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Effects of canola meal pellet conditioning temperature and time on ruminal and intestinal digestion, hourly effective degradation ratio, and potential nitrogen to energy synchronization in dairy cows

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ABSTRACT

The increase in bio-oil production in North America has resulted in millions of tonnes of co-products: canola meal and carinata meal. Little research has been conducted to determine the effect of pellet conditioning temperature, time, and their interaction on processing-induced changes in nutrient digestibility in the rumen and intestine (in vitro) of dairy cattle. The objectives of this study were to investigate the effects of conditioning temperature (70, 80, and 90°C), time (50 and 75 s), and their interaction (temperature × time) during the pelleting of canola meal on (1) rumen degradation kinetics and effective rumen degradability of dry matter, crude protein (CP), and neutral detergent fiber; (2) intestinal digestibility of rumen-undegradable protein (RUP); and (3) hourly effective rumen degradation ratio and potential N to energy synchronization in dairy cattle. The results showed that the temperature and duration of pellet conditioning significantly altered the degradation characteristics of nutrients in the rumen. Pelleting increased CP degradation in the rumen, and CP digestion site was shifted to the rumen rather than to the small intestine. When conditioning temperature was set 80°C, the rumen degradation of CP and neutral detergent fiber was highest, but postrumen digestion was lowest. With respect to intestinal digestion, the available CP for intestinal digestion became less because of reduced RUP supply to the small intestine. The pelleting process tended to significantly affect the intestinal digestibility of RUP. However, the total digestible CP content of canola meal was not affected. In conclusion, pelleting induced changes in rumen and intestinal digestion profiles, and altered the potential N to energy synchronization and hourly effective rumen degradation ratio of canola meal in dairy cattle.

Key words: pelleting canola meal, ruminal and intestinal digestion of nutrients, hourly effective degradation ratio, nitrogen to energy synchronization

INTRODUCTION

The production of Canadian canola was over 15 million tonnes in 2013 (Canola Council of Canada, 2013). Canola meal, a co-product from bio-oil extraction processing of canola seed, has high CP content and premium protein quality because it contains low concentrations (<30 μmol) of antinutritional compounds called glucosinolates (Theodoridou and Yu, 2013). Therefore canola meal is used in both monogastric and ruminant diets (Newkirk, 2009a,b) and together with rapeseed meal is the second most traded protein source in the global animal feed market (Newkirk, 2009a,b; Heendeniya et al., 2012). To further improve the competitiveness of canola meal in the feed market, it is necessary to develop suitable canola meal-based pelleted products with an improved or undamaged nutrient quality, and high transportation efficiency and durability.

Although the nutritional values of canola meal for dairy cows have been extensively studied (Heendeniya et al., 2012; Theodoridou and Yu, 2013), information about the effects of conditioning temperature and time during the pelleting on the nutritional value of processed meal is insufficient. Specifically, the digestible NDF in canola meal is an important factor contributing to the energy content of canola meal; however, little attention has been paid to the effect of different processing conditions on NDF availability of canola meal. Pelleting has been widely used in the animal feed industry and proved advantageous in improving protein digestibility of both single feed ingredients and compound feeds (Thomas and van der Poel, 1996; Thomas et al., 1997; Abdollahi et al., 2013). Van der Poel et al. (1995) and Goelema et al. (1999) reported that degradation and passage rates of feeds through animals' digestive system can be altered by feed processing methods. Pelleting improved

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rumen degradation of resistant starch by 15% (Tamminga and Goelema, 1995; Thomas and van der Poel, 1996) and also improved CP degradation in the rumen of dairy cattle (Goelema et al., 1999). However, the effects of the pelleting process on feed materials should take into consideration the interrelations between conditioning, pelleting, and cooling (Thomas et al., 1997).

Understanding how rumen degradation kinetics and intestinal digestion characteristics, and nutrient supply to dairy cattle, are affected by pellet processing conditions is vital for feed evaluation. Hence, it is of great interest to investigate the effects of pelleting under different conditioning temperatures and time on nutrient profiles and digestion characteristics of canola meal to find the optimal processing conditions. In the previous study (Huang et al., 2015), we reported the effects of conditioning temperature and time during the pelleting process of canola meal on processing-induced changes in protein molecular structure, pellet durability index, detailed chemical profile, CP and carbohydrate subfractions, total digestible nutrients, and energy values. The objectives of this second study were to investigate the effects of conditioning temperature (70, 80, and 90°C), time (50 and 75 s), and their interaction (temperature × time) during the pelleting process of canola meal on (1) rumen degradation kinetics and rumen availability of DM, total carbohydrates (**CHO**), CP, and NDF; (2) intestinal digestibility (in vitro) of RUP; and (3) hourly effective rumen degradation ratio and potential N to energy synchronization in dairy cattle.

MATERIALS AND METHODS

Pelleting-Process

Information on canola meal and the procedure of pelleting process is reported in the previous manuscript (Huang et al., 2015). Briefly, 2 representative sources of the meal were obtained from a commercial feed company (Federated Cooperatives Ltd., Saskatoon, SK, Canada) with different manufacturing dates. A California laboratory pellet mill (California Pellet Mill Co., Crawfordsville, IN) was used to produce canola meal pellets at 3 different conditioning temperatures (70, 80, and 90°C) arranged in a factorial combination with 2 different conditioning time (50 and 75 s), resulting in a total of 6 treatment samples (3 temperatures × 2 time) for each batch (n = 2) of canola meal. Steam conditioning was used before meal mash went through the pelleting die. Pellets were exposed in the air for 24 h to cool pellets before the pellet durability test. The detailed chemical profile and changes in pellet durability index during the different pellet processing were reported earlier (Huang et al., 2015; Supplemental Table S1; http://dx.doi.org/10.3168/jds.2014-9295).

Animal, Diets, and Rumen Incubation

Five nonlactating Holstein cows were used in the in situ trial to evaluate degradation characteristics of canola meal pellets processed under different conditions. Each cow was fitted with a rumen cannula with an internal diameter of 10 cm (Bar Diamond, Parma, ID). The cows were fed a TMR twice daily at 0800 and 1600 h with water available ad libitum. The TMR was formulated (on DM basis) with 56.1% barley silage, 14.3% chopped alfalfa, and 29.6% concentrate (containing barley, wheat, oats, canola meal, soybean meal, wheat DDGS, corn gluten meal, molasses, golden flakes, canola oil, minerals, and vitamins) to meet the nutrient requirement according to NRC (2001). The detailed diet information was reported previously (Nuez-Ortín and Yu, 2010). The animals were cared for under the guidance of the Canadian Council on Animal Care (CCAC, 1993) and the experiments were approved by Animal Research Ethics Board (AREB) at the University of Saskatchewan, Canada with Animal Use Approval Protocol #19910012.

The in situ method was used to conduct 2 experimental runs for the rumen incubation (Ørskov and McDonald, 1979; Tamminga et al., 1994). Around 7 g of coarsely ground pelleted samples (roller with a gap 0.203 cm) and unprocessed samples were weighed into each numbered nylon bag with pore size of 40 μm (Nitex 03–41/31 monofilament open mash fabric, Screentec Corp., Mississauga, ON, Canada). The maximum nylon bags in each cow did not exceed 30, with the number of bags for longer incubation periods increased to ensure sufficient sample residual for chemical analysis. Ruminal incubation processes were carried out for 48, 24, 12, 8, 4, 2, and 0 h according to the gradual addition/all-out schedule (Yu et al., 2000). At the end of incubation, incubated bags were taken out of the rumen, with all bags (incubated and 0 h bags) hand washed in cold water to rinse off ruminal contents. Washed bags were dried in a forced-air oven at 55°C for 48 h, weighed, and dry residues in the bags were pooled according to the treatments, incubation time, and run. Pooled samples were then ground through a 1-mm screen using a Restch ZM 200 rotor mill (Rose Scientific Ltd., Edmonton, AB, Canada) for chemical analysis.

Pelleting-Induced Changes in Rumen Degradation Kinetics

To determine the degradation kinetics of DM, CP, and NDF, the first-order kinetics degradation model