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Effects of Using Wheat Gluten and Rice Protein Concentrate in Dairy Calf Milk Replacers

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ABSTRACT

There is a limited amount of peer reviewed data on feeding milk replacers (MR) containing either hydrolyzed wheat gluten (HWG; 80% CP) or rice protein concentrate (RPC; 80% CP) to calves under 2 mo of age. Male Holstein calves less than 7 d old from multiple farms (trial 1) and 2- to 3-d-old calves from one dairy farm (trials 2 and 3) were used. Trial 1 compared feeding 0.454 kg/d of 20% CP, 20% fat MR powders that contained 0 and 4.3% HWG for 42 d. Trial 2 compared feeding 0.681 kg/d of 26% CP, 17% fat MR powders that contained 0, 6, and 12% HWG for 42 d. Trial 3 compared feeding 0.681 kg/d of 26% CP, 17% fat MR that contained 0, 8, and 16% RPC for 28 d. Within trial, the MR were formulated to have equal concentrations of major nutrients and be adequate in essential amino acids. In trial 1, preweaning ADG, starter intake, feed efficiency, and hip width changes were greater in calves fed the MR with 0 vs. 4.3% HWG. In trial 2, preweaning ADG, starter intake, and hip width change decreased linearly with increasing concentration of HWG in the MR. In trial 3, ADG and feed efficiency declined linearly as RPC increased in the MR. In these 3 trials, preweaning ADG of calves less than 2 mo old was reduced when either HWG or RPC replaced whey protein in a MR.

Key words: hydrolyzed wheat gluten, rice protein concentrate, milk replacer

INTRODUCTION

Some vegetable proteins are lower cost sources of protein than milk protein. However, many contain antinutritional factors such as antigens and poorly digested carbohydrate fractions (Davis and Drackley, 1998). Unlike various soy proteins commonly used in calf milk replacers (**MR**), hydrolyzed wheat gluten (**HWG**) appears to have no antinutritional factors (Davis and Drackley, 1998). Yet there is a report of unhydrolyzed wheat gluten causing jejunal villus atrophy and mucosal abnormalities in milk-fed calves (Kilshaw and Slade, 1982). Similarly, rice protein concentrate (**RPC**) has no known antinutritional factors (Piedad-Pascual et al., 1970); however, research is lacking using calves. The amino acid profiles of HWG and RPC are low in Lys and Met compared with skim milk or whey proteins (Chen et al., 1967; Toullec and Formal, 1998).

In veal calves over 8 wk old (Branco-Pardal et al., 1995) and over 12 wk old (Toullec and Formal, 1998), the amino acids in HWG are about 95% as digestible as amino acids in milk protein. Research of this kind is lacking in younger calves.

Ortigues-Marty et al. (2003) reported similar ADG in veal calves fed either an all milk protein MR or one with 50% of the milk protein replaced with HWG from 29 to 83 d of age. Veal calves were not introduced to the test MR until 29 d of age, missing the first month of life when the digestive system is immature (Davis and Drackley, 1998; NRC, 2001) and the time that dairy herd replacement calves are fed MR. Terui et al. (1996) reported similar ADG in very slow growing (0.2 kg/d from 0 to 42 d) calves fed MR with 0, 30, or 50% of the milk protein replaced with HWG.

A series of 3 trials were conducted to evaluate the inclusion of HWG or RPC in calf MR on calf ADG, efficiency, and health related measurements.

MATERIALS AND METHODS

Trial 1

Trial 1 compared feeding 20% CP, 20% fat MR that contained 0 or 4.3% HWG (0 or 15% of the formulated CP; Table 1). The test amount of CP from HWG (15%) is approximately half the amount of the soy protein

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Table 1. Ingredient composition and analyzed nutrient concentration of milk replacers and test protein sources in trials 1 and 2 made from hydrolyzed wheat gluten (HWG)

	Trial 1			Trial 2			
Item	0% HWG	4.3% HWG	HWG	0% HWG	8% HWG	16% HWG	HWG
Ingredient, % of as-fed							
HWG	0.00	4.30	—	0.00	6.00	12.00	—
Whey (12% CP)	49.82	50.33	—	42.57	42.80	43.08	—
Dry fat (7% CP, 60% fat)	29.88	29.52	—	0.00	0.00	0.00	—
Whey protein concentrate (78% CP)	14.86	10.04	—	23.85	16.73	9.61	—
Dry fat (9% CP, 48% fat)	0.00	0.00	—	28.09	28.21	28.31	—
Lecithin-based emulsifier	2.00	2.00	—	2.56	2.56	2.56	—
Decoquinate premix, 0.5%[1]	1.00	1.00	—	0.68	0.68	0.68	—
Flow agent	0.70	0.70	—	0.96	0.96	0.96	—
Ca carbonate	0.46	0.44	—	0.35	0.32	0.28	—
DL-Met	0.28	0.25	—	0.17	0.21	0.24	—
L-Lys	0.28	0.60	—	0.05	0.67	1.28	—
Trace mineral, vitamin premix[2]	0.25	0.25	—	0.17	0.17	0.17	—
Dicalcium phosphate	0.24	0.33	—	0.25	0.39	0.53	—
Choline chloride	0.15	0.15	—	0.10	0.10	0.10	—
Flavor	0.10	0.10	—	0.20	0.20	0.20	—
Nutrient, % of as-fed							
DM	97.78	97.92	95.90	95.92	95.75	95.63	95.97
Protein	19.98	20.27	80.56	26.54	26.65	26.33	80.78
Fat	20.32	20.40	5.51	17.33	17.34	17.22	5.96
Ash	6.91	6.99	0.73	6.30	6.37	6.47	3.82
Ca	0.75	0.73	0.04	0.71	0.71	0.70	0.05
P	0.62	0.63	0.15	0.56	0.58	0.58	0.16
Na	0.37	0.39	0.10	0.46	0.46	0.46	0.09
Cl	1.21	1.22	0.10	0.97	0.97	0.95	0.10
Mg	0.07	0.07	0.02	0.08	0.08	0.08	0.03
K	1.20	1.23	0.10	1.35	1.33	1.31	0.11
S	0.35	0.37	0.33	0.41	0.41	0.39	0.30
Met	0.56	0.57	1.74	0.73	0.72	0.71	1.78
Cys	0.44	0.42	3.11	0.58	0.56	0.51	3.15
Lys	1.80	1.82	1.34	2.34	2.36	2.33	1.37
Thr	1.27	1.23	2.35	1.71	1.47	1.18	2.41
Trp	0.44	0.42	0.98	0.65	0.60	0.50	1.02
Arg	0.46	0.47	2.94	0.70	0.73	0.74	2.90
Ile	1.07	0.97	3.09	1.61	1.45	1.24	3.11
Leu	1.86	1.72	5.65	2.82	2.56	2.23	5.59
Val	1.04	0.99	3.35	1.56	1.44	1.26	3.37
His	0.35	0.34	1.73	0.51	0.51	0.49	1.76
Phe	0.59	0.64	4.19	0.88	0.95	1.00	4.13
Calculated NFC[3]	50.57	50.26	9.1	45.75	45.39	45.61	8.41
Calculated NFC from HWG[4]	0.00	0.39	—	0.00	0.50	1.01	—
Calculated CP from HWG[4]	0.00	3.46	—	0.00	4.85	9.69	—

[1]Alpharma Inc., Fort Lee, NJ.

[2]Labeled concentrations: 30,800 KIU vitamin A/kg, 0.12 g Se/kg; Akey, Lewisburg, OH.

[3]NFC = nonfiber carbohydrate = 100 – (100 – DM) – CP – fat – ash (fiber was not accounted for but should have been <0.3% of milk replacer powders and HWG).

[4]NFC or CP concentration of HWG × HWG concentration in MR.

recommended for veal finishing calves over 6 wk old (Toullec, 1989) and 40% the amount of plasma protein used by Morrill et al. (1995) in calves less than 6 wk old. The MR were formulated to have equal concentrations of CP, fat, Lys (L-Lys, Ajinomoto, Eddyville, IA), Met (using DL-Met; Evonik Degussa, Mobile, AL), Ca, P, and added trace minerals, vitamins, and decoquinate. The MR were fed at 0.454 kg/d (recon-

Table 2. Ingredient composition and analyzed nutrient concentration of starters fed in trials 1, 2, and 3

Item	Trial 1	Trial 2	Trial 3
Ingredient, % of as-fed			
Corn, ground	60.00	60.00	60.00
Soybean meal	24.29	24.29	24.29
Dried distillers grains with solubles	5.00	5.00	5.00
Alfalfa meal	5.00	5.00	5.00
Ca carbonate	1.10	1.10	1.10
Fat	1.00	1.00	1.00
Pellet binder	1.00	1.00	1.00
Dicalcium phosphate	0.76	0.76	0.76
Vitamin mineral premix[1]	0.75	0.75	0.75
Salt	0.60	0.60	0.60
Decoquinate premix, 0.5%[2]	0.50	0.50	0.50
Nutrient, % of as-fed			
DM	87.36	87.14	87.39
Protein	18.52	18.48	18.26
Fat	3.66	3.59	3.73
Ash	5.36	5.03	5.38
Ca	0.94	0.84	0.88
P	0.49	0.52	0.51

[1]Labeled concentrations: 800 kIU vitamin A/kg, 0.04 g Se/kg; Akey, Lewisburg, OH.

[2]Alpharma Inc., Fort Lee, NJ.

stituted to 3.8 L) halved into a.m. and p.m. feedings for 39 d, followed by 0.227 kg/d for d 40 to 42 (a.m. feeding only). This trial used Holstein bull calves (16/treatment) <1 wk of age from multiple dairy farms. They were all received at one time at approximately 1600 h after a 10-h transit, immediately fed 0.227 kg of a nutrient and electrolyte product (Critical Care; Akey, Lewisburg, OH) reconstituted to 1.9 L with warm water, and randomly assigned to treatment. The first MR was fed at the following a.m. feeding. Calves were fed a completely pelleted 18% CP starter (Table 2) ad libitum starting on d 2. Fresh water was available at all times from time of arrival. Measurements were made for 42 d. Trial 1 was conducted from September through October. The average temperature was 13°C and ranged from −2 to 31°C based on hourly measurements.

Trial 2

Trial 2 compared feeding 26% CP, 17% fat MR that contained 0, 6, or 12% HWG (0, 19, or 38% of the formulated CP; Table 1). The MR were formulated to have equal concentrations of CP, fat, Lys, Met (using L-Lys and DL-Met), Ca, P, added trace minerals, vitamins, and decoquinate. The MR were fed at 0.681 kg/d (reconstituted to 4.6 L) halved into a.m. and p.m. feedings for 39 d, followed by 0.341 kg/d for d 40 to 42 (a.m. feeding only). Trial 2 used Holstein bull calves (16/treatment) 2 to 4 d of age sourced from a single dairy farm. They were all received at one time at approximately 1100 h after a 3-h transit and randomly assigned to treatment. Their first MR was fed at approximately 1600 h. Calves were fed a completely pelleted 18% CP starter (Table 2) ad libitum starting on d 2. It was formulated to 18% CP and tested 18.5% CP, 5.0% ash, 0.8% Ca, and 0.5% P. Fresh water was available at all times from time of arrival. Measurements were made for 56 d. Trial 2 was conducted from November through December. The average temperature was 2°C and ranged from −17 to 22°C based on hourly measurements.

Trial 3

Trial 3 compared feeding 26% CP, 17% fat MR that contained 0, 8, or 16% RPC (0, 25, or 50% of the formulated CP; Table 3). The MR were formulated to have equal concentrations of CP, fat, Lys, Met (using L-Lys and DL-Met), Ca, P, added trace minerals, vitamins, and decoquinate. The MR were fed at 0.681 kg/d (reconstituted to 4.6 L) halved into a.m. and p.m. feedings for 25 d, followed by 0.341 kg/d for d 26 to 28 (a.m. feeding only). Trial 3 used Holstein bull calves (16/treatment) 2 to 4 d of age sourced from a single dairy farm. They were all received at one time at approximately 1100 h after a 3-h transit and randomly assigned to treatment. Their first MR was fed at approximately 1600 h. Calves were fed a completely pelleted 18% CP starter (Table 2) ad libitum starting on d 2. Fresh water was available at all times from time of arrival. Measurements were made for 56 d. Trial 3 was conducted from September through October. The average temperature was 19°C and ranged from −2 to 35°C based on hourly measurements.

Measurements

In all trials, calves were weighed initially and blood was sampled from the jugular vein and serum protein measured using an optical refractometer (ATAGO U.S.A. Inc., Bellevue, WA) at approximately 1130 h the day after arrival. Calves were randomly assigned to treatment. Calves were weighed every 7 d at approximately 1130 h. All calves were housed in individual 1.2 × 2.4 m pens in a curtain sidewall barn with no added heat. Pens were bedded with straw.

Approximately 110% of the estimated feeds needed for each trial

Table 3. Ingredient composition and analyzed nutrient concentration of milk replacers and test protein source in trial 3 made from rice protein concentrate (RPC)

Item	0% RPC	8% RPC	16% RPC	RPC
Ingredient, % of as-fed				
RPC, %	0.00	8.00	16.00	—
Whey (12% CP)	46.11	45.99	45.86	—
Whey protein concentrate (78% CP)	22.46	21.59	4.72	—
Dry fat (7% CP, 60% fat)	21.23	4.00	21.94	—
Dry fat (12% CP, 26% fat)	4.00	13.59	4.00	—
Lecithin-based emulsifier	2.56	2.56	2.56	—
Decoquinate premix, 0.5%[1]	0.68	0.68	0.68	—
Flow agent	0.96	0.96	0.96	—
Ca carbonate	0.46	0.57	0.68	—
DL-Met	0.36	0.25	0.14	—
L-Lys	0.31	0.78	1.25	—
Trace mineral, vitamin premix[2]	0.17	0.17	0.17	—
Dicalcium phosphate	0.40	0.37	0.34	—
Flavor	0.20	0.20	0.20	—
Choline chloride	0.10	0.10	0.10	—
L-Thr	—	0.20	0.40	—
Nutrient, % of as-fed				
DM	96.22	96.38	96.53	97.44
Protein	26.04	26.18	26.31	80.53
Fat	16.98	17.11	17.24	1.59
Ash	5.83	5.90	5.97	2.31
Ca	0.73	0.74	0.75	0.12
P	0.60	0.61	0.62	0.48
Na	0.42	0.44	0.46	0.05
Cl	0.94	0.97	0.99	0.34
Mg	0.07	0.08	0.09	0.08
K	1.29	1.31	1.33	0.02
Sr	0.39	0.38	0.37	1.14
Met	0.71	0.73	0.75	2.59
Cys	0.57	0.55	0.53	1.92
Lys	2.37	2.36	2.35	2.75
Thr	1.69	1.65	1.61	3.01
Trp	0.67	0.65	0.62	1.02
Arg	0.71	1.08	1.45	7.24
Ile	1.58	1.45	1.32	3.59
Leu	2.78	2.65	2.51	6.78
Val	1.59	1.58	1.57	4.73
His	0.53	0.54	0.55	1.79
Phe	0.86	1.01	1.15	5.11
Calculated NFC[3]	47.37	47.19	47.01	13.01
Calculated NFC from HWG[4]	0.00	1.04	2.08	—
Calculated CP from HWG[4]	0.00	6.44	12.88	—

[1]Alpharma Inc., Fort Lee, NJ.

[2]Labeled concentrations: 30,800 kIU vitamin A/kg, 0.12 g Se/kg; Akey, Lewisburg, OH.

[3]NFC = nonfiber carbohydrate = 100 – (100 – DM) – CP – fat – ash (fiber was not accounted for but should have been <0.3% of milk replacer powders and RPC).

[4]HWG = hydrolyzed wheat gluten; NFC or CP concentration of RPC × RPC concentration in milk replacer.

were manufactured at one time. Samples were collected from every other bag (22.7 kg) of feed at the time of manufacture. All analyses were by AOAC (2000) methods. Composites were analyzed before the animal phase of the studies for DM (oven method 930.15), CP (Keldahl method 988.05), fat (MR using alkaline treatment with Roese-Gottlieb method 932.06; starters using diethyl ether extraction, method 2003.05), ash (muffle furnace method 923.03), Ca, P, Na, K, Mg, S (dry ashing, acid digestion, analysis by inductively coupled plasma spectoscopy, method 985.01), Cl (extraction, digestion, method 969.10, 973.51), S (combustion, method 990.03), and amino acids by HPLC (Table 1). Amino acids were determined after acid hydrolysis [method 982.30 E(a)]. Total sulfur amino acids were determined after performic acid oxidation and then acid hydrolysis [method 982.30 E(b)]. Tryptophan content was determined after alkaline hydrolysis [method 982.30 E(c)].

Feed offered and refused was weighed daily. Fecal scores were assigned daily based on a 1 to 5 system (1 being normal, thick in consistency; 2 being normal, but less thick; 3 being abnormally thin but not watery; 4 being watery; 5 being watery with abnormal coloring). Hip widths (measured with a caliper) were measured initially and every 14 d thereafter. Feed efficiency was calculated as BW gain divided by MR plus starter intake.

Animal Care

Calves were cared for by acceptable practices as described in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1999). Vaccines and health protocols were based on the recommendations of a veterinarian. Calves received an intranasal tissue sensitive respiratory disease vaccine (TSV-2, Pfizer, Exton, PA) and subcutaneous injections of vitamins A, D, and E (Vital E-A+D, Schering-Plough Animal Health, Union, NJ) and Se (MU-SE, Schering-Plough Animal Health) upon arrival. Calves received an intramuscular respiratory disease vaccine (Bovashield Gold 5, Pfizer, Exton, PA) at d 7 and again at d 28. At d 14 they received an intramuscular vaccine for *Clostridium* types C and D (Ultra Choice 7, Pfizer). A pasturella vaccine (Presponse HM, Fort Dodge, Fort Dodge, IA) was administered i.m. on d 28 and 42. Calves were castrated and dehorned on d 36. Animals that required medication for digestive (subcutaneous ceftiofur sodium, Naxcel, Pharmacia and Upjohn, Kalamazoo, MI) or navel (subcutaneous penicillin G procaine, Agri-Cillin, AgriLabs, St. Joseph, MO) infections were treated per veterinary recommendation and treatments were recorded daily. Digestive infections were diagnosed based on rectal temperatures (>39.5°C), lack of vitality, and fecal scores >2. Four calves in trial 1 (2 calves/treatment) received penicillin for navel infections. All other medical treatments were because of digestive upsets (scouring).

Statistical Analysis

Data from each trial were analyzed separately as completely randomized designs using the MIXED procedure of SAS (1999). Means for treatments (concentration of test protein in MR) were separated using linear and quadratic contrast statements when the overall F-test for treatment was significant ($P < 0.05$) in trials 2 and 3. The model included terms for treatment, day, and the interaction of treatment and day. Calf within treatment was included as a random effect that was used to test the main effect of treatment. Day was modeled as a repeated measurement using an autoregressive type 1 covariance structure within pre- and postweaning periods. Data reported are least squares means for the experimental unit of calf in all trials.

RESULTS AND DISCUSSION

No calves died or were removed from the trials. In each trial, there were no differences ($P > 0.05$) in initial BW, serum protein, or hip widths. In each trial, all of the MR offered was consumed.

In trial 1, ADG, starter intake, feed efficiency, and hip width changes were greater ($P < 0.05$) in calves fed the MR with 0 vs. 4.3% HWG (Table 4). Other preweaning (0 to 42 d) measures did not differ between treatments. Postweaning measurements were not made.

In trial 2, calf ADG decreased linearly ($P < 0.05$) with increasing concentration of HWG in the MR (Table 5). The ADG for calves fed the MR with 12% HWG was 21% less than for calves fed the MR with 0% HWG. Feed efficiency decreased linearly ($P < 0.05$) with increasing concentration of HWG in the MR. Feed efficiency for calves fed the MR with 12% HWG was 16% worse than for calves fed the MR with 0% HWG. Hip width change decreased linearly ($P < 0.05$) with increasing concentration of HWG in the MR. Other preweaning measurements did not differ ($P > 0.05$). Postweaning (28 to 56 d) ADG (1.01 kg/d), starter intake (2.56 kg/d), efficiency (0.454), hip width change (1.6 cm), and abnormal fecal score days (1.3 d) did not differ ($P > 0.05$) because of treatment indicating no compensatory BW gain.

Branco-Pardal et al. (1995) and Toullec and Formal (1998) have shown that the amino acids in HWG are about 95% as digestible as the amino acids in milk protein in calves over 8 wk old, but this type of information is not available in younger calves when the digestive system is immature. Ortigues-Marty et al. (2003) reported similar ADG in veal calves fed either an all milk protein MR or one with 50% of the milk protein replaced with HWG from 29 to 83 d of age. The amino acid profile of HWG is low in Lys and Met relative to skim milk or whey proteins (Toullec and Formal, 1998). The concentration of Lys and Met are low in milk proteins and limiting to ADG of MR fed calves (Hill et al., 2008). However Lys and Met can be supplemented cost-effectively. Essential amino acids in all MR in trials 1 and 2 were adequate based on estimates of Van Weerden and Huisman (1985) in calves 5 to 7 wk of age and estimates of Hill et al. (2008) in calves less than 5 wk of age.

Terui et al. (1996) reported similar performance of calves fed MR with 0, 30, or 50% of the milk protein replaced with HWG. The calves only gained approximately 0.2 kg/d from 0 to 42 d (preweaning), which is approximately 40% less than typical based on nutrients consumed (NRC, 2001), making it difficult to evaluate the MR CP sources.

Table 4. Preweaning performance (42 d) of calves fed milk replacers with or without hydrolyzed wheat gluten (HWG) in trial 1

Item	0% HWG	4.3% HWG	SEM	*P*-value
Calves, n	16	16	—	—
Initial serum protein, mg/dL	5.5	5.7	0.31	0.76
Initial BW, kg	45.6	45.3	1.32	0.92
Initial hip width, cm	18.3	18.5	0.32	0.67
ADG, kg/d	0.555	0.477	0.0321	0.01
Starter intake, kg/d	0.614	0.514	0.0448	0.01
Milk replacer intake, kg/d	0.438	0.438	—	—
Feed efficiency[1]	0.521	0.493	0.0102	0.03
Hip width change, cm	2.8	2.5	0.11	0.02
Abnormal fecal score,[2] d	4.0	4.9	0.75	0.23

[1]Gain divided by milk replacer plus starter intake.

[2]Days with fecal scores greater than 2 in a 1 to 5 system, with 1 being normal.

Table 5. Preweaning performance (42 d) of calves fed milk replacers with 3 concentrations of hydrolyzed wheat gluten (HWG) in trial 2

Item	0% HWG	6% HWG	12% HWG	SEM	Linear[1]
Calves, n	16	16	16	—	—
Initial serum protein, mg/dL	4.9	5.1	4.9	0.20	0.99
Initial BW, kg	44.1	43.0	42.6	1.04	0.30
Initial hip width, cm	17.9	17.5	17.6	0.19	0.32
ADG, kg/d	0.64	0.561	0.505	0.0248	0.01
Starter intake, kg/d	0.449	0.365	0.379	0.0403	0.21
Milk replacer intake, kg/d	0.657	0.657	0.657	—	—
Feed efficiency[2]	0.588	0.547	0.492	0.0227	0.01
Hip width change, cm	3.6	3.4	3.0	0.16	0.02
Abnormal fecal score,[3] d	10.8	9.0	11.1	1.37	0.87

[1]*P*-value for linear contrast across concentrations of test protein. No quadratic contrasts were significant ($P < 0.05$).

[2]Gain divided by milk replacer plus starter intake.

[3]Days with fecal scores greater than 2 in a 1 to 5 system, with 1 being normal.

Davis and Drackley (1998) cite unpublished data in which calves fed a MR with 50% of the protein from HWG grew at 95% the rate of calves fed an all milk protein MR from 0 to 42 d on test. However, calf ADG from 0 to 14 d was 17% less for calves fed the milk replacer with 50% vs. 0% HWG protein. In a recent abstract, Hayes et al. (2007) reported that calves fed 0.568 kg/d of a 20% CP, 20% fat MR with 50% of the protein from HWG had lower ADG than calves fed the MR with all milk protein.

In trial 3, ADG and feed efficiency declined linearly ($P < 0.05$) as RPC increased in the MR (Table 6). Other measures preweaning (0 to 28 d) did not differ ($P > 0.05$). Postweaning (28 to 56 d) ADG (0.63 kg/d), starter intake (1.59 kg/d), efficiency (0.40), hip width change (2.1 cm), and abnormal fecal score days (0.2 d) did not differ ($P > 0.05$) because of treatment indicating no compensatory BW gain.

Research with RPC is very limited, and it apparently has no known antinutritional properties (Piedad-Pascual et al., 1970). The first limiting amino acid in RPC appears to be Lys, followed by Met plus Cys (Chen et al., 1967). In trial 3, L-Lys and DL-Met were supplemented to equalize and make Lys and Met adequate. Other essential amino acids were adequate based on estimates of Van Weerden and Huisman (1985) and Hill et al. (2008). Gottlob et al. (2006) reported that apparent and standardized ileal digestibilities for all essential amino acids except Trp were low for RPC compared with whey protein concentrate in pigs over 30 kg BW. The low digestibility of

Table 6. Preweaning performance (28 d) of calves fed milk replacers with 3 concentrations of rice protein concentrate (RPC) in trial 3

Item	0% RPC	8% RPC	16% RPC	SEM	Linear[1]
Calves, n	16	16	16	—	—
Initial serum protein, mg/dL	4.8	4.8	4.9	0.15	0.62
Initial BW, kg	41.8	42.1	42.6	1.13	0.64
Initial hip width, cm	17.3	17.2	17.6	0.21	0.55
ADG, kg/d	0.389	0.34	0.178	0.0177	0.01
Starter intake, kg/d	0.132	0.133	0.108	0.0209	0.53
Milk replacer intake, kg/d	0.657	0.657	0.657	—	—
Feed efficiency[2]	0.497	0.428	0.211	0.0176	0.01
Hip width change, cm	1.2	1.1	0.9	0.14	0.09
Abnormal fecal score,[3] d	3.9	3.5	3.8	0.53	0.64

[1]*P*-value for linear contrast across concentrations of test protein. No quadratic contrasts were significant ($P < 0.05$).

[2]Gain divided by milk replacer plus starter intake.

[3]Days with fecal scores greater than 2 in a 1 to 5 system, with 1 being normal.

most of the essential amino acids in RPC as reported in pigs might have been the reason for the poor performance of the calves fed RPC in trial 3.

Most alternative protein MR in the United States contain approximately 50% of CP from plant proteins and support a fraction of the ADG of MR based on all milk protein (Davis and Drackley, 1998). The NRC (2001) suggests only milk protein MR be fed to calves less than 3 wk old. This is because the immature proteolytic digestive system of neonatal calves limits their ability to digest plant proteins and antinutritional factors in some protein sources that decrease the efficiency of protein use. The reduced ADG in trials 1, 2, and 3 substantiate statements in the NRC (2001) and affirm the recommendation that use of alternative proteins is not recommended in MR during the first 3 wk to possibly 6 wk of a calf's life.

The young calf has an immature enzyme system for digesting both plant carbohydrates and CP (NRC, 2001). The carbohydrate fraction as calculated by difference was approximately 9% of HWG (Table 1) and 13% of RPC (Table 3) compared with approximately 25 to 40%, respectively, in soy protein concentrate and soy flour, 2 commonly used plant proteins. Thus, the total plant carbohydrates in the MR powder with HWG and RPC would have only been 0.39 to 2.08% (0.7 to 4.4% of the total carbohydrate) and the MR would be virtually void of antigens (i.e., glycinin) and troublesome oligosaccharides (i.e., stachyose) common to soy. The low content of plant carbohydrates (2.08% or less) in these MR cannot account for the reductions in ADG regardless of potential reductions in digestibility unless HWG or RPC contain other harmful antigens or oligosaccharides. Kilshaw and Slade (1982) did report that unhydrolyzed wheat gluten caused jejunal villus atrophy and mucosal abnormalities in preruminant calves. Plant proteins accounted for 3.46 to 9.69% CP in the MR powders with HWG (Table 1; 17 to 36% of the CP) and 6.44 to 12.88% of CP in the MR powders with RPC (Table 3; 24 to 49% of the CP). Amino acids are critical for growth of the neonate; specifically, moderate CP, Lys, and Met deficiencies in the calf less than 4 wk of age have been shown to reduce ADG by more than 20% (Hill et al., 2008). It is our hypothesis that the CP and essential amino acids supplied by HWG and RPC were inefficiently digested and contributed to reduced ADG and other performance measures in trials 1, 2, and 3. However, we did not measure CP digestibility and limited data addresses this hypothesis.

For comparative purposes, ADG of calves fed MR with no plant proteins were predicted using NRC (2001) and the average BW, intake of MR and starter, and average trial ambient temperature. In trial 1, ADG was predicted to be 0.52 kg/d. Observed ADG was 0.56 kg/d. In trial 2, ADG was predicted to be 0.61 kg/d. Observed ADG was 0.64 kg/d. In trial 3, ADG was predicted to be 0.64 kg/d. Observed ADG was 0.39 kg/d, considerably less than predicted, unlike predicted vs. observed in trials 1 and 2.

In all 3 trials, relative to the energy supplied, the MR were formulated to be adequate and equal in CP, fat, Lys, Met, Thr, Ca, P, and added trace minerals and vitamins and fed to Holstein dairy calves less than 2 mo of age. Preweaning ADG was reduced 12 to 21% when CP from HWG (80% CP) replaced 15 to 38% of the CP from whey protein concentrate (78% CP). Preweaning ADG was reduced 12 to 54% when CP from RPC (80% CP) replaced 25 to 50% of CP from whey protein concentrate. Thus, the inferior performance of calves fed MR with HWG and RPC was not because of limiting gross nutrients. The carbohydrates contributed by HWG and RPC were minimal (0.4 to 2%). It is hypothesized that the poor performance is significantly related to an inability of the neonatal calf to efficiently digest the CP and amino acids in HWG and RPC.

IMPLICATIONS

Hydrolyzed wheat gluten and RPC (each 80% CP ingredients) were included in MR for Holstein dairy calves less than 2 mo of age. All MR were formulated to be equal in CP, fat, Lys, Met, Ca, P , and added trace minerals and vitamins, and all were adequate in essential amino acids. Body weight gains were reduced 12 to 21% when wheat protein replaced 15 to 38% of whey protein. Body weight gains were reduced 12 to 54% when rice protein replaced 25 to 50% of whey protein.

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