Feed intake, milk production and dry matter digestibility in cows fed CTMR

F. Petters[1], M. Lindberg[1] & C. Kronqvist[1]
[1]*Swedish University of Agricultural Sciences (SLU), Department of Animal Nutrition & Management, P.O. Box 7024, SE-75007 Uppsala, Sweden*
Correspondence: faps0001@stud.slu.se

Introduction

Total mixed ration (TMR) is an established feeding strategy for dairy cows in Sweden. One of the challenges with total mixed rations is to prevent sorting of the feed ration (Leonardi & Armentano, 2003). Sorting of TMR has been linked to health conditions such as sub-acute ruminal acidosis (Shaver, 2002). A development of the total mixed ration, called compact total mixed ration (CTMR), has recently been suggested as a way to reduce sorting of the ration (Kristensen, 2015). The CTMR is a wetter and more finely chopped version of the TMR. The dry matter (DM) target is 37 % and feed components should be close to indistinguishable from each other (Kristensen, 2015). Practical results from farms in Denmark using CTMR have shown that it can lead to increased milk production and improved feed efficiency (Kristensen, 2015). However, no controlled experiments have previously been done using this procedure.

The aim of this study was to evaluate the effects of reduced particle size and DM content in a TMR fed to lactating dairy cows on feed intake, milk production and DM digestibility.

Materials and methods

Forty dairy cows in early to mid-lactation, 48±19 (mean ± standard deviation; SD) days in milk at the start of the experiment were housed in a loose housing system and batch milked two times a day in an automatic milking rotary (DeLaval, Tumba, Sweden). Both primi- and multiparous cows were used and were allocated into seven blocks according to calving date and parity. Within the blocks, cows were randomly allocated to one of two groups. The experiment had a change-over design with two dietary treatments and two treatment periods, each 21 days. The first 14 days were used for adaption to the diet while the last 7 days within a treatment period were for sampling and measurements.

The dietary treatments TMR and CTMR were total mixed rations that differed in forage particle size and dry matter content. The diets were similar in chemical composition and based on the same forage and concentrate. The forage to concentrate ratio was 60:40, according to standards for organic milk production (KRAV, 2017). The forage was a second harvest grass silage chopped to 2 cm theoretical length of cut and preserved in a bunker silo. The concentrate was in the form of crushed pellets and produced from ingredients available as organically produced. Nutritional values for forage and concentrates are in Table 1. Both diets were mixed in a mixer wagon with a vertical auger without knives (DeLaval, Tumba, Sweden). The CTMR diet was altered in forage particle size and dry matter content. To decrease forage particle size, the forage in CTMR was mixed in a vertical auger with knives (SiloKing, Tittmoning, Germany) for 60 minutes before added to the mixer wagon. To alter DM content of CTMR, water was added into the mixer to achieve a 37% DM content, while TMR DM content averaged 58.1%. Dry matter content in forage was measured weekly for adjustment of the recipe. The diets were distributed in individual feeding mangers on scales three (TMR) or two (CTMR) times a day with the goal to provide *ad libitum* access.

Table 1 Nutritional composition of forage and concentrate used in the experiment

Forage			Concentrate[6]		
DM[1]	41	%	DM	88.1	%
Energy[2]	10.7	MJ ME kg DM^{-1}	Energy	13.4	MJ ME kg DM^{-1}
Crude protein[3]	165	g kg DM^{-1}	Crude protein	170	g kg DM^{-1}
NDF[4]	452	g kg DM^{-1}	Crude fat	55	g kg DM^{-1}
Ca[5]	8.2	g kg DM^{-1}	Crude fiber	66	g kg DM^{-1}
P[5]	2.2	g kg DM^{-1}	Ash	62	g kg DM^{-1}
Mg	2.3	g kg DM^{-1}	Ca	8	g kg DM^{-1}
K[5]	27.3	g kg DM^{-1}	P	6	g kg DM^{-1}
			Mg	3	g kg DM^{-1}
			K	9	g kg DM^{-1}
			Na	3.2	g kg DM^{-1}

[1]Dry matter, analysed by drying in 60°C over night; [2]Estimated by analysis of VOS (Lindgren, 1979) and calculated using the equation from Lindgren (1983); [3]Estimated by the Kjeldahl method; [4]Analysed according to Chai and Udén (1988); [5]Analysed by plasma emission spectroscopy; [6]Data on nutrient composition of concentrate were provided by the manufacturer (Lantmännen).

The Penn State Particle Separator with 19 and 8 mm sieves was used to assess particle size distribution of the diets. Feed samples were collected at feeding four times during each sampling period. Particle size proportions of the diets were calculated on fresh and DM basis. Dry matter intake was measured using data collected from the feed mangers and were recalculated using the DM content of each diet. Drinking water intake was measured using water cups fitted with water meters and transponder sensors (Biocontrol A/S, Rakkestad, Norway). Total water intake was calculated by using registered water intake from water cups, feed intake and DM content of diets. Milk yield data were collected from all milkings during the sampling week. Milk composition was determined by analysis of milk samples derived from morning and evening milking for two consecutive days during the sampling week within each period. Milk samples were analysed with a Delta Combiscope (Combiscope FTIR 300, Delta instruments, the Netherlands) for fat, protein and lactose content. Dry matter digestibility was measured by analysis of acid insoluble ash (AIA) in feed and faeces. Forage and concentrates were analysed separately in duplicates during both treatment periods. Faeces were spot sampled three times on three separate days for each cow during the sampling weeks and frozen. The three samples from the same animal and treatment period were then thawed and composited to one 180-g sample for further analysis. The 180-g samples were freeze dried, ground to pass a 1-mm sieve, combusted at 550°C, boiled in hydrochloric acid to remove acid soluble components and then filtered (Van Keulen & Young, 1977).

Data were analysed by SAS 9.4 with procedure Mixed and class variables: animal, block breed, period and treatment. Random variable was animal and fixed factors were breed, block, period and treatment. The covariance between samples within animal was modelled with a spatial power covariance structure. Significant results were considered when $P<0.05$.

Results and discussion

In this study, the effect of forage particle size and DM content was evaluated as one factor and therefore it is not possible to determine which of them affected the results, or if there was an interaction between them. The CTMR diet had a smaller forage particle size and a lower DM content. The fraction of DM in the diet that remained on the top sieve in the Penn State particle separator was 32 % for the TMR diet and 6 % for the CTMR diet. Dry matter intake decreased, even though fresh matter intake increased, when cows were fed CTMR diet compared to TMR diet (Table 2). This was inconsistent with previous literature that studied the effect of forage particle size in forage based TMR's. Reducing forage particle size has been seen to increase DM intake in dairy cows in forage based TMR diets (>50 %, DM basis) (Kononoff & Heinrichs, 2003; Maulfair *et al*., 2010). However, decreasing DM content of a TMR to below 50 % has previously been shown to decrease DM intake (Miller-Cushon & DeVries, 2009; Felton & DeVries 2010). Total water intake was higher when CTMR was fed compared with when TMR was fed (Table 2). This was a result from the added water to the CTMR ration, since water intake from water troughs was lower when cows were fed CTMR (Table 2). It has previously been suggested that adding water to a TMR can decrease DM intake because of water's ruminal filling effect, as well as that the rumen's capacity to transport water is exceeded (Robinson *et al*., 1990; Miller-Cushon & DeVries, 2009). Therefore, it is suggested that the effect of reduced forage particle size was overridden by the effect of lowered DM content in the CTMR diet and that this caused the decrease in DM intake.

Table 2 Effects of feeding total mixed rations TMR[1] and CTMR[2], differing in forage particle size and dry matter content

	TMR	CTMR	SEM	P-value
Dry matter intake, kg day^{-1}	28.6	26.8	0.6	<0.001
Water intake, kg day^{-1}	109.6	98.9	2.6	<0.001
Total water intake, kg day^{-1}	136.3	144.3	3.0	<0.001
Dry matter digestibility, %	61.35	62.1	0.01	0.187
Milk yield, kg day^{-1}	35.2	35.1	0.4	0.495
Milk yield, kg ECM day^{-1}	34.7	33.8	0.8	0.151
Fat content, %	3.83	3.71	0.01	0.239
Fat yield, kg day^{-1}	1.36	1.28	0.04	0.062
Protein content, %	3.24	3.25	0.01	0.621
Protein yield, kg day^{-1}	1.15	1.13	0.03	0.189
Lactose content, %	4.77	4.78	0.01	0.748
Lactose yield, kg day^{-1}	1.71	1.68	0.04	0.237

[1] TMR was forage from the bunker silo and dry matter content 58.1%. [2]CTMR was re-chopped forage and water added to achieve dry matter content 37%.

Even if dietary treatments affected DM intake, there was no effect on milk production or milk composition (Table 2). This was consistent with TMR studies on the effect of forage particle size (Kononoff & Heinrichs, 2003; Maulfair *et al*., 2010) and effect of DM content (Miller-Cushon & DeVries, 2010; Felton and DeVries, 2012). It can be speculated that the higher energy intake on the TMR diet was used for body fat synthesis rather than milk synthesis and that with time, this should result in a weight gain and increase in body condition score. There was a tendency towards a lower milk fat yield when CTMR diet was fed (Table 2). Reduction of forage particle size has previously resulted in reduced milk fat percentages when the forage proportion of a TMR was 40 % (Krause & Combs, 2003).

Since CTMR resulted in lower DM intake at the same time as milk production was maintained, the reduced forage particle size of CTMR could have increased digestibility. There was, however, no effect of dietary treatment on DM digestibility (Table 2). This is inconsistent with previous work that used forage based TMR (>50 %, DM basis) where DM digestibility increased when forage particle size was reduced (Kononoff & Heinrichs, 2003). There are, however, previous research where forage proportions were <50% of DM and no effect of forage particle size on DM digestibility could be found (Krause *et al*., 2002; Alamouti *et al*., 2009). The AIA concentration of the forage was higher in one of the treatment periods, for unknown reasons. The higher AIA concentration occurred in both duplicate samples and therefore not thought to be due to an analytical error. This led to that an effect of period on calculated DM digestibility was found. Also, there was a significant interaction between dietary treatment and period, showing that the CTMR increased DM digestibility with 2.2 percentage units in the second treatment period ($P<0.05$), although not in the first period. A dietary treatment's effect on DM digestibility could therefore not be fully established.

Conclusions

When CTMR, where particle size as well as DM content of the diet were decreased, was fed to dairy cows in early to mid-lactation, DM intake decreased and total water intake increased, compared to when a conventional TMR was fed. However, no effects on milk production or milk composition was shown. The effect of CTMR on DM digestibility could not be fully established.

References

Alamouti, A.A., Alikhani, M., Ghorbani, G.R. & Zebeli, Q., 2009. Effects of inclusion of neutral detergent soluble fibre sources in diets varying in forage particle size on feed intake, digestive processes, and performance of mid-lactation Holstein cows. Anim. Feed Sci. Technol. 154, 9-23.

Chai, W. & Udén, P., 1998. An alternative oven method combined with different detergent strengths in the analysis of neutral detergent fibre. Anim. Feed Sci. Technol. 74:281-288.

Felton, C.A. & DeVries, T.J., 2010. Effect of water addition to a total mixed ration on feed temperature, feed intake, sorting behavior, and milk production of dairy cows. J. Dairy Sci. 93(6), 2651-2660.

Kononoff, P.J. & Heinrichs, A.J., 2003. The effect of reducing alfalfa haylage particle size on cows in early lactation. J. Dairy Sci. 86(4), 1445-1457.

Krause, K.M. & Combs, D.K., 2003. Effects of forage particle size, forage source, and grain fermentability on performance and ruminal pH in midlactation cows. J. Dairy Sci. 86(4), 1382-1397.

Krause, K.M., Combs, D.K. & Beauchemin, K.A., 2002. Effects of forage particle size and grain fermentability in midlactation cows. I. Milk production and diet digestibility. J. Dairy Sci. 85, 1936-1946.

KRAV, 2017. Standards for organic production. Uppsala, Sweden.

Kristensen, N. B., 2015. Implement Compact TMR to increase productivity, feed efficiency and health in dairy herds. In: Djurhälso- & utfodringskonferensen. Växa Sverige, Sollentuna, Aug 25-26^{th,} (p. 68-79.

Lindgren E., 1979. Vallfodrets näringsvärde bestämt in vivo och med olika laboratoriemetoder. Report 45. Dept. of Animal Nutr. and Managm., Swedish Univ. Agric. Sci., Uppsala, Sweden (English summary).

Lindgren, E. 1983. Nykalibrering av VOS-metoden för bestämning av energivärde hos vallfoder. Dept. of Animal Nutr. and Management. Swedish Univ. Agric. Sci., Uppsala, Sweden.
Maulfair, D.D., Zanton, G.I., Fustini, M. & Heinrichs, A.J., 2010. Effect of feed sorting on chewing behavior, production, and rumen fermentation in lactating dairy cows. J. Dairy Sci. 93, 4791-4803.
Miller-Cushon, E.K. & DeVries, T.J., 2009. Effect of dietary dry matter concentration on the sorting behavior of lactating dairy cows fed a total mixed ration. J. Dairy Sci. 92, 3292-3298.
Robinson, P.H., Burgess, P.L. & McQueen, R.E., 1990. Influence of moisture-content of mixed rations on feed-intake and milk-production of dairy-cows. J. Dairy Sci. 73, 2916-2921.
Van Keulen, J. & Young, B.A., 1977. Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. J. Anim. Sci. 44, 282-287.