest. It was harvested approximately 400 kg each morning before the morning feeding. Half of the harvested grass was stored in a cooler container at 3°C and fed in the evening.

3.3 Sampling and Chemical Analyses

Representative samples were collected during feed out in the morning each Monday to Friday from week 1, giving 38 in total. Samples were also collected during feed out in the evening to control that the storage in the cooler container didn´t compromise the quality of the grass. The samples were taken each Monday, Wednesday, and Friday, in week 2, 5 and 6 giving 12 samples. In addition, samples from grass residues were taken on the 31st of August (Week 4), 10th of September (Week 5) and 17th of September (Week 6).

A portion of these samples was oven-dried av 103°C to constant weight and weighed warm to obtain DM concentration and formed the basis for the calculation of daily DMI of the grass. Another portion of the morning samples was further composited to 6 samples (one for each week) and 3 evenings samples (for week 2, 5, and 6). All of these samples were stored frozen at -20°C until analysis. The residue samples were composited to one sample per breed from each sampling day. The composited samples were freeze-dried prior to analysis of ash, total-Nitrogen (Kjeldahl-N), ash corrected Neutral Detergent Fiber (NDF) and Water-Soluble Carbohydrates (WSC) at LabTek, NMBU.

3.4 Animals

Twenty adult ewes of NWS and 20 ewes of ONS were used for the experiment, given that they had delivered at least one (ONS) or two (NWS) lambs the previous spring. They were stalled in individual pens throughout the 6 weeks. All the ewes were treated for internal parasites and their lambs were weaned off prior to the trial. All ewes were offered grass *ab libitum* (i.e., approximately 10% leftovers). The grass was fed twice a day, at 07:00 and 17:00 h, with leftovers removed before morning feeding. No concentrate was offered.

In week 2, 4 and 6 the ewes were weighed before enteric methane measuring in the Portable Accumulation Chamber (PAC) was conducted (data not included). Before PAC measurement, the ewes were closed off from the feed for 1 hour. The ewes were either weighed 1 or 2 times, corresponding to the number of PAC measurements.

3.5 Feed Intake Registration

The feed intake was automatically measured using feed troughs placed on electronic weight cells produced by BioControl AS (BioControl, n.d.). The weight changes in the feed trough before and after the visit were counted as the feed intake and these registrations were made continuously throughout the day and added up to daily intake in g. By this, the diurnal variation in feed intake was also recorded. By these recordings, the number of trough visits equals the number of recorded eating sessions where the lower limit for recording a through visit is at 7g change in feed weight.

3.6 Statistical analyzes

Calculations in Excel

For those ewes that were weighed two times a day the average weight of the two weighings was used.

Calculation of average weight difference was done by equation 1.

$$Weight\ difference\ (\%) = \frac{Average\ Weight\ Difference}{Average\ Start\ Weight} \times\ 100 \qquad (1)$$

Calculations in SAS

The statistical analysis was carried out in SAS using the procedure Proc Mixed. Significant differences were declared as P<0.05 and tendencies at P<0.1. The statistical model (Model 1) was:

$$Y_{il} = \mu + Breed_i + Week_j + Breed_i \times Week_j + Weighings_k + e_{ijk} \qquad (1)$$

Where Y_{il} is daily intake of DM (g), NDF (g), CP (g), WSC (g) and Number of Trough Visits, μ is the overall mean, Breed is the fixed effect of breed (i=ONS or NWS), Week is the fixed effect of week (n=2,...6), Breed × Week is the effect of interaction between Breed and Week, $Weighings_k$ is the effect of the number of weighing per day to correct for less eating time when conducting the PAC measurements (k= 0, 1 or 2), e_{ijk} is the residual error term of the model.

4. Results

4.1 Grass Analysis

The chemical composition of the morning samples is shown in table 4.1. The DM content increased slightly throughout the experiment. It decreased, however, the last week, due to rainfall (Figure 3.1). The concentration of NDF was quite stable, while the concentration of CP decreased and WSC increased throughout the experiment.

The chemical composition of the evening samples and the residue samples is listed as Appendix 1 in the Appendix.

Table 4.1. Chemical composition of grass herbage. The dry matter content is an average of each day per week, and the values of ash, NDF, CP and WSC are from one composited sample per week.

	DM[1]	Ash	NDF[2]	CP[3]	WSC[4]
	%	g/kg DM	g/kg DM	g/kg DM	g/kg DM
			Morning samples		
Week 1	16.9	139	438	200	69.7
Week 2	18.2	96.1	474	175	95.5
Week 3	22.8	96.5	465	149	105
Week 4	24.5	99.6	463	135	117
Week 5	24.8	95.8	475	123	132
Week 6	21.9	81.2	467	113	165

[1] *Dry Matter*, [2]*Neutral Detergent Fiber*, [3]*Crude Protein*, [4]*Water Soluble Carbohydrates*.

4.2 Feed Intake and Trough Visits

The type 3 F-test for Model 1 is shown in Table 4.2. The effect of Breed was significant for intake of DM, NDF, CP and WSC. The effect of Week was significant for the intake of CP and WSC, and for the Number of Trough visits. The effect of interaction between Breed*Week was significant for the intake of DM, NDF, CP and WSC, and tended to be significant for Number of

Trough visits. The effect of Number of Weight Recordings was significant for all measures of feed intake and the Number of Trough visits. Least Square Means for the significant effects of DMI is shown in Figure 4.1 and Table 4.3, and Number of Trough visits in Table 4.4.

Table 4.2 Type 3 Tests of Fixed Effects of Model 1 for DMI, NDF intake, CP intake, WSC intake and the Number of Trough Visits.

Effect	*Num DF*	*Den DF*	*F value*	*Pr > F*
DMI[a]				
Breed[1]	*1*	*38*	*79.3*	*<.0001*
Week[3]	*4*	*26*	*0.15*	*0.960*
*Breed*Week[2]*	*4*	*1,204*	*16.4*	*<.0001*
Number of Weight Recordings[4]	*2*	*49.3*	*8.50*	*0.0007*
NDF intake[b]				
Breed	*1*	*38*	*79.3*	*<.0001*
Week	*4*	*26*	*0.21*	*0.929*
*Breed*Week*	*4*	*1,204*	*16.8*	*<.0001*
Number of Weight Recordings	*2*	*49.3*	*8.56*	*0.0006*
CP intake[c]				
Breed	*1*	*38*	*79.4*	*<.0001*
Week	*4*	*26*	*10.6*	*<.0001*
*Breed*Week*	*4*	*1,204*	*63.3*	*<.0001*
Number of Weight Recordings	*2*	*49.4*	*9.70*	*0.0003*
WSC intake[d]				
Breed	*1*	*38*	*80.2*	*<.0001*
Week	*4*	*26*	*6.37*	*0.001*
*Breed*Week*	*4*	*1,204*	*3.30*	*0.0117*
Number of Weight Recordings	*2*	*49.3*	*6.99*	*0.0021*

Trough Visits[e]				
Breed	*1*	*38*	*0.16*	*0.690*
Week	*4*	*27*	*7.92*	*0.0002*
*Breed*Week*	*4*	*1,243*	*2.29*	*0.0578*
Number of Weight Recordings	*2*	*52.7*	*8.40*	*0.0007*

[1]ONS and NWS, [2]interaction between breed and week, [3]week 2-6, [4]The effect of the number of weight recordings 0, 1 or 2.

[a]Dry Matter Intake, [b]Neutral Detergent Fiber Intake, [c]Crude Protein Intake, [d]Water Soluble Carbohydrate intake, [e]Number of trough visits per day.

Least Square Means of the effect of the interaction between breed and week on DMI is shown in Figure 4.1. The figure shows that the mean DMI for NWS has a linear decrease from week 2 to 5 and increases for week 6, none of the interactions for NWS are significant (*P*>0.57). The mean DMI for ONS increases and decreases every other week throughout the 6 weeks, none of the interactions for ONS are significant (*P*>0.30).

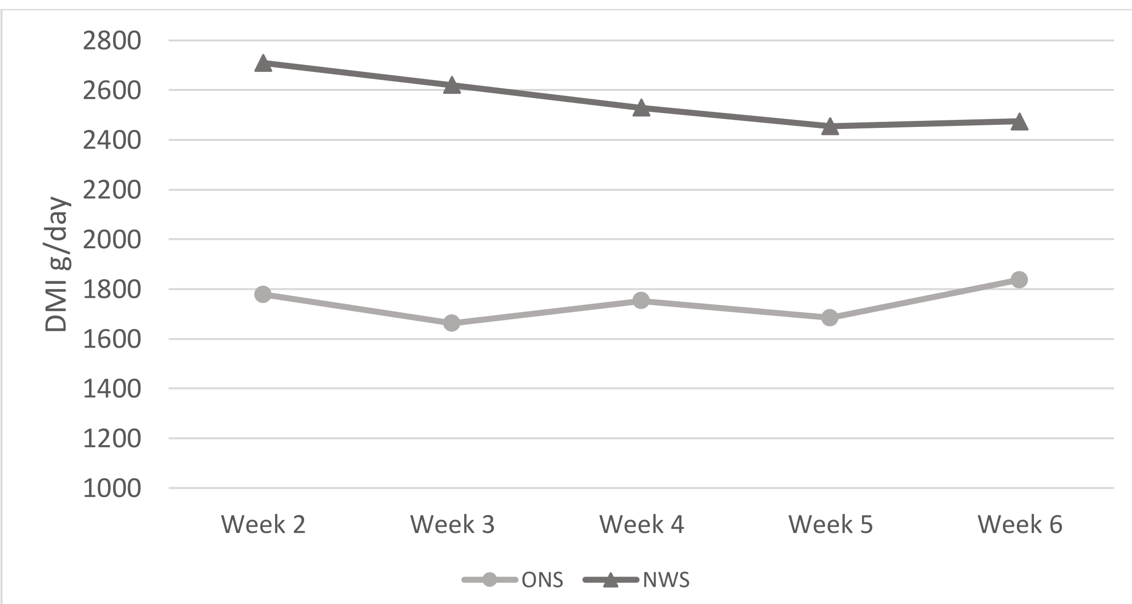

*Figure 4.1 Least Square means for effect of interaction Breed*Week on dry matter intake. The figure starts at 1000g.*

Least Square Means for the effects of Breed and number of weight recordings on DMI is shown in Table 4.3. NWS has a significantly higher DMI per day than ONS (*P*<.0001). There is a significant reduction of DMI by weighing 2 times against 1 (*P*<.0001).

Table 4.3 Least Squares Means for Model 1 for the effects of Breed and Number of Weight Recordings on Dry Matter Intake.*

Effect		*DMI g/day*	*SE*
Breed	*ONS*	*1,743*	*100.36*
	NWS	*2,558*	*100.36*
Number of Weight Recordings	*0*	*2,337ab*	*130.73*
	1	*2,099a*	*139.58*
	2	*2,015b*	*139.58*

*means with different subscripts differ (*P*<0.05).

Least Square Means for the effects of week and number of weight recordings on the number of trough visits is shown in table 4.4. There is a significant difference for week 2, 3 and 4 versus week 6 (*P*<0.0088). In addition, there is a significant difference between week 3 and 5 (*P*<0.0013). The number of trough visits was significantly decreased from 1 weighing to 2 weighings (*P*<.0001).

Table 4.4. Least Squares Mean for Model 1 for the effects of Week and Number of Weighings on Number of Trough Visits.*

Effect		*Number of Trough Visits per Day*	*SE*
Week	*2*	*58.8abc*	*4.0786*
	3	*65.5ad*	*4.9950*
	4	*52.3bde*	*4.0786*
	5	*51.5cef*	*4.9950*
	6	*39.7f*	*4.6639*
Number of Weight Recordings	*0*	*55.6ab*	*3.8745*
	1	*54.6a*	*3.9762*
	2	*50.4b*	*3.9767*

*means with different subscripts differ (*P*<0.05).

4.3 Diurnal feed intake

Average DMI for ONS and NWS throughout the day from hour 0 to 23 is shown in Figure 4.2. Hour 0 is the first hour after midnight. The DMI spikes at the morning feeding at 07:00 h and the evening feeding at 17:00 h. From hour 21 to 5 the DMI is low and decreasing.

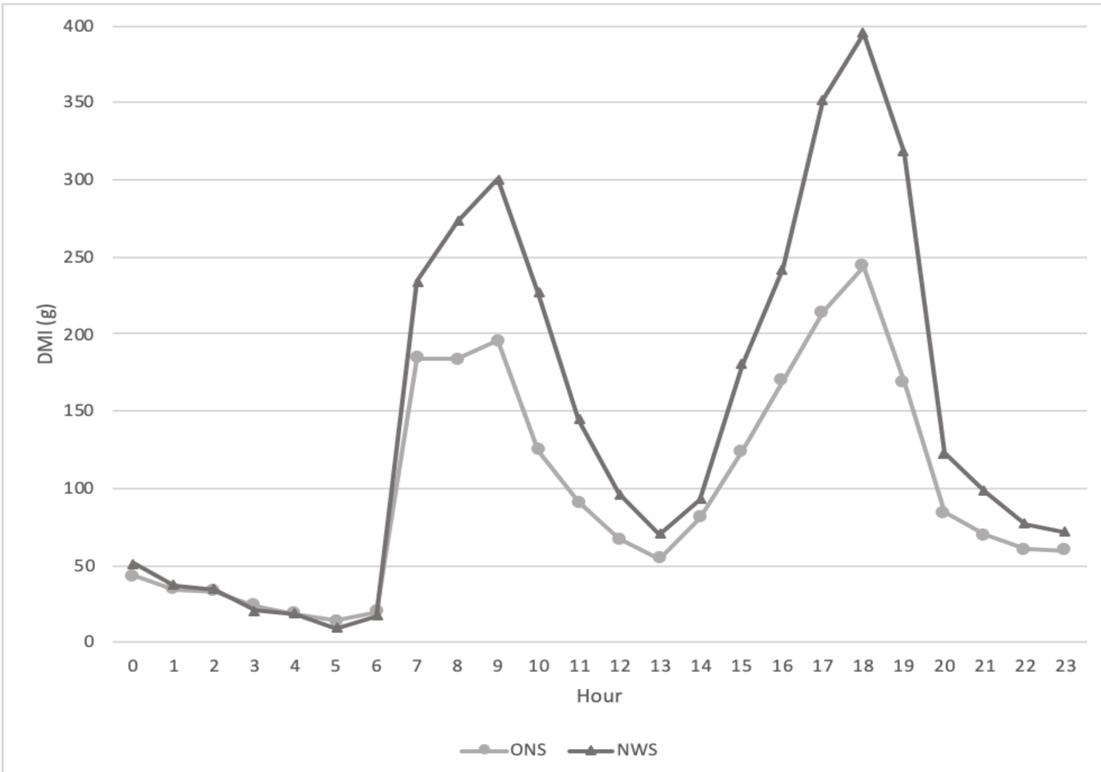

Figure 4.2 Average Dry Matter Intake (g) for ONS and NWS throughout the day from hour 0 – 23, where hour 0 is the first hour from midnight, for week 2-6. Ewes were fed at 07:00 h and 17:00 h.

4.4 Body Weight

The average body weight for week 2, 4 and 6 and the weight difference from start to end for ONS and NWS is shown in Table 4.5. The average weight increased for both ONS and NWS from week 2 to week 6. ONS had a higher weight difference in percent than NWS. The highest individual difference from start to finish was 13.8 kg for both breeds. The lowest individual difference was 1.6 kg and 4.5 kg for ONS and NWS, respectively.

Table 4.5. Average bodyweight (kg) ± standard deviation for week 2, 4 and 6 for ONS and NWS. Total weight difference in % ± standard deviation from start to the end of the trial.

	Average body weight (kg)			Weight difference from
	Week 2	Week 4	Week 6	start to end (%)
ONS	54.6 ± 7.01	58.6 ± 7.46	61.5 ± 7.51	13.0 ± 4.92
NWS	82.7 ± 8.86	88.0 ± 8.71	92.2 ± 8.95	10.6 ± 3.33

5. Discussion

5.1 Nutritional Development of The Grass

As expected, CP concentration decreased as the grass aged, and WSC concentration increased. However, the concentration of NDF did not have a markable difference, and the concentration fluctuated throughout the trial. This is most likely due to the low light intensity and shorter day length in late August/September which limits the growth (Jørgensen et.al, 2018) even though the temperature is high enough (Figure 3.1). If the grass was harvested in the early summer, there would probably be a greater significant change in the NDF content. In a practical matter, this suggest that the correlation between feed quality and phenological development (Bakken et.al, 2005) is lower, especially for NDF, for the second regrowth and later in the season.

The method of harvesting may also have influenced the results. The circular harvest method was chosen to harvest feed and samples from different areas in order to achieve a more evenly distributed harvest with samples that were representative of the whole field. However, the weather was warm and dry (Figure 3.1), and in the field some areas were more exposed to the sun, making these more vulnerable to drought. Therefore, depending on where the samples were taken from, the NDF content may be at a different concentration.

The evening samples taken as control samples for quality after storage shows that the quality is maintained by storage at 3°C (Appendix 1). There were only taken 3 samples of residue for each breed, which does not give enough data to interpret.

5.2 Effect of Phenological Development on Dry Matter Intake

There was expected to be a difference in DMI, but the result showed no significant effect on DMI throughout the trial and between weeks. Literature (e.g., Arzani et.al, 2004; Barnes et al. 2003; Jung & Allen, 1995; Kohler, 1944) suggests that there should be a difference in DMI as the grass matures beyond the reproductive stage due to increasing fiber concentration, however the analysis of the grass herbage did not show the development in NDF as expected.

The least square mean values of the effect of interaction between breed and week for DMI (Figure 4.1.), shows that NWS have an insignificant decrease in DMI from week 2 to week 5, and a slight increase from week 5 to week 6. For ONS the DMI decreased and increased insignificantly every other week and shows the lowest DMI in week 3 and week 5.

The pattern of DMI for ONS that shown in Figure 4.1 might be related to the weighing conducted in week 2, 4 and 6, which is corrected for in the model. However, the correction is an overall correction and not a correction for each breed, and therefore it can be an overcorrection for ONS which gives a higher intake in week 2, 4 and 6.

Even though there was not any significant change in DMI, there was a significant difference in CP and WSC intake. This is due to the change of CP and WSC concentration in the grass herbage. A meta-analysis done by Riaz et.al (2014) suggests that the CP concentration affects the DMI positively for sheep and that NDF had a positive influence. However, the result from this trial show no significant change in DMI even though the CP concentration decreases. This suggests that the concentration of both CP and WSC does not affect the DMI, and that the concentration of NDF might can be the determining factor of DMI.

5.3 Diurnal Feed Intake

Since the difference in DMI was not significant between any of the weeks, the average DMI for hour 0-23 for week 2-6 was calculated (Figure 4.2). The figure shows a clear increase in intake right after both feedings, and the lowest intake was through the night. NWS and ONS have the same eating pattern, however the NWS eats more than the ONS right after feeding which is expected as the NWS has had significantly higher total DMI than ONS.

Previous studies (Jørgensen et.al, 2017; Steinheim et.al, 2005) have shown that ONS flocking behavior on pasture would lead to faster depletion of food patches causing the animals to move on to other patches within a shorter timespan than the NWS. In other words, ONS is having more eating sessions and a lower consumption with each session than NWS which uses a longer time at one food patch. The results also show that the short-tailed breeds (i.e., ONS) chose more woody plants than the long-tailed breeds (i.e., NWS). If the results from these studies are to be transferred for this trial, it is reasonable to expect that the ONS would have more trough visits with a lower DMI than NWS.

Indoor eating behavior of ruminants have been extensively studied (Baumont et al., 2000) and it shows that when ruminants are fed indoors the eating behavior is scheduled by the feeding distribution, in this case two per day. Sixty to eighty percent of the daily intake is consumed during the main meals, and therefore the DMI is closely related to the amount consumed during main meals. With indoors feeding with two main meals, the rumen reaches its first maximum capacity at the first main meal, and the daily maximum after the evening main meal. This review suggests that the difference in eating behavior between the breeds as found by Jørgensen et.al (2017) and Steinheim et.al (2005) does not apply when the ewes are fed indoors.

The results show that the eating pattern on pasture found by Jørgensen et.al (2017) and Steinheim et.al (2005) does not apply when the ewes were fed indoors. There were no significant differences in the number of trough visits between the breeds. However, the hourly feed intake matches with the findings of Baumont et.al (2000) and shows that the eating behavior is scheduled after the two main meals. The first maximum is reached at hour 9 (morning feeding is at 07:00 h) and the second, and daily maximum, is reached after the evening meal at hour 18 (evening feeding is at 17:00 h). Apart from these two spikes after the main feedings, the feed intake is quite low and steady, most likely due to rumination which takes up about a third of a ruminant's lifespan (Sjaastad et.al, 2016).

5.4 Breed and Weights

All F-tests, except for trough visits, show a significant difference between breeds and between breeds within weeks, which is to be expected due to the differences in anatomy and body size (Steinheim et.al, 2003; Animalia, 2022). ONS has a lower DMI at 1,743 g/day (Table 4.3) compared to NWS which has a DMI at 2,558 g/day. The two breeds also have a different interaction effect with week, where ONS have a DMI which increases and decreases every other week, and NWS has a steadier decrease in DMI except the last week. However, these interactions are insignificant.

Before the trial, the lambs of the ewes were weaned off and the ewes were treated for internal parasites. This suggests that some or most of the ewes were somewhat underweight when the trial started. All the ewes gained weight during the trial, and the highest weight difference for both breeds was 13.8 kg. The smallest weight gain was 4.5kg and 1.6 kg for NWS and ONS, respectively. ONS had the largest average weight difference from the start to the end of the trial with 13.0%, and the NWS had a difference at 10.6 %. There is a significant difference in weights between the breeds as described in the statistics from the Norwegian sheep registration system, Animalia (2022).

5.5 Experimental Design

The possible challenge with the harvest method is already mentioned above, and in addition, to get a clearer difference in the quality of the grass herbage the experiment should have been conducted with the primary growth. The harvest used in this trial is equal to the 3rd harvest, which gives a slower and smoother development of NDF.

In Norway, the ewes usually graze on autumn pastures when the lambs are weaned off. The grass herbage used can be compared to the quality of these pastures. However, the indoors setup is more like the setup that is used in the winter period where the sheep are fed roughage. Desspite this, the results can be used to see how the grass quality of an autumn pasture or a 3rd harvest is changing as the grass matures.

Residue samples were also analyzed to see if there was any change in diet choice as described by Steinheim et.al (2003) which found that short-tailed (i.e., ONS) sheep eats more woody plants than long-tailed (i.e., NWS) sheep. It would be expected that the residue samples would show a higher NDF concentration for the NWS than for ONS, however, it was only taken 3 samples for each breed.

In week 2, 4 and 6 the ewes were weighed 1 or 2 times a day as they were measured in the PAC. This type of handling showed to have a great impact on the DMI. The animals were closed off feed for an hour before going into the chambers, and the handling might also have had a psychological impact on the animals. This is considered in the model (Model 1), but, as mentioned above, the correction is overall and not for each breed. This may have caused an overcorrection for the DMI for ONS.

6. Conclusion

In the grass herbage, which equaled an autumn pasture or a 3rd harvest, the concentration of CP increased, and the concentration of WSC decreased with increasing phenological development. However, the concentration of NDF held steady. This shows that the lower light intensity and shorter days do not give significant change in NDF as the grass matures in autumn. Furthermore, there was no significant change in DMI throughout the 6 weeks which suggests that the NDF concentration is the main factor determining DMI.

There was a significant breed difference for DMI, where ONS has a lower DMI than NWS, which was expected due to the difference in body size and anatomy of the digestive tract. All ewes gained weight during the trial, and ONS had a higher weight difference from start to finish than NWS. There was no significant breed effect for the number of trough visits, and for both breeds the number of visits decreased from the 3rd week to the last week. Furthermore, both breeds showed the same diurnal eating pattern with a spike in DMI after both feedings.

References

Allen, M. S. & Mertens D. R. (1988) Evaluating Constraints on Fiber Digestion by Rumen Microbes. *The Journal of Nutrition* 118(2): 261-270. doi: https://doi.org/10.1093/jn/118.2.261

Animalia (2022) *Årsmelding og statistikk.* Available from: https://www.animalia.no/no/Dyr/husdyrkontrollene/sauekontrollen/arsmeldinger/ (Read 23.02.2023)

Arzani, H., Zohdi, M., Fish, E., Zahedi Amiri, G.H., Nikkhah, A. & Wester, D. (2004) Phenological Effects on Forage Quality of Five Grass Species. *Journal of Range Management*, 57(6): 624-629. doi: https://doi.org/10.2111/1551-5028(2004)057[0624:PEOFQO]2.0.CO;2

Bakken, A. K., Bonesmo, H., Ekker, A. S., & Langerud, A. (2005). Fenologisk utvikling hos grovfôrvekstar vurdert etter ein numerisk skala. *Grønn kunnskap*, 9(3): 80-90.

Barnes, R.F., Nelson, C.J., Collins, M. & Moore, K.J. (2003) *Forages: an introduction to grassland agriculture. Environmental aspects of forage management.* 6th edition. Wiley-Blackwell.

Baumont, R., Prache, S., Meuret, M. & Morand-Fehr P. (2000) How forage characteristics influence behaviour and intake in small ruminants: A review. *Livestock Production Science.* 64(1): 15-28. doi: https://doi.org/10.1016/S0301-6226(00)00172-X

BioControl AS (n.d) *Registrering og Styring av Grovfôropptak.* Available from: https://www.biocontrol.no/nb/products/registrering-og-styring-av-grovforopptak/ (Read 12.01.2023)

Blix, A. & Vangen, O. (2023) *Sau*. Available from: https://snl.no/sau#-Vanlige_norske_saueraser (Read 23.02.2023)

Domingue, B. M. F., Dellow, D. W. & Barry, T. N. (1991) The efficacy of chewing during eating and ruminating in goats and sheep. *British Journal of Nutrition* 65(3): 355-363. doi: https://doi.org/10.1079/BJN19910096

Eidet, M. E. S. (2021) Fôropptak hos søyer av en liten og stor sauerase ved to ulike surfôrkvaliteter: Effekt av rase og kroppsvekt. Masteroppgave. Ås: Norges Miljø- og Biovitenksapelige universitet.

Eik, L.O. (2017) *Litt om fôring av sau.* Admastuen.

Felleskjøpet (2023) Grovfôr 2023. p. 12. Available from: https://ipaper.ipapercms.dk/TidRom/felleskjopet/grovfor/?page=1 (Read 02.02.2023)

Jung, H.G. & Allen, M.S. (1995) Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *Jornal of Animal Science*. 73(9): 2774-2790 doi: https://doi.org/10.2527/1995.7392774x

Jørgensen, N.H, Steinheim, G. & Holand, Ø. (2017) Does Scale Matter? Variation in Area Use Across Spatiotemporal Scales of Two Sheep Breeds in Two Contrasting Alpine Environments. *Rangeland Ecology & Management.* 71(2): 189-195 doi: https://doi.org/10.1016/j.rama.2017.11.001

Jørgensen, M., Bakken, A.K., Lunnan, T. & Østrem, L. (2018) Forvaltning av ettervekst i eng i varmere og våtere høstmåneder. *NIBIO Rapport* 4(34).

Kohler, G. E. (1944). The Effect of Stage of Growth on The Chemistry of The Grasses. Kansas City, Missouri: *Journal of Biological Chemistry*. Vol. 152: 215-223 ISSN: 0021-9258

Landslaget for Gammalnorsk Spælsau[a] (n.d.) Den Gammalnorske Spælsauens Historie. Available from: https://www.gammalnorskspelsau.no/historie/ (Read 23.02.2023)

Landslaget for Gammalnorsk Spælsau[b] (n.d) Avlsplan for Gammalnorsk Spælsau. Available from: https://www.gammalnorskspelsau.no/Avlsplan/ (Read 24.04.2023).

Moore, K. J., Moser, L. E., Vogel, K. P., Waller, S. S., & Johnson, B. E. (1991). Describing and Quantifying Growth Stages of Perennial Forage Grasses. *Agronomy & Horticulture - Faculty Publications.* 507. Available from: https://digitalcommons.unl.edu/agronomyfacpub/507?utm_source=digitalcommons.unl.edu%2Fagronomyfacpub%2F507&utm_medium=PDF&utm_campaign=PDFCoverPages

Norsk Sau og Geit[a] (n.d.) Sauerasene I Norge. Available from: https://www.nsg.no/sau/saueraser/sauerasene-i-norge#Norsk_kvit_sau (Read 23.02.2023).

Norsk Sau og Geit[b] (n.d) Avlsmål for sau. Avivailable from: https://www.nsg.no/sau/saueavl/avlsmal/ (Read 24.04.2023).

Norsk Sau og Geit[c], (n.d.). Egenskaper i avlsarbeidet hos NKS. Available from: https://www.nsg.no/sau/saueavl/avlsmal/nks-avlsmal/ (Read 23.04.2023).

Riaz, M.Q., Südekum, K.H., Clauss, M. & Jayanegara, A. (2014) Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: A meta-analysis. *Livestock Science,* Vol 162: 76-85. doi: https://doi.org/10.1016/j.livsci.2014.01.009

Sjaastad, Ø. V., Sand, O. & Hove, K. (2016) *Physiology of Domestic Animals.* Third Edition. Oslo: Scandinavian Veterinary Press.

Steinheim, G., Nordheim, L.A, Weladji, R.B., Holand, Ø. & Ådnøy, T. (2003) Digestive Tract Anatomy of Norwegian Sheep: Difference Between Breeds. *Acta Agriculturae Scandinavica, Section A- Animal Science* 53(3): 155-158. doi: https://doi.org/10.1080/09064700310012999

Steinheim, G., Nordheim, L.A., Weladji, R.B., Gordon, I.J., Ådnøy, T. & Holand, Ø. (2005) Differences in choice of diet between sheep breeds grazing mountain pastures in Norway. *Acta Agriculturae Scandinavica, Section A-Animal Science*, 55(1): 16-20 doi: https://doi.org/10.1080/09064700510009261

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant.* 2nd edition. Ithaca, N.Y: Comstock Pub.

Appendix

Appendix 1. Chemical composition of grass herbage. For the evening samples the dry matter content is an average of 3 days per week, and the values of ash, NDF, NDF, CP and WSC are from one composited sample per week for week 2, 5 and 6. The residue samples were taken 3 times and analyzed for DM, Ash, NDF, CP and WSC.

	DM %	Ash g/kg DM	NDF g/kg DM	CP g/kg DM	WSC g/kg DM
Evening Samples					
Week 2	17.9	98.6	471	189	85.9
Week 5	22.7	86.2	473	124	131
Week 6	21.5	101	443	159	198
Residue Samples					
NWS 31/8	25.1	94.2	485	138	98.4
ONS 31/8	25.6	92.8	489	129	110
NWS 10/9	28.9	88.3	492	121	123
ONS 10/9	28.7	89.1	476	124	124
NWS 17/9	25.8	76.8	514	114	143
ONS 17/9	25.5	82.2	496	120	146

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