Effect of rumen-protected fat on performance and serum concentration of T₃ hormone of Holstein young bulls during hot, humid weather

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Abstract

The growth performance and serum concentration of triiodothyronine (T₃) of 15 Holstein young bulls with an initial mean live weight of 200±25 kg was studied in response to a dietary rumen-protected fat (RPF) supplementation [3 or 5% of dry matter (DM)] during hot, humid climate (in Guilan, Iran, during summer season) in four sequential 21-d periods. The growth performance and serum T₃ concentration were measured at the end of each period. Results showed that there were no differences in the daily DM intake among the treatments in all experimental periods. During all 21-d periods and overall, the bulls fed RPF-containing diet gained significantly more weight than those receiving control diet. The young bulls fed diets containing 5% RPF gained more weight than those receiving 3% RPF-containing diets. The lowest weight gain was observed for young bulls fed the control diet. The highest (P<0.05) feed to gain (fg) ratios were observed for young bulls fed control diet and the lowest fg ratios were observed for those fed 5% RPF-containing diet. Serum T₃ concentration in the young bulls fed 5% RPF-containing diet was significantly higher than those fed 3% RPF or control diet in all experimental periods and overall. The variations in response to dietary RPF supplements among treatments could be related to lower metabolic heat production of RPFs rather than proteins and carbohydrates, especially in hot, humid conditions.

Introduction

The northern part of Iran is classified as humid subtropical and is characterised by high seasonal temperatures, humidity, and rainfall. One of the greatest challenges to production faced by the farmers in northern Iran is heat stress.

A variety of indices were used to estimate the degree of heat stress affecting animals. One of the most common indices is the temperature humidity index (THI) which has been used extensively to estimate the degree of heat stress in dairy and beef cattle (Mader et al., 2006; Dikmen and Hansen, 2009). Another indicator is zones of thermal comfort (ZTC) which are environmental conditions that provide maximum comfort for animals. Heat stress in cows is created by temperatures higher than ZTC. The ZTC generally ranges between 5 and 20°C for a mature beef cow consuming a maintenance diet. The upper comfort zone for young bulls is about 27°C (St-Pierre et al., 2003).

Energy intake or energy metabolism in young bulls may be limited by dry matter intake (DMI), especially under hot, humid conditions. At this condition, young bulls enter no sufficient energy for maximum yield. Therefore, young bulls should be supplemented by energy enough to achieve their genetic growth potential. Rumen-protected fats (RPFs) might be fed as an alternative to conventional dietary fat sources in order to increase the energy density in feedlot diets (Fluharty and Loerch, 1997; Malgorzata et al., 2001; Hess et al., 2008). Information about RPF supplementation of the diets for growing young bulls is limited. Ngidi et al. (1990) reported an increase in weight gains for calves receiving diets containing 20 vs 10% (of DM) of a protected lipid source.

On the other hand, triiodothyronine (T₃) concentration was declining by high ambient temperature and restricted intake (Bernabucci et al., 2010; Kumar et al., 2011). It has been shown that in cows T₃ and tetraiodothyronin (T₄) synthesis decreased to lower metabolic heat production (HP) in hot, humid conditions (Johnson et al., 1988). Reports show that thyroid activity decreased in summer in comparison with winter, so that the serum concentrations of T₃ and T₄ hormones decreased under heat stress conditions by 25% (Silanikove, 2000). Metabolic HP of feeds was decreased in ruminants by the use of protected plant lipids in their diets, which, in turn, decreased the animal energy requirements because of low heat increment (Kadzere et al., 2002). Beede and Collier (1986) identified three management strategies to minimise the effects of heat stress: i) physical modification of the environment (shading, cooling); ii) genetic development of heat-tolerant breeds; and iii) improved nutritional management practices.

However, information is limited with regard to the effects of RPF on the performance of growing young bulls especially during hot, humid weather. We hypothesised that dietary supplementation of RPF could enhance DMI and the average daily gain in growing young bulls at this condition. Thus, the objectives for this study were to determine the effects of RPF addition on feed intake, growth performance and serum T₃ in the growing young bulls.

Materials and methods

The Animal Science Committee of the University of Tarbiat Modares, Tehran, Iran, approved all animal procedures for this experiment. Current research was performed in Siyahkal Damonparvar Co. (Guilan, Iran) in an 84-d period between June and September 2012. Since the environmental temperature and day length in the experimental period were different, this period was divided into four sequential 21-d experimental periods. The temperature and relative humidity and calculated THI in the experimental periods are pre-
sented in Table 1.

Fifteen growing young bulls with an initial mean live weight of 200±25 kg of body weight (BW) were selected from 100 Holstein young bulls. The animals were fattened indoors on individual stalls, on tethers, on shallow litter. They had access to a salt block and water. The bulls were randomly allocated to one of 3 dietary treatments containing 0, 3 or 5% RPF. All bulls were individually fed a total mixed ration (TMR) 3 times daily (0500, 1200, and 1700 h) and orts were recorded daily before the a.m. feeding. Orts were weighed and subtracted from the amount fed the previous day to derive the daily feed intake. The TMR was formulated to meet or exceed the predicted requirements (National Research Council, 2000) of energy, protein, minerals, and vitamins (Table 2). Water was also provided ad libitum. The adaptation period for experimental diets was 15 days.

Body weights were obtained for all animals on d 21 of each period following an overnight fasting period.

At the end of each 21-d experimental period, at 09:00 o’clock, the blood samples were collected by coccygeal venipuncture (following an overnight fasting and before feeding), then the samples were placed in room temperature and before feeding), then at 09:00 o’clock, the blood samples were collected in room temperature and stored at -20°C until analysed for serum concentration of T₃. Radioimmunoassay of T₃ was done with the aid of an Amerlex-M T3 kit (Amersham plc., Amersham, UK). Bound radioactivity was counted in a LKB (OP5500; LKB Instruments, Melbourne, Australia) gamma counter. Sensitivity of the above method for measuring T₃ hormone is 0.15 ng/mL.

All data were evaluated for violation of the basic assumptions for ANOVA. Body weight gain (BWG) and serum concentration of T₃ data were analysed by the GLM procedure (SAS Inst. Inc., Cary, NC, USA) appropriate for a completely randomised design with 3 treatments and 5 replicate and one young bull in each replicate includes all young bulls. Significant differences between groups were determined by Duncan’s multiple range tests. The differences were considered significant at P<0.05 (Snedecor and Cochran, 1989).

Results and discussion

In all experimental periods, similar differences in daily BWGs were observed for all dietary treatments (Table 4). In comparison with control diet, feeding the RPF-containing diets (3 or 5%) resulted in a significant increase in daily BWG in all 21-d experimental periods and overall period of experiment. In these periods, the young bulls from 5% RPF-containing diets gained significantly more than those fed diets containing 3% RPF and the lowest (P<0.05) daily BWGs were observed for young bulls fed control diet (Table 4).

Like daily BWG, in all experimental periods and overall, similar differences in the feed to

Table 1. Temperature, relative humidity and temperature humidity index in the different experimental periods.

| Experimental period | Tdb | RH | THI1 | THI2 |
|---------------------|-----|----|------|------|
| First               | 25.43 | 77.14 | 75.38 | 75.25 |
| Second              | 27.95 | 73.75 | 78.91 | 78.75 |
| Third               | 28.87 | 72.33 | 81.66 | 81.48 |
| Fourth              | 28.12 | 78.50 | 79.80 | 79.66 |

Tdb, dry bulb temperature; RH, relative humidity; THI, temperature humidity index; THI1=(1.8×Tdb+32)-(0.55-0.0055×RH)×(1.8×Tdb-26.8); THI2=(0.8×Tdb)+(RH/100)×(Tdb-14.4)+46.4 (Mader et al., 2006).

Table 2. Composition of experimental diets (as-fed basis).

| Item, % | Dietary RPF, % |
|---------|----------------|
| Wheat straw | 0   | 3   | 5   |
| Hay alfalfa  | 10  | 10  | 10  |
| Barley        | 35  | 30  | 27  |
| Cottonseed meal | 4.5 | 6.5 | 7.5 |
| Wheat bran   | 15  | 15  | 15  |
| Rice bran     | 12  | 12  | 12  |
| Dried beet pulp | 5  | 5   | 5   |
| RPF           | 0   | 3   | 5   |
| Supplement    | 0.5 | 0.5 | 0.5 |
| Salt          | 0.5 | 0.5 | 0.5 |
| Limestone     | 1.87| 1.87| 1.87|
| Dicalcium phosphate | 0.63 | 0.67 | 0.69 |
| Forage        | 25  | 25  | 25  |
| Concentrate   | 75  | 75  | 75  |

Calcified chemical composition

| Item, % | Dietary RPF, % |
|---------|----------------|
| Net energy for maintenance, Mcal/kg | 1.74 | 1.76 | 1.77 |
| Net energy gain, Mcal/kg     | 1.08 | 1.11 | 1.13 |
| Crude protein, %            | 12.72| 12.8 | 12.83|
| Undegradable protein, %     | 3.65 | 3.62 | 3.60 |
| Calcium, %                  | 1.46 | 1.49 | 1.47 |
| Phosphorus, %               | 0.714| 0.745| 0.735|

RPF, rumen-protected fat.

Table 3. Mean (±standard deviation) daily dry matter intake (Kg/calf) of young bulls at different experimental periods and various levels of rumen-protected fat.

| Experimental period | Dietary RPF, % | P     |
|---------------------|----------------|-------|
| 0                   | 6.08±0.55      | 6.03±0.39 | 5.97±0.58 | ns  |
| 3                   | 5.92±0.51      | 5.88±0.59 | 5.79±0.56 | ns  |
| 5                   | 5.69±0.62      | 5.66±0.38 | 5.54±0.43 | ns  |
| Overall             | 5.7±0.41       | 5.77±0.43 | 5.6±0.41  | ns  |

RPF, rumen-protected fat; ns, not significant (P>0.05).
gain (fg ratio were observed for all dietary treatments (Table 5). The highest (P<0.05) fg ratios were observed for young bulls fed control diet and the lowest were observed for young bulls fed diet containing 5% RPF (Table 5).

In the current study it was observed that there were no (P>0.05) differences between 3% RPF-fed bulls and control diet-fed bulls in serum T3 concentration (P>0.05), but this parameter in young bulls fed diet containing 5% RPF was significantly (P<0.001) higher than 0 and 3% RPF-fed bulls in all experimental periods and overall (Table 6).

**General remarks**

Heat stress occurs when the animal cannot dissipate heat from their body. Although we did not evaluate the effects of heat stress on growth performance in young bulls in this study, the THI data (Table 1) showed that all of young bulls in this study were experiencing heat stress especially during the 3 last experimental periods. During heat stress large quantity of metabolic heat produces in cows and accumulates the additional heat from radiant energy. Heat production and accumulation causes heat load in the cow to increase to the point that body temperature rises, intake declines and ultimately the cow’s productivity declines. A portion of the negative effects of heat stress on production could be explained by decreased nutrient intake and uptake by the portal drained viscera of the cow (West, 2003).

About 70% of RPF is protected from ruminal biohydrogenation (Wu et al., 1991) and young bulls can be fed RPF without negative effect on ruminal fermentation and DMI, especially under hot, humid conditions (Hess et al., 2008). These fatty acids (RPF) bound to calcium are insoluble in rumen contents and, therefore, they may be digested and absorbed in the intestine (Golyan et al., 2002).

Feeding RPF (3 or 5%) to the young bulls had positive effects on growth performance [BWG and feed conversion ratio (FCR)] with no increase in DMI in all experimental periods conducted herein, supporting previous reports that RPF supplement had a positive influence on growth performance of bull calves and steers (Cruywagen et al., 2003; Brandt and Anderson, 1990). Our results would suggest that addition of 3% RPF to the bull’s diet can improve the growth performance and this improvement can be elevated by increasing the level of dietary RPF from 3 to 5%. These differences in dietary RPF concentrations between treatments may have influenced the ruminal bacteria population. However, we collected no ruminal data in these and similar trials at normal environmental conditions to support or refute either explanation. Another possible explanation for the observed variation in response to dietary RPF supplementation among treatments could be related to lower metabolic HP in fats and RPF rather than proteins and carbohydrates under hot, humid conditions. Therefore, from all aspects of our finding, dietary RPF supplements (by 5%) can increase the energy density and the growth performance without necessitating an increased level of DMI in the young bulls especially under hot, humid conditions. Some previous studies found similar results. In agreement with the current study, Cruywagen et al. (2003) reported that FCR but no DMI was improved by dietary protected fats for Holstein bull calves from 43 to 70 days of age. However, Waldern and Fisher (1978) found no effect on FCR when unprotected tallow was added to calf diets. Grummer et al. (1990) reported that the palatability of RPF-sources was different. According to Brandt and Anderson (1990), fat supplementation increased daily gain, feed efficiency and estimated dietary metabolisable energy concentration in the steers. Fallon et al. (1986) found that the inclusion of low levels of RPF seemingly produces some beneficial effects in energy intake and nutrient utilisation of calf without affecting fibre digestibility. Against previous reports (Huffman et al., 1992; Zinn, 1992) the dietary supplementation of RPF in the present study did not affect DMI and so the positive effects of RPF on BWG and FCR may be due to no effects of protected fats on...
ruminal fermentation, better digestion and absorption of RPF in the small intestine and the increase of dietary metabolisable energy concentration in the young bulls. These events may result in more available essential fatty acids (Bauchart, 1993), which in turn can improve the fluidity of membranes (Kahn et al., 1992) and the role of fats in nutrient metabolism and the reduction of heat increment and so can increase the diets energy accumulation (Palmquist and Jenkins, 1980). In this study we expected that DMI is affected by high THI in the second, third and fourth experimental periods in the control group but high THI cannot affect it. We have not any interpretation for this fact. At high THI, because of the beneficial role of fat in reduction of metabolic HP and increasing dietary energy concentrations, the daily BWG increased by dietary RPF supplements.

Plasma concentrations of thyroid hormones are relatively stable in normally growing steers during the first 16 months of life (Cassar-Malek et al., 2001). As evaluated by circulating concentrations of thyroid hormones, thyroid status is compromised during dietary energy restriction in steers (Blum et al., 1985) and bulls (Janan et al., 1995). Results of Jana et al. (1995) indicated that the concentration of T3 in bulls decreased during fasting. A similar result for thyroid hormone concentrations was reported by Murphy and Loerch (1994), investigating the effect of limited feed intake on the level of blood parameters of young steers. This research demonstrated that the concentration of feeding a ration limited in energy. Thus, thyroid status and metabolism are under the influence of several physiological, environmental and nutritional factors, such as energy availability, glucose or fatty acids (Blum et al., 1985; Jana et al., 1995), dietary intake and energy modifications (Eales, 1988). Energy restriction may be responsible for the decrease in circulating concentration of T3 in the growing bulls (Cassar-Malek et al., 2001). We observed an increase in serum T3 concentration in young bulls, when 5% of RPF were added to their diet. On the other hand, high THI may be resulted in a decrease in T3 concentration in control bulls and the supplementary RPF suppressed this T3 reduction in the treated bulls. It is probably due to high metabolic HP under hot, humid conditions in the control bulls but this metabolic HP may be decreased by dietary RPF supplementation (by 5%) rather than control diet. Available energy for the needs of organisms may be increased by dietary RPF supplementation in the heat stressed young bulls without any change in DMI, which, in turn, resulted in an increase in the energy uptake and metabolism reflected by an increase in serum T3 concentration. Hayden et al. (1993) stated that T3 concentrations are indicative of energy balance and T3 appears to be positively associated with energy consumption. West (2003) speculated that T3 reduction after feed restriction in hot condition was due to the suppression of hormone production in order to reduce the metabolic HP. Reduced concentrations T3 with heat stress are logical and probably reflect the cows attempt to reduce the metabolic HP. Moreover, to increase the dietary energy value for animals, the vegetable and animal fats can be used as a cheap source of energy. The main hormones responsible for the shift of carbohydrates metabolism to fat as a source of energy are epinephrine and thyroid hormones. More than 30% of extra-thyroidal body pools of T3 are derived from the peripheral monodeiodination of T2. In the centre of this mechanism stands the deiodinase enzyme that can convert thyroxin produced by the thyroid gland either to active T3 or to inactive reserve T3 dependent on the actual needs of organisms. Among a series of factors that might influence is the availability of energy equivalents to the cell (Jana et al., 1995). Thus, the factors that affect available energy in bulls can affect the blood T3 concentration. Reports showed that the use of protected plant lipids in ruminant’s nutrition can decrease the metabolic HP and provide high metabolisable energy for animal requirements, because of low heat increment, and consequently higher T3 serum concentration (Kadzere et al. 2002).

Conclusions

Dietary RPF supplementation at the rate of 3 or 5% of the diet improved the growth performance and at the rate of 5% increased the serum T3 concentration. In this trial, these differences in response to dietary RPF supplementation were observed in young bulls reared under hot, humid conditions. These differences among treatments were repeatable in all 21-d periods though they could not be clearly explained. More research with young bulls or steers on the response to dietary RPF supplementation and its effects on ruminal bacteria is thus necessary.

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