Novel *Saccharomyces cerevisiae* fermentation product affects growth performance, immune system, and antioxidant capacity of finishing beef steers

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INTRODUCTION

*Saccharomyces cerevisiae* fermentation products (SCFP) have been shown to improve cattle performance and health. Increased final body weight (BW) and average daily gain (ADG) were observed when steers were fed SCFP (Hinman et al., 1998). Increased immunity and antioxidant capacity have also been noted (Deters and Hansen, 2019; Burdick Sanchez et al., 2020; Mahmoud et al., 2020). The beta-agonist ractopamine hydrochloride (RAC) is commonly supplemented to cattle 28 to 42 d before harvest to improve BW, ADG, and feed efficiency (Bittner et al., 2017). Increased serum interleukin-8 (IL-8) concentration and leukocyte numbers indicate an inflammatory response in cattle fed RAC (Genther-Schroeder et al., 2016). Inflammation and changes in innate immunity due to beta-androgenic agonists have been observed in other species (Farsani et al., 2015; Sachett et al., 2018). Therefore, SCFP modulation of immunity and antioxidant capacity of RAC-fed cattle may further support growth and performance. Our objective was to determine the effects of feeding SCFP for 29 or 57 d before harvest on the feedlot performance and immune response of beef steers fed RAC. We hypothesized inclusion of SCFP in diets of finishing steers would improve growth by modulating the inflammatory and oxidative stress response induced by RAC.

MATERIALS AND METHODS

This study was approved by the Iowa State University Institutional Animal Care and Use Committee (IAUCUC # 20-115). Angus-cross steers (288; 435 ± 36 kg) from two sources were utilized in a 90-d finishing study at the Iowa State Beef Nutrition Research Farm (Ames, IA). Prior to trial initiation, steers were transitioned to a corn silage-based finishing diet consisting of 15% silage, 22% Sweet Bran (Cargill Corn Milling, Blair, NE), 48% corn, and 15% dried distillers grain (dry matter [DM] basis).

On day 0, steers were implanted with Component TE-200 with Tylan implant (Elanco Animal Health, Greenfield, IN) and stratified by initial BW into pens (3.7 × 12.2 m; 6 steers per pen; 16 pens per treatment). Pens within block were randomly assigned to one of three treatments: feeding a novel SCFP (Diamond V, Cedar Rapids, IA) 57 d prior to harvest (SCFP57), feeding the novel SCFP 29 d prior to harvest (SCFP29), and feeding no SCFP (control; CON). All steers were fed RAC (Optaflexx, Elanco Animal Health, Greenfield, IN) at 300 mg per steer per day for 29 d before harvest. Supplementation of SCFP was targeted at 12 g per steer per day.
Bunks were scored using a modified slick bunk system as in Drewnoski et al. (2014) with bunk scores and feed delivery recorded daily. Bunk discards and weekly total mixed ration samples were dried at 70 °C for 48 h to determine DM and dry matter intake (DMI) was calculated.

The pretreatment period where a common finishing diet was fed to all treatments was 32 d for group 1 and 34 d for group 2. Supplementation of SCFP and RAC was consistent between groups in relation to harvest with harvest staggered 2 wk apart. Individual BW was collected groups in relation to harvest with harvest stag-

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Blood was collected (n = 3 steers per pen) via jugular venipuncture in sodium heparin vacutainers 57, 29, and 13 d before harvest and in serum vacutainers 29 and 13 d preharvest. Complete blood count at the Iowa State University Veterinary Pathology lab (Ames, IA) was conducted 13 d preharvest, as were flow cytometry measures for B- and T-cell types (Mahmoud et al., 2020). One sodium heparin treated and serum vacutainer were centrifuged at 1,200 × g for 20 min at 4 °C, then aliquoted into microcentrifuge tubes for storage at −80 °C until analysis. Antioxidant status of plasma was measured with a ferric reducing antioxidant power (FRAP) detection kit (FRAP; K043-H1; Arbor Assays, Ann Arbor, MI). In serum samples, IL-8 concentration was measured using the Human IL-8/CXCL8 Quantine ELISA kit (D8000C; R&D Systems, Minneapolis, MN).

Statistical Analysis

Data were analyzed via the Mixed procedure in SAS (Cary, NC) with pen as experimental unit and fixed effects of treatment and group. Least-squared means and SEM are reported. Individual animal BW collected at start of SCFP57 supplementation was a significant covariate in analysis of BW and hot carcass weight (HCW) and was used to decrease model variation. In FRAP analysis, values from 57 d before harvest were used as a covariate. IL-8 data were log-transformed. Outliers were evaluated on an individual animal basis and individual animals were removed if more than 3 SDs from the treatment mean for BW, ADG, carcass characteristics, and blood measures.

### Table 1. Effects of a novel SCFP on live performance and carcass characteristics in beef steers

| Treatments* | Days relative to harvest |
|-------------|-------------------------|
| | CON | SCFP29 | SCFP57 | SEM | P-value |
| Pens | 16 | 16 | 16 |
| BW‡, kg | | | | |
| Day −57 | 520 | 514 | 517 | 1.66 | 0.149 |
| Day −29# | 577b | 578b | 583a | 1.27 | 0.001 |
| Day −13b | 616b | 619b | 622b | 1.72 | 0.03 |
| Day −1 | 641b | 645b | 648b | 2.03 | 0.047 |
| ADG, kg | | | | |
| Day −57 to −29 | 1.99b | 2.01b | 2.22b | 0.044 | 0.001 |
| Day −29 to −1 | 2.34 | 2.39 | 2.32 | 0.053 | 0.662 |
| Day −13 to −1 | 2.15b | 2.20b | 2.27b | 0.035 | 0.052 |
| DMI, kg | | | | |
| Day −57 to −29 | 13.16 | 12.96 | 13.16 | 0.143 | 0.493 |
| Day −29 to −1 | 12.70b | 12.56b | 12.61b | 0.138 | 0.063 |
| Day −13 to −1 | 12.93b | 12.56b | 12.88b | 0.123 | 0.073 |
| G:F | | | | |
| Day −57 to −29 | 0.148b | 0.158b | 0.167b | 0.0032 | 0.001 |
| Day −29 to −1 | 0.182 | 0.192 | 0.183 | 0.0038 | 0.159 |
| Day −13 to −1 | 0.165b | 0.173b | 0.176b | 0.0024 | 0.003 |
| Carcass characteristics | | | | |
| HCW‖, kg | 403.8 | 406.6 | 406.6 | 1.65 | 0.37 |
| Marbling*$ | 483b | 433b | 454ab | 10.8 | 0.007 |
| Backfat, cm | 1.37 | 1.29 | 1.23 | 0.043 | 0.41 |
| KPH | 2.0 | 1.9 | 2.0 | 0.03 | 0.31 |
| Ribeye area, cm² | 87.9 | 89.1 | 88.8 | 0.81 | 0.51 |
| Yield grade | 3.26 | 3.11 | 3.19 | 0.063 | 0.24 |
| Dressing ‡ | 62.9 | 63.0 | 62.7 | 0.21 | 0.56 |

*CON = no SCFP supplementation; KPH = % kidney pelvic heart fat; SCFP29 = SCFP at 12 g per steer per day 29 d prior to harvest; SCFP57 = SCFP at 12 g per steer per day 57 d prior to harvest; all treatments received ractopamine hydrochloride for final 29 d at 300 mg per steer per day.

#Highest SEM of any treatment.

‡BW with 4% pencil shrink.

Day −57 BW covariant used.

*Marbling scores: slight = 300, small = 400, modest = 500.

Within a row, means with unlike superscripts differ P ≤ 0.05.

Within a row, means with unlike superscripts differ 0.1 ≥ P > 0.05.
57 to 29 d before harvest \((P = 0.49)\). There was a tendency \((P = 0.07)\) for greater DMI in CON vs. SCFP29 during the RAC period and the entire treatment period, with SCFP57 being intermediate.

The CON treatment had greater marbling vs. SCFP29, and SCFP57 was intermediate \((P = 0.01)\). Treatment did not affect any other carcass results \((P = 0.24)\).

**Immune and Antioxidant Response**

After 28 d of SCFP supplementation, FRAP was greater in SCFP57 vs. CON, with SCFP29 being intermediate \((P = 0.03; \textbf{Table 2})\). There were no treatment differences 13 or 57 d before harvest in FRAP \((P = 0.24)\). Serum IL-8 concentrations were not different among treatments at either time point \((P = 0.25)\). At the mid-RAC time point, there was greater percentage activated \((\text{CD45RO}+)\) gamma delta \((\text{GD})\) T cells in the SCFP groups compared to CON \((P = 0.02; \textbf{Table 3})\) despite no differences in GD T-cell total concentration \((P = 0.50)\). Supplemented treatments had increased concentrations of natural killer \((\text{NK})\) cells \((P = 0.02)\) but no difference in the percentage of activated NK cells \((P = 0.41)\). Treatment did not affect other immune cell phenotyping measures \((P = 0.18)\).

**DISCUSSION**

In the current study, supplementing late-stage finishing steers with a novel SCFP increased ADG. Hinman et al. (1998) observed improved ADG when supplementing steers with SCFP compared to nonsupplemented controls, while Swyers et al. (2014) reported SCFP supplementation decreased ADG in steers. Others reported no effect on ADG in supplemented cattle (Geng et al., 2016; Shen et al., 2019). Inconsistency in SCFP supported growth may be due to differences in the growth potential of cattle. In this study, both supplemented and control cattle ate and gained exceptionally well, indicative of compensatory gain. Therefore, it is interesting to consider the mechanisms by which the novel SCFP supported growth in these fast-growing steers. In the current study, marbling was increased in nonsupplemented controls compared with SCFP-supplemented cattle, though all treatments averaged low choice.

Total antioxidant capacity was measured using FRAP. After 28 d of SCFP supplementation to SCFP57, FRAP was increased, corresponding with a period of increased growth. Similarly, Deters and Hansen (2019) reported SCFP-fed steers had increased antioxidant capacity leading to better recovery from transit stress. These data suggest feeding SCFP increases antioxidant capacity allowing for better performance.
Immune status can also affect growth and performance (Tidball, 2017). In the present study, increased activated GD T cells and number of NK cells in circulation suggest SCFP changes the innate immune system. Similarly, Mahmoud et al. (2020) observed increased GD and CD4 cells in bronchoalveolar lavage fluid of SCFP-supplemented calves. Another SCFP supplementation study of mastitis challenged dairy cows reported increased phagocytic activity of circulating monocytes and leukocytes after 36 h of challenge in controls only, suggesting SCFP cows managed the infection locally (Vailati-Riboni et al., 2021).

Cytokines are expressed via immune cells and can have many functions relating to health and growth (Lee and Jun, 2019). Decreased proinflammatory cytokines in SCFP-supplemented cattle have previously been observed (Burdick Sanchez et al., 2020). In the current study, while not statistically different, SCFP57 had a numerically lower serum IL-8 concentration after 28 d of SCFP supplementation. Investigating cytokines locally in skeletal muscle may be warranted to determine if inflammation is occurring during growth.

**IMPLICATIONS**

Understanding the physiological effects of high growth rates in cattle is increasingly important as the industry strives to optimize efficiency. In the current study, improvements in innate immunity and antioxidant capacity may have supported the increased growth and performance in SCFP-fed steers. Determining the cytokine and inflammation response within target tissues may help to better understand the mechanisms of SCFP increased growth in feedlot cattle.

**Conflict of interest statement.** The authors declare no conflicts of interest

**LITERATURE CITED**

Bittner, C. J., M. A. Greenquist, D. B. Burken, A. L. Shreck, J. C. MacDonald, T. J. Klopfenstein, W. J. Platter, M. T. Van Koevering, N. A. Pyatt, and G. E. Erickson. 2017. Evaluation of ractopamine hydrochloride (Optaflexx) on growth performance and carcass characteristics of finishing steers across different feeding durations. J. Anim. Sci. 95:485–498. doi:10.2527/jas.2016.0806

Burdick Sanchez, N. C., J. A. Carroll, P. R. Broadway, T. S. Edrington, I. Yoon, and C. R. Belknap. 2020. Some aspects of the acute phase immune response to a lipopolysaccharide (LPS) challenge are mitigated by supplementation with a *Saccharomyces cerevisiae* fermentation product in weaned beef calves. Transl. Anim. Sci. 4:txaa156. doi:10.1093/tas/txaa156

Deters, E. L., and S. L. Hansen. 2019. Effect of supplementing a *Saccharomyces cerevisiae* fermentation product during a preconditioning period prior to transit on receiving period performance, nutrient digestibility, and antioxidant defense by beef steers. Transl. Anim. Sci. 3:1227–1237. doi:10.1093/tas/txz1140

Drewnoski, M. E., P. Doane, and S. L. Hansen. 2014. Ferric citrate decreases ruminal hydrogen sulphide concentrations in feedlot cattle fed diets high in sulphate. Br. J. Nutr. 111:261–269. doi:10.1017/S000711451300210

Farsani, M. N., S. Mohammad, A. Jalali, and M. J. Dehkordi. 2015. Evaluation the meat composition and immunity parameters of rainbow trout (*Oncorhynchus mykiss*) fed by dietary different oil sources, L-carnitine and ractopamine supplement. J. Agric. Biol. Sci. 10:108–115.

Geng, C. Y., L. P. Ren, Z. M. Zhou, Y. Chang, and Q. X. Meng. 2016. Comparison of active dry yeast (*Saccharomyces cerevisiae*) and yeast culture for growth performance, carcass traits, meat quality and blood indexes in finishing bulls. Anim. Sci. J. 87:982–988. doi:10.1111/asj.12522

Genther-Schroeder, O. N., M. E. Branie, and S. L. Hansen. 2016. The effects of increasing supplementation of zinc-amino acid complex on growth performance, carcass characteristics, and inflammatory response of beef cattle fed ractopamine hydrochloride. J. Anim. Sci. 94:3389–3398. doi:10.2527/jas.2015-0209

Hinman, D. D., S. J. Sorensen, and P. A. Momont. 1998. Effect of yeast culture on steer performance, apparent diet digestibility, and carcass measurements when used in a barley and potato finishing diet. Prof. Anim. Sci. 14:173–177. doi:10.15232/S1080-7446(15)31819-2

Lee, J. H., and H. S. Jun. 2019. Role of myokines in regulating skeletal muscle mass and function. Front. Physiol. 10:1–9. doi:10.3389/fphys.2019.00042

Mahmoud, A. H. A., J. R. Slate, S. Hong, I. Yoon, and J. L. McGill. 2020. Supplementing a *Saccharomyces cerevisiae* fermentation product modulates innate immune function and ameliorates bovine respiratory syncytial virus infection in neonatal calves. J. Anim. Sci. 98:1–16. doi:10.1093/jas/jska252

Sachett, A., F. Bevlaqua, R. C. Garbinato, H. Gasparetto, J. Dal Magro, G. M. Conterato, and A. M. Siebel. 2018. Ractopamine hydrochloride induces behavioral alterations and oxidative status imbalance in zebrafish. J. Toxicol. Environ. Health. A 81:194–201. doi:10.1080/15287794.2018.1434484

Shen, Y., T. Davedow, T. Ran, A. M. Saleem, I. Yoon, C. Narvaez, T. A. McAllister, and W. Yang. 2019. Ruminally protected and unprotected *Saccharomyces cerevisiae* fermentation products as alternatives to antibiotics in finishing beef steers. J. Anim. Sci. 97:4323–4333. doi:10.1093/jas/skaa270

Swyers, K. L., J. J. Wagner, K. L. Dorton, and S. L. Archibeque. 2018. Ractopamine hydrochloride induces behavioral alterations and oxidative status imbalance in *Oncorhynchus mykiss* parameters of rainbow trout (*Oncorhynchus mykiss*). J. Toxicol. Environ. Health. A 81:194–201. doi:10.1080/15287794.2018.1434484

Tidball, J. G. 2017. Regulation of muscle growth and regeneration by the immune system. Nat. Rev. Immunol. 17:165–178. doi:10.1038/nri.2016.150

Vailati-Riboni, M., D. N. Coleman, V. Lopreiato, A. Alharthi, R. E. Bucktrout, E. Abdel-Hamied, I. Martinez-Cortes, Y. Liang, E. Trevisi, I. Yoon, et al. 2021. Feeding a *Saccharomyces cerevisiae* fermentation product improves udder health and immune response to a *Streptococcus uberis* mastitis challenge in mid-lactation dairy cows. J. Anim. Sci. Biotechnol. 12:62. doi:10.1186/s40104-021-00560-8