Influence of mixing supplements (dry or liquid) with monensin or soluble protein on the feeding value of finishing diets for feedlot cattle

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ABSTRACT

The influence of supplement form (dry vs. liquid) on the feeding value of diets for feedlot cattle was evaluated. Treatments were: (1) dry supplement (DS); (2) liquid supplement (LS, all supplemental macro- and micro-minerals, salt, monensin and urea provided as a uniform blend with cane molasses; (3) LS minus monensin, that was provided in a 3% premix with dried distillers grains plus solubles before combination into a complete mixed diet (LS-MON) and (4) LS, except that condensed molasses solubles replaced 41% (DM basis) of the cane molasses solids (LSUF). In a 112-day trial involving 160 Holstein steers (473 ± 32 kg) cattle fed DS, LS, LS-MON and LSUF diets had similar (P > .10) ADG, DMI, feed efficiency and estimated dietary NE. The effects on characteristics of digestion were evaluate using four Holstein steers with cannulas in rumen and proximal duodenum. There were no treatment effects (P > .10) on ruminal digestion of OM, and feed N, microbial efficiency and ruminal N efficiency. It is concluded that the form of incorporation of minor dietary ingredients during batch mixing (dry premix or in combination with a liquid carrier) will not appreciably affect the feeding value of growing-finishing diets for feedlot cattle.

1. Introduction

In the USA, 27% of feedlots incorporate minor ingredients into growing-finishing diets in the form of non-fat liquid supplements (Samuelson et al. 2016). For the most part, non-fat liquid supplements are co-products obtained from different industries, including condensed distiller’s solubles, fermentation solubles, molasses and molasses blends. Compared to conventional dry ingredients, the liquid supplements carriers provide cost competitive nutrients, and may contribute to dust reduction through adherence of fines to other components of diets (Oelker et al. 2009). Additionally, they facilitate the incorporation of minor ingredients (urea, salt, minerals and feed additives), and may potentially reduce sorting and enhance uniform intake of complete mixed diets (Firkins et al. 2008; DeVries and Gill 2012). Nevertheless, a direct comparison of form of incorporation of minor dietary ingredients during batch mixing (dry premix or in combination with a liquid carrier) on the feeding value of growing-finishing diets for feedlot cattle has not been previously reported.

The objective of present study was to directly compare these two methods of incorporating minor ingredients into complete mixed diets on growth performance, carcass characteristics and digestive function of feedlot cattle.

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.
composition (g/kg, DM basis) of diets (experiments 1 and 2) are shown in Table 1. Diets were formulated to achieve similar crude protein concentrations. Although nonisotonic, the LS treatments contained ammonium compounds that replace a portion of the urea N in DS treatment as an aid to thixotropic properties of liquid supplements for maintaining suspension. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Individual steers were weighed upon initiation and completion of the 112-day trial. Estimates of steer performance were based on pen means.

2.1.2. Estimation of digestive NE
For calculating steer performance, BW was reduced 4% to account for digestive tract fill. Energy gain (EG) was calculated by the equation: \( EG = ADG^{0.970} 0.0557 W^{0.75} \) where \( W \) is the daily energy deposited (Mcal/d), \( W = \text{mean shrink BW (kg; NRC 1984)}. \) Maintenance energy (EM) was calculated by the equation: \( EM = 0.084 W^{0.75} \) (NRC 1996). Dietary NEm was derived from NEm by the equation: \( \text{NEm} = 0.877 \text{NEm} - 0.41 \) (Zinn and Shen 1996). Dry matter intake is related to energy requirements and dietary NEm according to the equation: \( \text{DMI} = \text{EM}/\text{NEm} + \text{EG}/(0.877 \text{NEm} - 0.41) \), and can be resolved for estimation of dietary NE by means of the quadratic formula: \( x = [-b - (b^2 - 4ac^{0.5})]/2a \), where \( x = \text{NEm}, \ a = -0.877\text{DMI}, \ b = 0.877 \text{EM} + 0.41\text{DMI} + \text{EG} \) and \( c = -0.41 \text{EM} \) (Zinn and Shen 1996).

2.1.3. Carcass characteristics
Hot carcass weights (HCW) were obtained at harvest. After carcasses chilled for 48 h, the following measurements were obtained: Longissimus muscle area (LM, cm²) taken by direct grid reading of the (LM) at the 12th rib; subcutaneous fat (cm) over the LM at the 12th rib taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); KPH as a percentage of HCW; marbling score (USDA 1997; using 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc.), and estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (percentage of HCW; Murphey et al. 1960) = 52.56 – (1.95 × subcutaneous fat) – (1.06 × KPH) + (0.164 × LM area) – (0.0176 × HCW).

2.1.4. Statistical design and analysis
Pens were used as experimental units. The experimental data were analyzed as a randomized complete block design experiment according to the following statistical model: \( Y_{ij} = \mu + B_i + T_j + e_{ij} (\text{Hicks 1973}) \), where \( \mu \) is the general mean, \( B_i \) represents initial weight group effect, \( T_j \) represents dietary treatment effect and \( e_{ij} \) represents the residual error. Treatments effects were tested using the following contrasts: (1) DS vs. LS, (2) LS vs. LS-MON and (3) LS vs. LSUF. Treatment effects were considered significant at \( P \leq 0.05 \) and as trends for \( P > 0.05 \) and \( \leq 0.10 \) (Statistix 10, Analytical Software, Tallahassee, FL).

2.2. Experiment 2, influence of supplements on characteristics of digestion

2.2.1. Animals, diets and sampling
Four Holstein steers (360 ± 9 kg) with cannulas in the rumen (3.8 cm internal diameter) and proximal duodenum (Zinn and Plascencia 1993) were used in a 4 × 4 Latin square experiment to study treatment effects on characteristics of digestion. Treatments were the same as those used in experiment 1, with the inclusion of 3 g/kg chromic oxide as a digesta marker. Steers were maintained in individual pens (5.6 m²) with automatic waterers. Diets were fed at 0800 and 2000 h daily. As is customary with metabolism research conducted at this center, feed DMI was restricted to 2.2% BW to avoid the complications of feed refusals in estimates of digestion. Experimental periods were 14 day, with 10 day for dietary treatment adjustment, 4 day for collection. During collection, duodenal and fecal samples were taken twice daily as follows: day 1, 0750 and 1350 h; day 2, 0900 and 1500 h; day 3, 1050 and 1650 h, and day 4, 1200 and 1800 h. Individual samples consisted of approximately 700 mL of duodenal chyme and 200 g (watered).
basis) of fecal material. Samples from each steer within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer via ruminal cannula 4 h after feeding. Ruminal fluid pH was determined on fresh samples. Samples were strained through four layers of cheesecloth. Two milliliter of freshly prepared (25 gr/100 mL) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000 × g for 10 min), and supernatant fluid was stored at −20°C for VFA analysis (gas chromatography; Zinn 1988). Upon completion of the experiment, ruminal fluid was obtained via the ruminal cannula from all steers and composited for isolation of ruminal bacteria by differential centrifugation (Bergen et al. 1968). The purine:N ratio of bacterial isolate is used in estimation of microbial N contribution to duodenal chyme (Zinn and Owens 1986).

### 2.2.2. Sample analysis and calculations for experiment 2

Feed and fecal samples were subjected to the following analysis: DM (oven drying at 105°C until no further weight loss); ash (method 942.05, AOAC 1986); Kjeldahl N (method 984.13, AOAC 2000); ADFom (Van Soest et al. 1991), corrected for NDF-ash, incorporating heat stable α-amylase (Ankom FAA, Ankom Technology, Macedon, NY) at 1 mL per 100 mL of NDF solution; chromic oxide (Hill and Anderson 1958) and starch (Zinn 1990). Duodenal samples were subjected to the following analysis: DM (oven drying at 105°C until no further weight loss); ash (method 942.05, AOAC 1986), Kjeldahl N (method 984.13, AOAC 2000), ammonia N (method 941.04, AOAC 2000); ADFom (Van Soest et al. 1991), corrected for NDF-ash, incorporating heat stable α-amylase (Ankom FAA, Ankom Technology, Macedon, NY) at 1 mL per 100 mL of NDF solution; purines (Zinn and Owens 1986); chromic oxide (Hill and Anderson 1958); and starch (Zinn 1990). Duodenal flow and fecal excretion of DM were calculated based on marker ratio, using chromic oxide. Microbial organic matter (MOM) and N (MN) leaving the abomasum was calculated using purines as a microbial marker (Zinn and Owens 1986).

Organic matter fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N, MN and endogenous N (0.195 × BW0.75; Ørskov et al. 1986). Methane production (mol/mol glucose equivalent fermented) was estimated based on the theoretical fermentation balance for observed molar distribution of VFA (Wolin 1960).

#### 2.2.3 Statistical design and analysis for experiment 2

Treatment effects on characteristics of digestion were analyzed as a 4 × 4 Latin square design (Stastix 10, Analytical Software, Tallahassee, FL). The statistical model for the trial was as follows: \( Yijk = \mu + Si + Pj + Tk + Eijk \), where: \( Yijk \) is the response variable, \( \mu \) is the general mean, \( Si \) is the steer effect, \( Pj \) is the period effect, \( Tk \) is the treatment effect and \( Eijk \) is the residual error. Treatments effects were tested using the following contrasts: (1) DS vs. LS, (2) LS vs. LS-MON and (3) LS vs. LSUF. Treatment effects were considered significant at \( P \leq .05 \) and as trends for \( P > .05 \) and \( P \leq .10 \) (Stastix 10, Analytical Software, Tallahassee, FL).

### 3. Results and discussion

#### 3.1. Experiment 1, the influence of liquid supplements on growth performance, dietary energetics and carcass characteristics.

Treatment effects on growth performance and estimated NE value of the diet are shown in Table 2. Cattle fed DS, LS, LS-MON and LSUF diets had similar (\( P > .10 \)) ADG, DMI, feed efficiency and estimated dietary NE. Thus, results support the

### Table 2. Influence of liquid and dry supplement on growth performance of calf-fed Holstein steers and net energy (NE) value of the diet.

| Item                  | DS         | LS         | LS-MON     | LSUF       | SEM        | DS vs. LS | LS vs. LS-MON | LS vs. LSUF |
|-----------------------|------------|------------|------------|------------|------------|-----------|---------------|-------------|
| Days on test          | 112        | 112        | 112        | 112        |            |           |               |             |
| Pen replications      | 8          | 8          | 8          | 8          |            |           |               |             |
| Live weight (kg)b     | Initial    | 473.4      | 472.2      | 474.5      | 473.0      | 0.5       |               |             |
|                       | Final      | 622.4      | 620.5      | 623.4      | 620.4      | 4.9       | 0.79          | 0.68        | 0.99        |
| ADG (kg/d)            | 1.33       | 1.32       | 1.33       | 1.32       | 0.04       | 0.92      | 0.92          | 0.90        |
|                       | 1–112 d    |            |            |            |            |           |               |             |
| DMI (kg/d)            | 9.65       | 9.54       | 9.80       | 9.37       | 0.20       | 0.69      | 0.34          | 0.54        |
|                       | 1–112 d    |            |            |            |            |           |               |             |
| ADG/DMI (kg/kg)       | 0.138      | 0.139      | 0.135      | 0.140      | 0.003      | 0.82      | 0.42          | 0.67        |
| Diet net energy (Mcal/kg) | 2.29      | 2.30       | 2.26       | 2.33       | 0.03       | 0.77      | 0.36          | 0.48        |
|                      | Maintenance| 1.60       | 1.61       | 1.57       | 1.64       | 0.03      | 0.77          | 0.36        | 0.48        |
|                      | Gain       | 1.04       | 1.06       | 1.03       | 1.07       | 0.02      | 0.72          | 0.36        | 0.52        |
|                      |             | 1.04       | 1.06       | 1.03       | 1.07       | 0.02      | 0.72          | 0.36        | 0.52        |

aDS: Dry supplement; LS: Liquid supplement; LS-MON: LS except that monensin provided as part of the dry supplement; LSUF: LS + Ultraferm (condensed molasses soluble). Treatment 1 had all minerals and monensin in the dry supplement (DS). Treatment 2 had all minerals and the monensin combined with the molasses and was added as a liquid supplement (LS), treatment 3 was the same as treatment 2 except that the monensin was added to the diet in dry form (monensin was not part of the liquid supplement; LS-MON), treatment 4 had molasses plus a soluble protein in liquid supplement (ultraferm blend; LSUF).

bInitial and final live weights reduced 4% to account for fill.
hypothesis that liquid supplements (composed of molasses with mineral premix, monensin and soluble N) can be mixed with basal diet producing feedlot growth-performance responses comparable to that of cattle fed similar diets with supplements provided in dry form. Furthermore, results are supportive of earlier findings (Mader et al. 1985) that ionophore effectiveness is not diminished by prolonged storage in the liquid supplements (in the case of the present study, at least 112 days). Hence, advantages with the use of liquid vs. dry supplements in total mixed rations is largely a function of facilitation in the batching processes at the feed mill.

Treatment effects on carcass characteristics of the diet are shown in Table 3. Carcass characteristics were similar (P > .10) between cattle fed DS and LS diets, and between those fed LS and LS-MON diets. However, there was a tendency for decreased carcass fat thickness (14%, P = .07) when ultraferm replaced a portion of the molasses and urea in the liquid supplement (LS vs. LSUF). The basis for this effect is not clear. Block et al. (2001) observed that within cattle groups of similar genetics, fat thickness is expected to be largely a function of ADG and final carcass weight. However, neither ADG nor final carcass weight differed for this contrast (Table 2).

### Table 3. Influence of liquid and dry supplement on carcass characteristics of calf-fed Holstein steers.

| Item                        | Treatment* | P-value |
|-----------------------------|------------|---------|
|                             | DS         | LS-MON  | LSUF   | SEM    | DS vs. LS | LS vs. LS-MON | LS vs. LSUF |
| Hot carcass weight (kg)     | 389        | 385     | 385    | 385    | 4         | 0.54       | 0.94       | 0.99       |
| Dressing (%)                | 62.4       | 62.0    | 61.8   | 62.1   | 0.4      | 0.43       | 0.72       | 0.92       |
| Longissimus area (cm)       | 79.1       | 77.2    | 77.3   | 78.0   | 1.4      | 0.34       | 0.93       | 0.67       |
| Fat thickness (cm)          | 3.75       | 3.83    | 3.53   | 3.29   | 0.20     | 0.79       | 0.31       | 0.07       |
| KPH (%)                     | 2.4        | 2.3     | 2.4    | 2.3    | 0.1      | 0.48       | 0.56       | 0.80       |
| Yield grade (%)             | 48.9       | 48.5    | 49.1   | 49.7   | 0.5      | 0.65       | 0.46       | 0.11       |
| Quality grade               | 4.5        | 4.6     | 4.4    | 4.6    | 0.2      | 0.74       | 0.50       | 0.94       |

aDS: Dry supplement; LS: Liquid supplement; LS-MON: LS except that monensin provided as part of the dry supplement; LSUF = LS + Ultraferm (condensed molasses soluble). Treatment 1 had all minerals and monensin in the dry supplement (DS), Treatment 2 had all minerals and the monensin combined with the molasses and was added as a liquid supplement (LS), treatment 3 was the same as treatment 2 except that the monensin was added to the diet in dry form (monensin was not part of the liquid supplement; LS-MON), treatment 4 had molasses plus a soluble protein in liquid supplement (ultraferm blend; LSUF).

bKidney, pelvic and heart fat as a percentage of carcass weight.

### Table 4. Influence of liquid and dry supplement on characteristics of digestion.

| Item                        | Treatment* | P-value |
|-----------------------------|------------|---------|
|                             | DS         | LS-MON  | LSUF   | SEM    | DS vs. LS | LS vs. LS-MON | LS vs. LSUF |
| Intake                      |            |         |        |        |          |             |             |
| Dry matter                  | 7812       | 7810    | 7810   | 7810   | 7812      | 7810         | 7810         |
| Organic matter              | 7362       | 7360    | 7360   | 7360   | 7362      | 7360         | 7360         |
| NDF                         | 1939       | 1939    | 1939   | 1939   | 1939      | 1939         | 1939         |
| Total starch                | 2563       | 2562    | 2562   | 2562   | 2563      | 2562         | 2562         |
| Ruminal digestion (%)       |            |         |        |        |          |             |             |
| OM                          | 49.06      | 49.92   | 52.02  | 49.30  | 1.12      | 0.61         | 0.24         | 0.71       |
| NDF                         | 47.52      | 52.50   | 51.44  | 40.71  | 1.92      | 0.12         | 0.71         | <0.01      |
| Starct                      | 77.55      | 75.34   | 78.04  | 79.52  | 1.15      | 0.22         | 0.15         | 0.04       |
| Feed N                      | 42.21      | 43.72   | 46.83  | 46.13  | 3.21      | 0.73         | 0.52         | 0.62       |
| Microbial Efficiencyb       | 22.86      | 21.29   | 20.92  | 23.73  | 1.84      | 0.57         | 0.89         | 0.38       |
| N efficiencyc               | 1.14       | 1.10    | 1.09   | 1.11   | 0.03      | 0.49         | 0.71         | 0.79       |
| Postruminal digestion, %    |            |         |        |        |          |             |             |
| DM                          | 58.46      | 64.12   | 60.70  | 61.81  | 3.06      | 0.24         | 0.46         | 0.61       |
| N                           | 9.93       | 14.72   | 7.59   | 23.21  | 5.84      | 0.58         | 0.42         | 0.34       |
| Starct                      | 73.57      | 75.40   | 74.32  | 75.10  | 2.52      | 0.63         | 0.77         | 0.94       |
| Total tract digestion (%)   |            |         |        |        |          |             |             |
| DM                          | 72.42      | 77.00   | 75.20  | 75.27  | 2.30      | 0.21         | 0.60         | 0.62       |
| OM                          | 74.20      | 78.41   | 76.82  | 76.43  | 2.13      | 0.21         | 0.62         | 0.54       |
| N                           | 51.59      | 59.83   | 55.19  | 54.40  | 4.09      | 0.20         | 0.46         | 0.38       |
| Starct                      | 68.95      | 71.95   | 71.12  | 71.41  | 2.91      | 0.49         | 0.85         | 0.90       |

aDS: Dry supplement; LS: Liquid supplement; LS-MON: LS except that monensin provided as part of the dry supplement; LSUF = LS + Ultraferm (condensed molasses soluble). Treatment 1 had all minerals and monensin in the dry supplement (DS), Treatment 2 had all minerals and the monensin combined with the molasses and was added as a liquid supplement (LS), treatment 3 was the same as treatment 2 except that the monensin was added to the diet in dry form (monensin was not part of the liquid supplement; LS-MON), treatment 4 had molasses plus a soluble protein in liquid supplement (ultraferm blend; LSUF).

bMicrobial N, g/kg OM fermented.

cNonammonia N flow to the small intestine as a fraction of N intake.

3.2. Experiment 2, influence of liquid supplements on characteristics of digestion and ruminal fermentation

Treatment effects on characteristics of digestion are shown in Table 4. There were no treatment effects (P > .10) on ruminal digestion of OM, and feed N, microbial efficiency and ruminal N efficiency (non-ammonia N entering the small intestine/N intake). However, ruminal NDF digestion was decreased (22%, P < .01) and ruminal starch digestion increased (5.3%, P = .04) when ultraferm replaced a portion of the molasses and urea in the liquid supplement (LS vs. LSUF). The basis for this effect...
is not certain. Both urea and ultraferm are soluble N sources, and level of ruminally degradable N did not differ ($P > .62$) between the two treatments. Nevertheless, in as much as ultraferm N replaced urea N in the LSUF supplement, that replacement could be a factor. In some cases, decreasing the level of supplemental urea in steam-flaked corn-based diets decreased ruminal digestion of NDF ($P > .10; \text{Table 4}$). Treatment effects on characteristics of ruminal pH and VFA concentrations are shown in Table 5. There was a tendency for greater ruminal molar concentration of butyrate (19%, $P = .08$) when ultraferm (condensed molasses solubles) replaced a portion of the molasses and urea in the liquid supplement (LS vs. LSUF). Likewise, Potter et al. (1985) observed marked increase in ruminal butyrate molar proportions when condensed molasses solubles replaced cane molasses in the finishing diet for feedlot steers. The basis for this effect is not certain, but may be due to the greater ruminally available α-amino- vs. urea-N with the LSUF diet (Chumpawadee et al. 2009). Amino acids comprise 38% of the N in condensed molasses solubles (Weigand and Kirchgessner 1980), consisting largely of betaine (24%) and glutamate (30%). There were no treatment effects on ruminal pH, total VFA, molar proportions of acetate, propionate, isobutyrate, isovalerate, valerate, acetate to propionate ratio and estimated methane production ($P > .10$), consistent with lack of treatment effects on ruminal OM digestion ($P > .10; \text{Table 4}$).

### Table 5. Influence of liquid and dry supplement on ruminal characteristics of fermentation.

| Item                        | Treatment*                  | P-value |
|-----------------------------|-----------------------------|---------|
|                             | DS | LS | LS-MON | LSUF | SEM | DS vs. LS | LS vs. LS-MON | LS vs. LSUF |
| pH, rumen                   | 5.82 | 5.93 | 6.01 | 5.95 | 0.134 | 0.59 | 0.67 | 0.92 |
| Total VFA (mM)              | 119.76 | 110.29 | 100.92 | 96.31 | 6.14 | 0.32 | 0.32 | 0.16 |
| Ruminal VFA (mol/100 mol)   |                |         |         |       |      |      |      |        |
| Acetate                     | 46.08 | 48.09 | 44.78 | 48.23 | 1.51 | 0.38 | 0.17 | 0.95 |
| Propionate                  | 41.13 | 39.75 | 41.37 | 37.54 | 1.51 | 0.54 | 0.48 | 0.34 |
| Isobutyrate                 | 0.64 | 0.78 | 0.60 | 0.77 | 0.10 | 0.35 | 0.26 | 0.94 |
| Butyrate                    | 8.46 | 8.50 | 9.11 | 10.09 | 0.54 | 0.96 | 0.45 | 0.08 |
| Isovalerate                 | 1.46 | 1.25 | 1.95 | 1.33 | 0.32 | 0.66 | 0.17 | 0.86 |
| Valerate                    | 2.23 | 1.63 | 2.19 | 2.05 | 0.34 | 0.25 | 0.28 | 0.41 |
| Acetate:propionate ratio    | 1.14 | 1.21 | 1.12 | 1.31 | 0.09 | 0.60 | 0.48 | 0.48 |
| Methaneb                    | 0.33 | 0.35 | 0.32 | 0.37 | 0.02 | 0.44 | 0.32 | 0.47 |

*DS: Dry supplement; LS: Liquid supplement; LS-MON: LS except that monensin provided as part of the dry supplement; LSUF: LS + Ultraferm (condensed molasses soluble). Treatment 1 had all minerals and monensin in the dry supplement (DS), Treatment 2 had all minerals and the monensin combined with the molasses and was added as a liquid supplement (LS), treatment 3 was the same as treatment 2 except that the monensin was added to the diet in dry form (monensin was not part of the liquid supplement; LS-MON), treatment 4 had molasses plus a soluble protein in liquid supplement (ultraferm blend; LSUF).

bMethane production (mol/mol of glucose equivalent fermented) was estimated based on the theoretical fermentation balance for observed molar distribution of VFA (Wolin 1960).

#### 4. Conclusions

Inclusion of minor dietary ingredients as a dry premix or combined in a liquid molasses carrier will not affect growth-performance and digestive function of feedlot cattle. Ultraferm can partially replace molasses in liquid supplements without detrimental effects on feedlot cattle growth-performance. Replacing supplemental urea with otherwise soluble α-amino N contained in ultraferm increased ruminal starch digestion and reduced ruminal NDF digestion.

### Disclosure statement

No potential conflict of interest was reported by the authors.

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