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Extent of variability in nutrient composition within selected by-product feedstuffs

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Abstract

The nutrient composition of nine by-product feedstuffs (BPF) was determined. BPF were selected based on economic importance to the dairy industry, nutritional value, and availability. Three to nine different samples for each BPF were obtained throughout California. A total of 51 samples were collected: nine beet pulp (BP), eight rice bran (RB), seven almond hulls (AH), four citrus pulp (CT), five bakery waste (BW), eight wheat mill run (WMR), four brewers grains (BG), three distillery grains (DG), and three soy hulls (SH) samples. Chemical analyses measured included dry matter, ash, crude protein (CP), fiber fractions, macrominerals, and microminerals. The average chemical analyses determined for each BPF were compared with average values reported by the National Research Council (NRC). Considerable variation within a given BPF was observed in the present study. For example, BP was found to contain 18.81% acid detergent fiber (ADF) while the NRC reported an average composition of 25% ADF. The ether extract content of RB was found to be 20.48% compared with 15.1% reported by NRC. Much of this variability was related to how the commodity was handled during or after processing. In the second part of this study, two theoretical diets were formulated to calculate the effect of nutrient variability on diet composition. The BPF compositions of the two diets were 27% and 50% in Diet 1 and Diet 2, respectively. Specific by-products sources of BP, RB, DG, and SH were compared with the NRC diet composition used in the initial diet formulation. As the proportion of BPF in the diet was increased (Diet 2) nutrient composition of the diet was more variable with CP content ranging from 14.30 to 15.20%. Similar changes to those observed for CP were observed for the other chemical components. The effect of variability in by-product composition was more evident when evaluated on a concentrate mix basis. Variability in the chemical component of BPF influenced the composition of both the total diet and the concentrate mix, and the magnitude of effect depended upon the contribution of BPF to the total ration and the nutrient of interest.

Keywords: Chemical composition; Variability; By-products, general; Feedstuffs

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Table 2
Nitrogen concentration (% DM) in substrates after being deep-stacked with broiler litter

Substrate	Duration (weeks)	Position[a]	Urea[b]		SE	Cover[c]		SE	No urea		Urea added		SE
			−	+		−	+		Open	Covered	Open	Covered	
Bermudagrass									2.75a	2.83a	4.32c	4.11b	0.058
	3		2.83a	4.13b									
	9		2.75a	4.30c	0.058								
Wheat straw	3								0.95a	1.21b	2.20d	1.90c	
	9								1.15b	1.03a	2.25d	2.19d	0.039
Rice straw	3								1.17a	1.31b	2.11c	2.05c	
	9								1.32b	1.15a	2.00c	2.27d	0.040
	3	Top				1.58a	1.75b						
		Bottom				1.71b	1.60a						
	9	Top				1.64a	1.66a						
		Bottom				1.68ab	1.76b	0.040					
Rice hulls	3								0.79a	1.16b	1.79d	1.48c	
	9								0.91a	0.79a	1.85d	1.91d	0.081
Pine shavings	3		0.47a	1.35c									
	9		0.45a	1.47b	0.027								

[a]Positioned 36 cm and 72 cm from surface of 1.1-m-high deep-stack for top and bottom, respectively.
[b]Urea mixed with broiler litter before deep-stacking (0 or 5.4% of litter dry matter).
[c]Without (−) or with (+) plastic covering of broiler litter deep-stacks.
Means in a row or treatment grouping without a common letter differ ($P < 0.05$).

Table 1
Brief description of by-product feedstuffs (BPF) evaluated

By-product	Origin	Comments	Ref.[a]
Beet pulp	Sugar beet pulp remaining after extraction of sugar	Fed either in the wet or dry form. Drying includes direct heat and/or solar. Additives include cane beet molasses and/or $CaCO_3$ and/or Steffen's filtrate	1, 2, 3, 7
Rice bran	Bran layer and germ of the rice with small quantities of grain fragments	Composition depends on grain milling process, heating, additives, and amount of fat extracted	3, 4, 7
Almond hulls	Primarily mesocarp surrounding the almond fruit	Composition influenced by varietal differences and contamination from soil and almond shells	1, 5, 7
Citrus pulp	Pulp remaining after production of juice or canned fruit from citrus as well as cull fruits	Fed in either the wet or dry form. Seasonal availability, seed content variable. In California, wet pulp averages 80% orange and 20% grapefruit. Additives may be used	1, 3, 7
Bakery waste	Blended mix of unsold products from bakery and food processing	Usually in dry form. Chemical and ingredient composition is highly variable due to sources, products included, and fat content of ingredients. Regional variability	3, 6
Wheat mill run	Mainly the coarse outer coating of the wheat kernel	Composition varies according to wheat variety and milling technique	1, 3, 7
Brewers grains	Spent grain from brewing of beer. Mainly barley rice, and sometimes wheat	Often fed wet. Good source of protein and energy. Undegradable protein content higher than most BPF. Regional variability in composition and availability	1, 3, 7
Distillery grains	Residue of alcohol and distilled liquor manufacturing resulting from the yeast fermentation of grains including corn, sorghum, barley, and rye	Chemical composition depends on grain used. High in fat, crude protein, and undegradable protein	1, 3, 7
Soy hulls	Hulls removed from soybeans prior to extraction of fat or production of flour	Processing and handling alter digestibility. High in fiber, low in lignin content	1, 3, 7

[a] 1, Bath et al. (1980); 2, Bhattacharya and Sleiman (1970); 3, Morrison (1959); 4, Saunders (1990); 5, Aguilar et al. (1984); 6, Waldroup et al. (1982); 7, Feed Industry Red Book (1994).

modity contained samples collected from different sources throughout the state of California. A total of 51 samples from nine different BPF commonly used in the feeding programs of lactating dairy cows were obtained and analyzed to determine the differences in their chemical composition. The number of samples for each commodity varied because in some cases few sources were available. Samples obtained included nine beet pulp (BP), eight rice bran (RB), seven almond hulls (AH), four citrus pulp (CT), five bakery waste (BW), eight wheat mill run (WMR), four brewers grains (BG), three distillery grains (DG), and three soy hulls (SH). General descriptions of these BPF are shown in Table 1. In preparation for chemical analysis, all samples were ground to pass through a 1 mm screen using a Wiley Mill (Arthur A Thomas, Philadelphia, PA). BG and CT samples were obtained in the wet form and stored frozen until they were freeze dried prior to drying in preparation for grinding.

2.2. Chemical analysis

Samples were analyzed for dry matter (DM), ash, crude protein (CP), ether extract (EE), acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose (CELL), acid detergent lignin (LIG), calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), and selenium (Se) content. Ash, DM, and N were determined according to the Association of Official Analytical Chemists (AOAC, 1984) and CP was calculated as %N × 6.25. Neutral detergent fiber was analyzed according to Van Soest et al. (1991), and ADF and LIG were determined by procedures described by Goering and Van Soest (1970). Cellulose was calculated as the difference between ADF and LIG. For mineral determinations, samples were wet digested in 10 ml of nitric acid overnight on a steam bath and subsequently digested with 70% perchloric acid. Calcium, Mg, K, Na, Zn, Mg, Fe, and Cu were analyzed by atomic absorption spectrophotometry (Model 3030B, Perkin Elmer, Norwalk, CT) using standard procedures of the AOAC (1984). Phosphorus was analyzed with a technicon autoanalyzer using method N-4C (Kraul, 1966). Finally, Se was determined with an autoanalyzer fluorometric selenium method described by Brown and Watkinson (1977).

2.3. Theoretical diets

The two theoretical diets and the grain ingredient composition used to calculate the effect of nutrient variability on diet composition are shown in Table 2. The diets were generated using the following main inputs to calculate the requirements of a lactating dairy cow: 612 kg body weight, 29.5 kg milk per day, 3.5% milk fat, 100 days in milk, 21.8 kg DM intake per day, and a concentrate to forage ratio of 60:40. The two levels of by-products chosen were 16.3% and 30% of total DM for Diet 1 and Diet 2. The by-product compositions of the concentrate portion of the two diets were 27% in Diet 1 and 50% in Diet 2. Two levels of BPF were used to emphasize the effect of by-products at different amounts in the diet.

The diets were initially formulated to meet NRC animal requirements and NRC table compositions for all feedstuffs were used (NRC, 1989). To demonstrate the effect of nutrient variability in BPF on diet composition, specific by-product sources of BP, RB, DG, and SH were compared with the NRC diet compositions used in the initial diet formulation. The BPF composition of ADF was used to stratify the by-products into a low, high, and average

Table 2
Ingredient composition of two theoretical diets formulated for two by-product levels using NRC (1989) values and determined nutrient composition for selected by-products

Ingredient[a]	% DM	Total diet		Grain mix	
		Diet 1	Diet 2	Diet 1	Diet 2
Corn silage	33.00	10.50	10.50	0.00	0.00
Alfalfa	90.00	13.50	13.50	0.00	0.00
Haylage	30.00	15.00	15.00	0.00	0.00
Whole cotton seed	92.00	14.50	11.30	24.25	18.90
Corn rolled	89.00	22.00	15.00	36.79	25.08
Canola meal	91.00	7.00	3.50	11.71	5.85
Beet pulp	91.50	12.50	12.00	20.90	20.07
Rice bran	91.00	3.80	10.00	6.35	16.72
Distillery grains	92.00	0.00	4.00	0.00	6.69
Soy hulls	91.00	0.00	4.00	0.00	6.69
Dicalcium phosphate	97.00	0.40	0.40	0.00	0.00
Bicarbonate	100.00	0.80	0.80	0.00	0.00
Total		100.00	100.00	100.00	100.00

[a]Beet pulp, rice bran, distillery grains, and soy hulls were used as variable by-products.

ADF percentage. These BPF compositions were then used to calculate the nutrient compositions of Diet 1 and Diet 2. Hence, comparisons were made between NRC compositions and diets calculated from BPF sources which had low, high, or average ADF percentages. For feed ingredients not analyzed in this study, for example, whole cottonseed and forage feedstuffs, chemical compositions from a standard reference (NRC, 1989) were used.

3. Results and discussion

3.1. Variability in nutrient composition

The chemical analyses for each BPF are presented in Table 3 along with the number of samples analyzed for each BPF, the average composition, and the standard deviation (SD). The SD can be used as an indication of the dispersion of individual values about the mean or average.

In addition, the nine BPF analyzed were compared with reported average values from the NRC (1989) in Table 4. A major limitation of comparing the analyses obtained from this study with values reported by NRC is that NRC does not give the SD and the number of samples evaluated to obtain the reported chemical analyses for each BPF.

Feedstuffs are discussed individually because the primary objective of the study was to determine the amount of variability that exists within a given BPF. Although numerous analyses were conducted on each BPF, the discussion will be limited to chemical constituents demonstrating considerable variation.

Table 3
Chemical composition of by-products (DM basis)

Feed[a]	DM (%)	ASH (% DM)	EE (% DM)	CP (% DM)	ADF (% DM)	NDF (% DM)	CELL (% DM)	LIG (% DM)	Ca (% DM)	P (% DM)	Mg (% DM)	K (% DM)	Na (% DM)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Se (ppb)
BP	90.59	9.48	0.18	9.46	16.97	32.89	15.29	1.06	1.29	0.06	0.24	2.12	1.95	52	63	6	356	140
BP	91.09	9.55	0.75	9.61	17.21	33.22	15.44	1.12	1.26	0.07	0.24	2.38	1.32	36	65	9	368	167
BP	90.78	9.58	0.23	8.98	17.79	34.70	15.76	1.37	1.36	0.08	0.28	2.18	1.65	33	74	10	508	178
BP	91.09	9.79	0.45	9.31	18.23	35.82	16.43	1.23	1.24	0.04	0.23	2.33	1.38	29	51	5	330	13
BP	91.85	9.33	0.77	8.67	18.24	34.39	16.23	1.48	1.35	0.08	0.29	2.31	1.28	31	75	11	483	13
BP	91.80	9.14	0.53	8.13	18.79	33.81	16.36	1.38	0.98	0.05	0.28	2.46	0.92	25	61	11	657	184
BP	89.70	7.61	0.38	8.38	19.96	37.90	15.41	1.58	1.18	0.06	0.23	1.43	1.06	19	76	7	527	189
BP	89.58	5.23	0.61	7.09	20.86	38.75	19.08	1.41	0.77	0.06	0.32	1.43	0.32	25	95	6	548	142
BP	90.90	6.32	0.45	8.97	21.23	41.10	18.13	2.65	0.86	0.06	0.22	1.47	0.82	33	94	6	282	101
AVG	90.82	8.45	0.48	8.73	18.81	35.84	16.46	1.48	1.14	0.06	0.26	2.01	1.19	31	73	8	451	139
SD	0.79	1.67	0.21	0.79	1.54	2.82	1.31	0.47	0.22	0.01	0.04	0.44	0.48	9	15	2	123	55
RB	92.14	6.74	18.24	13.40	10.54	21.93	5.31	3.67	0.07	1.63	0.68	1.50	0.02	60	267	10	125	128
RB	90.30	6.46	18.40	12.94	9.38	20.12	5.52	3.10	0.05	1.61	0.72	1.42	0.03	87	230	6	136	120
RB	90.23	6.50	18.70	13.46	9.68	21.35	5.21	3.66	0.06	1.58	0.69	1.39	0.02	75	241	7	122	88
RB	90.45	6.79	29.35	13.32	9.64	22.67	5.90	3.24	0.04	1.73	0.74	1.54	0.28	86	251	7	102	101
RB	90.65	6.47	20.79	13.19	10.39	21.54	5.94	4.31	0.05	1.66	0.73	1.48	0.01	75	240	11	100	264
RB	92.72	7.73	21.38	14.15	9.15	21.19	5.54	3.25	0.18	1.76	0.75	1.59	0.39	164	389	20	142	338
RB	90.73	7.31	22.71	14.96	10.25	22.73	6.50	4.04	0.11	1.91	0.84	1.86	0.02	75	347	11	88	206
RB	90.84	6.97	24.25	14.39	9.12	21.49	5.40	3.41	0.04	1.89	0.83	1.66	0.01	69	241	10	107	151
AVG	91.01	6.87	20.48	13.73	9.77	21.63	5.67	3.59	0.08	1.72	0.75	1.55	0.10	86	276	10	115	174
SD	0.92	0.45	2.20	0.70	0.56	0.84	0.43	0.42	0.05	0.13	0.06	0.15	0.15	33	59	4	19	88
AH	89.45	4.50	2.29	3.87	20.72	28.66	13.88	6.56	0.20	0.07	0.12	2.36	0.02	37	5	4	230	82
AH	88.87	5.25	2.42	5.06	23.71	31.88	14.79	8.47	0.24	0.05	0.11	2.90	0.01	20	16	10	406	55
AH	88.16	5.45	2.74	5.17	24.68	31.81	14.63	10.03	0.26	0.08	0.14	2.82	0.02	27	14	9	361	55
AH	86.73	4.76	1.93	6.36	25.96	34.98	16.28	9.20	0.05	0.06	0.12	2.44	0.03	22	17	12	222	56
AH	89.18	5.20	2.41	4.71	26.01	33.94	15.97	9.08	0.24	0.07	0.13	2.61	0.02	25	16	11	436	35
AH	89.05	5.06	2.61	6.50	29.14	35.39	16.15	12.75	0.27	0.12	0.12	2.55	0.01	63	13	10	273	84
AH	84.68	5.01	2.36	8.00	33.44	39.26	17.82	14.95	0.29	0.11	0.37	2.27	0.01	20	69	19	406	104

Feed[a]	DM (%)	ASH (% DM)	EE (% DM)	CP (% DM)	ADF (% DM)	NDF (% DM)	CELL (% DM)	LIG (% DM)	Ca (% DM)	P (% DM)	Mg (% DM)	K (% DM)	Na (% DM)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Se (ppb)
AVG	88.02	5.03	2.39	5.67	26.24	33.70	15.65	10.15	0.22	0.08	0.16	2.57	0.02	30	21	11	334	67
SD	1.73	0.32	0.26	1.38	4.08	3.36	1.32	2.81	0.08	0.03	0.09	0.23	0.07	15	21	4	90	23
CT	89.09	2.84	1.09	6.26	13.76	14.48	12.76	0.99	0.73	0.11	0.10	0.55	0.87	19	7	3	77	ND
CT	90.95	2.85	1.14	6.60	13.85	14.86	13.07	0.78	0.83	0.10	0.09	0.70	0.91	57	6	2	47	ND
CT	90.96	7.31	1.14	5.84	18.06	18.98	17.07	0.99	1.98	0.11	0.10	0.66	1.37	29	9	2	62	ND
CT	91.14	7.54	1.10	6.87	21.60	22.43	20.73	0.88	2.16	0.10	0.11	0.76	1.14	42	7	2	144	ND
AVG	90.53	5.14	1.12	6.39	16.82	17.69	15.91	0.91	1.43	0.11	0.10	0.67	1.07	37	7	2	82	ND
SD	0.97	2.65	0.03	0.44	3.77	3.76	3.76	0.10	0.75	0.00	0.01	0.09	0.23	17	1	1	43	ND
BW	91.44	3.81	4.46	11.91	7.51	17.89	5.02	2.21	0.10	0.44	0.24	3.73	0.03	56	52	7	425	74
BW	90.25	3.57	6.35	11.38	6.45	15.27	3.73	1.86	0.17	0.32	0.15	0.23	0.70	56	40	6	425	164
BW	92.41	2.35	9.35	11.91	2.23	8.23	1.10	1.16	0.39	0.15	0.09	1.79	0.76	52	8	4	125	271
BW	90.33	3.03	10.80	13.26	3.58	10.39	2.46	1.40	0.15	0.33	0.15	0.14	0.73	52	47	9	388	334
BW	89.42	3.49	11.70	12.99	4.96	7.52	2.91	1.69	0.13	0.53	0.26	0.75	0.34	32	78	8	377	624
AVG	90.77	3.25	8.53	12.29	4.95	11.86	3.05	1.66	0.19	0.35	0.18	1.33	0.51	50	45	7	348	293
SD	1.16	0.58	3.05	0.80	2.13	4.53	1.46	0.41	0.12	0.14	0.07	1.49	0.32	10	25	2	127	210
WMR	87.43	3.32	5.31	18.64	8.06	29.91	5.69	2.69	0.10	0.85	0.41	0.83	0.01	132	121	15	111	444
WMR	87.75	3.96	3.65	19.45	9.80	37.92	7.20	3.01	0.12	1.03	0.50	1.01	0.02	98	128	16	103	536
WMR	88.71	4.35	3.91	18.29	10.14	39.33	7.49	2.78	0.23	1.15	0.64	1.17	0.02	100	117	15	117	520
WMR	87.87	4.24	7.71	20.27	10.75	38.54	6.93	3.78	0.12	1.13	0.65	1.04	0.02	101	249	21	130	473
WMR	88.41	4.53	3.94	17.94	11.43	40.16	8.23	3.16	0.29	1.11	0.49	1.16	0.03	101	135	16	151	287
WMR	87.82	4.36	7.23	17.44	12.25	41.05	9.02	3.34	0.23	1.07	0.49	1.16	0.02	91	142	15	166	716
WMR	87.84	4.67	4.06	18.41	12.79	45.86	9.19	3.68	0.20	1.20	0.55	1.24	0.01	145	148	15	121	766
WMR	87.90	4.86	4.39	18.37	13.12	44.05	9.23	3.98	0.13	1.13	0.56	1.12	0.01	101	157	16	153	532
AVG	87.97	4.29	5.03	18.60	11.04	39.60	7.87	3.30	0.18	1.08	0.54	1.09	0.02	109	149	16	131	534
SD	0.40	0.48	1.60	0.88	1.70	4.77	1.27	0.48	0.07	0.11	0.08	0.13	0.01	19	42	2	23	151
BG	91.13	2.92	4.96	23.82	15.50	38.72	11.48	4.02	0.18	0.49	0.25	0.03	0.02	98	46	18	105	ND
BG	92.95	3.76	5.52	26.23	20.06	51.36	13.40	6.17	0.39	0.53	0.18	0.02	0.02	101	39	28	174	ND
BG	93.66	3.75	6.36	26.80	20.42	58.21	15.04	4.66	0.24	0.55	0.26	0.04	0.03	113	60	18	166	ND
BG	92.22	4.19	7.49	26.92	20.10	54.95	13.36	4.66	0.25	0.19	0.43	0.34	0.07	75	53	35	145	ND

Feed[a]	DM (%)	ASH (% DM)	EE (% DM)	CP (% DM)	ADF (% DM)	NDF (% DM)	CELL (% DM)	LIG (% DM)	Ca (% DM)	P (% DM)	Mg (% DM)	K (% DM)	Na (% DM)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Se (ppb)
AVG	92.49	3.65	6.08	25.94	19.02	50.81	13.32	4.88	0.27	0.44	0.28	0.11	0.03	97	50	24	148	ND
SD	1.08	0.53	1.10	1.45	2.35	8.53	1.45	0.91	0.09	0.17	0.11	0.15	0.03	16	9	8	31	ND
DG	88.73	4.81	9.27	29.52	15.87	36.29	12.69	3.24	0.63	0.90	0.21	1.11	0.20	71	94	5	309	321
DG	85.47	4.20	11.20	30.12	21.17	38.87	16.39	4.63	0.55	0.98	0.39	1.24	0.24	66	36	9	147	354
DG	88.23	4.05	10.79	14.53	22.01	42.53	15.53	6.35	0.28	0.80	0.19	1.02	0.66	69	37	6	143	239
AVG	87.48	4.35	10.42	24.72	19.68	39.23	14.87	4.74	0.49	0.90	0.26	1.12	0.37	69	56	7	199	305
SD	1.76	0.41	1.02	8.84	3.33	3.14	1.94	1.56	0.18	0.09	0.11	0.11	0.26	2	33	2	95	60
SH	89.83	5.52	5.75	14.60	43.39	56.51	39.86	1.90	1.12	0.18	0.26	1.64	0.02	58	41	12	1401	343
SH	90.01	4.85	3.66	13.73	43.79	58.77	41.33	1.71	0.63	0.13	0.26	1.40	0.01	65	35	14	794	179
SH	88.72	5.05	3.79	10.62	49.11	57.13	46.20	1.82	0.60	0.08	0.23	1.49	0.02	53	29	10	865	189
AVG	89.52	5.14	4.40	12.98	45.43	57.47	42.46	1.81	0.78	0.13	0.25	1.51	0.02	58	35	12	1020	237
SD	0.70	0.34	1.17	2.09	3.19	1.17	3.32	0.09	0.29	0.05	0.02	0.12	0.01	6	6	2	332	92

[a]BP, beet pulp; RB, rice bran; AH, almond hulls; CT, citrus pulp; BW, bakery waste; WMR, wheat mill run; BG, brewers grain; DG, distillery grains; SH, soy hulls; AVG, average; SD, standard deviation; ND, not determined. Citrus pulp values and DM values for BG are after freeze drying.

[1]DM, dry matter; EE, ether extract; CP, crude protein; ADF, acid detergent fibre; NDF, neutral detergent fibre ash free; CELL, cellulose; LIG, lignin; Ca, calcium; P, phosphorus; Mg, mangnesium; K, potassium; Na, sodium; Zn, zinc; Mn, manganese; Cu, copper; Fe, iron; Se, selenium.

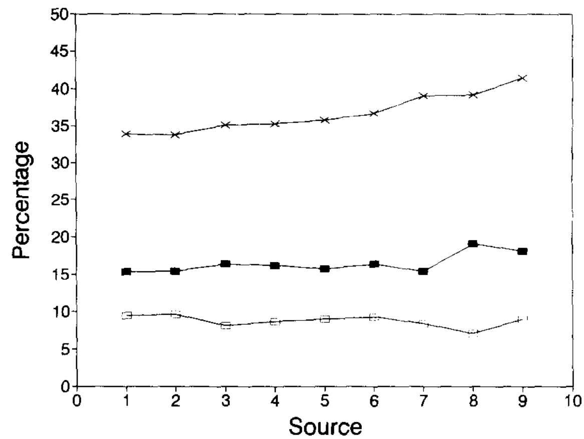

Fig. 1. Percentage of cellulose (■), crude protein (□) and neutral detergent fiber (×) in beet pulp across sources.

3.2. Beet pulp

The average ADF in BP was 18.81% with a SD of 1.54 (Table 3). The range in NDF content among sources was quite large (Fig. 1). However, the extent of lignification in this root crop is low compared with other by-products in this study. The low lignin content in BP may influence the extent of digestibility of this by-product (Bath et al., 1980). Furthermore, BP is low in fat with an average value of 0.48% EE and SD of 0.21 (Table 3).

BP is well known for its low P content (NRC, 1989) in agreement with previous findings (Huffman and Duncan, 1950; Ronning and Bath, 1962; Bhattacharya and Sleiman, 1970; Falk et al., 1992). Phosphorus varied from 0.04 to 0.08% with a mean value of 0.06%. In contrast, BP was considerably higher in most of the other macrominerals and microminerals when compared with reported values (Table 4). The total ash content of BP varied considerably ranging from 5.23 to 9.79% with an average of 8.45%. The amount of variation in ash content agrees with estimates reported early (Huffman and Duncan, 1950; Falk et al., 1992). The amount of variation was reported to be a consequence of handling and/or treatment of the pulp after extraction of the sugar (Bath et al., 1980). Crude protein content varied to some extent ranging from 7.09 to 9.61% with a mean of 8.73% (Table 3). Crude protein was slightly lower than reported by NRC (1989) (Table 4) and by others (Huffman and Duncan, 1950; Falk et al., 1992). Considerable difference was observed for ADF content (Table 4) which averaged 18.81% in the present study compared with the reported estimate of 25.00% for NRC (1989).

The chemical composition of BP varied considerably among sources. Therefore, it would be prudent to obtain the chemical composition of BP from different sources and to use these values in diet formulation.

3.3. Rice bran

RB is a high fat BPF. The variability in fat content was larger than the variability of its fiber content (Fig. 2). Fat content ranged from 18.24 to 24.25% (Table 3). The mean fat

Table 4
Comparison of the average chemical composition of by-products relative to NRC values

Feedstuff	Item[a]	No.[b]	DM (%)	ASH (%)	EE (%)	CP (%)	ADF (%)	NDF (%)	CELL (%)	LIG (%)
Beet pulp	NRC		92.00	6.10	0.60	10.10	25.00	44.00	22.00	3.00
	UCD	9	90.82	8.45	0.48	8.73	18.81	35.84	16.46	1.48
	Diff		1.18	−2.35	0.12	1.37	6.19	8.16	5.54	1.52
Rice bran	NRC		91.00	12.80	15.10	14.10	18.00	33.00	11.00	ND
	UCD	8	91.01	6.87	20.48	13.73	9.77	21.63	5.67	3.59
	Diff		−0.01	5.93	−5.38	0.37	8.23	11.37	5.33	ND
Almond hulls	NRC		90.00	7.60	3.60	2.70	20.00	25.00	14.00	6.00
	UCD	7	88.02	5.03	2.39	5.67	26.24	33.70	15.65	10.15
	Diff		1.98	2.57	1.21	−2.97	−6.24	8.70	−1.65	−4.15
Citrus pulp	NRC		91.00	6.60	3.70	6.70	22.00	23.00	18.00	3.00
	UCD	4	90.53	5.14	1.12	6.39	16.82	17.69	15.91	0.91
	Diff		0.47	1.46	2.58	0.31	5.18	5.31	2.09	2.09
Bakery waste	NRC		92.00	4.40	12.07	10.70	13.00	18.00	12.00	1.00
	UCD	5	90.77	3.25	8.53	12.29	4.95	11.86	3.05	1.66
	Diff		1.23	1.15	4.17	−1.59	8.05	6.14	8.95	−0.66
Wheat mill run	NRC		90.00	5.90	4.60	17.20	ND	ND	ND	ND
	UCD	8	87.97	4.29	5.03	18.60	11.04	39.60	7.87	3.30
	Diff		2.03	1.61	−0.43	−1.40	ND	ND	ND	ND
Brewers grains	NRC		92.00	4.80	6.50	25.40	23.00	42.00	18.00	5.00
	UCD	4	92.49	3.65	6.08	25.94	19.02	50.81	13.32	4.88
	Diff		−0.49	1.15	0.42	−0.54	3.98	−8.80	4.68	0.12
Distillery grains	NRC		94.00	2.40	9.80	23.00	17.00	43.00	12.00	5.00
	UCD	3	87.48	4.35	10.42	24.72	19.68	39.23	14.87	4.74
	Diff		6.52	−1.95	−0.62	−1.72	−2.68	3.77	−2.87	0.26
Soy hulls	NRC		91.00	5.10	2.10	12.10	50.00	67.00	46.00	2.00
	UCD	3	89.52	5.14	4.40	12.98	45.43	57.47	42.46	1.81
	Diff		1.48	−0.04	−2.30	−0.88	4.57	9.53	3.54	0.19

percentage of 20.48% was much higher than the 15.1% EE reported by NRC (1989), a difference which could be a consequence of the processing techniques (Table 4). The treatment and handling of the rice such as defatted, parboiled, and nonparboiled rice after or during the milling process greatly altered the chemical composition of the RB produced (Saunders, 1990). The same author reported variability in EE content of RB ranging from 0.5 to 32.0%, and the variability in chemical composition reflected processing differences. A knowledge of the processing methods employed in the production of RB could provide the nutritionist insight into the expected nutrient concentration of RB. The average ash value of 6.87% observed in this study was lower than the value reported by NRC (1989)

Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)	Se (ppb)
0.23	0.11	0.13	0.53	0.02	24	21	11	301	ND
1.14	0.06	0.26	2.01	1.19	31	73	8	451	139
−0.91	0.05	−0.13	−1.48	−1.17	−7	−52	3	−150	ND
0.08	1.70	1.04	1.92	0.04	32	415	15	210	440
0.08	1.72	0.75	1.55	0.10	86	276	10	115	174
0.00	−0.02	0.29	0.37	−0.06	−54	139	5	95	266
0.23	0.11	0.13	0.53	0.02	24	21	11	301	ND
0.22	0.08	0.16	2.57	0.02	30	21	11	334	67
0.01	−0.03	−0.03	−2.04	0.00	−6	ND	ND	−33	ND
1.84	0.12	0.17	0.79	0.09	15	7	6	378	ND
1.43	0.11	0.10	0.67	1.07	37	7	2	82	ND
0.41	0.01	0.07	0.12	−0.98	−22	ND	−4	296	ND
0.14	0.26	0.26	0.53	1.24	16	71	5	31	ND
0.19	0.35	0.18	1.33	0.51	50	45	7	348	293
−0.05	−0.09	0.08	−0.80	0.73	−34	26	−2	−317	ND
0.11	1.13	0.52	1.33	0.24	ND	116	21	105	ND
0.18	1.08	0.54	1.09	0.02	109	149	16	131	534
−0.07	0.05	−0.02	0.24	0.22	ND	−33	5	−26	ND
0.33	0.55	0.16	0.09	0.23	30	40	23	266	760
0.27	0.44	0.28	0.11	0.03	97	50	24	148	ND
0.07	0.11	−0.12	−0.02	0.20	−67	−10	−1	118	ND
0.11	0.43	0.07	0.18	0.10	35	23	48	223	480
0.49	0.90	0.26	1.12	0.37	69	56	7	199	305
−0.38	−0.47	−0.19	−0.94	−0.27	−34	−33	41	24	175
0.49	0.21	ND	1.27	0.01	24	11	18	324	ND
0.78	0.13	0.25	1.51	0.02	58	35	12	1020	237
−0.29	0.08	ND	−0.24	−0.01	−34	−24	6	−696	ND

[a]NRC, composition reported by NRC (1989); UCD, composition determined in the present study; Diff, Difference between NRC estimates and UCD determination; ND, not determined.
[b]Number of samples contributing to the UCD average value.
DM, dry matter; EE, ether extract; CP, protein; ADF, acid detergent fibre; NDF, neutral detergent fibre ash free; CELL, cellulose; LIG, lignin.

of 12.80% (Table 4). Similarly, the ADF mean of 9.77% was lower than the average value of 18% reported by NRC (1989). The LIG content of RB is influenced by the amount of rice hulls present. In this study (Table 3), the variability of LIG was small with a range in content from 3.10 to 4.31% with a mean of 3.59%.

The mean percentage of Ca in RB was much lower than the mean P percentage (0.08% and 1.72%, respectively; Table 3). The Ca and P composition agrees closely with previous

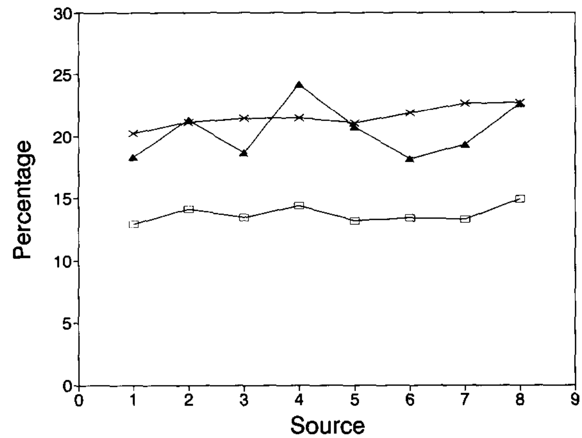

Fig. 2. Percentage of ether extract (▲), crude protein (□) and neutral detergent fiber (×) in rice bran across sources.

estimates (Table 4). However, considerable variation was found in the content of some microminerals including Zn, Mn, Cu, Fe, and Se (Table 4). Little information exists in the literature about the content of macrominerals and microminerals for RB.

In short, major discrepancies exist for ash, EE, and the fiber component of RB between reported values (NRC, 1989) and the observations of this study.

3.4. Almond hulls

The amount of variability for most of the chemical analyses was large for AH. Dry matter varied from 84.68 to 89.45% with a mean of 88.02% and a standard deviation of 1.73% (Table 3), while the NRC (1989) reports 90% for DM in AH (Table 4).

Ash ranged from 4.50 to 5.45% with an average of 5.03% and SD of 0.32%. The ash content was lower than previously observed at this station (Aguilar et al., 1984). The CP content of AH was variable with a low of 3.87% and a high of 8.00% (Table 3). The average CP content (5.67%) was twice the value (2.70%) reported by NRC (1989) (Table 4).

The ADF content ranged from 20.72 to 33.44% (Table 3). The average composition of 26.24% ADF exceeded the reported value of 20.00% by NRC (1989) (Table 4). Cellulose content (Table 3) ranged from 13.88 to 17.82% with a mean of 15.65%, which agrees with previous estimates (Aguilar et al., 1984). The range for LIG content was large, 6.56–14.95%, with a mean value of 10.15% (Table 3). Aguilar et al. (1984) also reported a wide range in LIG composition of AH; for example, LIG content for the nonpareil variety ranged from 7.7 to 16.6%.

Compared with NRC (1989) reported values (Table 4), the concentrations of macrominerals and microminerals were similar with the exception of K. The NRC (1989) value of 0.53% K was considerably lower than the 2.57% observed in the present study. The reasons for this difference are unknown.

3.5. Citrus pulp

The DM content of CT ranged from 23.63 to 34.56% on a wet basis, although values are not reported here. Ash content was quite variable (Table 3) and averaged 5.14%, the latter being lower than the value of 6.6% (Table 4) reported by NRC (1989).

The CP content of CT was similar across sources (Table 3), and the mean CP estimates of 6.39% agree closely with previous estimates of 6.8% (Brown and Johnson, 1991) and 6.9% (Bath et al., 1980). In contrast to CP, the ADF content varied considerably from source to source (Table 3). Content of ADF ranged from 13.76 to 21.60 with a mean of 16.82%. The mean ADF content agreed with the 18.1% reported by Brown and Johnson (1991), but both estimates were lower than the 23.00% reported by Bath et al. (1980).

The LIG content (Table 3) was lower than previously reported (NRC, 1989; Brown and Johnson, 1991). It is well known that CT is high in Ca and low in P content (Morrison, 1959), and Ca and P contents agreed with reported estimates (Bath et al., 1980; NRC, 1989). The concentration of other macrominerals agreed closely with reported estimates (Table 4). Although considerable variability existed in the content of microminerals among sources, average values agreed closely with reported estimates.

The variability for the chemical components in CT, particularly the ADF fraction, could make it difficult for nutritionists to use book values because source of the CT greatly influenced its nutrient content.

3.6. Bakery waste

The EE content varied greatly with source of the product (Fig. 3), and the average content was considerably lower than previously reported estimates (Champe and Church, 1980; Waldroup et al., 1982; Dale and Fuller, 1984). The CP averaged 12.29% which was higher (Table 4) than the 10.70% reported by NRC (1989).

The ADF content of BW averaged 4.95% (Table 4), markedly lower than the 13.0% ADF reported in the literature (NRC, 1989). Similarly, CELL content averaged 3.05%,

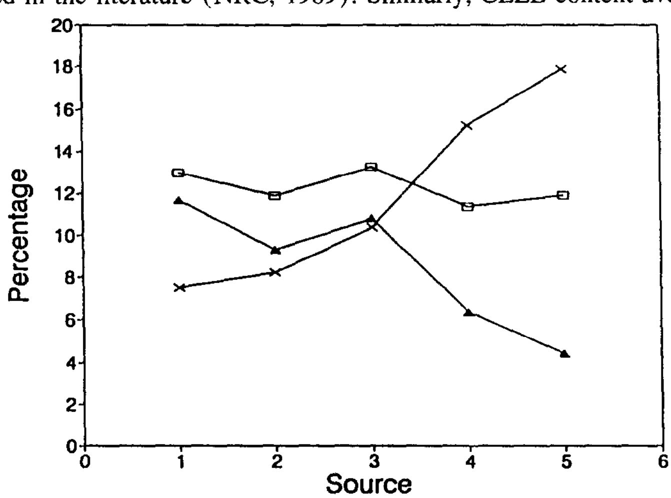

Fig. 3. Percentage of ether extract (▲), crude protein (□) and neutral detergent fiber (×) in bakery waste across sources.

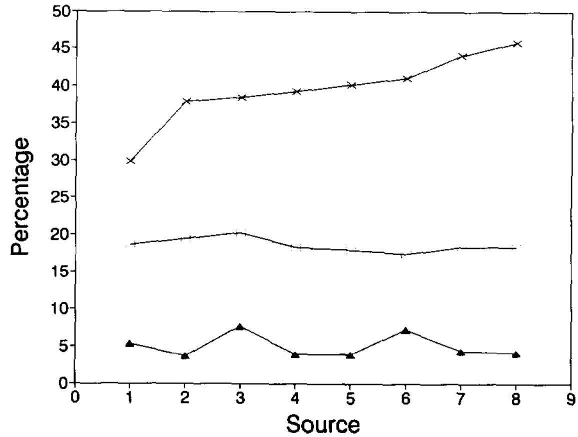

Fig. 4. Percentage of ether extract (▲), crude protein (□), and neutral detergent fiber (×) in wheat mill run across sources.

while NRC (1989) reported an average content of 12.0%. These differences in fiber composition likely reflect the variation in ingredients used to make BW.

Substantial variation existed in mineral composition. For the macrominerals, Na concentration was approximately half of the estimate (Table 4) reported by NRC (1989). Similarly, the micromineral composition varied considerably with source of the product (Table 3) and varied from reported estimates (Table 4). The range in chemical composition of BW was quite large for most of the components analyzed, especially EE. The sizable variability in EE content could substantially change the energy density of BW.

3.7. Wheat mill run

The ADF content of WMR varied across sources from a low of 8.06% to a high of 13.12% with an average of 11.04% and SD of 1.70% (Table 3). Falk et al. (1992) reported that WMR contained 11.85% ADF with a sample SD of 1.09%, estimates similar to those observed in the present study. The variability in fiber content was apparent when NDF was expressed on an ash free basis (Fig. 4). The NDF content of WMR ranged from 29.91 to 45.86% with an average value of 39.60% and SD of 4.77% (Table 3). Cellulose content also was highly variable. However, WMR was low in LIG content, averaging only 3.30%. A considerable amount of the variation observed in the fiber content of WMR is likely due to changes in the hemicellulose fraction.

Wheat mill run was low in Ca content (0.18%) and high in P content (1.08%) (Table 3) in agreement with previous reports (Bath et al., 1980; NRC, 1989). The concentration of other minerals agreed with NRC (1989) reported values (Table 4) with the exception of Na. In the present study, the Na concentration averaged 0.02% (Table 3) which was considerably lower than the NRC (1989) reported value of 0.24% (Table 4). The reason for this difference is not known.

3.8. Brewers grains

The range of variability between sources of BG was small for most of the chemical analyses (Table 3). Surprisingly, the variability in the as fed DM content was very small, ranging from 23.67 to 24.05% with an average value of 23.83% and SD of 0.20%. Total ash content was uniform, whereas EE content was highly variable ranging from 4.96 to 7.49% (Table 3). It is well known that the percentage of CP in BG is quite high, and BG are often used as a protein source for ruminant rations (Morrison, 1959). Crude protein ranged from 23.82 to 26.92% and averaged 25.94% in agreement with literature estimates (Bath et al., 1980; NRC, 1989; Falk et al., 1992).

The ADF content of BG varied according to the source (Table 3) with one low value of 15.50 and the rest around 20.0%. The average composition of ADF was lower than previously reported (Bath et al., 1980; NRC, 1989; Falk et al., 1992). Brewers grains averaged 50.81% NDF which was higher than the 46.0% reported by NRC (1989) but lower than the 56.6% reported by Murdock et al. (1981). The total LIG content of BG averaged 4.35%, a value considerably higher than the 0.5% reported by Murdock et al. (1981) but comparable to that reported by NRC (1989).

Even though considerable variation among sources in concentration of EE, ADF, and minerals was observed in the present study, BG are used predominantly as a protein source in dairy rations, and the amount of variability in CP content was small.

3.9. Distillery grains

Distillery grains contained 87.48% DM, 4.35% ash, and 10.42% EE (Table 3), and these constituents varied only slightly among sources. Distillery grains are commonly used as source of dietary protein. Crude protein averaged 24.7% in agreement with previous values (Table 4). However, there was tremendous variation in CP content from source to source with a low of 14.53% to a high of 30.12%. Similarly, ADF content varied, and DG also contained a high amount of LIG which could influence the digestibility of its fiber. The variability in fiber and protein content could significantly affect the energy value of DG, and the variability among sources is likely due to the type of grain that is used in the production of alcohol.

3.10. Soy hulls

Soy hulls averaged 12.98% CP, and 45.43% ADF (Table 3) which agreed with reported values (Table 4). Mineral contents varied with source of SH (Table 3). Variability was higher for Ca, P, Na, Fe, and Se compared with the other elements. Most elements were found to be in higher concentration than previously reported (Table 4). Even though SH were high in ADF content, LIG content was low. The low degree of lignification and the uniformity of composition from source to source make SH a desirable source of fiber in ruminant diets. In fact, SH often replaces BP in the diet of lactating dairy cows when economics justify the change.

In summary, considerable variability in some chemical constituents exits within each BPF analyzed. This variability may limit the amount of BPF used as part of the total diet or grain mix for ruminants.

Table 5
Diet composition calculations using ingredient analysis from by-products sources lowest in ADF, highest in ADF, mean in ADF, and NRC tabular values

Component	Diet 1				Diet 2			
	Low	High	Mean	NRC	Low	High	Mean	NRC
Total diet								
Crude protein	15.49	15.40	15.39	15.57	15.23	14.34	14.84	14.94
Crude fat	5.78	5.70	5.79	5.60	6.70	6.41	6.64	6.00
ADF	23.37	23.96	23.63	24.71	23.88	25.00	24.40	26.04
NDF	33.04	34.10	33.43	34.88	35.51	36.85	36.07	38.72
LIG	5.66	5.87	5.72	5.91	5.37	5.72	5.51	5.71
Calcium	0.83	0.77	0.75	0.63	0.96	0.86	0.74	0.62
Phosphorus	0.46	0.45	0.51	0.52	0.42	0.40	0.57	0.56
Total ash	6.68	6.25	6.52	6.45	7.00	6.46	6.75	6.99
From concentrate mix								
Crude protein	16.89	16.74	16.71	17.02	16.45	14.95	15.80	15.96
Crude fat	8.04	7.90	8.04	7.73	9.58	9.06	9.48	8.40
ADF	16.99	17.97	17.41	19.23	17.83	19.91	18.70	21.44
NDF	23.37	25.13	24.02	26.44	27.51	29.74	28.44	32.87
LIG	4.22	4.56	4.33	4.64	3.74	4.33	3.97	4.31
Calcium	0.57	0.47	0.43	0.24	0.79	0.62	0.42	0.22
Phosphorus	0.48	0.48	0.58	0.59	0.42	0.39	0.66	0.66
Total ash	5.10	4.38	4.83	4.72	5.63	4.74	5.23	5.61

ADF, acid detergent fiber; NDF, neutral detergent fiber; LIG, acid detergent lignin; BPF, by-product feeds; Low, by-products selected with the lowest ADF percentage; High, by-products selected with the highest ADF percentage; Mean, average composition for by-products in this study; NRC, National Research Council (1989) published chemical analysis.

3.11. Variability in diet composition

The calculated rations formulated are presented in Table 5. Diet 2 had the highest percentage of BPF. The nutrient composition of Diet 1 varied greatly with change in composition of BPF. For example, dietary CP content varied from 15.40 to 15.49% using analyses obtained from this study which were only slightly lower than the 15.57% obtained using NRC (1989) values for each BPF. However, as the proportion of BPF was increased in Diet 2, the nutrient composition of the diet was more variable with CP content ranging from 14.30 to 15.20%. Assuming an average intake of 21.80 kg DM, CP intake would vary from 3.10 to 3.30 kg per cow. The effect of variability in by-product composition increases when compared on a concentrate mix basis only as shown in Table 5. Hence, the importance of knowing ingredient composition increases as the contribution of by-products to the mix is increased. Similar changes to those observed for CP were observed for the other dietary components.

Variability in the chemical component of BPF influenced the composition of both the total diet and the concentrate mix. However, the impact on the total nutrient composition of the total diet was small compared with the concentrate mix in the present example. The magnitude of effect will depend upon the contribution of by-products to the total ration and the nutrient of interest.

4. Summary

Nutrient variation across all by-products analyzed in this study was considerable. The average nutrients of the by-products analyzed differed by more than 20% from NRC table results in almost every nutrient analyzed. BP, RB, AH, CT, and BW differed from NRC table results for ash, EE, and fiber components. WMR, BG, DG, and SH also differed from NRC table results but not for as many nutrients. Almost all BPF differed by more than 20% for most minerals although a few exceptions were found.

The by-product nutrients that differed from NRC table results were not always the nutrients that had the largest variation among the samples collected in this study. For example, DG had a large variation of CP for the samples collected but the average did not differ greatly from NRC table results. Conversely, the RB average ash percentage differed from NRC table results by almost 50% but only varied slightly in the eight samples collected. Confidence in using NRC table results is only possible if two criteria are met: the NRC table results are similar to nutrient analyses from samples collected and variation in nutrient analyses from samples collected is small. None of the by-products in this study meet both of these criteria but WMR would approach these conditions.

Another question that needs to be answered is how important is the effect of nutrient variability of different by-products on diet composition. As demonstrated in this study, the importance of accurate nutrient analyses becomes more critical as the concentration of BPF in the diet increased. Further research on the economic value of nutrient information for feed formulation is needed and will require accurate data on the nutrient variation.

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