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Milk production of Norwegian Red dairy cows on silages presumed either low or optimal in dietary crude protein content

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ABSTRACT

Dairy cow diets often exceed protein requirements for milk production. At the same time, dietary protein use efficiency for milk production is low leading to excretion of large amounts of nitrogen to the environment. We assessed the effects of feeding two grass/clover silages mainly differing in crude protein (CP) content on milk and component yields, nitrogen and gross feed utilization efficiency with Norwegian Red dairy (NRF) cows. Forty-eight early- to mid-lactation NRF dairy cows were randomly allocated to two dietary treatments (n = 24) after blocking by initial milk yield, stage of lactation, body weight and parity. Cows were fed silages either low in CP (late cut silage, LCPS; 112 g CP per kg dry matter (DM)) or optimal (mixture of 4 different silages, OCPS; 142 g per kg DM) *ad libitum* for a period of 54 days. These basal diets were augmented with a fixed level of concentrate feed (160 g CP per kg DM). This was estimated using the Nordic Feed Evaluation System (TINE Optfor KU optimization program) assuming OCPS as an available silage. We hypothesized that OCPS would support higher milk yield than LCPS, and the LCPS cows would consume more feed if they were to achieve similar level of milk yield as their OCPS counterparts. Contrary to our hypothesis, milk (23.7 vs. 24.5 kg per day), energy corrected milk (25.2 vs. 25.6 kg per day) yields and milk components were not significantly different between the groups (LCPS vs. OCPS). Furthermore, LCPS cows sufficiently matched DMI from the silage part of the diet to that of the OCPS cows (12.7 vs. 12.4 kg per day). However, OCPS decreased ($P < 0.01$) nitrogen use efficiency compared to the LCPS (30 vs. 33%). Our results confirm that reduction in dietary CP levels (ca 130 g per kg DM) can be achieved without loss of production, with reduced N excretion to the environment and reduced cost of milk production in moderately yielding cows. This would have a positive contribution to the current efforts being made to base our dairy production on locally available resources with minimal recourse to imported inputs.

1. Introduction

Ruminant production largely depends on the use of grazed and conserved forages. The digestibility and nutritive value of these forages vary considerably depending on stage of maturity of the crop (Rinne et al., 1999; Schroeder, 2012). Therefore, pasture management, feed conservation and feeding/grazing strategy have large effects on dry matter intake, animal performance (e.g. weight gain or milk yield) (Abrahamse et al., 2008; Kidane et al., 2014; Rinne et al., 1999) and nutrient use efficiency (e.g. nitrogen) (Kebreab et al., 2000).

In Norway, current efforts to improve milk production from dairy cows have largely relied on increased use of imported protein (more than 90%) ingredients (Landbruksdirektoratet, 2016). There is large variation between production systems in protein use efficiency (Whelan et al., 2013), and the extensive use and associated excretion of nitrogen (N) to the environment is challenged. Thus, reducing dietary N content in the feed is one of the potent strategies to improve efficiency, mitigate N emission (Dijkstra et al., 2013; Godden et al., 2001; Hristov and Huhtanen, 2008) and reduce feed costs (Godden et al., 2001) in ruminant production systems.

However, this should not be at the expense of production, as the global food demand is increasing mainly due to the projected human population growth in the years to come. In Norway, the human population is predicted to grow by 20% by the year 2030, and a similar increase in Norwegian agricultural production has been called for. At the same time, a greenhouse gas (GHG) emission reduction of 30% (equivalent to the 1990 level) by 2020 is targeted (Government.no, 2017). Furthermore, Norway aims to be carbon neutral by 2050. Such commitments require increased degree of self-sufficiency based on domestic feed resources (Aaby et al., 2014), through improved feed use efficiency and reduced recourse to imported feed resources.

Efficiency of dietary protein utilization by dairy cows varies considerably ranging from 10–40% with an average of about 25%

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(Calsamiglia et al., 2010; Hristov and Huhtanen, 2008). Therefore, there is a potential for substantial improvements to be made on many commercial dairy farms (Powell et al., 2010). The objective of this experiment was to assess protein and gross feed utilization efficiency and performance of Norwegian Red dairy (NRF) cows fed grass/clover silages considered to be either low in CP (LCPS) or optimal in CP (OCPS). The OCPS was a standard silage used at the experimental farm (Animal Production Experimental Centre, Norwegian University of Life Sciences, Norway) for lactating dairy cows at the time. The LCPS was selected for the purpose of this experiment and was of sub-optimal quality relative to OCPS for lactating cows. We hypothesized that OCPS would support higher milk yield than LCPS, and if the LCPS cows were to achieve similar level of milk yield as their OCPS counterparts, they would need to consume more of the silage part of their diet, on top of the fixed level of concentrate. The outcomes were expected to benefit the strategic allocation of available local feed resources to dairy cows.

2. Materials and methods

2.1. Animal grouping, housing, and feeding treatments

The experiment was carried out at the Animal Production Experimental Centre at the Norwegian University of Life Sciences following the laws and regulations controlling experiments on live animals in Norway under the surveillance of the Norwegian Animal Research Authority.

Forty-eight early- to mid-lactation NRF dairy cows were used in the experiment that lasted for 54 days. At start of the experiment, the cows had mean days into milk (DIM ± SD) of 126 ± 60, body weight (BW ± SD) of 566 ± 46.7 kg, and milk yield (mean ± SD) of 27.8 ± 5.4 kg/day. The herd was composed of cows from 1st to 4th lactation in the order of 21%, 46%, 21% and 13%, respectively. The cows were housed in a free-stall accommodation with concrete slatted floors and rubber mat beds with regularly applied sawdust in the resting areas. All cows had free access to drinking water and to mineral blocks.

The cows were blocked by parity, pre-experimental milk yield and composition, and BW at the start of the experiment. Thereafter, cows within a block were assigned to one of the two groups (later termed as LCPS or OCPS) balancing for the above parameters. The LCPS was a grass/clover mixture silage with a CP content of 112 g/kg DM whereas, the OCPS was a silage blend from different grass/clover swards used on the farm (Animal Production Experimental Centre, Norwegian University of Life Sciences) with a CP content of 142 g/kg DM. Chemical composition of the silages and concentrate feed is reported in Table 1 in detail.

The cows in each group received *ad libitum* access to their respective grass/clover silages prepared from timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) dominated swards. The silages were fed from individual automatic feeders (BioControl AS, Rakkestad, Norway) equipped with vertically moving gates where electronic cow identification ensured each cow's access to the correct silage source. The 24 feed troughs for each silage type were placed adjacent to each other so that cows in each treatment could get easy access to the correct silage type. The available feed troughs were matched to the number of cows. This ensured cow access to the feed at any given time. This was also meant to minimize cow displacement during feeding (Huzzey et al., 2006) and to avoid the ambiguity of using individual cow per feed trough as an experimental unit.

For daily dry matter intake (DMI), the automatic feed troughs registered summed daily intakes from multiple feeding episodes during a day. Feed troughs were filled with fresh silages twice a day (during morning and afternoon milking) after moving the cows to a resting and milking area. A manually controlled gate separated the milking and silage feeding zones. Feed refusal was cleared every Monday and Friday each week. Furthermore, cows were given a concentrate feed (FORMEL Favør 90, Felleskjøpet Agri, Gardermoen, Norway) (Table 1) that was estimated to meet the requirements for the expected milk yield based on 305 days lactation curve, and nutrient balance according to the Nordic Feed Evaluation System (NorFor) feeding standards (NorFor, 2011). For individual cow, the estimation took into account- along with the OCPS quality- expected milk yield at mid-point of the experiment, rumen fill, energy balance, amino acid supply to the small intestine (AAT), and rumen protein balance (PBV). For the 24 LCPS cows, the concentrate proportion of the diet was estimated by the NorFor system assuming the OCPS was the only available silage. This estimated level of concentrate feed was fixed for the whole experimental period and was fed from two central feeders on split basis (maximum 2.0 kg per cow per visit) throughout the day.

Table 1
Chemical composition and feed values (g/kg DM, unless otherwise mentioned) of the two silages and concentrate feed used for the experiment.

	Diet components and their chemical composition		
Characteristics	LCPS	OCPS	(FF90)[a]
Dry matter, g/kg	457	371	874
Crude protein	112	142	160
Neutral detergent fiber	550	457	198
Acid detergent fiber	349	300	82
iNDF[c]	183	195	385
pdNDF[c]	817	805	615
Crude fat	39	36	34
Starch	–	–	394
Residual CHO[b]	206	211	171
Ash	57	83	70
sCP (g/kg CP)	554	583	144
NEL at 20 kg DMI, MJ/kg[d]	6.09	6.49	6.82
AAT at 20 kg DMI[d]	85.8	82.3	117.0
PBV at 20 kg DMI[d]	−16	20	−4
CAD, meq/kg DM[e]	452	375	–
OM digestibility, %[d]	73.8	76.9	–
Additional silage parameters			
Ammonia-N, g/kg N	49.0	67.0	–
Lactic acid	19.6	48.0	–
Acetic acid	3.5	8.9	–
Butyric acid	1.0	< 0.0	–
Formic acid	5.0	6.8	–
Propionic acid	2.0	1.0	–
Ethanol	5.1	6.3	–
pH	4.9	4.5	–

sCP = buffer soluble CP.

[a] Commercial concentrate feed – FORMEL Favør 90 (Felleskjøpet Agri, Gardermoen, Norway).

[b] Residual CHO = 1000 – [Crude fat + Crude protein + Neutral detergent fiber + Ash + Fermentation products from feeds] (NorFor method, (NorFor, 2011)).

[c] iNDF (g/kg NDF) is total indigestible NDF as determined using 288 h in situ incubation according to NorFor (2011) standards and pdNDF is potentially degradable NDF (g/kg NDF) calculated as (1000-iNDF).

[d] Estimations made by Eurofins on net energy for lactation (NE_L), metabolizable protein (AAT), protein balance in the rumen (PBV), and organic matter (OM) digestibility.

[e] CAD is dietary cation anion difference calculated according to NorFor (2011).

2.2. Body weight and body condition score

The cows were weighed and body condition was scored by a trained assessor following morning milking every week. Body condition score (BCS) was taken on a scale from 1.0 to 5.0 (to the nearest 0.25, with 1.0 = emaciated and 5.0 = obese), using a scoring scheme prepared by GENO (GENO Global LTD.) for NRF cows.