Effect of level and source of supplemental tannin on growth performance of steers during the late finishing phase

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ABSTRACT

Two trials were conducted to evaluate the effect of tannin supplementation of steers during the feedlot finishing phase. In Trial 1, 96 Holstein steers (478 ± 6.5 kg) were used to evaluate the effects of level of supplemental condensed tannin (0%, 0.2%, 0.4%, and 0.6% of dry matter basis) on growth performance. Supplemental tannin increased (6.5%, P = 0.05) weight gain, gain efficiency (5.5%, P = 0.04), and tended to increase dietary net energy (3.2%, P = 0.06). In Trial 2, 96 Holstein steers (392 ± 4 kg) were used to evaluate the effect of tannin sources on growth performance. Treatments consisted of a steam-flaked corn diet supplemented with (1) no supplemental tannin, (2) 0.6% condensed tannin, (3) 0.6% hydrolysable tannin, and (4) a blend of 0.3% condensed and 0.3% hydrolysable tannin. Tannin supplementation tended to increase average daily gain (ADG, 6.8%, P = 0.08) and dry matter intake (DMI, 4%, P = 0.04). It is concluded that tannin supplementation promotes greater DMI, and hence, ADG of steers during the finishing feedlot phase. The basis for this effect on feed intake is not certain, but is apparently independent of potential tannin effects on metabolizable protein supply. Source of supplemental tannin (condensed vs. hydrolysable) have minimal effects on overall growth performance response to supplementation.

1. Introduction

Tannins are a complex group of polyphenolic compounds found in a wide range of plant species commonly consumed by ruminants (Mueller-Harvey & McAllan 1992; Van Soest 1994). They are conventionally classified into two major groups: hydrolysable and condensed tannins (McLeod 1974). High concentrations of tannins may be toxic, reducing voluntary feed intake and nutrient digestibility, however at low to moderate concentrations, tannin supplementation may shift site of protein degradation increasing metabolizable amino acid flow to the small intestine (Barry & McNabb 1999; Min et al. 2003). This tannin effect may help explain improvements observed in performance of feedlot calves during the initial growing phase (Barajas et al. 2010) where limitations in metabolizable protein supply are more particularly manifest (Zinn et al. 2000, 2007). However, very little information is available regarding possible extra protein effects of tannin supplementation on growth performance of finishing cattle when metabolizable amino acid supply of the basal diet is expected to exceed requirements. Other potential positive effects of tannin supplementation are reduced methane production (Patra & Saxena 2010; Goel & Makkar 2012) and ruminal biohydrogenation of lipids (Vasta et al. 2010). The objective of the present study was to evaluate the effects of source and level of supplemental tannin on growth performance and dietary energetics of feedlot steers during the late finishing phase, when metabolizable amino acid supply of the basal diet exceeds animal requirements.

2. Materials and methods

All procedures involving animal care and management were in accordance with and approved by the University of California, Davis, Animal Use and Care Committee.

2.1. Trial 1: tannin level

2.1.1. Animals, sampling and treatments

Ninety-six Holstein steers (478 ± 6.5 kg) were used in an 84-d trial to evaluate the effects of level (0%, 0.2%, 0.45, and 0.6% of dry matter (DM) basis) of supplemental condensed tannin (Quebracho, Silvateam, Ontario, CA) on feedlot growth performance during the late finishing phase. Cattle were implanted (Revalor-S, Intervet Inc., Millsboro, DE), injected with 500,000 IU of vitamin A (Vita-Jec A&D 500, Stuart Products, Bedford, TX), and grouped by weight into four weight blocks of four pens each (six steers per pen). Pens were 50 m² with 26.7 m² overhead shade, equipped with automatic drinkers, and 4.3 m fence-line feed bunks. Composition of the basal diet is shown in Table 1. Diets were prepared weekly and stored in plywood boxes in front of each pen. Calves were provided ad libitum access to the diet. Fresh feed was added to the feed bunk twice daily. Feed and refusal samples were collected daily for DM analysis,
which involved oven drying the samples at 105°C until no further weight loss occurred (method 930.15, AOAC2000)

2.1.2. Estimation of dietary net energy

Daily energy gain (EG; Mcal/d) was calculated by the equation:

\[ EG = ADG^{1.097} 0.0557W^{0.75} \]

where W is the mean shrunk body weight (BW) (kg; National Research Council1984). Maintenance energy (EM) was calculated by the equation: \( EM = 0.084 W^{0.75} \) (Garrett 1971). Dietary NEg was derived from NEm by the equation: \( NE_g = 0.877 N E_m - 0.41 \) (Zinn1987). Dry matter intake (DMI) is related to energy requirements and dietary NEm according to the equation: \( DMI = EG/(0.877 N E_m - 0.41) \), and can be resolved for estimation of dietary net energy (NE) by means of the quadratic formula:

\[
x = \frac{-b - \sqrt{b^2 - 4ac}}{2c}, \text{ where: } x = NE_m, a = -0.42, b = 0.887 EM + 0.41 DMI + EG, \text{ and } c = -0.887 DMI \text{ (Zinn \\& Shen1998).}
\]

2.1.3. Statistical design and analysis

The trial was analysed as a randomized complete block using pens as experimental units. Contrasts were (1) control vs. tannins supplementation. When significant effects of treatment were observed, the response to level of tannin supplementation was evaluated utilizing orthogonal polynomials (linear and curvilinear). Coefficients of polynomials for unequally spaced treatments were generated using ORPOL matrix function of the IML procedure of SAS.

2.2. Trial 2: tannin source

Ninety-six Holstein steers (392 ± 4 kg) were used in an 84-d feeding trial to evaluate the effect of tannin sources on feedlot cattle performance during the late finishing phase. Cattle management, basal diet, feeding, sampling, and experimental design were the same as in Trial 1. Treatments consisted of the basal diet (Table 1) supplemented with (1) no supplemental tannin, (2) 0.6% condensed tannin (Quebracho, Silvateam, Ontario, CA), (3) 0.6% hydrolysable tannin (Chestnut, Silvateam, Ontario, CA), and (4) a combination of 0.3% condensed and 0.3% hydrolysable tannin.

2.2.1. Statistical design and analysis

The trial was analysed as a randomized complete block design using pens as experimental units. Contrasts were: (1) control vs. tannin, (2) condensed vs. soluble tannin, and (3) single tannin vs. blend of tannins.

3. Results

3.1. Trial 1: tannin levels

Treatment effects on growth performance and estimated NE value of the diet are shown in Table 2. Supplemental tannin increased (6.5%, \( P = 0.05 \)) average daily gain (ADG), with a tendency (linear effect, \( P = 0.15 \)) for ADG to increase with level of supplementation. DMI likewise tended to increase (linear effect, \( P = 0.14 \)) with level of supplementation. Tannin supplementation increased gain efficiency (5.5%, \( P = 0.04 \)) and dietary NE (3.2%, \( P = 0.06 \)). However, neither gain efficiency nor dietary NE was improved (\( P > 0.74 \)) by feeding more than 0.2% of supplemental tannin.

### Table 1. Composition of experimental basal diet to be fed to Holstein steers.

| Ingredient composition | % (DM basis) |
|------------------------|--------------|
| Steam-flaked corn       | 64.56        |
| Distillers dried grains plus solubles | 15.00 |
| Sugarcane bagasse       | 10.00        |
| Molasses cane           | 5.00         |
| Yellow grease           | 2.50         |
| Urea                    | 0.90         |
| Limestone               | 1.50         |
| Magnesium oxide         | 0.14         |
| Trace mineral salt\(^a\) | 0.40         |
| Monensin, mg/kg         | 30.00        |

**Nutrient composition\(^b\)**

| NE, Mcal/kg               |
|---------------------------|
| Maintenance               | 2.19         |
| Gain                      | 1.52         |
| Crude protein, %           | 14.2         |
| Metabolizable protein, %\(^c\) | 11.34       |
| UIP, %                    | 38.85        |
| Calcium, %                | 0.70         |
| Phosphorus, %             | 0.36         |
| Potassium, %              | 0.79         |
| Magnesium, %              | 0.28         |
| Sulphur, %                | 0.18         |

\(^a\)Trace mineral salt contained: \( CoSO_4 \cdot 0.068\%; CuSO_4 \cdot 1.04\%; FeSO_4 \cdot 3.57\%; ZnO, 1.24\%; MnSO_4 \cdot 1.07\%; Kl, 0.052\%; and NaCl, 92.96\%.

\(^b\)Based on tabular values for individual feed ingredients (NRC 1996).

\(^c\)Estimated according to NRC (1996, Level 1) using the observed average DM intake in trial (11.4 kg).

### Table 2. Tannin level effects on 84-d feedlot growth performance Holstein steers (Trial 1).

| Supplemental condensed tannin (kg) | Initial | Final | ADG (kg) | DMI (kg/d) | ADG/DMI | Dietary NE (Mcal/kg) | SEM | Effects |
|-----------------------------------|---------|-------|----------|-----------|---------|---------------------|-----|---------|
|                                   | 0  | 0.2  | 0.4  | 0.6  | SEM | Linear | Quadratic | 0 vs. Tannin |
| LW (kg)\(^a\)                     |   |      |      |      |     |        |          |             |
| Initial                           | 476 | 477  | 478  | 479  | 3.26 | 0.80   | 0.97      | 0.55        |
| Final                             | 591 | 597  | 602  | 605  | 5.16 | 0.29   | 0.84      | 0.11        |
| ADG (kg)                          | 1.37| 1.42 | 1.48 | 1.50 | 0.04 | 0.15   | 0.78      | 0.05        |
| DMI (kg/d)                        | 11.2| 11.1 | 11.5 | 11.7 | 0.24 | 0.14   | 0.68      | 0.48        |
| ADG/DMI                           | 0.122| 0.128| 0.129| 0.129| 0.002| 0.74   | 0.95      | 0.04        |
| Dietary NE (Mcal/kg)              |    |      |      |      |     |        |          |             |
| Maintenance                       | 2.01| 2.08 | 2.07 | 2.07 | 0.03 | 0.80   | 0.82      | 0.06        |
| Gain                              | 1.35| 1.41 | 1.40 | 1.40 | 0.02 | 0.80   | 0.82      | 0.06        |
| Dietary NE ratio                  |    |      |      |      |     |        |          |             |
| Maintenance                       | 0.91| 0.94 | 0.93 | 0.93 | 0.01 | 0.80   | 0.82      | 0.06        |
| Gain                              | 0.88| 0.92 | 0.91 | 0.91 | 0.01 | 0.80   | 0.82      | 0.06        |

**Note:** LW, live weight.

\(^a\)Initial and final live weights reduced 4% to account for fill.
Table 3. Effect of source of supplement tannin on 84-d feedlot growth performance of Holstein Steers (Trial 2).

| Item                  | None       | Condensed | Soluble | Blend | SEM | Tannin | Condensed vs. soluble | Single vs. blend |
|-----------------------|------------|-----------|---------|-------|-----|--------|-----------------------|------------------|
| LW (kg)²               | 392        | 391       | 393     | 391   | 2.2 | 0.91   | 0.48                  | 0.67             |
| Final                 | 520        | 528       | 528     | 529   | 3.72| 0.08   | 0.99                  | 0.78             |
| ADG (kg)               | 1.53       | 1.64      | 1.61    | 1.65  | 0.05| 0.08   | 0.67                  | 0.60             |
| DMI (kg/d)             | 10.0       | 10.3      | 10.2    | 10.7  | 0.15| 0.06   | 0.66                  | 0.06             |
| ADG/DMI               | 0.152      | 0.159     | 0.157   | 0.155 | 0.005| 0.42   | 0.84                  | 0.60             |
| Dietary NE (Mcal/kg)   |            |           |         |       |     |        |                       |                  |
| Maintenance           | 2.12       | 2.17      | 2.17    | 2.11  | 0.04| 0.59   | 0.99                  | 0.39             |
| Gain                  | 1.45       | 1.49      | 1.49    | 1.45  | 0.04| 0.59   | 0.99                  | 0.39             |
| Observe:expected Neal ratio | 0.96     | 0.98      | 0.98    | 0.95  | 0.02| 0.59   | 0.99                  | 0.39             |
| Gain                  | 0.94       | 0.97      | 0.97    | 0.94  | 0.02| 0.59   | 0.99                  | 0.39             |

Note: lw, live weight.

Sources of tannins were supplemented at level of 0.6% of DM. Treatments were (1) no tannin, (2) Quebracho, (3) Chestnut, and (4) a blend of Quebracho and Chestnut (30 g eac/steer/d).

Initial and final live weights reduced 4% to account for fill.

3.2. Trial 2: tannin source

Treatment effects on growth performance and estimated NE value of the diet are shown in Table 3. Inclusion of 0.6% of tannin in diet tended to increase ADG (6.8%, P = 0.08). This response was not affected (P > 0.60) by tannin source. Tannin supplementation likewise tended to increase DMI (4%, P = 0.06). However, compared to controls, DMI was greater (7.1%, P < 0.05) for steers fed the 50:50 combination of the condensed and soluble tannins than when tannin sources were fed singly (2.4%, P > 0.10). The tendency for enhanced ADG in cattle supplemented with tannins was largely due to enhanced DMI. Thus, differences in gain efficiency and dietary NE were not statistically significant (P > 0.39).

4. Discussions

Based on estimated total digestible nutrients (TDN, 85.4%) and undegradable intake protein (UIP, 38.85%) of diet, and the average DMI (10.9 kg/d) and BW (499 kg) observed in both experiments, the estimated metabolizable protein that reached small intestine (National Research Council 1996) exceeds the Holstein steers requirements in both experiment (Zinn and Shen 1998). During the course of the study, the minimum and maximum air temperature averaged 22.3°C and 40.5°C, respectively. Relative humidity averaged 26% (minimum = 8.5% and maximum = 41.7%).

In experiment 1 tannin supplementation level did not affect DMI, but in experiment 2, tannin supplementation tended (P = 0.06) to enhance DMI, with the greater numerical increase observed with a combination of 0.3% condensed and 0.3% hydrolyzable tannin.

Increases in DMI of feedlot cattle fed finishing diets supplemented with tannins had been observed previously. In a 226-d study, Barajas et al. (2011) observed a 6% increase on DMI in bull (initial weight = 184 kg) fed a growing-finishing diet supplemented with 0.34% of a blend of condensed and hydrolyzable tannins. Likewise, in a 140-d trial, Tabke (2014) observed a linear in DMI of feedlot bulls fed a finishing diets supplemented with 0%, 0.3%, or 0.6% of blend of condensed and hydrolyzable tannin. Similar responses in DMI to tannin supplementation of higher forage diets have been also reported in feeding trials involving goats (Puchala et al. 2005), lambs (Douglas et al. 1995), and in cows (Woodward et al. 2000). In contrast, Krueger et al. (2010) and Mezzomo et al. (2011) did not observe effects of supplemental tannins (1.5% and 0.4% of diet, respectively) on DMI of finishing feedlot steers. High levels of dietary tannin (> 5% tannins of diet) have markedly depressed feed intake in ruminants (Frutos et al. 2004). This effect may be due to altered palatability, as an intra-ruminal dosage of 1.5 g condensed tannin/kg live-weight/d (approximately 78 g of condensed tannin) did not affect DMI in growing-finishing lambs (Hervás et al. 2003).

Based on supplemental tannin concentration of diet, and observed DMI, daily intake of tannin in the present studies (Trials 1 and 2) did not exceed 0.14 g/kg live weight. The improvement in gain efficiency (ADG/DMI) in Trial 1 was due in part to increases on ADG, and in part to increases on estimated NE value of the diet. Increases on ADG with improvements on dietary energy have been reported in both growing cattle and finishing cattle supplemented with tannins. Barajas et al. (2010, 2011) observed similar enhancements in ADG (11–13%) and dietary energy (4–5%) in growing-finishing bulls supplemented with 6–29 g tannin/d. In the present study, ADG and gain efficiency of Holstein steers was further enhanced by supplemental tannin levels greater than 0.2% of DM. Volpi-Lagreca et al. (2013) also observed enhanced DMI, ADG, and gain efficiency in feedlot heifers fed a whole corn diet supplemented with condensed tannin. However, responses were numerically greater (7.3% and 5.0%, respectively) for heifers supplemented with 83 g/d tannin than for heifers supplemented with 40 g/d tannin.

Because tannins are capable of binding with dietary proteins, rendering them less degradable within the rumen (Ben-Salem et al. 1999; Min et al. 2003), growth performance responses to supplemental tannins have been generally attributed to enhancements in intestinal metabolizable protein supply (Waghorn 1996). This may be a factor in calf-fed Holstein steers during the initial growing phase (within the weight range of 120–365 kg; Zinn et al. 2000, 2007). Indeed, in 49 of 52 trials summarized by NRC (1984) in which protein supplementation increased growth rates of cattle, energetic...
efficiency also increased. However, during the finishing phase, growth performance of calf-fed Holstein steers fed steam-flaked corn-based finishing diets (similar to that fed in the present studies) is not limited by metabolizable protein supply (Zinn et al. 2000; Carrasco et al. 2013).

Supplemental tannins may reduce ruminal methane production (Goel & Makkar 2012). However, in a meta-analysis Jayanegara et al. (2012) observed that low-level supplemental tannin effects on ruminal methane were inconsistent, with greater mitigation of ruminal methane observed with forage-based diets (Woodward et al. 2004; Puchala et al. 2005; Min et al. 2006; Grainger et al. 2009).

Direct comparisons of supplemental tannin sources (condensed vs. hydrolysable) on feedlot cattle performance have not been previously reported. Results of Trial 2 reveal that differences in feedlot cattle growth performance responses due to tannin source are small or non-appreciable. Enhancements in ADG due to tannin supplementation in Trial 2 were largely a reflection of tannin effects on DMI.

Although the 50:50 blend of condensed and soluble tannins resulted in a greater (4.4%) DMI than either tannin source fed alone, the blend did not further enhance either ADG or gain efficiency.

5. Conclusion

Tannin supplementation promotes greater DMI, and hence, ADG of steers during the finishing feedlot phase. The basis for this effect is not certain, but is apparently independent of potential tannin effects on metabolizable protein supply. Source of supplemental tannin (condensed vs. hydrolysable) have minimal effects on overall growth performance response to supplementation.

Disclosure statement

No potential conflict of interest was reported by the authors.

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