Effects of feeding diets based on transgenic soybean meal and soybean hulls to dairy cows on production measures and sensory quality of milk

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ABSTRACT

This experiment was conducted to determine whether feeding meal and hulls derived from genetically modified soybeans to dairy cows affected production measures and sensory qualities of milk. The soybeans were genetically modified (Event DAS-444Ø6–6) to be resistant to multiple herbicides. Twenty-six Holstein cows (13/treatment) were fed a diet that contained meal and hulls derived from transgenic soybeans or a diet that contained meal and hulls from a nontransgenic near-isoline variety. Soybean products comprised approximately 21% of the diet dry matter, and diets were formulated to be nearly identical in crude protein, neutral detergent fiber, energy, and minerals and vitamins. The experimental design was a replicated 2 × 2 Latin square with a 28-d feeding period. Dry matter intake (21.3 vs. 21.4 kg/d), milk yield (29.3 vs. 29.4 kg/d), milk fat (3.70 vs. 3.68%), and milk protein (3.10 vs. 3.12%) did not differ between cows fed control or transgenic soybean products, respectively. Milk fatty acid profile was virtually identical between treatments. Somatic cell count was significantly lower for cows fed transgenic soybean products, but the difference was biologically trivial. Milk was collected from all cows in period 1 on d 0 (before treatment), 14, and 28 for sensory evaluation. On samples from all days (including d 0) judges could discriminate between treatments for perceived appearance of the milk. The presence of this difference at d 0 indicated that it was likely not a treatment effect but rather an initial bias in the cow population. No treatment differences were found for preference or acceptance of the milk. Overall, feeding soybean meal and hulls derived from this genetically modified soybean had essentially no effects on production or milk acceptance when fed to dairy cows.

Key words: transgenic, soybeans, herbicide resistance, milk production, sensory analysis

INTRODUCTION

Feedstuffs derived from transgenic corn, soybeans, alfalfa, and cottonseed are commonly fed to dairy cattle. Several papers have been published comparing effects of feeding diets containing feed produced from transgenic plants with feed from conventional plants to dairy cows and no adverse effects have been reported (Donkin et al., 2003; Grant et al., 2003; Ipharraguerre et al., 2003; Castillo et al., 2004; Combs and Hartnell, 2008; Brouk et al., 2011). A recent review (Van Eenennaam and Young, 2014) reached the conclusion that food produced from animals (including meat, milk, and eggs) fed genetically engineered feeds did not differ from food produced by animals fed conventional feedstuffs.

Feed consumed by cows can affect the sensory qualities of milk and dairy products (Coulon and Priolo 2002; Steinshaman 2010; Kalac, 2011; Larsen et al., 2013). For example, diet-induced changes to protein and fat levels (Coulon and Priolo, 2002; Steinshaman, 2010; Kalac, 2011), FA composition (Coulon and Priolo, 2002; Steinshaman, 2010; Kalac, 2011), and volatile aroma compounds including hydrocarbons, terpenes, alcohols, aldehydes, ketones, esters, and sulfur compounds (Kalac, 2011) can have significant effects on the color and aroma properties of milk (Larsen et al., 2013). Although transgenic feeds are substantially equivalent nutritionally to their conventional counter parts, effects of feeding transgenic feeds to dairy cows on the sensory properties of milk have not been evaluated.

A new transgenic soybean was produced by modifying the soybean (*Glycine max*) line Maverick (Sleper et al., 1998) to produce event DAS-444Ø6–6 soybean (Dow AgroSciences, Indianapolis, IN) by the insertion of a single vector containing 3 genes; the *aad-12* gene from *Delftia acidovorans*; *2mepsps*, a modified version of the *epsps* gene from *Zea mays*; and the *pat* gene from *Streptomyces viridochromogenes*. The *aad-12* gene encodes aryloxyalkanoate dioxygenase-12, which provides tolerance to the herbicide 2,4-dichlorophenoxyacetic acid (Wright et al., 2010). The *2mepsps* gene encodes for a modified EPSPS protein, which provides toler-

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Table 1. Nutrient composition (DM basis) of meal and hulls produced from conventional (isoline) or transgenic soybeans

Item	Soybean meal		Soybean hulls	
	Isoline	Transgenic	Isoline	Transgenic
DM, %	93.9 (0.48) ¹	94.9 (0.45)	91.8	91.5
CP, %	52.5 (0.57)	50.7 (0.60)	16.9	16.7
NDF, %	10.1 (0.31)	11.7 (0.68)	59.9	57.3
ADF, %	5.8	6.6	43.4	42.5
Ash, %	6.3 (0.07)	6.7 (0.07)	4.8	4.9
Ca, %	0.39	0.43	0.61	0.59
P, %	0.70	0.73	0.17	0.22
Mg, %	0.30	0.31	0.22	0.21
K, %	2.5	2.6	1.4	1.5
Cu, mg/kg	18	20	8	10
Fe, mg/kg	98	109	303	319
Mn, mg/kg	36	35	17	16
Zn, mg/kg	55	59	34	36

¹Values in parentheses are the SD (n = 5). Nutrients without an SD were conducted on a single sample composited from the 5 original samples.

ance to the glyphosate herbicide (Herouet-Guicheney et al., 2009). The *pat* gene encodes phosphinothricin acetyl transferase protein, which provides tolerance to glufosinate-based herbicides (Hérouet et al., 2005).

We hypothesized that cows fed soybean meal and soybean hulls produced from transgenic soybeans (DAS-44406-6) would have similar milk production measures and produce milk with similar sensory properties as cows fed conventional soybean meal and hulls when fed in nutritionally equal diets. An experiment was conducted to compare the nutritional value of diets based on soybean meal and hulls produced from DAS-44406-6 soybeans with a similar diet containing soybean meal and hulls produced from nontransgenic Maverick soybeans (isoline) when fed to dairy cows. Sensory properties of the milk produced from the cows were also compared.

MATERIALS AND METHODS

Production Study

Test Material and Diets. Transgenic soybeans (DAS-44406-6) and a nontransgenic, near-isoline (var. Maverick) soybean were harvested from plots in Tolono, Illinois, during the 2013 growing season. Soybeans were processed into toasted soybean meal under commercial processing conditions and the hulls retained. Nutrient composition of the meals and hulls were determined by Covance Laboratories Inc. (Madison, WI) using methods previously described in Herman et al. (2011). Although nutrient composition of both DAS-44406-6 and isoline soybeans were similar, a larger proportion of the hull remained on the cotyledon during the dehulling process for the transgenic soybean, resulting in higher

NDF content of the transgenic meal compared with the isoline meal (Table 1). Thus, for diet formulation, incorporation rates of soybean meal and hulls differed between treatments; however, the concentration of total soy products was essentially equal between treatments and soy products contributed similar amounts of CP and NDF to both diets (Table 2).

Study Design. A replicated (13 squares) 2 × 2 Latin square experiment with 28-d feeding periods was used to compare diets containing transgenic soybean meal and hulls to diets containing the isoline products (Tables 2 and 3). Diets met or exceeded NRC (2001)

Table 2. Ingredient composition of diets (DM basis)

Item	Isoline diet	Transgenic diet
Corn silage	50.0	50.0
Alfalfa silage	10.0	10.0
Corn grain, ground	7.84	7.84
Soybean meal, ¹ isoline	17.33	—
Soybean hulls, ¹ isoline	3.90	—
Soybean meal, ¹ transgenic	—	18.09
Soybean hulls, ¹ transgenic	—	3.14
Wheat middlings	6.04	6.04
Fat, animal vegetable blend	0.61	0.61
Sodium bicarbonate	0.31	0.31
Potassium carbonate	1.46	1.46
Trace mineral salt	0.51	0.51
Limestone	1.29	1.29
Magnesium oxide	0.12	0.12
Trace mineral/vitamin premix ²	0.59	0.59

¹The concentrations of soybean meal and soybean hulls differ between treatments but the amount of CP and NDF provided by the sum of meal and hulls were formulated to be equal between treatments.

²Premix contained 270 g of selenium premix (0.20 mg/g of Se from sodium selenate), 4 g of copper sulfate, 7 g of zinc sulfate, 23 g of vitamin A premix (30,000 IU/g), 71 g of vitamin D premix (3000 IU/g), 83 g of vitamin E premix (44 IU/g), and 542 g of biotin premix (0.22 mg/g) per kg.

Table 3. Nutrient composition of the silages and TMR (DM basis)

Item	Corn silage	Alfalfa silage	Isoline TMR	Transgenic TMR
DM, %	36.2 (0.87) ¹	32.8 (5.25)	57.7	57.7
NDF, %	38.1 (1.81)	41.6 (4.48)	31.2	30.8
ADF, %	22.7 (0.61)	34.3 (4.66)	18.8	18.9
Lignin, %	2.2 (0.47)	6.2 (1.02)	2.4	2.4
CP, %	6.7 (0.24)	19.9 (1.78)	17.0	16.9
Ash, %	3.28 (0.15)	10.5 (1.32)	7.45	7.45
Ca, %	0.17 (0.016)	1.31 (0.14)	0.92	0.88
P, %	0.23 (0.022)	0.30 (0.019)	0.33	0.34
Mg, %	0.13 (0.004)	0.30 (0.042)	0.24	0.28
K, %	0.96 (0.033)	2.35 (0.29)	1.89	1.92
S, %	0.05 (0.0002)	0.17 (0.018)	0.15	0.15
Na, mg/kg	28 (2.12)	438 (263)	2963	2763
Cu, mg/kg	5 (0.11)	11 (0.9)	14	12
Fe, mg/kg	49 (7.9)	591 (241)	145	146
Mn, mg/kg	33 (2.4)	80 (12.4)	55	51
Zn, mg/kg	28 (4.9)	32 (4.0)	48	48

¹Values in parentheses are the SD (n = 8).

recommendations. Twenty-six Holstein cows were blocked into 2 groups based on parity (first-lactation and multiparous cows) and average milk yield before the start of the experiment. Days in milk at the start of the experiment averaged 176 (SD = 39, range = 112 to 229). Average milk yield at the start of the experiment was 33.0 kg/d (SD = 4.35; range = 26.6 to 43.4 kg/d). Cows within blocks were randomly assigned to 1 of 2 treatment sequences.

Cows were moved into a tiestall barn and fed the isoline diet for 6 d before the start of the experimental period. At d 0, one half of the cows were switched to the transgenic diet and the other 13 cows remained on the control (isoline) diet. Cows remained on those diets for 28 d (period 1) and then were abruptly changed to the opposite diet and fed for an additional 28 d (period 2). Cows were fed once daily for ad libitum consumption (feed delivery averaged 107% of feed consumed). Amounts of feed offered and refused were measured and recorded daily. Cows were milked twice daily (approximately 12 h apart) and milk yields recorded electronically. Milk from cows consuming the transgenic diet was discarded after yields were measured. Cows were weighed on d -2 (before the start of treatment diets), 7, 28 (period 1), 29 (period 2), 55, and 56. The original protocol called for 2 consecutive day weights at the start of the experiment but, because of problems with the scale, the weighing scheduled for d -1 had to be delayed until d 7. For calculations, the d -2 and 7 BW were averaged to estimate starting BW for period 1. Change in BW was calculated as the mean of d 28 and 29 BW minus the mean of d -2 and 7 divided by 25.5 d. For period 2, the average of the d 28 and 29 BW were subtracted from the average of the d 55 and 56 BW and divided by 27 d. Body condition was scored (1 = emaciated, 5 = obese) by 2 independent scorers on

-1 d, at the end of period 1, and at the end of period 2. The BCS of the 2 scorers were averaged.

Sampling and Analyses. Milk was sampled from all cows at the time of regular milking (morning and evening) every Tuesday (-2 d, and then d 6, 13, 20, and 27 of each period) and assayed for milk fat, protein, lactose, SCC (B2000 Infrared Analyzer, Bentley Instruments, Chaska, MN), and MUN (Skalar SAN Plus segmented flow analyzer, Skalar Inc., Norcross, GA) by DHI Cooperative Inc. (Columbus, OH). A subsample of the morning and evening milk samples taken on d 13 and 27 of each period was assayed for CP by Kjeldahl procedure (method 990.03; AOAC International, 2000). Additional subsamples of milk were taken from the evening sample of milk (d 27 of each period) for mineral analysis via inductively coupled plasma spectroscopy (method 985.01; AOAC International, 2000) and milk FA using a 2-step procedure for methylation (Jenkins, 2000) with separation by GLC using a CP-SIL88 capillary column (100 m × 0.25 mm × 0.2 µm film thickness; Varian Inc., Palo Alto, CA). At the evening milking on d -1, 14, and 28 of period 1, milk was diverted from the bulk tank into a clean stainless steel sink. First, only cows on the control treatment entered the milking parlor and, as cows were milked, the milk was collected in the sink and then transferred to new plastic 3.8-L containers (identical to containers used for retail sales of milk). A total of 53 L was collected representing all cows. After the control cows were milked, the receiver jar was emptied manually, the sink was cleaned, and then treatment cows entered the parlor. After approximately 60 L of milk from treatment cows was flushed through the milking system, the milk was diverted into the sink, and another 53 L of treatment milk was put into new containers. The milk was immediately transferred to a large walk-in cooler (4°C) and cooled. The

following morning, the containers were placed in ice chests, covered with ice, and transported to the laboratory for pasteurization and then sensory analysis.

Silages and concentrate mixes were sampled weekly ($n = 8$ samples per ingredient). Silage samples were dried (55°C for 48 h) and dried silage samples and concentrate samples were ground through a 1-mm screen (Wiley Mill, Arthur A. Thomas, Philadelphia, PA). Samples were analyzed for DM (100°C oven for 48 h), ADF (Method 5, Ankom 200 Fiber Analyzer, ANKOM Technology, Fairport, NY), sulfuric acid lignin (Method 7, ANKOM), NDF (Method 6, ANKOM) with sodium sulfite and amylase (Sigma A3306 Diagnostics, St. Louis, MO), ash (600°C overnight), minerals by inductively coupled plasma spectroscopy after digestion in perchloric and nitric acid, CP (method 990.03; AOAC International, 2000), and long-chain FA (Weiss and Wyatt, 2003). Acid and neutral detergent insoluble N were determined by measuring CP on the ADF and NDF residues.

Statistical Analysis. Daily milk yields and DMI were averaged by week (within cow). All measures that were weekly (milk yield, DMI, and milk components) were analyzed using Proc Mixed (SAS 9.3; SAS Institute, 2011) with a model that included square (random), cows within square (random), period (random), type of soy product (fixed), week (repeated, fixed), soy by week interaction, and error. Degrees of freedom were calculated using the Kenward-Roger method and the covariance structure used for all analyses was compound symmetry. Measures that were taken once per period (BW, BCS, BW and BCS change, milk minerals, and milk FA) were analyzed with the same model except week and week interaction were not included. All measures had 52 experimental units (cow-period) except for BW and BW change, which had 50 experimental units because 1 cow (both period) was removed because of an apparent error in weighing (apparent change in BW was >100 kg over 28 d).

Sensory Evaluation and Testing

One hundred twenty milk consumers (37 male and 83 female) ranging in age from 18 to 65 yr of age were recruited from the Columbus, Ohio, metropolitan area under approved protocol (#2013E0585) and provided written informed consent before participation. Retention rate was high, with 119 and 115 of the original consumers completing testing at d 14 and 28, respectively. Eligibility requirements included the consumption of milk at least twice weekly.

Pooled milk samples collected on d 0 (before treatments were fed), 14, and 28 of period 1 from each cohort

were pasteurized and homogenized on the day before sensory testing and refrigerated overnight. Briefly, milk from each cohort was comingled in a steam-jacketed kettle (Lee Model 20D, Lee Industries, Philipsburg, PA) and continually agitated and warmed to 60°C within 3 min. Batches were then homogenized (stage 1 at 6.9 MPa; stage 2 at 3.4 MPa) using a Gaulin Lab 100 homogenizer (SPX Corp., Charlotte, NC). Following homogenization, milk was pasteurized at 73°C , held for 17 s in the hold tube, and then cooled to 7°C . Cooled milk was poured into 38-L stainless steel cans and placed in a walk-in cooler set at 3°C . This process was repeated for each cohort on each sample day. Individual sample aliquots were prepared on the morning of sensory testing by pouring approximately 50 mL of each milk into 90-mL clear glass spice jars affixed with 3-digit random numbers. Each jar had a lid that prevented spillage but could be removed to evaluate the milk's aroma. Sensory and consumer testing was completed on milk samples served at ambient temperature (21°C).

Sensory measurements followed procedures outlined by Drake (2007). Panelists completed all 6 tests in the following sequence: preference, overall acceptance, appearance acceptance, aroma acceptance, appearance discrimination (tetrad test), and aroma discrimination (tetrad test). Data were collected in individual tasting booths under fluorescent light using a personal computer (Compusense At-Hand, Guelph, Canada). Preference data were adjusted by distributing the "no preference" responses equally over the 2 treatment groups and analyzed using binomial statistics (chance probability = $1/2$). Acceptance data were analyzed using paired t -tests. Discrimination testing (tetrad tests) were analyzed using binomial statistics (chance probability = $1/3$). The data analysis feature of Compusense At-Hand was used to perform statistical analyses; $P < 0.05$ was taken as significant.

For the preference test, milk samples from cows fed isoline and transgenic diets were presented to each subject simultaneously and in random order. Panelists were told to look at and smell each sample and choose the milk they preferred. If the panelist had no preference, they were instructed to select the "No preference" option. For the acceptance test, each milk sample was presented one at a time in random order. Panelists were instructed to look at and smell each sample and indicate their overall opinion by selecting the appropriate box on the 9-point hedonic scale. For the Tetrad test, 4 samples (2 isoline and 2 transgenic treatment) were presented simultaneously and in random order to each subject. Panelists were instructed to sort the samples into 2 groups of 2 based only on milk appearance or aroma.

Table 4. Effects of feeding meal and hulls derived from transgenic soybeans to dairy cows on production measures¹

Item	Isoline	Transgenic	SEM	P-value
BW, kg	698	710	19.6	0.12
BW change, kg/d	0.31	0.42	0.11	0.47
BCS	3.25	3.29	0.16	0.51
BCS change/28 d	0.06	0.09	0.13	0.71
DMI, kg/d	21.3	21.4	0.88	0.96
Milk, kg/d	29.3	29.4	1.64	0.82
3.5% FCM, ² kg/d	30.4	30.3	1.59	0.81
Milk/DMI	1.39	1.39	0.079	0.99
3.5% FCM/DMI	1.44	1.41	0.071	0.42
Milk composition				
Fat, %	3.70	3.68	0.125	0.62
True protein, ³ %	3.10	3.12	0.050	0.40
CP ³ %	3.23	3.24	0.066	0.45
Lactose, %	5.68	5.67	0.069	0.41
Solids, %	4.77	4.77	0.061	0.69
Energy, Mcal/kg	0.707	0.706	0.014	0.80
Milk component yields				
Fat, kg/d	1.1	1.1	0.060	0.94
Protein, kg/d	0.92	0.93	0.047	0.49
Lactose, kg/d	1.41	1.43	0.093	0.47
Solids, kg/d	0.68	1.70	0.109	0.42
Energy, Mcal/d	20.9	21.1	1.14	0.68
MUN, mg/dL	15.4	15.2	0.49	0.31
SCC, Log(10)/mL	1.897	1.836	0.116	0.04

¹Overall treatment mean.²3.5% FCM = $0.432 \times \text{kg of milk} + 16.22 \times \text{kg of milk fat}$ (Erdman, 2011). Milk energy calculated from milk protein, fat and lactose (NRC, 2001).³Milk CP was assayed using Kjeldahl procedure. True protein was assayed using infrared methods.

RESULTS AND DISCUSSION

Production Data

Compositional equivalence has previously been established between the transgenic soybean and nontransgenic soybean varieties used in our experiment (Lepping et al., 2013). The findings by Lepping et al. (2013) are consistent with the results of the compositional analysis presented here (Table 1). Therefore, production performance was not expected to differ between treatments. Indeed, except for SCC, we observed no significant differences between treatments for production measures

(Table 4). Cows fed the transgenic diet had lower ($P < 0.05$) SCC than control cows; however, the actual difference was not biologically meaningful (geometric means; 79,000 vs. 69,000 cells/mL). Both means are indicative of an uninfected, normal mammary gland (Bradley and Green, 2005). On average, cows produced about 29 kg/d of milk with normal milk composition, and, based on changes in BW and BCS, cows were in slightly positive energy balance (Table 4).

Treatment did not affect concentrations of most milk minerals (Table 5), except for lower concentrations of P ($P < 0.04$) and Zn ($P < 0.02$) in milk from cows fed the transgenic diet. Although the differences were statisti-

Table 5. Effect of feeding meal and hulls derived from transgenic soybeans to dairy cows on milk minerals (mg/L)^{1,2}

Item	Control	Transgenic	SEM	P-value
Ca	950	935	20.4	0.16
P	764	752	21.4	0.04
K	1253	1250	26.2	0.74
Mg	93.9	92.8	3.42	0.29
S	304	305	3.51	0.43
Na	404	407	34.3	0.62
Fe	0.52	0.46	0.056	0.21
Zn	4.11	3.93	0.202	0.02

¹Overall treatment mean.²Cu and Mn were below detection limits (0.55 and 0.025 mg/L, respectively) for all samples and not reported.

Table 6. Effect of feeding meal and hulls derived from transgenic soybeans to dairy cows on milk FA (mg/kg of total FA)¹

FA ²	Control	Transgenic	SEM	P-value
4:0	44.6	44.3	0.81	0.69
6:0	31.1	31.2	0.75	0.87
8:0	16.0	16.2	0.43	0.58
10:0	34.0	35.7	1.37	0.27
12:0	39.2	39.8	1.40	0.66
<i>iso</i> 13:0	0.38	0.39	0.013	0.64
<i>anteiso</i> 13:0	0.54	0.51	0.10	0.74
13:0	1.38	1.39	0.077	0.78
14:0	118.5	120.9	2.43	0.29
<i>iso</i> 14:0	1.00	0.98	0.068	0.56
14:1	10.7	10.8	0.42	0.74
<i>iso</i> 15:0	2.43	2.50	0.097	0.33
<i>anteiso</i> 15:0	5.46	5.49	0.27	0.88
15:0	12.0	12.1	0.48	0.91
16:0	294.8	295.7	7.93	0.74
<i>iso</i> 16:0	2.57	2.48	0.15	0.52
16:1 + <i>anteiso</i> 17:0	19.0	19.2	0.80	0.84
<i>iso</i> 17:0	3.64	3.65	0.092	0.83
17:0	4.86	5.59	1.13	0.16
17:1	2.08	1.99	0.19	0.69
18:0	94.9	93.5	3.10	0.55
<i>cis</i> -9 18:1	191.1	187.9	8.24	0.56
<i>cis</i> -11 18:1	5.30	5.09	0.36	0.44
<i>trans</i> -6+8 18:1	3.18	3.14	0.13	0.55
<i>trans</i> -9 18:1	2.40	2.41	0.12	0.82
<i>trans</i> -10 18:1	5.30	5.13	0.37	0.60
<i>trans</i> -11 18:1	10.9	10.2	0.39	0.08
<i>trans</i> -12 18:1	4.82	4.87	0.23	0.87
18:2	25.8	25.7	1.15	0.94
18:3	4.19	4.07	0.13	0.09
<i>cis</i> -9, <i>trans</i> -11 CLA	5.52	5.25	0.33	0.11
<i>trans</i> -10, <i>cis</i> -12 CLA	0.065	0.073	0.013	0.68
Short-chain FA	317.3	322.4	6.41	0.41
Long-chain FA	355.0	348.6	10.9	0.32

¹Overall treatment mean.²Fatty acids designated as number of carbons:number of double bonds. Short-chain fatty acids, <16 C; long-chain fatty acids, ≥18 C.

cally significant, the differences were very small (1.6% decrease in P and 4.4% decrease in Zn). Both treatment means for Zn are within the normal range for milk. Pechová et al. (2008) reported that Zn concentrations in milk ranged from 2.0 to 10.9 mg/L. The treatment means for milk P concentrations were lower (Castillo et al., 2013) than typical for both treatments, but Klop et al. (2014) noted significant variation in milk P and, although there may be a correlation to milk protein,

a considerable portion of the variation could not be explained. The average milk FA profiles for both treatments were quite similar and no statistical differences ($P > 0.08$) were observed (Table 6).

The lack of any statistical differences between treatments for most of the production measures are in agreement with previous studies on the effects of transgenic soybeans on cow performance and milk characteristics (Hammond et al., 1996; Clark and Ipharraguerre, 2001).

Table 7. Ability to perceive differences of milk from cows fed transgenic or isoline soybean meal and hulls

Item	Day	Total N	Pc ¹	P-value
Perceived appearance difference	0	120	45	0.003
	14	119	40	0.07
	28	115	46	0.002
Perceived aroma differences	0	120	28	0.93
	14	119	39	0.09
	28	115	33	0.56

¹Proportion correct = (N correct/N total) × 100, where N correct is the number of judges that correctly differentiated milk from cows fed different diets.

Table 8. Preference of milk from cows fed transgenic or isoline soybean meal and hulls

Item	Preference (% of panelists)			<i>P</i> -value
	Isoline	Transgenic	No preference	
d 0	26	27	47	0.99
d 14	31	29	40	0.93
d 28	27	37	36	0.30

A similar lack of differences in production measures has been observed when feeding transgenic corn and corn silage to dairy cattle (Flachowsky, 2014).

Sensory Evaluation

Perceived appearance of milk (Table 7) was generally judged to differ between treatment groups; however, this was likely a cow effect rather than a treatment effect. For d 0 samples (i.e., before cows were fed different diets), 45% of judges ($P < 0.01$) correctly discriminated between milk samples obtained from the transgenic and isoline cohorts (chance probability of correctly discriminating between 2 samples in the tetrad test is 33%). For d 14 samples, 40% of judges correctly discriminated ($P < 0.08$) between the samples obtained from the experimental and control cohorts. For d 28 samples, 46% of judges correctly discriminated between the samples obtained from the transgenic and isoline cohorts, which is greater ($P < 0.02$) than what is expected from chance. Treatment groups could be discriminated before cows were fed different diets, and this was likely because milk from cows that were randomly assigned to the control group in period 1 contained a higher percentage of fat (3.79 vs. 3.39%; $P < 0.01$) and protein (3.14 vs. 3.00%; $P < 0.01$) than milk from cows assigned to the transgenic treatment. Production measures (Table 4) are from both periods and the Latin square design adjusts for cow effects (each cow is on both treatments) and no differences were found in milk composition. Sen-

sory analysis was only conducted on period 1 samples (i.e., essentially a randomized block design) and cows were blocked by milk yield, not milk composition.

No aroma differences were identified between isoline and transgenic cohorts (Table 7). Judges showed no differences in preference between treatments (Table 8). Depending on sample day, 36 to 47% of judges had no preference between treatment groups, and those that had a preference were about evenly split between treatments. Overall acceptability and the acceptability of milk appearance were not affected by treatment; however, aroma acceptability differed between treatments on d 0 and 14, but not d 28 (Table 9). All measures of acceptability were stable over time. The significant differences in aroma acceptability are likely a spurious result due to scaling error because the same subjects were unable to discriminate the milk aromas in a tetrad test.

To our knowledge, previous data evaluating sensory perception of milk from cows fed transgenic or nontransgenic feed are not available. The general lack of any treatment effects on sensory evaluation likely reflects the essentially equal chemical composition of the soy products from the transgenic or isoline soybeans. Although essentially no differences were observed in this blind sensory evaluation, consumer acceptance of foods (e.g., cheese) identified as transgenic is often less than conventional food even when the food choice identified as transgenic is indeed conventional (Lähteenmäki et al., 2002). The few differences in sensory measures between treatments that did occur were likely not caused by genetic modification because the differences were also observed before cows were fed actual treatment diets, and, thus, factors confounding statistical interpretation were present. Furthermore, such a result is not unexpected, as multiple comparisons are well known to increase the false discovery rate (Curran-Everett, 2000). However, because no differences were found in perceived aroma difference, preference, appearance acceptability, and overall acceptability or in nutrient composition of the milk, we conclude that milk from cows the transgenic

Table 9. Acceptance of milk from cows fed transgenic or isoline soybean meal and hulls based on a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely)

Item	Day	Isoline	Transgenic	<i>P</i> -value
Overall acceptance	0	6.98	6.94	0.65
	14	6.97	7.00	0.66
	28	7.15	7.17	0.71
Appearance acceptance	0	7.20	7.25	0.56
	14	7.07	7.15	0.39
	28	7.31	7.24	0.39
Aroma acceptance	0	5.65	5.32	0.03
	14	5.71	6.13	0.01
	28	5.81	5.59	0.17

soybean products is equivalent to milk produced from cows fed nontransgenic soybean meal and hulls.

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