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Effects of rumen-undegradable protein on intake, performance, and mammary gland development in prepubertal and pubertal dairy heifers

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ABSTRACT

The objective of this study was to evaluate the influence of different amounts of rumen-undegradable protein (RUP) on intake, N balance, performance, mammary gland development, carcass traits, and hormonal status of Holstein heifers at different physiological stages (PS). Sixteen prepubertal (PRE) heifers (initial BW = 106 ± 7.6 kg; age = 4.3 ± 0.46 mo) and 16 pubertal (PUB) heifers (initial BW = 224 ± 7.9 kg; age = 12.6 ± 0.45 mo) were used in an experiment over a period of 84 d. Four diets with increasing RUP contents (38, 44, 51, and 57% of dietary crude protein) and heifers at 2 PS (PRE or PUB) were used in a 4 × 2 factorial arrangement of treatments in a completely randomized design. Throughout the experiment, 2 digestibility trials were performed over 5 consecutive days (starting at d 36 and 78) involving feed and ort sampling and spot collections of feces and urine. At d 0 and 83, body ultrasound images were obtained for real-time carcass trait evaluation. The mammary gland was ultrasonically scanned at d 0 and every 3 wk during the experiment. Blood samples were taken at d 0 and 84 to determine serum concentrations of progesterone, estrogen, insulin-like growth factor I (IGF-I), and insulin. No interaction between PS and the level of RUP was found for any trait. Apparent digestibility of dry matter, organic matter, and neutral detergent fiber corrected for ash and protein was not affected by RUP level but was lower for PRE compared with PUB heifers. Sorting against neutral detergent fiber corrected for ash and protein (tendency only) and for crude protein was greater for PUB than PRE heifers. Pubertal heifers had greater average daily gain (905 vs. 505 g/d) and N retention (25.9 vs. 12.5 g/d) than PRE heifers. In addition, average daily gain and N retention were greatest at 51% RUP of dietary protein. Mammary ultrasonography indicated no effects of RUP amounts on mammary gland composition, whereas PRE heifers had greater pixel values than PUB, indicating higher contents of fat rather than protein in the mammary glands of PRE heifers. Serum progesterone and IGF-I concentration was affected only by PS, and PRE heifers had greater values of progesterone and IGF-I concentrations than PUB heifers. Serum insulin concentration was unaffected by PS but tended to be higher at 51% of RUP. In conclusion, an RUP level of 51% increases body weight, average daily gain, feed efficiency, and N retention in heifers regardless of the PS. In addition, PRE heifers have a lower sorting ability and reduced intake, total-tract digestibility, and N retention. They also have higher amounts of fat in their mammary glands, even at moderate growth rates.

Key words: growth, mammary gland ultrasound, nitrogen retention

INTRODUCTION

The rearing of heifers is a key issue on dairy farms because these animals represent the herd's maintenance and renovation. However, the replacement of cows by heifers accounts for a large proportion of milk production costs, and practices that allow heifers to grow faster from birth to the first calving can increase profits by reducing the effects of heifers on farm costs (Sejrsen and Purup, 1997; Geiger et al., 2016). As reproductive characteristics are correlated with BW, high growth rates have been used as a strategy to reduce age at first calving (NRC, 2001; Piantoni et al., 2012; Albino et al., 2015).

One way to improve the ADG of growing heifers is to increase the RUP content in the diet, providing more MP (Tomlinson et al., 1997). However, studies of the RUP use in dairy heifers' diets are still scarce, and the

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results are not conclusive. For instance, cattle fed with fish or blood meals showed improved performance and N retention (Bethard et al., 1997; Zanton et al., 2007); in contrast, feeding corn gluten meal had no positive effect on performance (Santos et al., 1998; Ribeiro et al., 2005). To the best of our knowledge, no studies have used rumen-protected soybean meal as an RUP source in heifer diets, although soybean meal has been widely used as feedstuff for cattle and is easy to treat to improve RUP contents.

Besides improving the ADG, there is another persistent concern about a potential negative effect of growth rate on the mammary gland development of dairy heifers in which a high growth rate at key periods has been linked to the deposition of fat instead of epithelial secretory tissue (Geiger et al., 2016). Diets with additional dietary protein, which increases MP provision, may prevent excessive body fat deposition (Bascom et al., 2007) and may induce greater parenchymal tissue deposition than fat pad accumulation on the mammary gland of growing dairy heifers. In this sense, Capuco et al. (2004) demonstrated that the provision of additional dietary protein (from 14.9 to 16.9%), supplied as RUP, was associated with increasing growth rates of dairy heifers without negative effects on mammary gland development or milk production at first lactation. Additionally, Albino et al. (2015) demonstrated that diets with high MP/ME ratio induced greater parenchymal tissue deposition in Holstein heifers. Therefore, as RUP supply is able to increase MP flow (Mezzomo et al., 2011; Batista et al., 2106, 2017), it could be expected that increases in dietary RUP could also affect mammary gland development.

Most studies have proposed that mammary gland development is more pronounced during the prepubertal phase (Whitlock et al., 2002; Daniels et al., 2009; Piantoni et al., 2012), and for this reason, this phase is more sensitive to changes in the mammary gland composition (Sinha and Tucker, 1969). However, inadequate feed management (e.g., excessive ADG or low MP/ME ratio) may negatively affect mammary gland development, even during the pubertal phase (Sejrsen et al., 1986; Purup et al., 2000; Rowson et al., 2012).

Furthermore, despite the large number of studies about dairy heifer performance and mammary gland development, to the best of our knowledge, the study of Sejrsen et al. (1982) was the only work to evaluate mammary gland development in prepubertal (**PRE**) and pubertal (**PUB**) heifers simultaneously. Therefore, we hypothesized that increasing amounts of RUP from soybean meal would increase the available MP and improve intake, performance, and mammary gland development; we further hypothesized that the response would be different for PRE and PUB Holstein dairy heifers. We evaluated the influence of increasing dietary RUP amounts from soybean meal on intake, performance, N balance, carcass traits, mammary gland development, and hormonal status of Holstein dairy heifers before and after puberty.

MATERIALS AND METHODS

All animal handling and procedures described in the present study were approved by the Ethics Commission on the Use of Farm Animals of the Universidade Federal de Viçosa (Viçosa, MG, Brazil) under protocol no. 039/2015.

Animals, Experimental Design, and Feeding

Thirty-two Holstein heifers were divided into 2 groups according to their physiological stage (**PS**): PRE heifers (106 ± 7.6 kg of BW, 4.3 ± 0.46 mo old, and serum progesterone concentration of 0.24 ± 0.023 ng/mL) and PUB heifers (224 ± 7.9 kg of BW, 12.6 ± 0.45 mo old, and serum progesterone concentration of 1.04 ± 0.012 ng/mL). Four diets with increasing RUP contents (38, 44, 51, and 57% of dietary protein) and heifers at 2 PS stages (PRE or PUB) were used in a 4 × 2 factorial arrangement of treatments in a completely randomized design. Thus, 8 treatments, with 4 replicates each, were established: 38, 44, 51, and 57% of RUP for PRE heifers and 38, 44, 51, and 57% of RUP for PUB heifers.

The heifers were individually housed in stalls with an area of 10 m^2 and provided with feed bunks and drinkers. A fresh TMR of the respective diet (Table 1; Supplemental Table S1, https://doi.org/10.3168/jds.2017-13230) was delivered twice per day at 0700 and 1500 h, providing ad libitum access to feed. Diets were formulated to meet nutrient requirements according to the NRC (2001) guidelines for Holstein heifers with 1.0 kg/d of ADG. The experiment lasted for a period of 84 d, which was preceded by a 15-d pre-experimental period to adapt the animals to the diets, facilities, and management. Heifers were weighed in the morning at d 0 (immediately before beginning the experiment) and on the last day of the experiment after 16 h of fasting to obtain the shrunk BW.

Total Apparent Digestibility Trial, Analyses, and Calculations

Two digestibility trials were carried out from d 36 to 40 (first digestibility trial) and from d 78 to 82 (second digestibility trial), recording individual intake and sampling offered feeds, orts, feces, and urine. During the 5 consecutive days of the digestibility trial, 8 spot