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Effects of rumen-protected choline with calcium salts of long chain fatty acids on milk yield and milk composition of middle and late lactation Holstein cows

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ABSTRACT

The objective of this study was to evaluate the effect of rumen-protected choline (RPC) supplementation on milk production and milk composition of dairy cows. Fifty lactating multiparous Holstein cows >80 days in milk were randomly assigned to one of two treatments groups. Cows were fed with: (1) control diet (CON; $n=25$), not supplemented with RPC and (2) supplemented diet (RPC; $n=25$), supplemented with RPC (115 g/cow/d). Control and supplemented cows were fed at ad libitum intake twice daily. Body weight and body condition score were measured weekly. Milk production and dry matter intake were recorded daily. Milk samples were collected twice weekly on week 3, 6, and 9 and analyzed for fat, protein, lactose, urea nitrogen, somatic cell count, fatty acid (FA) composition, and free choline concentration. Plasma was obtained on week 1, 3, 4, 6, 7, and 9 and analyzed for concentrations of free choline and non-esterified fatty acids. Cows remained in the experiment for 9 weeks. Data were analyzed using the MIXED procedure of SAS (v9.4). Higher free choline concentration in plasma ($P<0.001$) confirmed intake and absorption of RPC by supplemented cows. Dry matter intake (23.6 vs. 23.4 kg/d), body weight (704 vs. 703 kg), and body condition score (2.86 vs. 2.90; 1–5 scale) were not affected ($P>0.05$) by RPC supplementation (CON vs. RPC, respectively). There was no difference ($P>0.05$) on milk yield (36.72 and 36.81 kg/d, respectively), 3.5% fat corrected milk, or energy corrected milk between supplemented and non-supplemented cows, respectively. Although production parameters were not affected by RPC supplementation, they were significantly affected ($P<0.01$) by period and lactation stage. While concentration of de novo and mixed (16:0+*cis*-9 16:1) FA in milk fat were greater in CON cows, preformed FA were greater in RPC ($P<0.05$) supplemented cows. Concentration of total saturated FA ($P<0.001$) was higher in CON cows, whereas total monounsaturated FA (*cis* and *trans*) and *cis* polyunsaturated FA concentrations were greater in RPC cows ($P<0.05$). Yield of polyunsaturated omega-3 FA was greater when RPC was added to the diet. Although milk production was not affected, supplemental RPC either in middle or late lactation resulted in milk fat composition enriched by long chain polyunsaturated FA.

1. Introduction

Choline inclusion is of great interest in diets of dairy cows. Even though the NRC (2001) did not establish requirements for choline and B vitamins for dairy cows,

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choline is referred as an essential nutrient that must be supplied in the diets of several animal species (Sharma and Erdman, 1989). Choline is a trimethylated quaternary amine that is crucial for the brain and neuromuscular signaling (Hartwell et al., 2000), is usually grouped within the B-complex vitamins, however it does not fit the traditional role of a vitamin (NRC, 2001). Choline is a key compound for the synthesis of two important molecules, phosphatidylcholine (PC) and acetylcholine (Pinotti et al., 2002). Phosphatidylcholine is essential to maintain cell membrane structure (Davidson et al., 2008), hepatic synthesis and secretion of very low density lipoprotein from the liver (Cooke et al., 2007), and biosynthesis and secretion of milk (Kinsella, 1969); whereas acetylcholine is an important neurotransmitter (Pinotti et al., 2002).

Early studies evaluating the effect of dietary choline on milk yield and duodenal flow indicated its rapid and extensive rumen degradation (Atkins et al., 1988) and the need to protect it from rumen degradation to be available for absorption in the duodenum (Sharma and Erdman, 1988a,b). Subsequently, numerous studies have evaluated the effects of feeding choline in rumen-protected form (RPC) on production, reproduction, and health of dairy cows. Responses across research trials have not been consistent and therefore questions regarding its value remain still prevalent. Whereas some studies have reported positive effects of RPC on milk yield (Pinotti et al., 2003), milk composition (Sharma and Erdman, 1989; Erdman and Sharma, 1991), and dry matter intake (DMI; Zahra et al., 2006); others have reported only a tendency to increase 3.5% fat corrected milk (FCM) and milk fat yield (Piepenbrink and Overton, 2003) or no effects on the previous variables (Deuchler et al., 1998). Few studies have devoted their interest on the possible effects of RPC on improving reproductive parameters and the incidence of metabolic diseases (Ardalan et al., 2010; Lima et al., 2012). Most research trials have focused their interest on evaluating the effects of RPC on production performance parameters, blood metabolite status (Janovick-Guretzky et al., 2006; Zahra et al., 2006), and fat mobilization (Cooke et al., 2007; Goselink et al., 2013). These experiments have been done during either the transition period or early lactation. Few studies have investigated the effects of RPC in cows during middle and late lactation and its effect on milk production and milk composition. In our study, the primary objective was to assess if the supplementation of RPC to the diet of dairy cows in middle and late lactation would improve milk production, milk composition, and fatty acids (FA) profile of milk fat.

2. Materials and methods

2.1. Animal management, diets, and experimental design

All procedures were conducted under protocols approved by the University of Illinois Institutional Animal Care and Use Committee. Fifty lactating multiparous Holstein cows over 80 days in milk (DIM) were selected, balanced, and randomly assigned to one of two treatments groups. Twenty-five cows were allocated in each group; each group was made up of an equal number of cows in middle ($n=26$; DIM $=104\pm25$) and late lactation ($n=24$; DIM $=224\pm39$). Cows were balanced regarding DIM, lactation number (2.88 ± 1.1), previous lactation 305-day milk yield ($12{,}634\pm1727$ kg), and body condition score (BCS; 2.91 ± 0.42; 1–5 scale). Cows were housed in free stalls at the University of Illinois Dairy Research Unit that meet or exceed requirements specified in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

Table 1
Ingredient composition of the basal lactation diet in dry matter (DM) basis fed to control (CON=not supplemented with RPC) or rumen protected choline supplemented (RPC) group throughout the experiment.

Ingredient, % DM	CON	RPC
Alfalfa hay	1.97	1.97
Grass hay	0.97	0.97
Corn silage	3.81	3.81
Alfalfa silage	4.13	4.13
Wet brewers grain	2.37	2.37
Dry corn gluten feed	1.02	1.02
Cottonseed	1.22	1.22
Soy hulls	0.83	0.83
Dry ground corn grain	6.91	6.91
Lactating cow supplement[a]	2.11	2.11
RPC[b]	–	0.12

[a] Lactating cow supplement: formulated for 17.3% CP, 8.4% NDF, 3.4% ADF, 0.6% lignin, 6.3% crude fat, and 36.4 mEq/100 g DCAD, and contained: 65.8% dry ground corn grain, 8.4% bypass protein, 5.1% blood meal, 3.9% soybean meal, 3.5% Energy Booster 100 (MSC, Eden Prairie, MN), 2.9% sodium bicarbonate, 2.3% limestone, 1.6% dicalcium phosphate, 1.5% molasses, 1.3% biotin, 1.2% white salt, 1.1% KCl, and $<1\%$ of each of the following; trace minerals, vitamin E, vitamin A, vitamin D, selenium and monensin.

[b] Rumen protected choline: coated with calcium salts and long chain omega fatty acids. RPC-supplemented group received 115 g/cow daily that provided 7.60 g/cow daily of bypass choline.

All cows received the same basal total mixed ration (TMR) diet for ad libitum intake, formulated according to NRC (2001) to meet the requirements for metabolizable protein, rumen degradable protein, rumen undegradable protein, macrominerals, microminerals, and vitamins A, D, and E. The diet (Table 1) was based on (DM basis) corn silage (15.02%), alfalfa silage (16.29%), alfalfa hay (7.79%), grass hay (3.81%), ground corn (27.29%), wet brewer's grain (9.36%), dried corn gluten feed (4.01%), cottonseeds (4.83%), soy hulls (3.26%), and mineral and vitamin mix (8.33%). Cows were fed with: (1) control diet (CON; $n=25$), not supplemented with choline and (2) rumen-protected choline supplemented diet (RPC; $n=25$), supplemented with 115 g/cow daily of RPC (Robert Morgan, Inc., Paris, IL) to provide 7.60 g/cow of bypass choline daily. The RPC supplement was protected with calcium (Ca) salts of long chain fatty acids (FA) and mixed in the TMR for the supplemented cows. Control and RPC supplemented cows were fed twice daily for 3 consecutive 3-wk periods, as follows: period 1 (wk 1–3), cows in group A fed RPC supplemented diet ($n=25$) and cows in group B fed CON diet ($n=25$); period 2 (wk 4–6), cows in group B fed RPC supplemented diet ($n=25$) and cows in group A fed CON diet ($n=25$); and period 3 (wk 7–9), cows in group A fed RPC supplemented diet ($n=25$) and cows in group B fed CON diet ($n=25$). Cows remained in the same