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Feeding fat from distillers dried grains with solubles to dairy heifers: I. Effects on growth performance and total-tract digestibility of nutrients

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ABSTRACT

The objective of this study was to determine if increased dietary fat from dried distillers grains with solubles (DDGS) in diets of growing heifers affected dry matter intake, average daily gain (ADG), growth performance, and nutrient digestibility. Thirty-three Holstein heifers (133 ± 18 d old) were used in a 24-wk randomized complete block design. Treatments were (1) control (CON) containing ground corn and soybean products, (2) low-fat (LFDG) containing low-fat, high-protein DDGS and ground corn, and (3) high-fat (HFDG) with traditional DDGS. All diets contained 39.8% grass hay, 24.8% corn silage, and 1.5% vitamins and minerals. The HFDG diet was formulated to contain 4.8% fat compared with 2.8% in the CON and LFDG diets, which were greater in nonfibrous carbohydrate. Diets had a net energy gain of 1.0 Mcal/kg of dry matter and were limit-fed at 2.45% of body weight. Heifers were weighed every 2 wk and rations were adjusted accordingly. Heart girth, hip and wither heights, body length, and body condition score were recorded every 2 wk. Total-tract digestion of nutrients was evaluated during wk 16 using fecal grab sampling and an external marker. No treatments by time interactions were found. Dry matter intakes, body weights, ADG, and gain-to-feed ratio were similar among treatments; however, ADG averaged 0.96 kg/d among treatments, which is greater than recommended. All body frame measurements and body condition scores were similar among treatments. Total-tract digestibilities of dry matter and organic matter were not different among treatments. However, crude protein and neutral detergent fiber digestibility were increased in the HFDG diet compared with the CON and LFDG diets. These results demonstrate that using DDGS or low-fat DDGS with corn in growing heifer rations can maintain performance. Utilizing the fat in DDGS as a dietary energy source in replacement of starch from corn did not influence growth performance or negatively affect nutrient digestion.

Key words: distillers grains, dairy heifer, dietary fat

INTRODUCTION

Very limited research regarding the feeding of dried distillers grains with solubles (**DDGS**) to growing dairy replacement heifers over long periods of time is available. Only a few studies (Anderson et al., 2009; Suarez-Mena et al., 2013; Schroer et al., 2014) have been published on feeding distillers grains to dairy heifers. These studies typically fed heifers for only a few weeks to a few months and with dietary inclusion rates of distillers grains at less than 25% of diet DM. Despite this lack of research, it has been observed in the field that dairy producers are feeding heifers distillers grains over longer periods because it is economically attractive compared with corn and soybean meal. This is a cause for concern because little substantiated knowledge and only circumstantial evidence exists on how it affects heifer growth performance and nutrient utilization. Some understanding of the effects of feeding distillers grains to dairy heifers can be implied from comparatively abundant research on beef cattle or mature dairy cattle (Klopfenstein et al., 2008; Schingoethe et al., 2009). However, more research on specifically feeding distillers grains to dairy heifers is warranted.

Past research (Klopfenstein et al., 2008; Anderson et al., 2009; Schingoethe et al., 2009) demonstrated that feeding distillers grains can improve feed efficiency. Improvements in efficiency are thought to be from the additional fat, fermentable fiber, and RUP provided by distillers grains, compared with nutrients from corn and soybean meal (Klopfenstein et al., 2008; Schingoethe et al., 2009). When considering whether to feed dairy heifers distillers grains, the additional dietary fat is of particular concern. Traditional dairy heifer diets typically contain between 2 to 3% fat. In research by Anderson et al. (2009), it was noticed that dietary fat was close to 5% when a large portion of the heifer diet was distillers wet grains with solubles. Lammoglia et al., (2000) found with beef heifers that leaner breeds exhib-

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ited increased sensitivity to dietary fat compared with fatter breeds. We speculated that because Holsteins are a leaner breed of cattle an increase from 2 or 3 to 5% dietary fat could alter heifer growth performance.

In the past, the unique composition of distillers grains has made it difficult to formulate experimental diets to examine the specific effects of its fat component without also altering dietary protein or fiber composition. Recently, however, the ethanol industry began to manufacture a new product, low-fat DDGS or reduced-fat DDGS. With low-fat DDGS, diets could be formulated that are close in protein and fiber composition compared with traditional DDGS but different in fat and starch composition. Because of the newness of low-fat DDGS only a few studies have been published on feeding it to ruminants and only one study was found by the authors on feeding it to dairy heifers. Over a 12-wk period, Schroer et al. (2014) fed growing dairy heifers a ration containing low-fat DDGS at 20% of the diet versus a ration containing traditional DDGS at 20% of the diet or a control diet formulated with corn and soybean meal. To make diets isocaloric, Schroer et al., (2014) did vary corn silage and corn grain across treatments, which caused variation in dietary compositions of fiber and fat. Starch and NFC dietary compositions were not reported. Their research found that hip heights, ADG, DMI, and feed efficiency were similar among treatments, indicating that total dietary energy may have more influence on growth performance than form of energy. In contrast to the Schroer et al., (2014) study, we wanted to conduct a longer experiment on feeding DDGS in which only fat and starch content varied, whereas forage fiber content was more consistent across treatments.

The objective of the present study was to determine the effects on growth performance and nutrient digestion of heifers fed increased dietary fat from DDGS over a longer period of time (6 mo). A secondary objective was to compare the 2 distillers grains diets to a control diet containing corn and soybean meal. This helped determine if effects of the fat or starch on protein and fiber utilizations could be detected. Overall effects were determined by measuring a variety of parameters, including gain-to-feed ratios, body frame growth, and total-tract digestibility of DM, CP, and NDF. We hypothesized that when fat from DDGS was fed as a replacement for starch from corn, growth performance would be maintained as dietary energy was formulated to be consistent across treatments. However, it was also hypothesized that total-tract digestibilities of protein and fiber may slightly decrease with additional fat in the diet. Differences in nutrient utilization could also potentially alter growth performance.

MATERIALS AND METHODS

Experimental Design

Thirty-six Holstein heifers (133 ± 18 d old) were used in a randomized complete block design with 3 treatment diets. Three heifers were removed from the study for reasons described herein. Heifers were blocked in groups of 3 based on birth date. After assignment to block, heifers were randomly assigned to treatment. Heifers were started on the study at different times in multiples of 3, with the target of starting to feed treatment diets at 4.5 mo of age. Heifers were acclimated to the barns and feeding system for approximately 2 wk, followed by an experimental feeding period of 24 wk. The feeding portion of the study was completed over a 20-mo period from May 2009 through December 2010, because of the staggered start dates for each group and pen availability.

Treatment diets fed were (Table 1) a corn-soybean meal control diet (**CON**), a diet utilizing a low-fat DDGS with corn (**LFDG**), and a higher-fat diet containing traditional DDGS (**HFDG**). The diets were formulated to be isonitrogenous and isocaloric. Diets were formulated using the NRC (2001) software to provide for 0.8 kg/d of ADG when fed to a 250-kg Holstein heifer at 2.45% of BW on a DM basis. The 250 kg of BW was the rough preestimated average for heifers on the study based on age range and herd data. The HFDG diet was formulated first for high inclusion of DDGS (33.8%) and, consequently, higher fat content compared with the other diets. The HFDG was formulated to be 4.8% ether extract (**EE**) versus 2.6% EE in the LFDG and CON diets. After the HFDG diet was formulated, the LFDG and CON diets were formulated for similar energy and CP content. Diets were formulated to provide 16.3% CP, 9.8% RDP, and 6.5% RUP as a percent of DM. The protein sources in the LFDG and HFDG were formulated to be similar in protein composition by using low-fat DDGS with corn in LFDG and traditional DDGS in HFDG. This also resulted in close formulation of other nutrients between these 2 diets, such as nonforage fiber, allowing for the observation of specific effects of fat from DDGS. The RUP and RDP concentrations were balanced in CON to match the concentration in DDGS diets by using expeller soybean meal and regular soybean meal as protein sources. The expeller soybean meal also helped to balance the formulated EE content between the LFDG and CON diet. Comparison of the 2 diets containing DDGS to CON allowed for observation of the effects of fat versus starch on the utilization of other nutrients such as protein and fiber.

Table 1. Ingredient composition for a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG) fed to growing Holstein heifers[1]

	Diet		
Ingredient, % of DM	CON	LFDG	HFDG
Grass hay	39.79	39.78	39.79
Corn silage	24.86	24.86	24.85
DDGS	—	—	33.80
Low-fat DDGS	—	21.88	—
Corn grain, ground	15.91	11.93	—
Soybean meal, 44% CP	8.95	—	—
Expeller soybean meal[2]	8.95	—	—
Limestone	0.40	0.40	0.40
Mineral premix[3]	0.78	0.78	0.80
Salt[4]	0.36	0.36	0.36

[1]Formulated using NRC (2001).

[2]SoyPlus (West Central Cooperative, Ralston, IA).

[3]Contained 2.2 g/kg of lasalocid sodium, 16.05% Ca, 10.0% P, 20.45% NaCl, 2.0% Mg, 0.7% K, 0.8% S, 5,520 mg/kg of Zn, 3,700 mg/kg of Mn, 1,000 mg/kg of Fe, 1,010 mg/kg of Cu, 86 mg/kg of I, 25 mg/kg of Co, 53 mg/kg of Se, 704,000 IU/kg of vitamin A, 140,800 IU/kg of vitamin D_3, and 5,280 IU/kg of vitamin E (Future Cow Supreme Premix B2000, Land O' Lakes Inc., St. Paul, MN).

[4]Heifers were provided ad libitum access to white salt (NaCl) blocks, which are not accounted for in these values.

Ethanol by-products have been found to vary significantly by time of production within plant and between different plants (Powers et al., 1995; Kleinschmit et al., 2007). To avoid this confounding factor, enough traditional DDGS and low-fat DDGS to last throughout the study (20 mo) were purchased at the start of the experiment and stored at the South Dakota State University feed mill. Hay was purchased in 2 batches by year, with efforts made to match the nutrient composition between years. Corn silage source varied over the course of the study; however, forage dietary inclusion rates were kept equal across diets (Table 1), minimizing impact on treatment effects.

Animal Care and Feeding

All aspects of the heifer experimental use and care were approved by the South Dakota State University Institutional Animal Care and Use Committee. The farm portion of the experiment was completed in its entirety at the South Dakota State University Dairy Research and Training Facility. Animals were observed daily for any health problems and treated according to routine management practices at the Dairy Research and Training Facility.

Heifers were housed in pens in groups of 3 or 6 heifers. Each pen had an inside roofed area and an outside small dirt exercise lot. The inside areas of the pens were manure pack, bedded only once every 2 wk with straw. Water and white salt (NaCl) blocks were provided ad libitum to each pen. Heifers were fed once daily at approximately 0900 h using the Calan gate feeding systems (American Calan Inc., Northwood, NH) so that individual intakes could be measured. As mentioned, rations were limit-fed to 2.45% of BW (DM basis). Rations were adjusted every 2 wk based on BW measurements and DM analysis of feeds. Diet components (hay, corn silage, and grain mixes) were individually weighed into a large tub for each heifer and then hand-mixed into a TMR before being placed in the Calan boxes. Bales of hay were coarsely preground with a large vertical tub grinder to ease hand mixing. Sorting was not an issue because rations were limit-fed and heifers consumed the majority of the feed offered on most of d during the feeding period. Any feed refusals were weighed and recorded in the morning before feeding to determine daily intakes. Samples of hay, corn silage, and grain mixes were taken each week and stored at −20°C until processing and analysis could be completed as described herein.

Animal Measurements and Sampling

Body growth measurements, including BW, withers and hip heights, heart girth, and body length, were taken on 2 consecutive days at 5 h postfeeding at the start of the study and then every 2 wk throughout the study. Body length was measured from the point of the withers to the end of the ischium (Hoffman, 1997). Body condition scores were recorded every 2 wk by 3 independent observers based on a quarter-point scale, with 1 being emaciated and 5 being obese (Wildman et al., 1982).

Samples for analysis of total-tract nutrient digestibility were collected during wk 16 of the feeding period. Titanium dioxide was used as an external marker. Starting 10 d before the collection period, 10 g of TiO_2 was mixed in the daily allotment of concentrate mix for each heifer. Over 3 d in wk 16, orts and fecal grab samples were collected. As heifers were being limit-fed, only a few had any orts samples during the collection period. The fecal grab sampling was scheduled such that samples would represent every 3 h over the 24-h period relative to time of feeding. Orts and fecal samples were stored at −20°C until processing and analysis could be completed.

Laboratory Analysis

Feed samples were dried for 24 h at 105°C every 2 wk for DM analysis to check for dietary ingredient inclusion rates and determine DMI. Samples of concentrate mixes, hay, and corn silage were collected once weekly and kept frozen (−20°C) until processing for analysis. At processing time, feeds were thawed and samples from 4 consecutive weeks were composited on an as-fed basis. Concentrate mix ingredients (corn, soybean meal, expeller soybean meal, DDGS, and low-fat DDGS) were sampled for each batch of concentrate mix made (5 batches total over the 20 mo). Composite samples and concentrate ingredients were dried in duplicate for 48 h at 55°C in a Despatch oven (Style V-23, Despatch Oven Co., Minneapolis, MN). Forage composites were first ground to 4-mm particle size with a Wiley Mill (model 3; Arthur H. Thomas Co., Philadelphia, PA). Ground forages and concentrates were then reground to 1-mm particle size using an ultracentrifuge mill (Brinkman Instruments Co., Westbury, NY). To correct analysis to 100% DM, 1-g aliquots of samples were dried for 4 h in a 105°C oven. Ash content was analyzed by incinerating a 1-g sample for 8 h at 450°C in a muffle furnace (AOAC International, 2002; method 942.05). Organic matter was calculated as OM = (100 − %Ash). Samples were analyzed for nitrogen content via Dumas combustion analysis (AOAC International, 2002; method 968.06), on a Rapid N cube (Elementar Analysensysteme, GmbH, Hanau Germany). Nitrogen content was then multiplied by 6.25 to calculate CP. Neutral detergent fiber (Van Soest et al., 1991) and ADF (Robertson and Van Soest, 1981) were analyzed sequentially using the Ankom 200 fiber analysis system (Ankom Technology Corp., Fairport, NY). For the NDF, heat-stable α-amylase and sodium sulfite were used; also, samples with fat concentration expected to be greater than 5% were presoaked in acetone before NDF analysis, according to procedure recommendations. Ether extracts were analyzed using diethyl ether (AOAC International, 2002; method 920.39) in an Ankom XT10 fat analysis system (Ankom Technology Corp.). Nonfibrous carbohydrates were calculated as %NFC = 100 − (%Ash + %CP + %NDF + %EE) according to the NRC (2001).

Dried and ground samples of concentrate mixes and forages were further composited into 4- or 5-mo composites to yield 2 per year (2009 or 2010). Dried and ground samples of ingredients comprising the concentrate mixes were further composited by year (1 per year for 2009 or 2010). These larger composites were then sent to a commercial laboratory (Analab Inc., Fulton, IL) for analysis of minerals, starch, and oil. Mineral composition analyses included Ca, P, Mg, K, Na (AOAC International, 1998; method 985.01), S (AOAC International, 1998; method 923.01), and Cl (AOAC International, 1998; method 915.01). Oil and starch compositions were analyzed using near-infrared spectroscopy to compare with analysis of EE and calculated NFC values from analysis of monthly samples.

Fecal and orts samples for each heifers were composited on an as-is basis by volume. One hundred-milliliter aliquots of fecal samples were taken from each time point and composited. As heifers were limit-fed, only a few had any orts during collection, and most of these samples were on only a single day during the collection period. When orts were present on multiple days, equal portions, depending on the amount of sample available, were composited from each day. Samples were then processed (dried and ground) as described for the monthly feed composites. Fecal and orts samples were analyzed for DM, ash, CP, NDF, and ADF as previously described for feeds. Titanium dioxide concentration in both fecal and orts samples was analyzed according to procedures described by Myers et al. (2004), with minor modifications as described by Herrick et al. (2012). Digestion of the samples with sulfuric acid was performed using 250-mL micro-Kjeldahl digestion tubes for 2 h at 420°C on micro-Kjeldahl digestion block (Foss North America, Eden Prairie, MN). After samples were cooled, 30% hydrogen peroxide was added to produce a color change. Samples were then read using Cary 50 Bio UV Visible Spectrophotometer (Varian Inc., Palo Alto, CA) with a wavelength of 410 nm. These analyses were then used to calculate total-tract digestibility of DM, OM, CP, ADF, and NDF for each heifer.

Statistical Analysis

Data were compiled for feed analysis and standard errors were calculated using the MEANS procedure in SAS version 9.3 (SAS Institute Inc., Cary, NC). Total dietary nutrient values were calculated based on analysis of concentrate mixes, corn silage, and hay for each treatment over the course of the study.

Heifer intake and growth data were analyzed in a randomized complete block design with repeated measures using MIXED procedures (Littell et al., 2008). The model included treatment, week, and treatment by week interactions. Initial body size measurements and BW were included as covariates within the model. Repeated measures by week of the feeding period were done on intakes, BW, and body measures using block as the subject. Akaike's criterion was used to determine the most suitable covariance structure in repeated measures for each parameter. Least squares means for each treatment are reported in the tables and were separated using Tukey's test. Significant differences among treatments were declared at $P \leq 0.05$ and tendencies were declared at $0.05 < P \leq 0.10$.

Regression procedures of SAS were used to determine average change per day (slope) for ADG and body frame measurements. The *P*-values for the interaction term of treatment and time from MIXED procedure analysis were used to determine if change over time was significantly different among treatments (Kutner et al., 2004). Gain-to-feed ratio was calculated as the ratio of ADG (slope of BW regression) to DMI for each treatment.

The MIXED procedures of SAS were used for analysis of data for the total-tract digestibility of nutrients. The model included only treatment with block included as a random variable. Similar to the growth data, least squares means for each treatment are reported in the tables and were separated using Tukey's test.

RESULTS

Feed Analysis

Table 2 presents the nutrient composition based on laboratory analyses of the distillers grains, concentrate mixes, and forages used. The average nutrient composition of diets was calculated based on component (concentrate mix, corn silage, and hay) analysis over the course of the study and is presented in Table 3. The corn silage and hay nutrient compositions were consistent over the study; however, percent DM fluctuated, mainly because of weather and humidity changes. Low-fat DDGS had 41.6% CP versus 30.6% in traditional DDGS. Overall, the dietary CP was formulated to be 16.3% and actual diets were fairly close to this value. Crude protein was slightly lower in the CON diet and slightly higher in the HFDG because of variation in the CP of the soybean products and traditional DDGS from values used for formulation. Ether extract was much greater, at 15.2% in traditional DDGS versus 4.30% in low-fat DDGS. Ether extracts of the corn, soybean meal, and expeller soybean meal were 3.7, 1.2, and 6.0%, respectively. This allowed for CON diet to have only 2.91% EE (Table 3), which is in range of EE found in traditional heifer diets. In general EE values were large for DDGS, which is because diethyl EE was used instead of petroleum EE (Cao et al., 2009). Fat concentration, as measured by diethyl EE and near-infrared oil analyses, was doubled in the HFDG diet compared with the CON and LFDG diets, which aligned with the study objectives. Starch was doubled in the CON and LFDG diets compared with the HFDG diet, which also aligned with study objectives. Fiber composition was very similar between the formulated and analyzed diets. There was more nonforage NDF with the addition of DDGS and low-fat DDGS to the diet compared with CON. Minerals did vary between the formulated diets and the analyzed diets, but based on heifer skeletal growth and ADG performance, concentrations were adequate to meet requirements and support growth. There was more sulfur in the low-fat DDGS compared with the traditional DDGS. Dilution of the low-fat DDGS with corn in the LFDG concentrate mix decreased the difference between diets some and then further dilution with forages put the sulfur content of the 2 DDGS diets within a closer range. When nutrient composition of ingredients based on analysis was reentered into the NRC (2001) software, the energy values of the analyzed diets were consistent with original formulations across treatments. However, heifer growth performance indicated that estimated of dietary energy content was underestimated or that heifer requirements were over-predicted.

Heifer Performance

Three heifers had to be removed from the study because of reasons unrelated to treatments. Two heifers left the study a few weeks into the experimental period for health reasons; one developed coccidiosis and the other had hardware disease. A third heifer had significant problems adapting to the Calan door feeding system and no replacement heifer of comparable size and age was available for substitution. The loss of these heifers resulted in 11 heifers per treatment instead of 12. A fourth heifer was only kept on study until wk 16 and then removed because she started stealing from and severely bullying pen mates at feeding time. Her data were kept in the growth data set for the weeks she completed and for total-tract nutrient digestibility analysis.

Body weight, DMI, and gain-to-feed results are presented in Table 4 and no treatment effects or interactions of treatment by week were found for these 3 parameters. Average daily gains, found by regression analysis of BW, were similar among treatments. Dry matter intakes were similar among treatments and increased over time. This was anticipated as heifers were limit-fed based on a percentage of BW. Gain-to-feed ratios decreased over time because the nutrient requirements for maintenance increases with BW, but the ratio of feed to overall BW was held constant over the feeding period.

Frame size measurements and BCS are presented in Table 5. Similar to BW findings, heifer frame sizes were not different among treatments and increased over the course of the study. Likewise, no interactions of treatment by week were noted for frame size measurements. Heifers grew daily approximately one-tenth of a centimeter in height, approximately 0.12 cm in length, and approximately 0.18 cm in heart girth. Body condition scores were similar across treatments, with minor increases per day. Over the 24-wk feeding period average BCS went from approximately 2.97 to 3.11, which

Table 2. Nutrient composition of the concentrate mixes, distillers grains, and forages used to make the TMR of a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG)

Item, % of DM (unless otherwise indicated)	Concentrate mix						Dried distillers grains with solubles (DDGS)				Forage			
	CON		LFDG		HFDG		DDGS		Low-fat DDGS		Hay		Corn silage	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
DM,[1] %	86.3	0.22	88.5	0.28	85.5	0.29	89.0	0.97	94.6	0.57	83.9	0.76	28.9	0.62
Ash[1]	7.65	0.178	5.55	0.148	8.16	0.239	4.75	0.280	2.22	0.10	7.67	0.254	5.11	0.149
OM[1]	92.3	0.18	94.5	0.15	91.8	0.24	95.3	0.28	97.8	0.10	92.3	0.25	94.9	0.15
CP[1]	27.3	0.20	28.6	0.17	29.76	0.16	30.6	0.82	41.6	0.60	9.52	0.373	9.75	0.344
ADF[1]	3.91	0.04	5.15	0.102	8.66	0.163	10.0	0.94	8.3	0.43	40.0	0.97	24.8	0.72
NDF[1]	11.7	0.11	18.4	0.187	30.04	0.439	32.1	0.44	26.2	0.79	67.5	1.19	44.3	1.03
Ether extract[1]	3.10	0.121	3.59	0.129	14.78	0.205	15.2	0.48	4.30	0.08	1.69	0.061	4.56	0.061
Oil[2]	2.67	0.05	3.41	0.062	10.55	0.195	10.81	0.065	5.44	0.115	1.02	0.097	2.50	0.050
NFC[1,3]	50.3	0.23	43.9	0.31	17.3	0.51	17.3	0.56	25.1	1.09	13.6	1.11	36.3	1.24
Starch[2]	39.3	0.53	35.1	0.14	4.5	0.58	4.6	0.62	11.1	1.02	ND[4]	ND	26.7	2.17
S[2]	0.26	0.003	0.54	0.013	0.45	0.065	0.58	0.035	0.83	0.025	0.11	0.006	0.07	0.008

[1]Results from analysis of monthly composites (n = 19).
[2]Results from analysis of 4- or 5-mo composites (n = 4).
[3]%NFC = 100 − (% Ash + % CP + % NDF + % ether extract) (NRC, 2001).
[4]ND = not determined.

indicates no treatment diet promoted excess body fat deposition or over conditioning.

Total-Tract Nutrient Digestion

The total-tract nutrient digestibilities are presented in Table 6. Digestibilities of DM and OM were similar among treatments. Digestibility of CP was greater ($P = 0.02$) in heifers fed HFDG compared with heifers fed the CON and LFDG diets. Heifers fed the HFDG diet had greater ($P = 0.02$) NDF digestibility compared with LFDG fed heifers, with heifers fed CON similar to both.

DISCUSSION

Overall, the nutrient compositions of treatment diets were on target with the objectives of this research. Fat was doubled and starch was approximately half in the HFDG diet compared with LFDG and CON diets. Composition of fiber and total CP were close between HFDG and LFDG diets. The CON diet was very close in composition to LFDG, although slight variation in nonforage fiber was observed. Therefore, true to experimental design, the major difference between diets was the nutrient supplying the energy (fat vs. NFC or starch). The similarity in energy density of the diets was further illustrated by the consistent ADG among treatments. In past research conducted with feeding ensiled wet distillers grains (Anderson et al., 2009), heifers were allowed ad libitum intake resulting in ADG that were greater than in the current study. To ensure diet palatability did not lead to over consumption and overweight heifers, confounding our objectives to evaluate energy source, it was decided to limit feed DMI to 2.45% of BW. Despite being limit-fed, displays of hunger behavior, such as vocalization and agitation, were not prevalent because the diets were high in forage and were fed at a relatively moderate percentage of BW. It was observed (although no formal observations were conducted) that several hours after feeding heifers still had feed left, although rations were consumed within the 24-h period relative to the morning feeding. The only time any vocalization or agitation was noted was in the morning right before feeding time. When limit-feeding heifers, consumption of bedding material can be an issue, but in the current study we limited bedding to approximately every 2 wk on the day after body measurements took place to avoid consumption and interference with experimental measures.

In our study, the frame growth and ADG was similar among treatments, which is in agreement with findings from other research on limit-feeding heifers for similar energy intakes among treatments (Zanton and Hein-

Table 3. Nutrient composition of a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG) fed to dairy heifers

Item, % of DM (unless otherwise indicated)	Treatment					
	CON		LFDG		HFDG	
	Mean	SE	Mean	SE	Mean	SE
DM,[1] %	71.0	0.38	71.8	0.40	70.7	0.41
OM[1]	93.0	0.11	93.7	0.11	92.8	0.13
Ash[1]	7.02	0.11	6.29	0.11	7.20	0.13
CP[1]	15.8	0.16	16.3	0.18	16.7	0.17
ADF[1]	23.6	0.52	24.0	0.51	25.2	0.50
NDF[1]	42.2	0.68	44.5	0.68	48.6	0.614
Ether extract[1]	2.91	0.050	3.08	0.052	7.00	0.075
Oil[2]	1.97	0.023	2.22	0.039	4.72	0.067
NFC[1,3]	32.1	0.70	29.9	0.70	20.6	0.63
Forage NDF[1]	38.1	0.68	38.1	0.68	38.1	0.68
Nonforage NDF[1]	4.08	0.039	6.44	0.066	10.51	0.154
Starch[2]	20.4	0.64	19.0	0.54	8.3	0.94
Ca[2]	0.54	0.040	0.48	0.021	0.49	0.137
P[2]	0.33	0.007	0.29	0.005	0.44	0.007
Mg[2]	0.20	0.003	0.16	0.003	0.24	0.001
K[2]	1.23	0.116	0.90	0.111	1.15	0.114
S[2]	0.16	0.002	0.25	0.005	0.22	0.023
Na[2,4]	0.19	0.044	0.22	0.044	0.22	0.046
Cl[2,4]	0.32	0.030	0.33	0.018	0.41	0.028
ME,[5] Mcal/kg of DM	2.48	—	2.45	—	2.46	—
NE_G,[5] Mcal/kg of DM	0.97	—	0.96	—	0.96	—

[1]Results from analysis of monthly composites (n = 19).

[2]Results from analysis of 4- or 5-mo composites (n = 4).

[3]% NFC = 100 − (% Ash + % CP + % NDF + % ether extract) (NRC, 2001).

[4]Heifers were provided ad libitum access to white salt (NaCl) blocks, which are not accounted for in these values.

[5]Values are calculated based on inputting sample nutrient analysis into ration formulations in the Dairy NRC (2001) computer program.

richs, 2007). Despite being able to cause similar ADG among treatments, in our study ADG averaged 0.96 kg/d across treatments, which was greater than the recommended 0.8 kg/d (Zanton and Heinrichs, 2005). The NRC (2001) software was used to formulate the diets. These results demonstrate that it overestimates the energy requirements by growing dairy heifers. Additionally, the NRC (2001) may underestimate the energy

Table 4. Intakes, BW, and gain-to-feed ratios for Holstein heifers fed a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG) for 24 wk

Item	Treatment			SEM	*P*-value		
	CON	LFDG	HFDG		Treatment	Week	Treatment × week
Age, initial, d	129.8 ± 19.06	134.6 ± 18.63	134.3 ± 17.91				
BW, kg							
Mean	254.6	250.7	252.9	3.99	0.79	<0.01	0.98
Initial	168.8[b]	175.6[a]	170.6[ab]	2.02			
Final	329.2	322.2	325.3	7.05			
ADG,[1] kg/d	0.95 ± 0.055	0.96 ± 0.067	0.98 ± 0.054	—			
DMI, kg							
Mean	6.97	7.12	6.92	0.310	0.86	<0.01	0.83
Final	9.20	9.18	8.99	0.380			
Gain:Feed							
Mean	0.153	0.148	0.153	0.008	0.88	<0.01	0.82
Final	0.108	0.107	0.111	0.005			

[a,b]Values with unlike superscripts differ within row ($P < 0.05$).

[1]Calculated using regression analysis of BW over the day of the study.

Table 5. Frame size measurements for Holstein heifers fed a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG) for 24 wk

Item	Treatments			SEM	*P*-value		
	CON	LFDG	HFDG		Treatment	Week	Treatment × week
Withers height, cm							
Mean	116.4	115.4	115.4	0.60	0.36	<0.01	0.20
Initial	102.2	105.8	104.5	0.66			
Final	124.8	123.5	123.9	0.73			
Change,[1] cm/d	0.115 ± 0.008	0.115 ± 0.007	0.123 ± 0.007	—			
Hip height, cm							
Mean	120.2	119.8	120.0	0.41	0.77	<0.01	0.96
Initial	108.2	109.6	108.0	0.58			
Final	128.9	127.7	128.2	0.48			
Change,[1] cm/d	0.120 ± 0.012	0.109 ± 0.008	0.111 ±.007	—			
Body length, cm							
Mean	104.9	104.9	104.7	0.68	0.97	<0.01	0.29
Initial	90.8	90.9	89.4	0.68			
Final	114.1	114.1	115.0	0.92			
Change,[1] cm/d	0.121 ± 0.011	0.131 ± 0.010	0.141 ± 0.010	—			
Heart girth, cm							
Mean	140.2	140.5	140.4	1.49	0.99	<0.01	0.92
Initial	106.3	109.8	108.3	1.16			
Final	155.2	154.3	154.6	1.89			
Change,[1] cm/d	0.183 ± 0.010	0.185 ± 0.012	0.185 ± 0.012				
BCS							
Mean	3.09	3.06	3.08	0.020	0.49	0.01	0.45
Initial	2.92	2.99	3.01	0.017			
Final	3.11	3.13	3.09	0.035			

[1]Calculated using regression analysis of body measurement over the day of the study.

content of distillers grains (Schingoethe et al., 2009). The ADG in our study was closer to the recommended ADG compared with other research studies with distillers grains (Anderson et al., 2009; Schroer et al., 2014). When Schroer et al. (2014) fed traditional DDGS versus reduced-fat DDGS at 20% of the diet they also found similar intakes and growth performance among treatment; however, they allowed heifers ad libitum intake of experimental diets and had ADG of approximately 1.14 kg/d. When Anderson et al. (2009) allowed for ad libitum intake diets containing large inclusion rates of distillers wet grains ensiled with soyhulls, ADG close to or greater than 1 kg/d were also found. Results from these studies and the current study indicate that distillers wet grains or DDGS are highly palatable and have underestimated amounts of energy. The current study demonstrates that limit-feeding could work to limit ADG when feeding DDGS, but that rate of feeding must be less than what is currently predicted by NRC (2001) to achieve the 0.8 kg/d recommended by Zanton and Heinrichs (2005).

Table 6. Total-tract digestibility of nutrients by Holstein heifers fed a control diet (CON), a diet containing low-fat dried distillers grains with solubles (LFDG), and a high-fat diet containing traditional dried distillers grains with solubles (HFDG)

Item, % digested	Treatment			SEM
	CON	LFDG	HFDG	
DM	69.3	68.0	69.0	0.76
OM	72.0	70.6	71.7	0.75
CP	69.8[b]	70.1[b]	73.1[a]	0.88
NDF	58.4[ab]	57.8[b]	61.2[a]	1.09
ADF	55.3[ab]	53.7[b]	57.0[a]	1.35

[a,b]Values with unlike superscripts differ within a row ($P < 0.05$).

Most importantly, the findings of the current project also agree with many past research projects which demonstrated that distillers grains could maintain performance of ruminants compared with corn and soybean meal, as highlighted in reviews by Klopfenstein et al. (2008) and Schingoethe, et al. (2009). Meaning that decision on whether to feed traditional DDGS, low-fat DDGS with corn, or corn with soybean products can be made based on feed pricing.

Contrary to the original hypothesis, when traditional DDGS were included in the ration, total-tract digestibilities of CP and fiber were increased rather than decreased. Fat from DDGS in sheep research was found not to alter total-tract digestibilities of DM, OM, NDF, ADF, or CP compared with a control and free oil treatment (Redding et al., 2012). However, our results agreed with findings by Ranathunga et al. (2012), who found that ruminal digestion of NDF in mature dairy cows was improved in high-forage diets containing

DDGS compared with high-concentrate diets containing DDGS. Because the fat from DDGS is bound in the feed particle and slowly introduced to the rumen, we believe it could have less adverse effects on the rumen compared with other dietary fat sources. It is speculated that the relatively low starch content in the HFDG diet may have encouraged more efficient fiber utilization in the rumen. The amount of CP digestion agreed with findings by Kleinschmit et al. (2007), who found that, based on rumen in situ procedures followed by in vitro intestinal digestion procedures, total digestible protein in distillers grains could range from 70.7 to 84.9%. Mjoun et al. (2010) found that total digestible protein in distillers grains could range up to 96%. In our research total-tract digestion of the complete diets, which included low-protein forages, was approximately 77%. It was speculated that because of the low starch content in the HFDG diet, efficiency of utilization of CP may be increased, resulting in improved total-tract digestion compared with the CON and LFDG diets. However more in-depth research would be necessary to test this hypothesis. Starch digestibility was not measured in our research, but we believe that differences in diet content and utilization of starch or NFC among treatments accounts for why digestibility of DM and OM were similar among treatments, whereas CP and NDF digestibility differed.

CONCLUSIONS

In agreement with our hypothesis, growing dairy heifers performed equally well when limit-fed high-forage diets that contained corn and soybean products, low-fat DDGS with ground corn, or traditional DDGS. Body frame growth and ADG were similar among treatments. Limit-feeding diets with distillers grains was moderately more successful at achieving target ADG compared with past research that allowed ad libitum intakes; however, ADG was still 20% greater than recommended. In contrast, with our second hypothesis, providing energy in the form of dietary fat from DDGS may slightly improve digestion and utilization of NDF and CP compared with providing energy as starch with low-fat DDGS. With advances in ethanol production, more fat-extracted DDGS may become available. This research indicated dairy producers can use these new products or traditional DDGS to feed heifers, as long as energy content of DDGS is accounted for, without consequences to heifer growth performance.

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