Effects of increasing dietary level of a commercial liquid supplement on growth performance and carcass characteristics in feedlot steers

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ABSTRACT: Feeding cattle liquid supplements has become increasingly popular in the feedlot industry; however, optimal inclusion of liquid supplements in feedlot cattle diets is not known. The objectives of this study were to determine the optimal inclusion of liquid supplementation to maximize growth performance and improve carcass characteristics, as well as estimate the energy value of liquid supplementation when used as a direct corn replacement, for feedlot steers fed a concentrate-based diet. Two hundred and eighty steer calves were stratified by BW into light (BW = 208 ± 9 kg; n = 24) and heavy (BW = 275 ± 8 kg; n = 16) pens. Pens within BW block were randomly assigned to 1 of 4 supplements: 1) dry at 4.5% inclusion (0LIQ), 2) liquid (a proprietary blend from Quality Liquid Feeds; Dodgeville, WI) at 4.5% inclusion (4.5LIQ), 3) liquid at 9% inclusion (9LIQ), or 4) liquid at 13.5% inclusion (13.5LIQ). The remainder of the diet was 47.5% to 55.5% dry rolled corn, 20% corn silage, and 20% modified wet distillers grains with solubles (DM basis). Data were analyzed as a randomized complete block design and linear and quadratic were examined to determine effects of increasing dietary concentrations of liquid. Steers fed 4.5LIQ and 9LIQ had greater (quadratic; P ≤ 0.05) final BW, HCW, and NEm and NEG, and less DMI as a percent of BW compared to steers fed 13.5LIQ. Steers fed 0LIQ were intermediate and not different from other treatments. However, ADG and total BW gain did not differ (P ≥ 0.15) among treatments. Despite the lack of treatment effect on live measures of gain, feeding steers 4.5LIQ and 9LIQ resulted in greater carcass ADG (quadratic; P = 0.03), total carcass gain (quadratic; P = 0.04), and more efficient carcass gain (quadratic; P ≤ 0.01) compared to carcasses from steers fed 13.5LIQ. Feeding steers a liquid supplement at 9% of the diet, DM allowed for the greatest final BW and ADG in this study; however, there was no benefit of increasing liquid to 13.5%.

Key words: cattle, glycerin, liquid supplementation, molasses

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INTRODUCTION

Liquid supplementation of cattle is not a new topic and has been studied since the early 1970s (Fisher et al., 1973; Heinemann and Hanks, 1977). Liquid supplements used in livestock diets contain readily available energy, such as glycerin, molasses, or a combination of molasses and glycerin (Pate,
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1983; Hales et al., 2013; Ciriaco et al., 2015); NPN, usually in the form of urea (Kunkle et al., 1997); as well as a balance of trace minerals. Thus, one of the main reasons for including a liquid supplement in the diet is the synchrony of N and energy in the rumen (NASEM, 2016) to promote microbial protein synthesis. Liquid has often been supplemented with the intention of increasing the digestibility and intake of poor-quality forages (Bowman et al., 1995; Ciriaco et al., 2015). Liquid supplementation increased in situ NDF digestibility and ruminal butyrate concentrations in beef steers fed corn stover (Stierwalt et al., 2017). While the combination of molasses and glycerin has been evaluated in cattle consuming hay (Ciriaco et al. 2015, 2016), little is known of the effects of supplementing a molasses and glycerin commercial liquid supplement to feedlot steers fed a concentrate-based diet. Both molasses and glycerin can be used by microorganisms to make propionate in the rumen, a precursor to glucose synthesis (Johns, 1953), or they may be used as a direct energy source. However, the ability of liquid supplements to improve carcass characteristics, namely quality grade, through the increased supply of glucose is not known.

We hypothesized that optimal liquid supplementation to replace energy for corn, thereby enhance growth performance and carcass characteristics, would be between 4.5% and 13.5% of the diet DM inclusion. Therefore, the objectives of this study were to determine the optimal inclusion of liquid supplementation to maximize growth performance and improve carcass characteristics, and to estimate the energy value of liquid supplementation when used as a direct corn replacement, for feedlot steers fed a concentrate-based diet.

MATERIALS AND METHODS

All animal procedures were approved by the University of Illinois Institute of Animal Care and Use Committee (#15007) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

Animals and Management

Two hundred and eighty Simmental × Angus steer calves (age = 9 ± 2 mo) were transported 350 km to University of Illinois Beef Cattle and Sheep Field Laboratory (Urbana, IL). Steers were housed in confinement barns on slatted concrete floors that were covered by interlocking rubber matting (EasyFix Rubber; Kirkton, Ontario, Canada). Pen dimensions were 4.88 × 4.88 m, and pens were constructed of 5.08 cm galvanized steel tubing. A pre-trial weight was taken upon arrival after a 24-h rest period. Pre-trial weights were used to allot calves to treatment prior to their initial BW. Cattle were held at the feedlot for 7 d to adapt to diet. This was done so that by the start of the trial, all cattle were consuming a similar basal diet: 20% corn silage, 55.5% dry rolled corn, 20% modified wet distillers grains with solubles, and 4.5% dry vitamin/mineral supplement. After the 7 d, the average of a 2-d consecutive initial BW (collected on d −1 and d 0) was used to block steers by BW and allot steers to 40 pens in 2 barns (12 light pens, 8 heavy pens in each barn) such that the average BW in both barns was equal.

Pens within block were randomly assigned to one of four dietary treatments (Table 1): 1) dry supplement at 4.5% inclusion (0LIQ), 2) liquid supplement (a proprietary blend from Quality Liquid Feeds; Dodgeville, WI) at 4.5% inclusion (4.5LIQ), 3) liquid supplement at 9% inclusion (9LIQ), or 4) liquid supplement at 13.5% inclusion (13.5LIQ). The increasing liquid supplement inclusions directly replaced dry supplement (which was corn-based) and corn grain in the diet. Three separate liquid supplements were formulated to allow for consistency of nutrient addition (urea, ionophores, and vitamins and minerals) to the diet. In addition, the trace mineral package used in the liquid supplement was supplied by the company to formulate the dry supplement to ensure that trace mineral inclusion, or supplementation, was not confounding. Thus, the difference in the treatments was just the amount of liquid carrier each treatment supplied. Diets were fed once daily beginning on d 0. Steers were transitioned slowly (over 28 d) to ad-libitum intakes and then fed for ad-libitum intake for the duration of the trial. Individual steer feed intake was monitored using a GrowSafe system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada). Steers were weighed intermittently, approximately every 28 d, throughout the feeding period. BW was also collected on two consecutive days was taken prior to shipping for slaughter. One steer, fed the 4.5LIQ, died due to polioencephalomalacia while on study. Due to excessive heat between the dates of August 21, 2015, and September 17, 2015, causing sporadic intakes, 12 steers were treated for bloat but were not removed from study. In an attempt to reduce the incidence of bloat, researchers initiated twice daily feeding on August 30, 2016, through September 17, 2015, at which time, once a day feeding resumed. One steer was diagnosed as chronically bloated, bloat was constantly reoccurring after treatment, and was removed from study.

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On day 194, when steers averaged 1.27 cm of back fat (predicted with visual appraisal), steers were shipped 296 km and slaughtered at a federally inspected commercial beef processing facility. HCWs were recorded at the end of the slaughter line before each carcass entered the cooler. Dressing percentage was calculated for each steer using a 4% shrunk live BW. Carcasses were chilled at least 24 h before grading. Carcass sides were separated at the 12th and 13th rib interface by plant personnel. Carcasses were evaluated for 12th rib back fat, rib-eye area, percent kidney, pelvic and heart fat, ribeye subjective color score, and ribeye marbling score via camera grading.

After the trial was completed, NE\textsubscript{m} and NE\textsubscript{g} of the total diets were calculated based on steer performance (initial BW, final BW, ADG, and DMI) using NRC (1996) iterative equations. When NE\textsubscript{m} and NE\textsubscript{g} of a feedstuffs, such as the liquid supplement, is unknown, the calculations of the dietary energy values can aid in describing treatment effects even though they may not be a more sensitive measure statistically (Vasconcelos and Galyean, 2008). Carcass ADG, carcass G:F, and estimated total carcass gain were calculated using equations from Tatum et al. (2012):

\[
\text{Carcass ADG} = \frac{\text{Average Daily Feed Intake} \times \text{Carcass ADG}}{\text{Average Days on Feed}}
\]

\[
\text{Carcass G:F} = \frac{\text{Estimated Carcass Gain} - \text{Estimated Beginning HCW}}{\text{Final HCW} - \text{Beginning HCW}}
\]

\[
\text{Estimated Carcass Gain} = \frac{\text{Average Final HCW} - \text{Est. Beginning HCW}}{0.2598 \times \text{Initial BW}^{1.1378}}
\]

**Feedstuff Sampling and Analysis**

Samples of individual dietary ingredients (50 g dry corn, dry supplement, MWDGS; 100 g silage) were composited every 2 wk. They were then lyophilized (FreeZone, Labconco, Kansas City, MO), and ground through a Wiley mill (1-mm screen; Arthur H. Thomas, Philadelphia, PA).

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**Table 1. Diet composition**

| Ingredient, % DM basis | 0LIQ | 4.5LIQ | 9.0LIQ | 13.5LIQ |
|------------------------|------|-------|-------|---------|
| DM                     | 67.99| 68.08 | 65.88 | 65.63   |
| OM                     | 95.32| 96.33 | 95.22 | 95.70   |
| NDF                    | 21.32| 22.07 | 22.82 | 23.72   |
| ADF                    | 9.26 | 9.65  | 10.05 | 10.51   |
| CP                     | 13.00| 13.05 | 12.91 | 13.12   |
| Fat                    | 4.30 | 5.46  | 4.04  | 3.95    |
| Ca                     | 0.65 | 0.63  | 0.38  | 0.52    |
| P                      | 0.32 | 0.32  | 0.32  | 0.32    |
| Mg                     | 0.13 | 0.12  | 0.13  | 0.13    |
| S                      | 0.20 | 0.19  | 0.20  | 0.22    |

- Analyzed composition, mg/kg DM

  | Fe  | Cu  | Mn  |
  |-----|-----|-----|
  | 67.3| 12.7| 34.5|
  | 30.6| 11.4| 24.6|
  | 78.8| 12.5| 27.4|
  | 92.8| 13.6| 30.2|

\textsuperscript{a}Liquid supplement inclusion in the diet consisted of 0%, 0LIQ (4.5% dry supplement); 4.5% (4.5LIQ); 9% (9LIQ); or 13.5% (13.5LIQ) inclusion on a DM basis.

\textsuperscript{b}Dry supplement contained (DM basis): 46.02% ground corn, 12.376% urea, 33.35% limestone, 0.472% dicalcium phosphate, 1.52% Vitamin mix, 0.83% trace mineral salt (supplied by Quality Liquid Feeds [Dodgeville, WI] to ensure the same source as the liquid supplements), 0.31% Rumensin 90 (200 mg monensin/kg; Elanco Animal Health, Greenfield, IN), 3.779% potassium sulfate, and 1.55% salt.

\textsuperscript{c}Three separate liquid supplements were supplied by Quality Liquid Feeds. Formulation is proprietary, but was supplied by the company to ensure the dry supplement met similar parameters including urea, Rumensin (Elanco Animal Health), and vitamins and minerals.
Samples (250 mL) of liquid supplements were taken 2 wk after each new delivery and later composited. Upon completion of the trial, ingredient composites were analyzed for DM (24 h at 105 °C), OM (calculated as DM—ash; [500 °C for 12 h, HotPack Muffle Oven Model: 770750, HotPack Corp., Philadelphia, PA]), ADF and NDF (method 5 and 6, respectively; Ankom200 Fiber Analyzer, Ankom Technology, Macedon, NY), CP (Leco TruMac, LECO Corporation, St. Joseph, MI), fat (method 2 [Ankom Technology, 2014]; Ankom Technology), and complete mineral concentrations (method 975.03: AOAC, 1988; STAR Lab, Wooster, OH). Analyzed individual ingredient composites were used to calculate total dietary nutrient composition for each treatment.

**Statistical Analysis**

This experiment was a randomized complete block design. Data were analyzed using the MIXED procedures of SAS 9.3 (SAS Inst., Cary, NC). The model was:

\[ Y_{ijkl} = \mu + B_i + p_{j(i)} + D_k + e_{ijkl} \]

where \( Y_{ijkl} \) was the response variable, \( \mu \) was the response variable; \( B_i \) was the fixed effect of block; \( p_{j(i)} \) was the random effect of pen nested within block; \( D_k \) was the fixed effect of diet (liquid inclusion), and \( e_{ijkl} \) was the experimental error. Linear and quadratic contrasts were examined and reported to determine the effects of increasing dietary liquid inclusion. Pen was the experimental unit and significance was declared at \( P \leq 0.05 \) and trends are discussed at \( 0.05 < P \leq 0.10 \).

**RESULTS AND DISCUSSION**

**Growth Performance**

There were no effects \((P \geq 0.08)\) of liquid supplementation on initial BW, DMI, ADG, G:F, or live BW gain during the 194 d study (Table 2). However, there was a quadratic \((P \leq 0.05)\) effect of liquid inclusion on final BW and NE\(_m\) and NE\(_g\) calculated based on steer performance. The final BW of steers fed 4.5LIQ and 9LIQ were similar (596 kg and 595 kg, respectively) to each other but greater than the final BW of steers 13.5LIQ. Steers fed 0LIQ were intermediate and not different from other treatments. These differences in final BW occurred despite the lack of difference \((P \geq 0.05)\) in initial BW, DMI, or ADG throughout the trial. Cattle were stratified by BW to pens and then pens were randomly assigned to treatment. Thus, there was an attempt to keep initial BW similar; therefore, it was not used as a covariate in the analysis. However, it is prudent to point out that initial BW was numerically 6 to 7 kg greater for steers fed 4.5LIQ and 9LIQ when compared to those fed 0LIQ and 13.5LIQ and this may have affected the differences realized in final BW.

**Table 2. Effects of the interaction of liquid supplementation strategy (either 0, 4.5, 9, or 13.5% of diet DM inclusion) on growth performance of finishing steers**

| Liquid inclusion\(^a\) | 0LIQ | 4.5LIQ | 9LIQ | 13.5LIQ | SEM | L | Q |
|------------------------|------|--------|------|---------|-----|---|---|
| \( n, \) pens          | 10   | 10     | 10   | 10      | -   | - | - |
| Initial BW, kg         | 234  | 240    | 241  | 234     | 4.92| 0.92| 0.19|
| Final BW, kg           | 586  | 596    | 595  | 578     | 6.54| 0.39| 0.05|
| DMI, kg                | 9.01 | 8.86   | 8.78 | 8.84    | 0.10| 0.23| 0.30|
| ADG, kg                | 1.81 | 1.84   | 1.82 | 1.77    | 0.02| 0.11| 0.08|
| G:F                    | 0.205| 0.210  | 0.211| 0.204   | 0.002| 0.98| 0.11|
| NE\(_m\), Mcal/kg     | 2.20 | 2.25   | 2.26 | 2.19    | 0.02| 0.96| 0.01|
| NE\(_g\), Mcal/kg     | 1.51 | 1.56   | 1.57 | 1.51    | 0.02| 0.96| 0.01|
| BWG,\(^d\)kg          | 352  | 356    | 354  | 344     | 3.99| 0.17| 0.15|
| BWI,\(^e\)%           | 2.17 | 2.12   | 2.10 | 2.14    | 0.02| 0.34| 0.04|

\(^a\)Liquid inclusion in the diet consisted of 0%, 0LIQ (4.5% dry supplement); 4.5% (4.5LIQ); 9% (9LIQ); or 13.5% (13.5LIQ) inclusion on a DM basis.

\(^b\)P value descriptions: L = the linear effect of liquid inclusion in the diet; Q = the quadratic effects of liquid inclusion in the diet.

\(^c\)Calculated after the trial was completed based on animal performance (initial BW, final BW, ADG, and DMI) using NRC (1996) iterative equations.

\(^d\)BWG = live BW gain for the duration of the trial.

\(^e\)BWI = DMI calculated as a percent of BW.
We had hypothesized that increasing concentration of liquid in the diet would linearly increase ADG up to 9% inclusion, and then ADG would decrease in steers fed 13.5LIQ. This is because previous research reported a decrease in ADG when supplementing finishing cattle over 10% inclusion with molasses when fed a concentrate diet (Heinemann and Hanks, 1977), or over 10% glycerin (Long et al., 2015). Additional work with glycerin suggests that ADG and final live weight are maximized when the product is fed at 7.5% of the diet DM (Hales et al., 2013). Furthermore, one study fed molasses and glycerin in a 50:50 blend and reported a linear increase in ADG with increasing dietary inclusion of the blend (Ciriaco et al., 2015); however, these authors were supplementing the liquid blend to cattle consuming forage. While the liquid advantage for ADG did not exist in the present trial when steers were fed a grain-based diet, the reason for the lack of benefit there is unclear. All cattle gained well (1.81 kg as a group), which may have masked any differences in treatment.

Intake, reported as kg DMI/d, was not different ($P \geq 0.23$) and averaged 8.87 kg per steer each day. However, there was a quadratic ($P = 0.04$) effect of liquid supplement inclusion on DMI as a percent of BW. Steers fed 9LIQ had the least DMI as a percent of BW, followed by steers fed 4.5LIQ and 13.5LIQ, respectively, and steers fed 0LIQ had the greatest DMI as a percent of BW. Weeks of extreme heat events occurred near the middle of the trial (days 123–143). During this time, cattle intakes were variable and twice a day feeding was implemented (per the Materials and Methods). Cattle returned to feed after the heat subsided and gains continued (Figure 1); therefore, authors do not expect the weather events had any lasting effects on growth performance or intake.

Upon initial comparison, the minor differences among liquid supplements and the lack of ADG affect do not appear biologically relevant. However, energy values of the diet were calculated off of the live animal performance (NRC, 1996). There was a quadratic effect for both $\text{NE}_m$ ($P = 0.01$) and $\text{NE}_g$ ($P = 0.01$) calculated from steer performance. Steers fed 4.5LIQ, which replaced 2.1% corn on a DM basis, and 9LIQ, which replaced 6.6% corn on a DM basis, were similar to each other and had the greatest calculated $\text{NE}_m$ and $\text{NE}_g$ when compared to steers fed 0LIQ or 13.5LIQ. These increases suggest that, although ADG was not different among treatments, diets contain 4.5% and 9% liquid supplement provided more energy to cattle than the corn they replaced. This is in agreement with Hales et al. (2015) that suggested greater retention of energy in steers fed 5% and 10% dietary inclusion of glycerin when compared to those fed 0% or 15% glycerin. The intermediate inclusions of other liquid ingredients have continuously shown net energy advantages (Hales et al., 2013; Long et al., 2015; Stierwalt

![Figure 1](image-url). Effects of liquid supplementation (either 0, 4.5, 9, or 13.5% of diet DM inclusion) on steer DMI by 28-d period. Steers were fed varying concentrations of liquid supplementation: 0% of diet DM (filled bars), 4.5% of diet DM (cross-lined bars), 9% of diet DM (horizontal lined bars), 13.5% of diet DM (dotted bars) on a DM basis. There was a significant linear (*) effect ($P = 0.02$) of liquid supplementation at the period of d 0–28 and a quadratic (^) effect ($P < 0.01$) of liquid supplementation at the period of d 57–83.

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et al., 2017) over corn, and data from the current trial would suggest these advantages hold true for commercial liquid supplements as well.

Carcass Characteristics

Similar to the response observed in final BW, there was a quadratic \((P = 0.03)\) effect of liquid supplement inclusion on HCW (Table 3). Carcasses from steers fed 4.5LIQ and 9LIQ had the greatest HCW (367 and 364 kg, respectively) compared to carcasses from steers fed 0LIQ and 13.5LIQ (358 and 353 kg, respectively). There was a linear tendency \((P = 0.07)\) for grading yield grade 4. Steers fed 0LIQ tended to have the greatest percentage of yield grade 4 carcasses, meanwhile carcasses from steers fed 13.5LIQ had the least percentage of yield grade 4 carcasses. There were no differences observed in marbling score; thus, the components of the liquid supplement (glycerin and molasses) did not increase intramuscular fat deposition via gluconeogenesis as previously reported (Johns, 1953). Replacing 10% corn with glycerin in diets fed to growing steers tended to increase marbling in steers fed concentrate-based diets (Long et al., 2015). However, supplementing molasses independently to finishing cattle has not improved marbling (Heinemann and Hanks, 1977). It was hypothesized that liquid supplementation may increase marbling due to the increase in observed ruminal propionate concentrations when cattle were fed liquids in previous trials (Long et al., 2015), but this was not the case in the current study.

Because it represents true economics, carcass gain and efficiency have become industry-preferred measures of feedlot performance. Steers fed 4.5LIQ had the greatest carcass ADG (0.55 kg), steers fed 0LIQ and 9LIQ were intermediate and equal (0.54 kg), and steers fed 13.5LIQ had the lowest carcass ADG (0.53 kg)(Table 4). This response was likely driven by the difference observed in HCW because there was no difference in initial BW or average days on feed.

In summary, feeding increasing liquid supplement inclusions to feedlot cattle increased NE\textsubscript{m} and NE\textsubscript{g} calculated from steer performance, and increased final BW, at 4.5% and 9% inclusion of liquid. These data suggest that commercial liquid supplementation supplied more energy to finishing cattle than the 2.1% and 6.6% corn (DM basis) that the 4.5% and 9% inclusions of liquid replaced, respectively. However, there was no advantage of increasing to 13.5% liquid for feedlot steers fed a concentrate-based diet in the present trial.

### Table 3. Effects of liquid supplementation (either 0, 4.5, 9, or 13.5% of diet DM inclusion) on carcass characteristics of finishing steers

| Liquid inclusion\(^a\) | 0LIQ | 4.5LIQ | 9LIQ | 13.5LIQ | SEM  | L  | Q  |
|-------------------------|------|-------|------|---------|------|---|---|
| \(\eta\), pens         | 10   | 10    | 10   | 10      | -    | - | - |
| HCW, kg                 | 358  | 367   | 364  | 353     | 4.34 | 0.37 | 0.03 |
| DP, %                   | 61.23| 61.55 | 61.20| 61.06   | 0.21 | 0.36 | 0.28 |
| LM area, cm\(^2\)      | 78.8 | 80.6  | 80.5 | 80.1    | 0.87 | 0.34 | 0.19 |
| Marbling score\(^b\)   | 469  | 445   | 469  | 465     | 11.4 | 0.82 | 0.40 |
| BF, cm\(^d\)           | 1.55 | 1.44  | 1.50 | 1.40    | 0.06 | 0.15 | 0.90 |
| KPH                    | 2.11 | 2.01  | 2.05 | 2.04    | 0.25 | 0.11 | 0.05 |
| USDA quality grade\(^e\) |  | | | | | |
| Select                  | 14.49| 19.90 | 18.80 | 15.89   | 5.14 | 0.87 | 0.37 |
| Choice                  | 78.29| 72.43 | 69.57| 68.20   | 5.67 | 0.17 | 0.65 |
| Prime                   | 4.11 | 0.01  | 4.11 | 7.11    | 3.12 | 0.97 | 0.97 |
| Dark                    | 2.90 | 0.01  | 7.11 | 8.24    | 3.41 | 0.09 | 0.87 |
| USDA yield grade\(^e\) | | | | | | |
| 2                       | 14.48| 26.00 | 19.63| 28.92   | 5.48 | 0.11 | 0.72 |
| 3                       | 57.03| 50.71 | 52.51| 55.09   | 6.21 | 0.88 | 0.47 |
| 4                       | 27.30| 21.70 | 25.63| 12.97   | 5.40 | 0.07 | 0.38 |

\(^a\)Liquid supplement inclusion in the diet consisted of 0%, 0LIQ (4.5% dry supplement); 4.5% (4.5LIQ); 9% (9LIQ); or 13.5% (13.5LIQ) inclusion on a DM basis.

\(^b\)P value descriptions: L = the linear effect of liquid inclusion in the diet; Q = the quadratic effects of liquid inclusion in the diet.

\(^c\)Marbling score scale: 400 = small, 500 = modest, 600 = moderate.

\(^d\)Back fat measured between the 12th and 13th rib after 24 h chill.

\(^e\)Grade called at the kill plant.
Table 4. Effects of liquid supplementation (either 0, 4.5, 9, or 13.5% of diet DM inclusion) on carcass adjusted measures of efficiency of finishing steers

| Liquid inclusion* | 0LIQ | 4.5LIQ | 9LIQ | 13.5LIQ | SEM | L | Q |
|------------------|------|-------|------|--------|-----|---|---|
| n, pens          | 10   | 10    | 10   | 10     |     |   |   |
| Carcass ADG, kg  | 0.54 | 0.55  | 0.54 | 0.53   | 0.06 | 0.10 | 0.03 |
| Carcass G:F      | 0.060 | 0.063 | 0.062 | 0.060 | 0.006 | 0.01 | 0.65 |
| Est. Carc. Gain, kg | 104 | 106   | 105  | 102    | 1.13 | 0.09 | 0.04 |

*Liquid supplement inclusion in the diet consisted of 0%, 0LIQ (4.5% dry supplement); 4.5% (4.5LIQ); 9% (9LIQ); or 13.5% (13.5LIQ) inclusion on a DM basis.

P value descriptions: L = the linear effect of liquid inclusion in the diet; Q = the quadratic effects of liquid inclusion in the diet.

Carcass ADG = (average final HCW − Est. beginning HCW)/average days on feed (Tatum et al., 2012).

Carcass G:F = carcass ADG/ADFI (Tatum et al., 2012).

Estimated carcass gain = (final HCW − Est. beginning HCW)/average days on feed (Tatum et al., 2012).

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