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Further Studies on the Ohio High Roughage System for Raising Dairy Herd Replacements

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Further Studies on the Ohio High Roughage System for Raising Dairy Herd Replacements

J. W. HIBBS and H. R. CONRAD[1]

INTRODUCTION

Based on the initial studies of Pounden and Hibbs on early rumen development in dairy calves beginning in 1948 (15, 23, 22, 16, 21, 17, 24, 20, 3, 25), a high roughage system for raising dairy calves was developed and first proposed in 1953 (18). The high roughage system was based on early development of rumen function utilizing approximately a 2:1 ratio of high quality legume hay to a non-complex grain mixture fed after 3 days of age with limited whole milk. Rumen inoculation in the early weeks with cud material from adult cows was initially used to help establish adult-type rumen organisms as soon as possible. Cud inoculation as a recommended procedure was discontinued later (9) when it was found that this practice did not result in improved calf growth despite the earlier establishment of adult-type rumen microflora and fauna.

In a series of 13 papers published in the Journal of Dairy Science between 1953 and 1978 (18, 11, 4, 5, 12, 13, 6, 9, 7, 14, 1, 2, 10), the results of a number of experiments involving various aspects of high roughage calf feeding were presented. In these experiments efforts were made to simplify adjustment of roughage to grain ratio, including complete pelleted rations, to determine the optimum roughage to grain ratio and protein level for normal growth, to test various sources of roughage, and to determine the minimum amount of milk needed as well as optimum weaning time.

This research bulletin describes and gives the results of a number of additional experiments, not published previously, which were conducted between 1955 and 1970 and were designed to help achieve the above objectives.

EXPERIMENT 1

In this experiment a comparison was made between two complete high roughage pelleted diets, one containing soybean meal as a protein supplement (D pellets) and the other containing no protein supplement (DC pellets), with nearly all of the protein provided by the ground alfalfa hay.

Experimental Procedures

Ten of the 24 Holstein calves included in this experiment and all of the 20 Jerseys were housed at OARDC, Wooster, and 14 of the Holstein calves were housed at the OARDC North Central Branch, Castalia. All calves were fed whole milk to 7 wk of age, using the extra milk program previously described (9) to provide for the high energy needs in the first 2 wk: first 3 days, nursed the dam; 4 to 7 days, Holsteins 3.64 kg, Jerseys 2.27 kg twice daily; second wk, Holsteins 2.73 kg, Jerseys 1.82 kg twice daily; 3-6 wk inclusive, Holsteins 2.27 kg, Jerseys 1.36 kg twice daily; 7th wk, gradually reduce to zero. Extend milk feeding if calves are not eating dry feed at 6 wk. Open buckets were used for feeding milk. Ingredient formulae for the two pelleted diets fed to 16 wk are shown in Table 1. The average chemical composition and digestion trial data are given in Table 2.

TABLE 1.—Ingredients in D and DC Pellets, Experiment 1.

Ingredient	D Pellets*	DC Pellets*
Alfalfa hay, %†	66.7	66.7
Shelled corn, %	25.5	33.0
Soybean meal, 44 %	7.5	0.0
Iodized salt, %	0.3	0.3

*0.64 cm diameter.
†Ground through a 1.27 cm hammermill screen.

The pelleted diets were offered free choice after 3 days of age until 16 wk of age. From the end of the 16th wk through the 26th wk, a 2:1 ratio of good quality alfalfa hay and a simple grain concentrate mixture (1B) was fed. Hay was fed free choice and the grain concentrate was regulated to about one-half the amount of hay eaten. The grain concentrate (1B) consisted of ground shelled corn, 40 lb; ground oats, 30 lb; wheat bran, 10 lb; soybean meal 10 lb; and salt, 0.9 lb. The soybean meal was 44% protein and the total protein in the mixture was 14.8%.

Records were kept of daily feed consumption. Withers height and body weight were measured at birth (3 days of age), 8 wk, 16 wk, and 26 wk of age. Data from 16-26 wk were available only for the 14 Holstein calves housed at the OARDC North Central Branch.

Results and Discussion

Table 3 shows the average performance of the Holstein and Jersey calves in the two pellet groups, with growth (body weight) compared to the Beltsville standard (19). In both breeds, pellet consumption ($P<0.05$), TDN intake ($P<0.10$), and body weight ($P<0.10$) to 16 wk were significantly higher in the D pellet group than in the DC pellet (no soybean meal) group. Body weight gains to 16 wk were significantly higher ($P<0.10$) in the D pellet fed Jersey calves and insignificantly higher in the Holstein calves.

When both breeds were combined in a least squares analysis of variance (8), the DC pellet fed calves were

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TABLE 2.—Average Chemical Composition and Digestibility of Feeds Used in Experiment 1.

	D Pellets	DC Pellets	Milk	1B Grain Concentrate	Alfalfa Hay
			Chemical Composition		
Dry matter, %*	85.7	85.7	12.0	89.0	85.0
Total Protein, %*	14.3	12.3	3.3	14.7	16.1
Digestible protein, %†	9.2	7.4	2.5	9.6	10.9
Cellulose, %*	18.1	17.7			
Fat, %*	2.8	3.0	3.6	3.8	2.6
Ash, %*	6.8	6.4			
TDN, %‡	62.3	62.1	16.0	71.6	55.0
Digestible energy, Mcal/kg‡	2.68	2.68	0.7	3.11	2.38
NEg, Mcal/kg‡	0.78	0.78	0.3	1.13	0.55
Nutritive ratio**	1:5.8	1:7.4	1:5.4	1:6.5	1:4.1
			Average Digestibility		
Dry matter, %	64.9 (3)‡‡	66.5 (3)			
Cellulose, %	52.4 (3)	50.3 (3)			
Protein, %	59.3 (3)	59.5 (3)			
TDN, %	56.0	58.4			

*Samples for analyses obtained as fed. Results are on air-dry basis.
†Based on formula of Knight and Harris, 1966: % Digestible Protein = (0.908 x % Total Protein) — 3.77.
‡Based on US-Canadian Tables of Feed Composition (26).
**Nutritive ratio = 1: (% TDN — % Digestible Protein) ÷ Digestible Protein.
††Determined in digestion balance trials using Jersey male calves, 13-17 weeks of age.
‡‡Numbers in parentheses indicate number of digestion trials.

significantly lower ($P<0.05$) than the D pellet fed calves in 16 wk pellet consumption, 16 wk TDN intake, 16 wk body weight, and 16 wk body weight gain. Milk consumption to 7 wk, 8 wk pellet consumption, 8 wk body weight and 8 wk body weight gains, and 8 wk TDN intake were not significantly different.

Percent protein digestibility was similar in both pellet groups. After the milk feeding period, from 8-16 wk, the DC pellet fed Holstein calves (12.3% protein) consumed only 0.50 kg of protein/kg of body weight gain, mostly derived from the roughage, while the D pellet fed Holstein calves (14.3% protein) consumed 0.59 kg of protein/kg of body weight gain. Respective values for Jersey calves were 0.56 kg for the DC pellets and 0.69 kg for the D pellets.

Protein level and availability as well as cellulose digestibility in the roughage used would be important factors in determining how much soybean meal could be successfully replaced by corn in complete high roughage pellets fed to 16 wk. As shown in Table 2, energy content, TDN, and NEg were similar for both pellets. Differences in nutritive ratio were due to the differences in protein content.

From 16 to 26 wk, both groups of Holstein calves were fed alike, consuming an average 2.3:1 ratio of alfalfa hay to grain concentrate. Feed and TDN consumption were similar in both groups, resulting in no significant differences in body weight gain, withers height gain, or TDN/kg body weight gain from 16 to 26 wk of age.

Average body weights at 26 wk for the Holstein calves fed either D or DC pellets to 16 wk at the North Central Branch were respectively 188 kg and 183 kg, compared to 181 kg for Holsteins according to the Beltsville standard. Respective 26-week gains for the Holstein calves were 145 kg and 142 kg compared to 137 kg for the Beltsville standard.

This further demonstrates that calves can be raised satisfactorily on the high roughage system using limited whole milk to 7 wk, with a complete 2:1 pelleted diet (more than 14% crude protein) to 16 wk and an approximately 2:1 ratio of good alfalfa hay and a simple grain mixture from 16 to 26 wk.

The economic advantages of this system are based on the relative costs of corn, hay, and protein supplements, and the maximum use of home-grown feeds. Either whole milk or a good milk replacer can be used to weaning at approximately 7 wk of age.

TABLE 3.—Performance of Holstein Calves Fed a Complete High Roughage Pelleted Diet with or without Soybean Meal to 16 Weeks of Age, Experiment 1.

	D Pellets‡	DC Pellets‡	Beltsville Standard	D Pellets‡	DC Pellets‡	Beltsville Standard
	Holstein			Jersey		
No. of calves	13	11	400	10	10	378
Whole milk, 7 wk, kg	211.5 ± 2.0††	209.7 ± 1.4		132.0 ± 1.1††	129.9 ± 1.5	
Pellets, 8 wk, kg	27.3 ± 2.9	26.9 ± 3.7		29.4 ± 2.4	27.9 ± 2.2	
Pellets, 16 wk, kg	209.8 ± 9.3^{A*}	182.2 ± 7.2^{B*}		152.0 ± 7.8^{A*}	131.5 ± 3.5^{B*}	
Grain concentrate, 16-26 wk, kg*†	122.7 ± 1.8	124.9 ± 0.7				
Alfalfa hay, 16-26 wk, kg*†	287.9 ± 21.1	298.4 ± 29.1				
TDN intake, 8 wk, kg	49.8 ± 1.5	49.9 ± 2.2		38.0 ± 1.4	37.5 ± 1.4	
TDN intake, 16 wk, kg	152.0 ± 5.1^{A**}	140.6 ± 4.2^{B**}		106.7 ± 4.4^{A**}	98.0 ± 2.0^{B**}	
TDN intake, 26 wk, kg*†	392.6 ± 15.9	384.4 ± 17.1				
Initial body wt, 3 d, kg	44.5 ± 1.3	42.9 ± 1.2	43.6 ± 0.3	27.6 ± 0.9	27.9 ± 1.0	25.5 ± 0.4
Body wt, 8 wk, kg	75.6 ± 2.5	72.8 ± 2.4	70.0 ± 0.9	46.9 ± 1.8	44.9 ± 1.2	44.3 ± 0.7
Body wt, 16 wk, kg	120.0 ± 4.1^{A**}	110.8 ± 3.1^{B**}	115.5 ± 1.5	72.0 ± 2.6^{A**}	67.4 ± 0.8^{B**}	76.5 ± 1.2
Body wt, 26 wk, kg	188.2 ± 5.8	183.0 ± 5.9	180.9 ± 2.0			125.9 ± 1.5
Initial withers ht, cm	74.6 ± 0.6	73.9 ± 0.6		64.7 ± 0.7^{A*}	66.4 ± 0.6^{B*}	
Withers ht, 8 wk, cm	82.8 ± 0.6	83.1 ± 1.1		73.3 ± 1.0	73.0 ± 0.7	
Withers ht, 16 wk, cm	92.7 ± 0.9	91.6 ± 1.4		82.3 ± 0.8	81.4 ± 0.3	
Withers ht, 26 wk, cm	103.6 ± 1.2	103.2 ± 0.9				
Body wt gain, 8 wk, kg	31.1 ± 1.9	29.9 ± 1.6	26.4	19.2 ± 1.8	17.0 ± 0.7	18.8
Body wt gain, 16 wk, kg	75.2 ± 3.7	67.8 ± 2.8	71.9	44.4 ± 2.6^{A**}	39.5 ± 1.2^{B**}	41.9
Body wt gain, 26 wk, kg†	145.3 ± 5.5	141.9 ± 5.9	137.3			100.4
TDN/kg gain, 8 wk, kg	1.65 ± 0.1	1.72 ± 0.1		2.13 ± 0.2	2.22 ± 0.1	
TDN/kg gain, 16 wk, kg	2.05 ± 0.1	2.09 ± 0.1		2.43 ± 0.1	2.50 ± 0.1	
TDN/kg gain, 26 wk, kg†	2.71 ± 0.1	2.71 ± 0.8				

* = $P < 0.05$; ** = $P < 0.10$.

†Data from 16-26 wk based on eight D-pellet fed calves and six DC-pellet fed calves raised at the OARDC North Central Branch, Castalia, Ohio, to 16 wk. Loose hay and grain were fed after 16 wk.

‡D pellets contained 7.5% soybean meal; DC pellets contained no soybean meal (see Table 1).

††Within feeds, means in the same row not followed by the same letter are significantly different.

EXPERIMENT 2

The purpose of this experiment was to compare the performance of Holstein and Jersey calves when fed one of three pelleted high (60%) roughage mixtures (S, T, or U pellets). All three pellets contained 10% dehydrated alfalfa and 50% ground corn cobs, No. 4, (Andersons) from which the woody ring next to the pith had been removed for use in industrial abrasives. Other experiments in which corn cobs (Andersons) were used in complete pelleted diets for calves, from 7.5% to 17.0% of the total diet, were previously reported (10). The major differences in the pelleted mixtures involved variations in amount of shelled corn, soybean meal, urea, and added animal fat in the 40% concentration portion.

Experimental Procedures

The Holstein and Jersey calves used in this experiment were allowed to nurse their dams for 3 days, then were bucket fed whole milk to 7 wk of age using the extra milk system previously described (9). Good alfalfa hay was fed free choice to 3 wk of age, after which they were fed one of the three high roughage pelleted diets to 16 wk. A record was kept of daily feed consumption and weekly body weight. Withers height was measured at birth, 8 wk, and 16 wk, and chest circumference was measured in the calves housed at the North Central Branch at birth, 8 wk, and 16 wk of age. Fresh water was available at all times along with salt and bone meal in separate containers.

During the 7-wk milk feeding period, Aureomycin [100 mg/d as Aurofac D (American Cyanamid Co.)] was added to the milk daily. Also, 100,000 IU of vitamin A supplement as Capstress (Nopco Chemical Co.) was added to the milk twice a week.

The three high roughage pelleted diets, fed as the only dry feed after 3 wk of age, are described in Table 4. The chemical composition of the pelleted diets is shown in Table 5. Values are on the air dry basis. Performance of the calves to 16 wk of age is shown in Table 6.

The calves also were bled at 8 and 16 wk of age and serum urea nitrogen, cholesterol, and protein bound iodine (PBI) were determined using Technicon Autoanalyzer procedures. Average values for these blood constituents are shown in Table 7.

At 16 wk of age, volatile fatty acids were determined in strained rumen fluid of some of the calves. The strained rumen fluid was acidified with 10 ml of 10N H_3PO_4/50 ml of rumen fluid. This was diluted two times the original rumen fluid volume. The diluted acidified rumen fluid was then centrifuged at 3500x gravity for 10-20 minutes after standing 24 hours or more in the refrigerator. The supernatant was then injected into the gas chromatograph. The average concentrations of the various fatty acids are shown in Table 8.

Results and Discussion

Based on least squares analysis of variance (8) (Table 6), the only significant differences ($P<0.05$) in calf performance among the pellet groups was that the T pellet fed Holstein and Jersey groups consumed more TDN from 8 to 16 wk (117.9 kg/d, Holsteins; 96.9 kg/d, Jerseys) than the U pellet fed groups (102.3 kg/d, Holsteins; 70.9 kg/d, Jerseys). T pellet fed Jerseys were also higher in 8 wk withers height (77.2 cm) than the U pellet fed Jerseys (70.2 cm).

The overall, uniformly good performance of the calves fed these three pelleted mixtures, which differed markedly in the concentrate portion, is rather striking. All compared favorably in body weight gain with the Beltsville standard (Fig. 1).

TABLE 4.—Composition of Complete High Roughage Pelleted Diets, Experiment 2.

Ingredient	S (121) %	T (122) %	U (123) %
Ground corn cobs*	50.0	50.0	50.0
17% dehydrated alfalfa	10.0	10.0	10.0
Ground shelled corn	16.0		22.5
Soybean meal†	16.0	27.8	8.0
Dried molasses‡	5.0	5.0	5.0
Urea (281% protein equivalent)	1.7		3.0
Inedible animal fat**		6.0	
Deflour rock phosphate	0.8	0.8	1.0
Monosodium phosphate	0.2	0.1	0.2
Salt (iodized)	0.3	0.3	0.3
Total	100.0	100.0	100.0

Added per 454/g mix: 10,000 IU of vitamin A and 1,000 IU of vitamin D.

*Ground corn cobs, NO4, obtained from The Andersons, Maumee, Ohio.

†Soybean meal used in S pellets was 50% protein, in T pellets 50%, and in U pellets 44%.

‡Sweetone manufactured by A. D. Staley Co., Decatur, Ill.

**HEF manufactured by the Proctor and Gamble Co., Cincinnati, Ohio.

TABLE 5.—Chemical Composition of Pelleted Diets* Used in Experiment 2.

	S	T	U
Dry matter, %†	90.5	90.7	90.1
Total protein, %†	18.2	16.7	17.9
Digestible protein, %‡	12.8	11.4	12.5
Fat, %**	1.4	6.3	1.5
TDN, %**	56.3	65.7	54.5
NEg (Mcal/kg)**	0.63	0.84	0.61
Digestible E (Mcal/kg)**	2.44	2.89	2.38
Nutritive ratio††	1:3.4	1:4.8	1:3.4
Cellulose, %†	16.8	19.2	17.5
Ca, %**	0.58	0.57	0.59
P, %**	0.36	0.36	0.35
Ca:P ratio**	1.6:1	1.6:1	1.7:1

*Values are based on the wet (as fed) basis.

†Based on actual chemical analysis.

‡Digestible protein % calculated from fomula of Knight and Harris, 1966: % Digestible Protein = (0.908 x Total Protein %) — 3.77.

**Based on US-Canadian Tables of Feed Composition (26).

††Nutritive ratio based on the following formula: 1: (% TDN — Digestible Protein %) ÷ Digestible Protein %.

TABLE 6.—Performance of Holstein and Jersey Calves Fed Either S, T, or U Complete High Roughage Pellets to 16 Weeks of Age, Experiment 2.

	S Pellets	T Pellets	U Pellets	S Pellets	T Pellets	U Pellets
	Holsteins			Jerseys		
No. of calves	22	20	19	6	4	5
Whole milk, 7 wk, kg	180.3 ± 4.6	184.1 ± 6.1	174.4 ± 6.0	113.4 ± 4.3	124.7 ± 7.0	116.8 ± 4.9
Alfalfa hay, 3 wk, kg	0.5 ± 0.1	0.8 ± 0.2	0.5 ± 0.1	0.6 ± 0.3	0.7 ± 0.4	0.3 ± 0.3
Pellets, 3-8 wk, kg	29.3 ± 2.3	26.3 ± 1.9	25.0 ± 2.1	21.0 ± 3.4	25.4 ± 3.0	19.6 ± 2.9
Pellets, 16 wk, kg	229.7 ± 9.1	205.8 ± 8.6	212.7 ± 7.5	160.8 ± 15.9	172.9 ± 7.8	153.4 ± 10.5
Initial body wt, 3 d, kg	41.2 ± 1.3	42.3 ± 1.4	41.8 ± 1.4	23.1 ± 1.6	25.3 ± 0.7	23.1 ± 0.6
Body wt, 8 wk, kg	66.0 ± 1.9	67.2 ± 1.9	65.1 ± 1.9	40.1 ± 1.8	44.7 ± 2.2	38.8 ± 1.8
Body wt, 16 wk, kg	115.0 ± 3.0	116.0 ± 2.9	112.3 ± 2.5	72.4 ± 2.9	78.6 ± 2.4	69.5 ± 2.5
Body wt gain, 8-16 wk, kg*	49.0 ± 1.5	48.8 ± 1.6	47.2 ± 1.4	32.4 ± 1.7	33.9 ± 1.1	30.7 ± 1.5
Initial withers ht, cm	73.0 ± 1.0	72.8 ± 0.9	72.0 ± 1.3	65.0 ± 1.3	64.0 ± 1.0	64.1 ± 0.6
Withers ht, 8 wk, cm	80.2 ± 1.0	81.6 ± 1.0	80.8 ± 0.9	73.1 ± 1.8[ab]	77.2 ± 0.8[a]	70.2 ± 1.0[b]
Withers ht, 16 wk, cm	90.2 ± 1.0	91.4 ± 1.0	89.5 ± 0.9	81.4 ± 1.6	85.1 ± 2.1	81.0 ± 0.9
Withers ht gain, 8-16 wk, cm	10.0 ± 0.7	9.8 ± 0.6	8.7 ± 0.7	8.3 ± 1.0	7.9 ± 1.4	10.8 ± 1.4
Initial chest circumference, cm	83.2 ± 1.9	78.1 ± 1.3	76.1 ± 1.3			
Chest circumference, 8 wk, cm†	90.3 ± 1.9	91.6 ± 1.3	87.1 ± 1.9			
Chest circumference, 16 wk, cm†	109.0 ± 1.9	108.4 ± 1.3	108.4 ± 1.9			
Gain in chest circumference, 8-16 wk, cm†	18.7 ± 0.7	16.8 ± 1.3	21.3 ± 1.9			
TDN intake, 8-16 wk, kg	112.9 ± 4.1[ab]‡	117.9 ± 4.6[a]	102.3 ± 4.6[b]	78.7 ± 7.2[ab]	96.9 ± 3.6[a]	72.9 ± 4.7[b]
TDN intake/kg body wt gain, 8-16 wk, kg	3.32 ± 0.07	2.42 ± 0.06	2.18 ± 0.07	2.42 ± 0.15	2.87 ± 0.2	2.39 ± 0.15

*Beltsville Standard body wt gain 8-16 wk = 45.5 kg for Holsteins and 32.2 kg for Jerseys (19).
†Seven calves/pellet group (OARDC North Central Branch).
‡Superscripts which differ within breed indicate a significant difference ($P < 0.05$).

TABLE 7.—Serum Urea Nitrogen, Cholesterol, and Protein Bound Iodine (PBI) at 8 and 16 wk of Age in Calves Fed S, T, or U Pellets, Experiment 2.

	S (1.7% Urea)	T (No Urea)	U (3% Urea)
		Serum Urea Nitrogen (mg/100 ml)	
No of calves	13	12	11
8 wk	17.8 ± 1.0	17.3 ± 1.5	18.0 ± 1.0
16 wk	18.5 ± 0.8[a*]	15.1 ± 0.9[b]	20.2 ± 1.2[a]
		Serum Cholesterol (mg/100 ml)	
No. of calves	16	14	15
8 wk	74.4 ± 6.0[b]	96.4 ± 8.4[a]	76.6 ± 7.4[ab]
16 wk	65.1 ± 6.3[b]	117.6 ± 9.8[a]	68.3 ± 7.6[b]
		Serum PBI (g/100 ml)	
No. of calves	15	14	13
8 wk	6.7 ± 0.5	6.6 ± 0.4	7.0 ± 0.4
16 wk	7.2 ± 0.4[ab]	6.4 ± 0.4[b]	8.5 ± 0.8[a]

*Means followed by different superscripts indicate significant differences ($P < 0.05$).

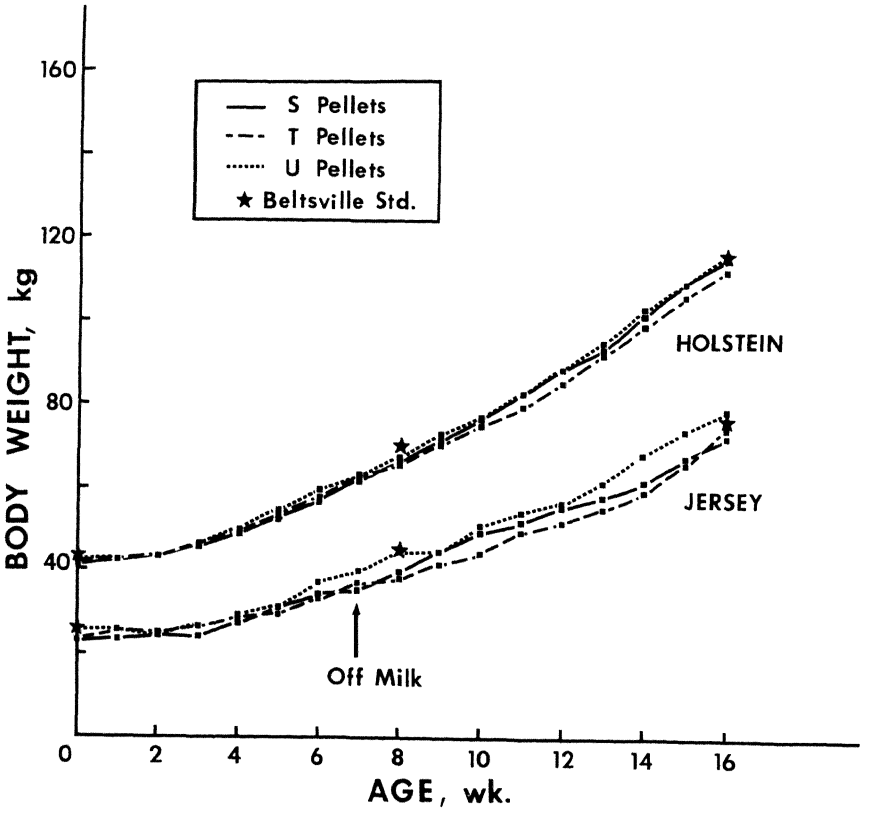

FIG. 1.—Changes in body weight of Holstein and Jersey calves fed S, T, or U pellets to 16 wk of age. Growth curves are compared to the Beltsville standards (19). Experiment 2.

It was significant that the T pellet fed calves, where there was no corn added but where 6% fat was included, grew at a rate equal to the Beltsville standard. It appears, therefore, that 6% added fat supplied more than sufficient energy to make up for the lack of corn in the diet. This was reflected in the higher TDN and NEg in the T pellets.

The basic difference between the S and U pellets was that the S pellets contained 1.7% urea compared to 3% urea in the U pellets. That the calves were able to tolerate 3% urea in the total diet along with the relatively high, adult levels of volatile fatty acids in the rumen (Table 8) attests to the high level of rumen function attained prior to 16 wk when fed these balanced high roughage diets. Serum urea nitrogen values at 16 wk (Table 7) showed that the level of urea in the diet was reflected in the blood urea nitrogen (T pellets, no urea = 15.1 mg/100 ml; S pellets, 1.7% urea = 18.5 mg/100 ml; U pellets, 3% urea = 20.2 mg/100 ml). The T pellet fed calves (no urea in diet) were significantly lower in blood urea nitrogen than the S and U pellet fed calves at 16 wk. Serum urea nitrogen in the S and U pellet fed calves was not significantly different (Table 7).

Serum cholesterol (Table 7) was significantly higher ($P<0.05$) in the T pellet fed calves at 16 wk where the diet contained no corn but included 6% added fat. S and U pellet calves were not different from each other in serum cholesterol (Table 7).

Serum PBI values at 16 wk (Table 7) were significantly lower ($P<0.05$) in the T pellet fed calves than in the U pellet fed calves at 16 wk. PBI in the S pellet fed calves was not significantly different than either the T pellet fed calves or the U pellet fed calves (Table 7).

Determination of the volatile fatty acid content of strained rumen juice at 16 wk of age from several of the calves fed the three pelleted diets did not show any major differences (Table 8). Calves fed the T pellets had molar percentages somewhat higher in acetic and lower in propionic acid than the other two pellet groups. Total volatile fatty acids in terms of millimoles/l averaged higher in the U pellet fed calves; however, none of these differences was statistically different. The overall fatty acid content of the rumen juice in all three pellet groups indicated adult levels of rumen fatty acids in these 16 wk old calves.

TABLE 8.—Volatile Fatty Acid Content of Rumen Juice from Calves at 16 wk of Age Fed S, T or U Pellets, Experiment 2.

	S (4)*	T (2)	U (2)
	M moles/l		
Acetic acid	47.9	51.4	65.7
Propionic acid	19.2	15.1	25.7
Butyric acid	8.9	8.2	13.5
Valeric acid	0.3	0.3	0.4
Isovaleric acid	0.4	0.6	0.9
Caproic acid	0.1	0.1	0.1
Total VFA†	76.8	75.7	106.3
	Molar %		
Acetic acid	63.3	67.2	62.2
Propionic acid	24.3	20.3	23.5
Butyric acid	11.4	11.2	12.9
Valeric acid	0.3	0.3	0.4
Isovaleric acid	0.4	0.7	0.8
Caproic acid	0.0	0.0	0.0
Total VFA	98.7	99.7	99.8

*Numbers in parentheses indicate no. of calves in average.
†S pellets contained 1.7 % urea, T pellets no urea, and U pellets 3.0 % urea.

EXPERIMENT 3

The purpose of this experiment was to compare the performance of Holstein calves to 16 wk fed two complete pelleted high roughage diets containing no corn. One diet contained soybean meal plus 6% added hydrolyzed fat (VSF pellets). The other contained ground whole soybeans (VSB pellets).

Experimental Procedures

All calves were housed at the North Central Branch and fed whole milk, using the same schedule as in previous experiments (9) to 7 wk of age. Alfalfa hay was offered free choice, unmeasured, until 3 wk of age; then one of the two complete pelleted diets, VSF or VSB, was offered free choice until 16 wk of age. After 16 wk until 26 wk of age, all 35 calves were fed alike, alfalfa hay free choice with 1B grain concentrate in a 2 parts hay to 1 part grain ratio with a 4 lb limit on grain concentrate.

The composition of the complete pelleted high roughage diets is shown in Table 9. Both diets contained 56.7% soybran flakes as the basic roughage and 10% dehydrated alfalfa. The VSB pellets contained 32.4% ground whole soybeans. The VSF pellets contained 26.4% soybean meal plus 6% added hydrolyzed animal fat (HEF). Other ingredients were the same in both diets.

TABLE 9.—Composition of Complete, No Corn, High Roughage Pelleted Diets, Experiment 3.

Ingredient	VSF (179) %	VSB (180) %
Dehydrated alfalfa (17%)	10.0	10.0
Soybran flakes	56.7	56.7
Soybean meal	26.4	
Ground whole soybeans		32.4
Inedible animal fat (HEF)*	6.0	
Bone meal	0.3	0.3
Ground limestone	0.3	0.3
Salt (iodized)	0.3	0.3
	100.0	100.0

Added/454 kg mix: 10,000 IU of vitamin A and 1,000 IU of vitamin D.

*HEF manufactured by the Proctor and Gamble Co., Cincinnati, Ohio.

Table 10 shows the chemical composition of the two pelleted diets as well as the composition for the milk, 1B grain concentrate, and alfalfa hay, based on the US-Canadian tables of feed composition (26). Digestible protein was estimated using the formula of Knight and Harris: Percent Digestible Protein = (0.908 x Percent Crude Protein) — 3.77 (26). Nutritive ratio was calculated: 1: [(Percent TDN — Digestible Protein Percent)] ÷ Digestible Protein Percent.

The calves were weighed at 3 days and at weekly intervals thereafter until 26 wk of age. Withers height and chest circumference were measured at 3 days, 8 wk, 16 wk, and 26 wk. Feed intake was measured daily and refuse was recorded. Analyses of the volatile fatty acid content of rumen juice were carried out on the gas chromatograph as described in Experiment 2.

Results and Discussion

Table 11 shows the feed and estimated TDN intake data as well as body weight, withers height, and chest circumference measurements to 26 wk of age, with standard error and statistically significant differences based on analysis of variance (8). Efficiency of VSF and VSB pellet utilization is shown based on both TDN and NEg intake/kg BW gain from 8-16 wk.

The calves fed the VSF pellets, containing soybean meal plus 6% added fat, ate significantly more ($P<0.05$) pellets and gained significantly more ($P<0.05$) in body weight, withers height, and chest circumference to 16 wk than those fed the VSB pellets containing ground whole soybeans.

Figure 2 shows the changes in body weight from birth (3 days) until 26 wk as related to the feeds fed during this period and compared to the Beltsville growth standard

TABLE 10.—Chemical Composition of Feeds Used in Experiment 3.

	VSF Pellets	VSB Pellets	Milk	Alfalfa Hay	1B Grain
Dry matter (%)	91.4	91.4	12.0	85.0	89.0
TDN (%)	79.2	72.1	16.0	55.0	71.6
Total protein (%)	19.4	20.7	3.3	16.1	14.7
Digestible protein (%)†	13.9	15.0	2.5	10.9	9.6
Fat (%)	7.5	6.9	3.6	2.6	3.8
NEg (Mcal/kg)	1.28	1.14	0.30	0.55	1.13
Digestible E (Mcal/kg)	3.47	3.19	0.70	2.38	3.11
Nutritive ratio‡	1:4.7	1:3.8	1:5.4	1:4.0	1:6.5
Ca (%)	0.68	0.69	0.12	1.27	0.08
P (%)	0.34	0.37	0.09	0.20	0.43
Ca:P ratio	2:1	1.8:1	1.3:1	6.4:1	0.2:1

*Estimated from US-Canadian Tables of Feed Composition (26).

†Digestible protein calculated from formula of Knight and Harris, 1966: Digestible Protein = (0.908 x % Total Protein) — 3.77.

‡Nutritive ratio based on the formula: 1: (% TDN — Digestible Protein %) ÷ Digestible Protein %.

for Holstein calves (19). The growth performance of the VSF pellet fed calves closely paralleled the body weights of the Beltsville standard (19) from birth to 26 wk.

The superior performance to 16 wk of the calves fed the VSF pellets was a reflection of greater feed intake and the fact that the VSF pellets contained a higher percent fat, percent TDN, and Mcal NEg/kg than the VSB pellets. Kg TDN intake/kg BW gain from 8-16 wk was 2.5 for the VSF pellet fed calves and 2.3 for the VSB pellet fed calves. Estimated values for Mcal NEg/kg BW gain from 8 to 16 wk were 4.1 for the VSF pellet fed calves and 3.6 for the VSB pellet fed calves.

It is concluded that the substitution of 32.4% ground whole soybeans for 26.4% soybean meal and 6% fat in this type of ration will result in less energy intake and lowered body weight gain. It was estimated that approximately equal fat, 7.5%, would have resulted in both of the pellets if an additional 3.9% ground whole soybeans had been substituted for 3.9% of the soybran flakes in the VSB pellets. However, this alteration would have made little difference in the TDN percent or Mcal NEg/kg.

The results of this experiment also indicated that satisfactory growth can be achieved without the use of corn in complete high (67%) roughage pelleted diets, using soybran flakes as the major (57%) source of roughage, with 6% added fat as a supplemental source of energy.

From 16-26 wk there was no significant difference in body weight gains where both groups were fed alike on an approximately 2:1 ratio of alfalfa hay to grain concentrate. However, the difference in body weight at 16 wk due to the pelleted diets still persisted at 26 wk.

It is significant that there was no break in the growth curve at 7 wk when milk was removed from the diet (Fig. 2), indicating that at this age there was already adequate rumen capacity and development to permit normal gains in body weight when fed this diet.

Table 12 shows the average volatile fatty acid content of the strained rumen juice from stomach tube samples taken at 13-16 wk of age. There were no significant differences between calves fed VSF or VSB pellets, except that isovaleric acid was higher ($P < 0.05$) in the VSB pellet fed calves. Average total rumen VFA levels in both pellet groups indicated that adult fatty acid levels were attained at 13-16 wk.

TABLE 11.—Performance of Holstein Calves to 6 Months, Fed No Corn, High Roughage Pellets to 16 wk, Containing Either Soybean Meal Plus 6% Fat (VSF) or Ground Whole Soybeans (VSB), Experiment 3.

	VSF*	VSB*
No. of calves	17	18
Whole milk, kg	204.1 ± 4.2	201.9 ± 4.1
Pellets, 8 wk, kg	26.3 ± 2.6	27.4 ± 1.8
Pellets, 16 wk, kg	172.2 ± 4.7[a]†	151.3 ± 5.0[b]
Grain concentrate, 16-26 wk, kg	103.4 ± 2.6	99.6 ± 2.1
Alfalfa hay, 16-26 wk, kg	216.3 ± 9.9	209.2 ± 8.6
TDN intake, 8 wk, kg**	53.5 ± 2.4	52.1 ± 1.6
TDN intake, 16 wk, kg	169.1 ± 3.9[a]	141.4 ± 3.7[b]
TDN intake, 26 wk, kg	369.0 ± 9.4[a]	334.5 ± 9.6[b]
TDN intake, 8-16 wk, kg	115.6 ± 2.3[a]	89.3 ± 3.0[b]
TDN intake, 16-26 wk, kg	200.0 ± 6.7	193.1 ± 6.7
TDN intake/kg BW gain, 8-16 wk††	2.5 ± 0.1[a]‡	2.3 ± 0.1[b]‡
Initial body weight, 3 d, kg	41.1 ± 1.1	39.0 ± 1.2
Body weight, 8 wk, kg	70.3 ± 1.3	68.5 ± 2.2
Body weight, 16 wk, kg	116.0 ± 2.0[a]	107.7 ± 3.1[b]
Body weight, 26 wk, kg	177.6 ± 4.3	170.2 ± 4.2
Gain in body weight, 8-16 wk, kg	45.8 ± 1.1[a]	39.2 ± 1.9[b]
Initial withers height, 3 d, cm	72.1 ± 1.5	71.4 ± 0.4
Withers height, 8 wk, cm	80.6 ± 0.5[a]	78.3 ± 0.7[b]
Withers height, 16 wk, cm	90.6 ± 0.6[a]	88.2 ± 0.5[b]
Withers height, 26 wk, cm	101.5 ± 0.8	99.5 ± 0.6
Gain in withers height, 8-16 wk, cm	10.1 ± 0.7	9.8 ± 0.6
Initial chest circumference, 3 d, cm	77.7 ± 1.1	76.9 ± 0.7
Chest circumference, 8 wk, cm	94.6 ± 0.9[a]	88.2 ± 1.0[b]
Chest circumference, 16 wk, cm	110.3 ± 1.0[a]	106.0 ± 1.0[b]
Chest circumference, 26 wk, cm	127.9 ± 1.4[a]	122.6 ± 1.1[b]
Gain in chest circumference, 8-16 wk, cm	15.7 ± 1.2	17.8 ± 1.6

*Feed weights and TDN values are on air-dry basis, sampled as fed.

†Means followed by different superscripts are significantly different ($P < 0.05$), ‡ indicates ($P < 0.10$).

**TDN values used were: milk 16%, alfalfa hay 58% (DM 85%), grain 72.1% (DM 90%), VSF pellets 79.2% (DM 90%), VSB pellets 72.1% (DM 90%).

††Mcal NEg/kg BW gain 8-16 wk, for VSF pellets = 4.1; for VSB pellets = 3.6.

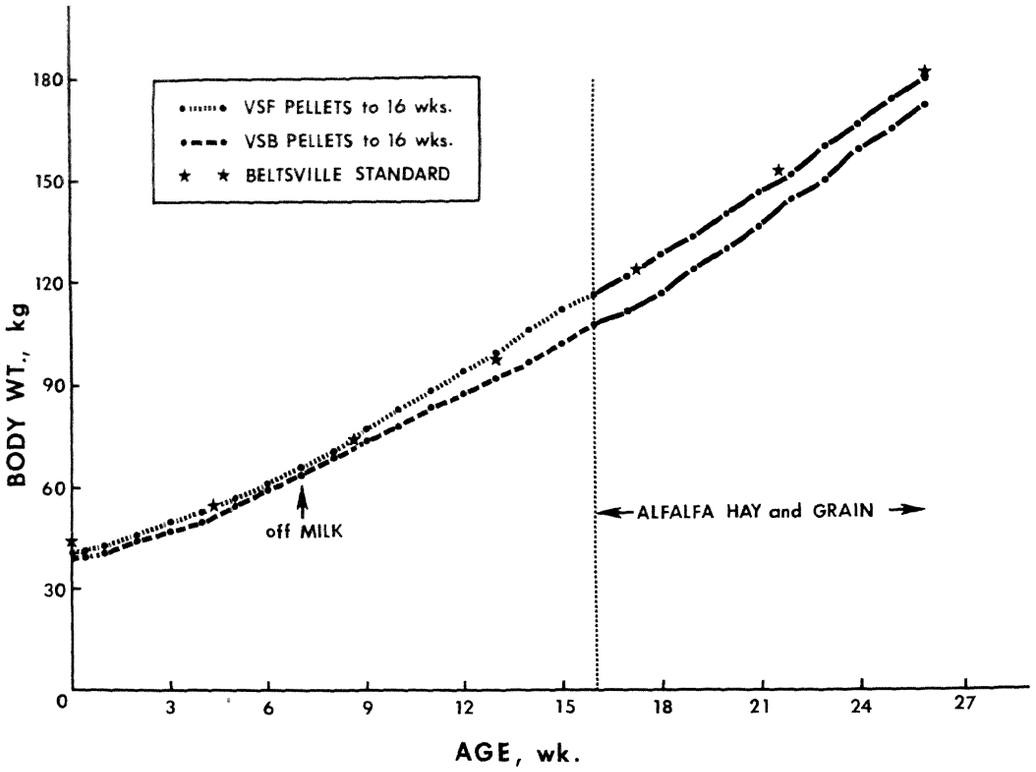

FIG. 2.—Changes in body weight of Holstein calves fed VSF or VSB pellets to 16 wk and 2 parts of loose hay and 1 part of grain concentrate 16 to 26 wk. Growth curves are compared to the Beltsville growth standard for Holsteins (19). Experiment 3.

TABLE 12.—Volatile Fatty Acids in Rumen Juice at 13-16 wk of Age, Experiment 3.

	VSF (9)*	VSB (9)*
	m moles/l	
Acetic acid	66.2 ± 3.8	63.8 ± 4.8
Propionic acid	23.1 ± 2.1	21.1 ± 1.2
Butyric acid	9.1 ± 1.2	7.3 ± 0.7
Valeric acid	3.5 ± 0.7	2.3 ± 0.4
Isovaleric acid	1.4 ± 0.2	1.7 ± 0.2
Caproic acid	0.2 ± 0.2	0.1 ± 0.1
Total VFA	114.6 ± 12.5	96.4 ± 5.6
	Molar %	
Acetic acid	64.6 ± 1.6	66.2 ± 2.0
Propionic acid	22.2 ± 1.1	22.2 ± 1.6
Butyric acid	8.5 ± 0.6	7.6 ± 0.6
Valeric acid	3.1 ± 0.4	2.5 ± 0.5
Isovaleric acid	1.3 ± 0.1[a]†	1.8 ± 0.2[b]†
Caproic acid	0.1 ± 0.1	0.1 ± 0.1
Total VFA	99.8	100.4

*Indicate number of calves sampled per group.

†Means followed by different superscripts are significantly different ($P < 0.05$).

EXPERIMENT 4

In this experiment efforts to evaluate different roughages and sources of energy in complete high roughage calf diets were continued. A comparison was made, using Jersey and Holstein calves, of three complete pelleted high roughage diets containing 67% roughage. Two of the diets contained no corn and 6% added fat.

Experimental Procedures

In diet D-100-65 (OSF), the roughage fraction was 57.7% soybran flakes and 10% alfalfa. In diet D-101-65 (QCF), the roughage fraction consisted of 56.7% ground corn cobs and 10% alfalfa. In diet D-102-65 (R), the roughage fraction consisted of a variety of roughages, 16.7% alfalfa, 16.7% ground corn cobs, 16.7% soybran flakes, and 16.7% beet pulp. The OSF pellets also contained 26.4% soybean meal and 6% animal fat, the QCF pellets contained 26.0% soybean meal and 6% fat, while the R pellets contained 15.3% shelled corn and 17% soybean meal. Other additions included Ca and P sources and NaCl. The details of the pellet formulations are shown in Table 13.

Table 14 shows the average chemical composition and average digestibility of dry matter, total protein, fat, and TDN based on three digestion trials per pellet group using 4-6 month old Jersey male calves fed the different pelleted diets from 3 days of age.

A total of 55 Holstein and 23 Jersey female calves were used in this experiment. All calves nursed their dams for 3 days, after which they were bucket fed whole milk twice a day to 7 wk of age when they were weaned. The

TABLE 13.—Ingredients in OSF, QCF, and R Pellets, Experiment 4.

	OSF (D-100-65)*	QCF (D-101-65)*	R (D-102-65)*
	Percent		
Dehydrated alfalfa (17 %)	10.0	10.0	16.7
Ground corn cobs†		56.7	16.7
Soybran flakes	56.7		16.7
Dried beet pulp			16.7
Ground shelled corn			15.3
Soybean meal (50 %)	26.4	26.0	17.0
Hydrolyzed animal fat	6.0	6.0	
Defl. rock phosphate	0.3	1.0	0.6
Ground limestone	0.3		
Salt (iodized)	0.3	0.3	0.3
Total	100.0	100.0	100.0

*Pellets were 0.64 cm in diameter.
†Ground, whole corn cobs obtained from local elevator at Decatur, Ill.

TABLE 14.—Chemical Composition and Digestibility of the OSF, QCF, and R Pellets, Experiment 4.

	OSF (D-100-65)		QCF (D-101-65)		R (D-102-65)	
	Average Chemical Composition*					
Dry matter, %	91.1	(89.2)‡	90.8	(89.4)	90.4	(87.9)
Total protein, %	21.1	(18.5)	16.2	(17.4)	16.5	(17.4)
Digestible protein, %†	15.4		10.9		11.2	
Fat, % (ether extract)	7.5		6.8		1.7	
TDN, %	79.2		64.7		63.9	
NEg, Mcal/kg	1.28		0.88		0.88	
Digestible E, Mcal/kg	3.47		2.82		2.82	
Nutritive ratio**	1:4.1		1:4.9		1:4.7	
	Average Digestibility††					
Dry matter, % digestible	74.4		69.2		74.4	
Total protein, % digestible	71.4		75.2		71.7	
Fat (ether extract), % digestible	93.0		87.7		93.0	
TDN, % digestible	75.2		68.9		75.2	

*Based on US-Canadian Tables of Feed Composition (26).
†Based on formula of Knight and Harris, 1966: % Digestible Protein = (0.908 x % Total Protein) — 3.77.
‡Numbers in parentheses are values obtained by chemical analysis of the feeds.
**Nutritive ratio = 1: (% Total Protein — % Digestible Protein) ÷ % Digestible Protein.
††Based on the average of three digestion trials/pellet group using Jersey male calves, 4-6 mo of age.

TABLE 15.—Performance of Holstein and Jersey Calves Fed OSF, QCF, or R Pellets to 16 wk of Age, Experiment 4.

	OSF (D-100-65)	QCF (D-101-65)	R (D-102-65)	OSF (D-100-65)	QCF (D-101-65)	R (D-102-65)
	Holsteins			Jerseys		
No. of calves	16	15	14	7	6	9
Whole milk, 7 wk, kg	177.0 ± 5.4	184.0 ± 5.6	172.7 ± 6.1	114.8 ± 1.9	121.1 ± 2.0	119.9 ± 2.1
Pellets, 8 wk, kg*	20.6 ± 2.2	25.2 ± 2.4	22.8 ± 1.3	14.3 ± 2.1	15.6 ± 3.3	16.3 ± 1.7
Pellets, 16 wk, kg	147.3 ± 9.0[b]‡	197.9 ± 7.1[a]	179.9 ± 8.4[a]	97.6 ± 12.0	135.2 ± 17.7	124.8 ± 7.9
Pellets, 8-16 wk, kg	126 ± 7.0[b]	172.5 ± 7.0[a]	157.1 ± 7.4[a]	83.4 ± 11.0[b]	119.5 ± 14.5[a]	108.5 ± 6.7[ab]
Pellets/BW gain, 8-16 wk, kg	2.9	3.8	3.3	3.6	3.9	3.6
TDN intake, 8 wk, kg†	44.6 ± 2.1	45.8 ± 1.5	42.2 ± 0.9	29.7 ± 1.9	29.5 ± 2.2	29.6 ± 1.2
TDN intake, 16 wk, kg	144.9 ± 7.4	157.4 ± 4.7	142.6 ± 5.5	95.7 ± 9.6	106.8 ± 11.7	98.9 ± 5.2
TDN intake, 8-16 wk, kg	100.3 ± 5.5	111.6 ± 4.6	100.4 ± 4.9	66.0 ± 8.7	77.4 ± 9.4	69.3 ± 4.3
TDN intake/BW gain, 8-16 wk, kg	2.4 ± 0.1[a]	2.5 ± 0.1[a]	2.1 ± 0.0[b]	3.1 ± 0.4	2.5 ± 0.1	2.3 ± 0.1
Initial body wt, 3 d, kg	41.5 ± 1.1	43.5 ± 1.4	41.5 ± 1.8	21.9 ± 0.9	21.1 ± 1.2	21.6 ± 1.3
Body wt, 8 wk, kg	64.6 ± 2.4	67.6 ± 2.1	65.9 ± 2.0	38.9 ± 1.8	36.8 ± 2.4	37.6 ± 1.9
Body wt, 16 wk, kg	107.0 ± 3.9	113.2 ± 2.6	114.1 ± 3.5	62.3 ± 3.4	67.8 ± 4.6	68.0 ± 3.8
Gain in BW, 8-16 wk, kg	43.4 ± 2.0	45.5 ± 1.9	48.1 ± 2.2	23.3 ± 3.4	31.0 ± 2.9	30.4 ± 2.4
Av. daily gain, 8-16 wk, kg	0.78	0.80	0.86	0.42	0.55	0.54
Initial withers ht, 3 d, cm	74.4 ± 0.9	75.2 ± 0.9	75.1 ± 0.8	66.2 ± 1.5	63.0 ± 1.2	65.1 ± 0.6
Withers ht, 8 wk, cm	81.6 ± 1.0	81.6 ± 0.9	80.6 ± 0.8	71.0 ± 1.3	70.2 ± 1.1	71.4 ± 0.7
Withers ht, 16 wk, cm	89.9 ± 0.9	91.9 ± 0.9	90.2 ± 0.9	78.4 ± 0.9	79.2 ± 0.7	80.0 ± 0.7
Gain in withers ht, 8-16 wk, cm	8.1 ± 1.0	10.3 ± 0.9	9.6 ± 0.9	7.3 ± 1.2	9.0 ± 0.9	8.6 ± 0.4

*Pellet weights are on air-dry basis, sampled as fed.
†TDN % used in calculating TDN intakes were: milk 16% — OSF pellets 79.2%, QCF pellets 64.7%, R pellets 63.9%, based on U. S.-Canadian Tables of Feed Composition (26).
‡Means within breed followed by different letters are significantly different ($P < 0.05$).

same milk feeding schedule was used as in the previous experiments, with extra milk provided during the first 2 wk to help meet the high energy needs during this time (9).

One of the three pelleted diets was fed free choice beginning at 3 wk of age and extending to 16 wk of age. From 3 days until 3 wk, alfalfa hay was offered (unmeasured) free choice mainly to discourage eating the straw bedding. Usually not more than 0.5 kg of hay was consumed during this time (see Experiment 2).

Feed intake was recorded daily, body weight was measured weekly, and withers height was recorded at 3 days, 8 wk, and 16 wk of age. TDN intake was calculated for 8 wk, 16 wk, and 8 to 16 wk when pellets were the only feed fed. TDN was calculated for the first 8 wk, for 16 wk, and 8 to 16 wk based on U.S.-Canadian tables of feed composition (26).

Results and Discussion

Performance data based on these records with standard errors are shown in Table 15 for both Jersey and Holstein calves. Least squares analysis of variance showed that Holstein pellet consumption was significantly lower ($P < 0.05$) for the OSF pellets compared to the other two diets, which did not differ significantly. The lower pellet consumption of the OSF pellet fed calves did not result in significantly less growth, however. Jersey pellet consumption was significantly lower ($P < 0.05$) in the OSF pellet fed group than in the QCF pellet group. However, the R pellet fed group did not differ in intake from either the OSF or QCF pellet groups. Neither were there significant differences in growth, either in body weight or in withers height, in the Jersey groups. Weekly changes in body weight are shown in Figure 3, with body weights for the Beltsville growth standard at birth, 8 wk, and 16 wk for comparison.

The growth curves for both Jerseys and Holsteins showed that while the differences at 8 and 16 wk were not significant, there was a consistent reduction in growth (body weight) in both Jerseys and Holsteins fed OSF pellets after 9 wk of age. In body weight gains, the Holsteins compared favorably with the Beltsville standard (19), whereas the Jerseys gained considerably less rapidly than the standard, likely reflecting their higher requirement for energy compared to the Holsteins.

The comparisons of these three diets along with the results in Experiments 1, 2, and 3 emphasize the wide divergence in kinds of roughage and sources of energy which can be utilized in the formulation of complete high roughage pelleted diets. This suggests that least cost formulation involving a wide range of ingredients could be used successfully to obtain complete pelleted calf diets which would result in satisfactory growth and development of the calves. Extra energy will need to be provided for optimum growth of Jersey calves compared to Holsteins.

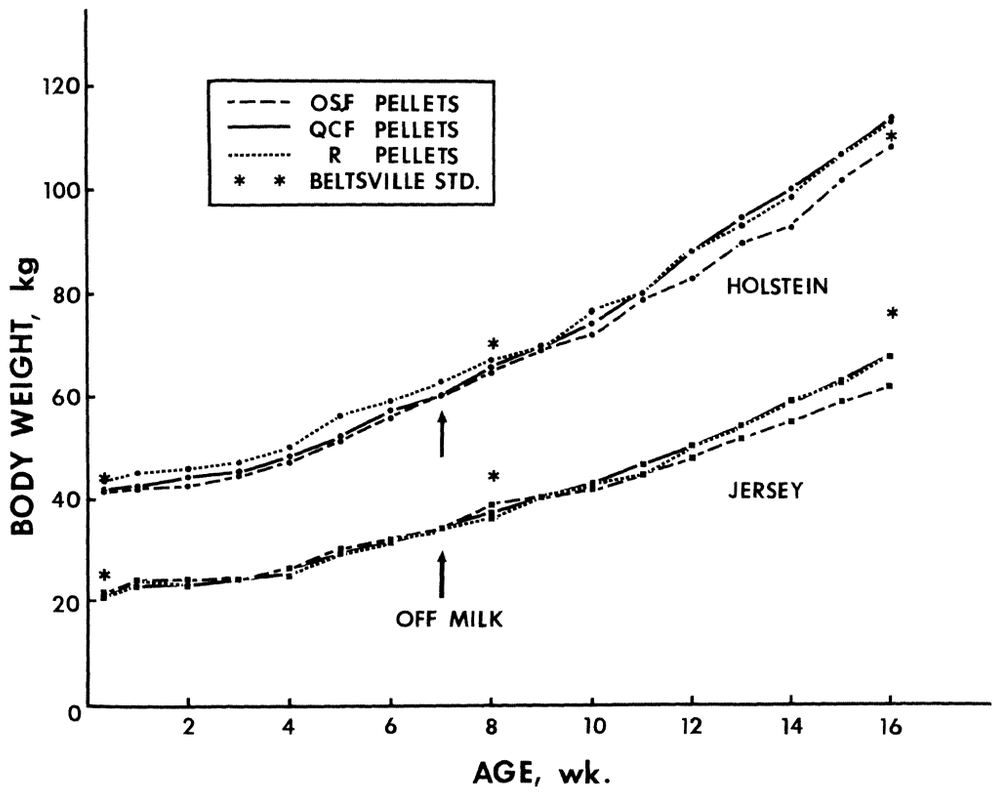

FIG. 3.—Changes in body weight to 16 wk in calves fed OSF, QCF, and R pellets. These weights are compared to the Beltsville standards (19). Experiment 4.

TABLE 16.—Grain Concentrate Feeding Schedule,* Experiment 5.

Age (wk)	Large Breeds (g/d)	Small Breeds (g/d)
0-4	0	0
5	136	91
6	227	182
7	318	272
8	454	363
9-10	590	499
11-12	908	681
13-14	1135	817
15-16	1362	908
17-18	1498	999
19-20	1725	1090
21-22	1816†	1180
23-24	1816	1271
25-26	1816	1362†

*From OARDC Dairy Science Departmental Series 5 (11), Nov. 1961.

†1816 g/d (4 lb/d) grain concentrate limit for large breeds and 1362 g/d (3 lb/d) grain concentrate limit for small breeds.

EXPERIMENT 5

The purpose of this experiment was to determine if adding vitamin D_2 (1,000 IU 454 g) to the grain concentrate mixture in two diets, one having "normal" phosphorus content (0.28% P) and the other "high" phosphorus content (0.42% P), would influence calf growth and performance.

Experimental Procedures

Forty-eight Holstein female calves housed at the OARDC North Central Branch were used in this experiment. The calves were assigned at birth to one of four diet groups. All calves nursed their dams for 3 days and then were bucket fed whole milk according to the schedule previously described (9). Alfalfa hay of excellent quality was offered free choice after 3 days of age, allowing 10-15% refusal. The calves had access to water, salt, and bone meal at all times. One of the four concentrate mixtures shown in Table 17 was fed to 16 wk according to the following schedule (shown in Table 16) which,

TABLE 17.—Ingredients in Grain Concentrates Used in Experiment 5.

	D-93-65 I No Vitamin D	D-94-65 II + Vitamin D	D-95-65 III No Vitamin D	D-96-65 IV + Vitamin D
	Percent			
Flaked shelled corn	61.0	61.0	61.0	61.0
Crimped oats	15.0	15.0		
Wheat bran			14.5	14.5
Soybean meal (44%)	20.0	20.0	19.0	19.0
Molasses	2.0	2.0	2.0	2.0
Monosodium phosphate			2.5	2.5
Bone meal	1.0	1.0		
Salt (trace mineralized)	1.0	1.0	1.0	1.0
Added:				
Vitamin A (IU/454 gm)	10,000	10,000	10,000	10,000
Vitamin D (IU/454 gm)		1,000		1,000

TABLE 18.—Chemical Composition of Feeds, Experiment 5.*

	Milk	1B Grain Concentrate	Alfalfa Hay	Concentrate D-93-65 + Vitamin D I	Concentrate D-94-65 II	Concentrate D-95-65 III	Concentrate D-96-65 + Vitamin D IV
Dry matter, %	12.0	89.0	85.0	88.9	88.9	89.1	89.1
Total protein, %	3.3	14.7	17.3	16.9	16.9	16.7	16.7
Digestible protein, %†, ‡	2.5	9.6	11.9	11.6	11.6	11.4	11.4
Fat, %	3.6	3.8	2.6	2.2	2.2	2.1	2.1
TDN, %‡	16.0	71.6	56.0	73.8	73.8	72.0	72.0
NEg, Mcal/kg	0.30	1.33	0.55	1.19	1.19	1.15	1.15
Digestible E, Mcal/kg	0.70	3.11	2.38	3.17	3.17	3.27	3.27
Ca, %	0.12	0.08	1.20	0.41	0.41	0.11	0.11
P, %	0.09	0.43	0.19	0.46	0.46	1.00	1.00

*Based on US-Canadian Tables of Feed Composition (26), except that actual determined values were used for dry matter percent and total protein percent for groups I-IV.

†% Digestible Protein = (0.908 x % Total Protein) — 3.77, formula of Knight and Harris, 1966.

‡Nutritive ratio for the complete diets, 8-16 wk (Table 3), all groups, was 1:4.3.

based on previous records, when fed with free choice alfalfa hay resulted in approximately a 2:1 ratio of hay to grain intake. The schedule for both large and small breeds is included.

From 16 to 26 wk, all groups were fed alike using 1B grain concentrate and alfalfa hay with a 1.8 kg (4 lb/d) limit on grain concentrate and alfalfa hay free choice. 1B grain concentrate consisted of ground shelled corn, 40 lb; ground oats, 30 lb; wheat bran, 10 lb; soybean meal, 10 lb; and salt, 0.9 lb. Weights were recorded for daily feed offered and refused. Weekly body weight, withers height, and chest circumference were measured at birth, 8 wk, 16 wk, and 26 wk.

The ingredient composition of the feeds used in Experiment 5 is shown in Table 17. The chemical composition of the feeds used in Experiment 5 is shown in Table 18. It should be noted that the principal differences in the four grain concentrate mixtures fed to 16 wk

TABLE 19.—Performance of Holstein Calves to 26 wk of Age, Experiment 5.

	D-93-65 I No Vitamin D	D-94-65 II + Vitamin D	D-95-65 III No Vitamin D	D-96-65 IV + Vitamin D
No. of calves	12	12	12	12
Whole milk, 7 wk, kg	198.3 ± 5.8	200.1 ± 6.4	200.9 ± 5.6	203.2 ± 4.6
Grain concentrate, 8 wk, kg*	5.7 ± 0.9	6.6 ± 0.8	5.1 ± 0.8	5.3 ± 0.8
Grain concentrate, 16 wk, kg	59.3 ± 1.8	63.1 ± 1.2	54.4 ± 4.4	54.3 ± 3.0
Grain concentrate, 26 wk, kg	177.4 ± 4.0	182.1 ± 1.7	165.4 ± 9.8	164.9 ± 5.8
Grain concentrate, 8-16 wk, kg	53.7 ± 1.4	56.4 ± 0.7	49.2 ± 3.8	49.0 ± 2.4
Grain concentrate, 16-26 wk, kg	118.1 ± 3.3	119.0 ± 1.0	111.0 ± 5.6	110.7 ± 3.6
Alfalfa hay, 8 wk, kg	16.2 ± 2.0	15.9 ± 2.2	16.3 ± 3.0	16.8 ± 2.0
Alfalfa hay, 16 wk, kg	131.5 ± 8.3	128.9 ± 6.8	131.8 ± 9.1	137.6 ± 9.0
Alfalfa hay, 26 wk, kg	355 ± 13.7	352.2 ± 17.1	384.6 ± 14.2	357.0 ± 14.0
Alfalfa hay, 8-16, wk, kg	115.3 ± 7.3	113.0 ± 6.2	115.5 ± 7.2	120.8 ± 7.9
Alfalfa hay, 16-26 wk, kg	224.0 ± 8.4	223.3 ± 14.2	252.8 ± 9.2	219.4 ± 9.0
TDN intake, 8 wk, kg†	45.0 ± 1.8	45.8 ± 1.8	45.0 ± 2.2	45.7 ± 1.9
TDN intake, 16 wk, kg	149.1 ± 5.5	150.7 ± 3.9	145.1 ± 6.4	148.6 ± 4.5
TDN intake, 26 wk, kg	361.7 ± 8.7	363.6 ± 9.8	366.6 ± 10.3	351.2 ± 6.9
TDN intake, 8-16 wk, kg	104.2 ± 4.0	104.9 ± 3.1	100.1 ± 5.0	102.9 ± 3.4
TDN intake, 16-26 wk, kg	212.6 ± 5.0	212.9 ± 8.1	221.5 ± 5.6	202.6 ± 4.3
TDN intake/BW gain, 8-16 wk	2.4 ± 0.1	2.3 ± 0.1	2.2 ± 0.1	2.3 ± 0.1
TDN intake/BW gain, 16-26 wk	3.1 ± 0.1	3.2 ± 0.2	3.4 ± 0.1	3.2 ± 0.1
Initial body wt, 3 d, kg	39.6 ± 1.5	39.5 ± 1.9	39.2 ± 1.0	39.9 ± 1.2
Body wt, 8 wk, kg	69.3 ± 2.4	68.8 ± 2.2	66.3 ± 1.8	69.0 ± 2.7
Body wt, 16 wk, kg	113.9 ± 3.7	114.3 ± 3.7	111.1 ± 3.1	113.5 ± 2.6
Body wt, 26 wk, kg	182.3 ± 3.8	181.3 ± 5.3	177.1 ± 3.7	177.9 ± 4.1
Body wt gain, 8-16 wk, kg	44.5 ± 1.9	45.5 ± 1.9	44.8 ± 1.9	44.5 ± 1.1
Body wt gain, 16-26 wk, kg	68.5 ± 2.3	67.1 ± 3.0	66.0 ± 1.4	64.4 ± 2.4
Initial withers ht, cm	72.4 ± 1.0	72.9 ± 1.0	71.6 ± 1.0	73.2 ± 0.5
Withers ht, 8 wk, cm	81.0 ± 0.7	81.4 ± 0.9	80.1 ± 1.1	82.0 ± 0.8
Withers ht, 16 wk, cm	90.8 ± 0.9	90.2 ± 1.0	89.6 ± 0.9	92.2 ± 0.7
Withers ht, 26 wk, cm	102.5 ± 1.0	101.3 ± 0.9	101.1 ± 0.8	102.7 ± 0.8
Withers ht gain, 8-16 wk, cm	9.8 ± 0.7	8.8 ± 1.1	9.5 ± 0.7	10.1 ± 0.7
Withers ht gain, 16-26 wk, cm	11.8 ± 0.7	11.0 ± 8.8	11.5 ± 2.9	10.5 ± 0.9
Initial chest circumference, 3 d, cm	80.2 ± 1.3	79.1 ± 1.2	78.2 ± 1.0	78.8 ± 1.1
Chest circumference, 8 wk, cm	95.4 ± 1.4[a]‡	94.2 ± 1.0[a]	90.6 ± 1.5[b]	93.7 ± 0.8[ab]
Chest circumference, 16 wk, cm	110.0 ± 1.0	109.5 ± 1.4	109.3 ± 1.1	111.3 ± 2.9
Chest circumference, 26 wk, cm	130.6 ± 1.1	128.1 ± 1.1	126.8 ± 1.0	127.6 ± 1.0
Chest circumference gain, 8-16 wk, cm	14.6 ± 1.3	15.3 ± 1.4	18.8 ± 1.8	17.7 ± 2.8
Chest circumference gain, 16-26 wk, cm	20.6 ± 1.4	18.6 ± 0.8	17.5 ± 1.2	16.3 ± 3.1
Ca intake, 8-16 wk (g/d)	28.6	28.3	25.7	26.8
P intake, 8-16 wk (g/d)	8.3	8.5	12.7	12.9
Ca in total diet, 8-16 wk (%)	0.95	0.94	0.87	0.89
P in total diet, 8-16 wk (%)	0.28	0.28	0.43	0.42
Ca:P ratio, 8-16 wk	3.4:1	3.3:1	2.0:1	2.1:1
Vitamin D added/454 g (IU)	0	1000	0	1000

*Feed weights are on air-dry basis, sampled as fed.
†TDN percent used is shown in Table 17.
‡Means followed by different letters are significantly different ($P < 0.05$).

of age to groups I, II, III, and IV were in the Ca and P content and in the presence or absence of supplemental vitamin D_2. The Ca and P intake in the total diets from 8-16 wk, the percent Ca and percent P in the total diets from 8-16 wk, and the Ca:P ratios are shown at the bottom of Table 19. The amounts of supplemental vitamin D_2 added to the grain concentrate are also shown in Table 19.

Results and Discussion

Table 19 shows the average of all additional parameters measured or calculated with standard errors. The only statistically significant difference was a lower chest circumference at 8 wk in group III compared to group II.

The extremely uniform growth in body weight of all four groups to 16 wk compared to the Beltsville standard is readily seen in Figure 4. This uniformity of growth persisted through the 16-26 wk period when all 48 calves were fed alike.

It is concluded that at neither of the two levels of P intake fed at 8 to 16 wk in this experiment (8.4 or 12.8 g/d of P, with approximately 27.4 g/d of Ca and Ca:P ratios of approximately 3.3:1 or 2.1:1) did adding 1,000 IU of vitamin D_2/454 g to the grain concentrate portion of the diet have any significant effect on calf growth to 16 wk as indicated by body weight, withers height, or chest circumference.

The data also emphasize that uniformly good growth equal to the Beltsville standard can be achieved by feeding unpelleted diets, loose hay, and grain concentrate according to the schedule outlined.

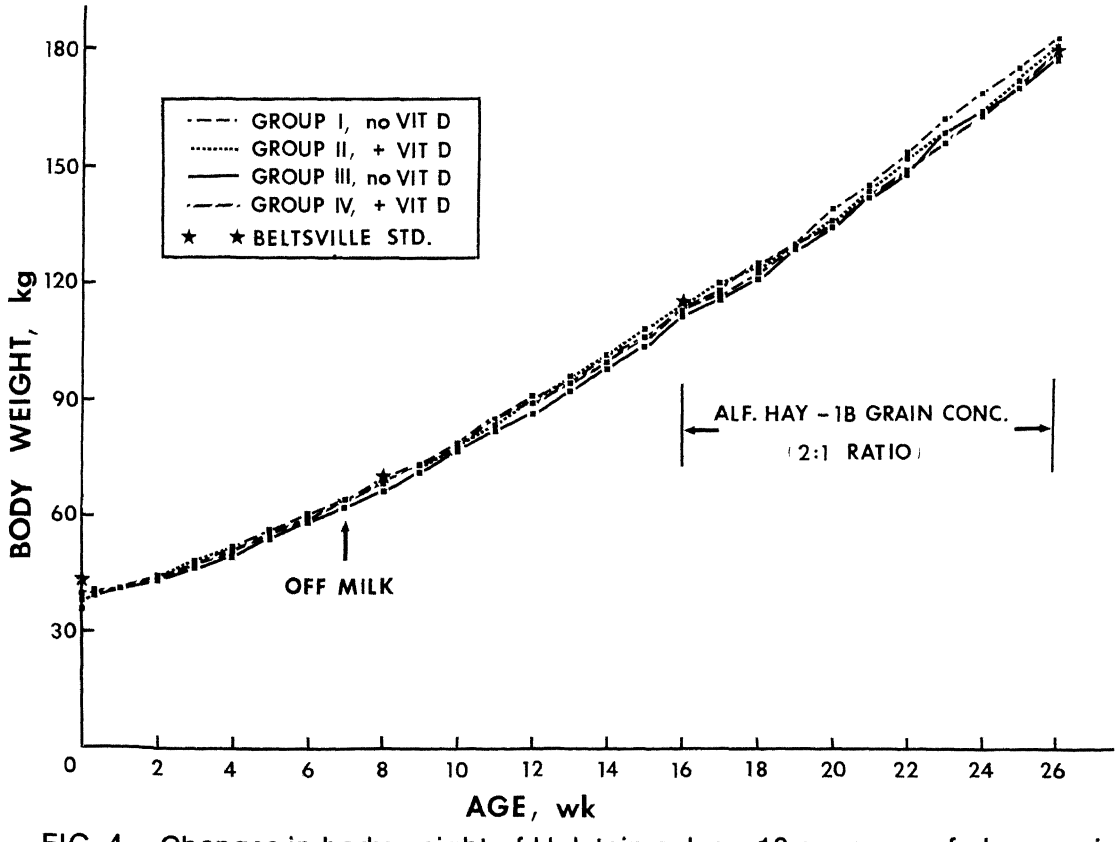

FIG. 4.—Changes in body weight of Holstein calves, 12 per group, fed approximately a 2:1 ratio of alfalfa hay and one of the four concentrate mixtures to 16 wk, compared to the Beltsville standard (19). Respective Ca and P intakes, g/day, 8-16 wk, were: Group I—28.6, 8.3; Group II—28.3, 8.5; Group III—25.7, 12.7; and Group IV—26.8, 12.9. Experiment 5.

TABLE 20.—Summary of Parameters Used in Regression and Multiple Regression Analyses.

Experiment No.	No. of Calves	Body Wt Gain 8-16 wk kg	Dry Matter 8-16 wk kg	TDN %	TDN 8-16 wk kg	NEg 8-16 wk Mcal	DE 8-16 wk Mcal	Protein %	Protein 8-16 wk kg	Digestible Protein %	Digestible Protein 8-16 wk kg	Nutritive Ratio 1: —
1 D	13	44.4	156.0	62.3	102.2	142.0	489.1	14.3	26.1	9.2	16.8	5.8
1 DC	11	37.9	133.0	62.1	90.7	121.0	416.2	12.3	19.1	7.4	11.5	7.4
2 S	22	49.0	114.0	56.3	112.9	126.0	489.0	18.2	36.7	12.8	25.7	3.4
2 T	20	48.8	137.0	65.7	117.9	151.0	515.8	16.7	30.0	11.4	20.5	4.8
2 U	19	47.2	103.0	54.5	102.3	115.0	446.7	17.9	33.6	12.5	23.4	3.4
3 VSF	17	45.8	133.0	79.2	115.6	187.0	506.3	19.4	28.3	13.8	20.2	4.7
3 VSB	18	39.2	113.0	72.1	89.3	141.0	395.2	20.4	25.6	15.4	18.5	3.8
4 OSF	16	43.4	183.0	79.2	100.3	162.0	439.0	21.1	26.7	15.4	19.5	4.1
4 QCF	15	45.5	163.0	64.7	111.6	152.0	486.0	16.2	27.9	10.9	18.8	4.9
4 R	14	48.1	170.0	63.9	100.4	138.0	443.3	16.5	25.9	11.2	17.6	4.7
5 I	12	44.5	145.7	61.7	104.2	127.3	433.1	16.9	17.5	11.6	12.0	4.3
5 II	12	45.5	146.2	61.9	104.9	129.3	447.7	16.9	17.6	11.6	12.1	4.3
5 III	12	44.8	142.0	60.8	100.1	119.1	435.8	16.7	16.7	11.4	11.4	4.3
5 IV	12	44.5	146.4	60.6	102.9	122.8	447.7	16.7	17.5	11.4	11.9	4.3

GENERAL DISCUSSION, EXPERIMENTS 1 TO 5

In the five experiments there were a total of 213 Holstein calves, all fed high roughage diets containing either a 2:1 or a 3:2 ratio of roughage to grain concentrate. The concentrates varied primarily in the amounts of corn, soybean meal, and added fat. The source of roughage varied, using alfalfa, corn cobs, soybran flakes, or beet pulp in various combinations to equal approximately 60 to 66.7% of the total diet.

In order to have a look at the overall effects on body weight gain from 8-16 wk, when only dry feed free choice and water were fed, simple linear regression analyses were performed, with body weight gain from 8-16 wk as the dependent variable and one of the following parameters as the independent variable: dry matter intake from 8-16 wk, kg; TDN, percent in feed; TDN intake from 8-16 wk, kg; NEg intake from 8-16 wk, mcal; digestible E intake from 8-16 wk, mcal; total protein, percent in the feed; total protein intake from 8-16 wk, kg; digestible protein, percent in the feed; digestible protein intake from 8-16 wk, Mcal; and nutritive ratio in the feed. The averages of the data for all parameters in the five experiments are in Table 20. These indicate the ranges covered in the regression analyses.

Of all the independent variables regressed on body weight gain from 8-16 wk, only four were significant ($P < 0.05$). These were TDN intake from 8-16 wk (Fig. 5); digestible energy intake from 8-16 wk (Fig. 6); total protein percent in the feed (Fig. 7); and total protein intake, 8-16 wk (Fig. 8). Following are the formulae for these regressions:

1) Body wt. gain = 13.42 + 30.28 TDN intake, $r^2 = 0.62$.
2) Body wt. gain = 16.19 + 0.06 digestible energy intake, $r^2 = 0.48$.
3) Body wt. gain = −56.53 + 11.96% protein −0.35% protein, $r^2 = 0.63$.
4) Body wt. gain = 38.70 + 0.25 protein intake, $r^2 = 0.25$.

Plots of these regressions are shown in Figures 5, 6, 7, and 8, respectively. All were straight line regressions within the range of the experiments except 3, protein percent, which was curvilinear, showing that percent total protein had the maximum effect on gain in groups which were fed between 16% and 18% protein in the diet. The computed maximum gain from 8-16 wk was at 17.1% protein in the feed. Feed protein either above 19% or below 16% resulted in gains from 8-16 wk which were progressively diminished and below standard.

Multiple regression analyses were also performed with body weight gain from 8-16 wk as the dependent variable, with either: 1) TDN intake from 8-16 wk and nutritive ratio, or 2) digestible energy intake from 8-16 wk and total protein percent in the feed as the independent variables. The formulae for these multiple regressions are:

1) Body wt. gain = 21.77 + 0.27 x TDN intake — 1.06 x nutritive ratio, $r^2 = 0.7300$.

2) Body wt. gain = 11 12 + 0 0640 x digestible energy intake + 0.27 x total protein percent, r^2 = 0 51.

It is concluded that within the range of dietary constraints in these experiments (Table 20), where roughage comprised 60-67% of the free choice fed diets, growth approximating the Beltsville standard can be expected. Most of the variation in growth depended on energy and protein intake, including nutritive ratio, to the extent that the calves were unable to regulate these factors by adjusting dry matter intake. Some 73% of the variation in body weight gain from 8-16 wk was accounted for by TDN intake and nutritive ratio. In this age range, total protein in the total diet should be held between 16 and 18% for maximum growth. A wide range of feed ingredients can be utilized, both roughage and concentrates, including urea and fat and excluding corn in formulating satisfactory high roughage calf diets.

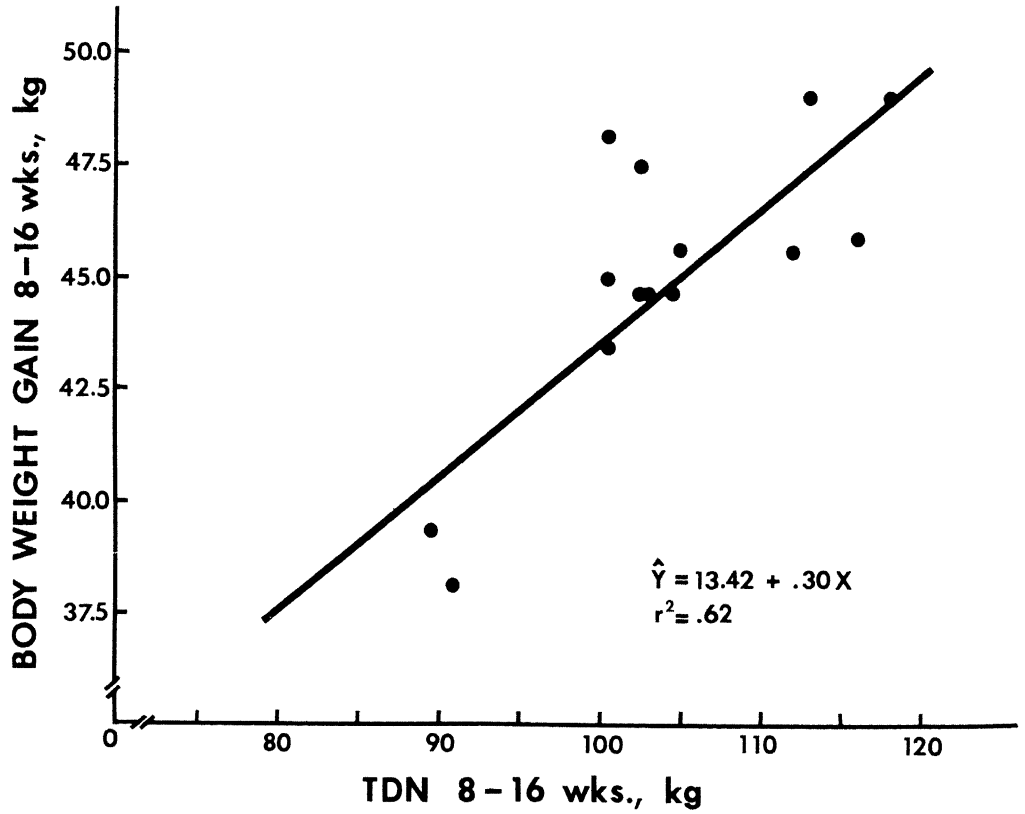

FIG. 5.—Regression of body weight gain from 8 to 16 wk on TDN intake from 8 to 16 wk.

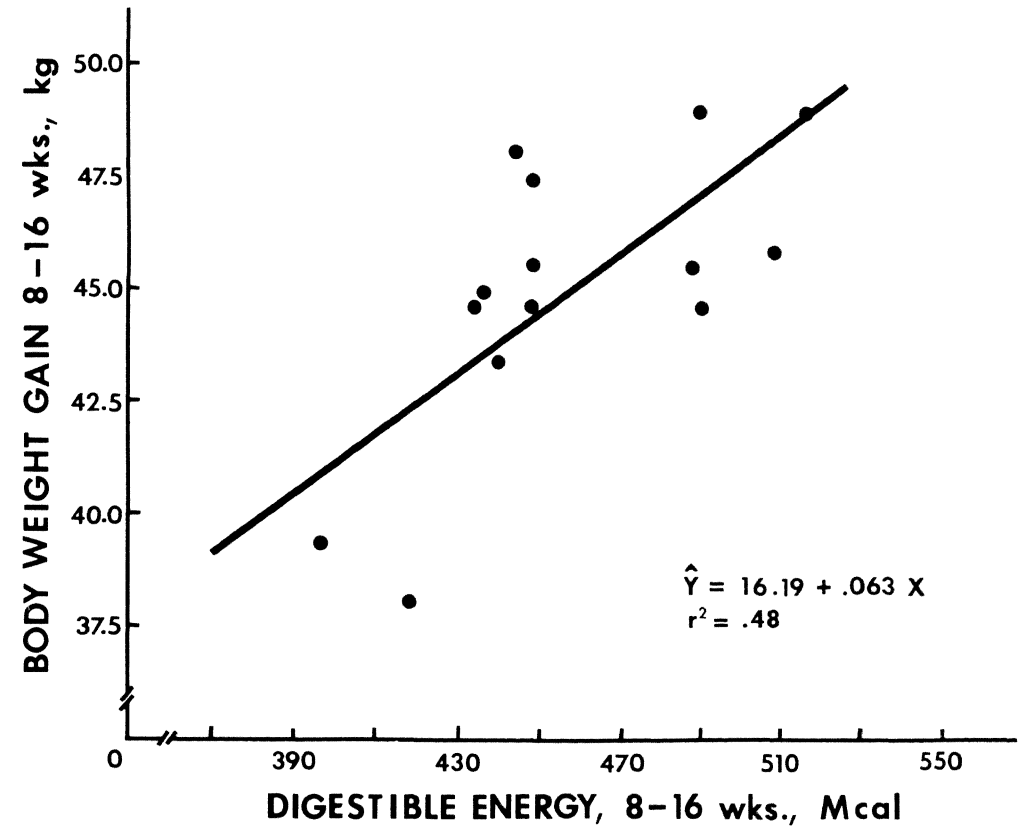

FIG. 6.—Regression of body weight gain from 8 to 16 wk on digestible energy intake from 8 to 16 wk.

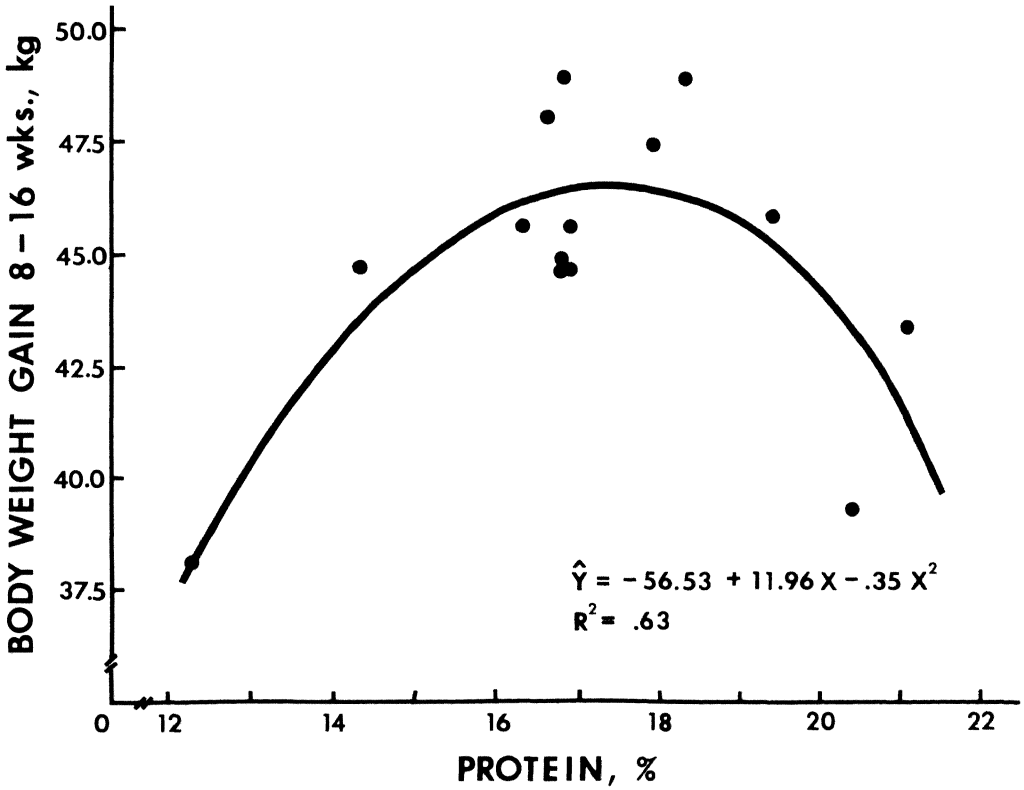

FIG. 7—Regression of body weight gain from 8 to 16 wk on protein percent in the feed.

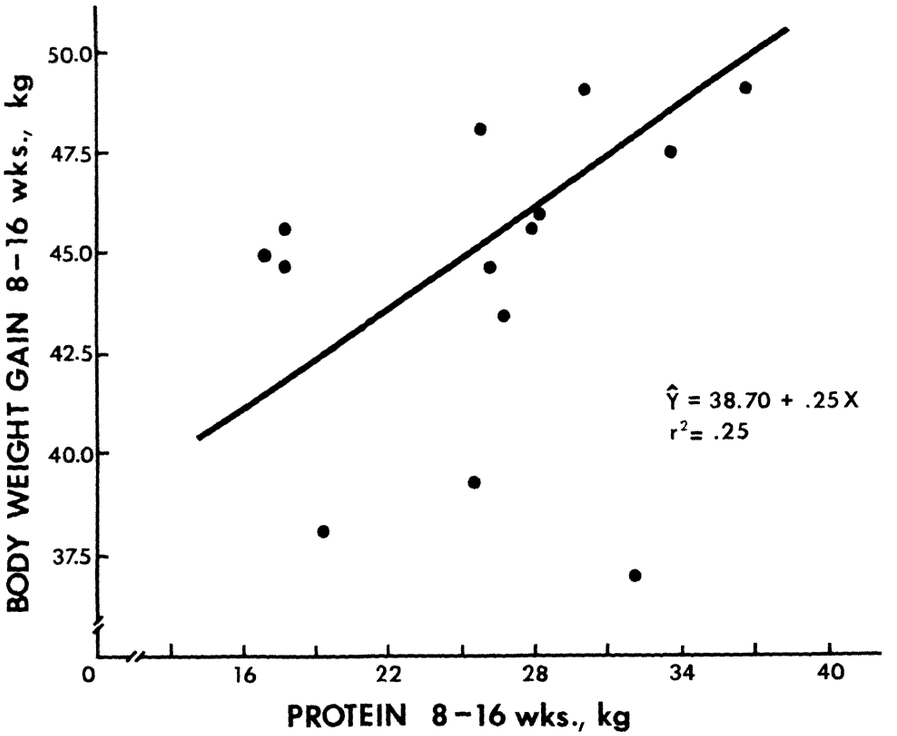

FIG. 8—Regression of body weight gain from 8 to 16 wk on total protein intake from 8 to 16 wk.

REFERENCES

1. Addanki, S., J. W. Hibbs, and H. R. Conrad. 1966. High roughage system for raising calves based on the early development of rumen function. XI. Performance of calves fed alfalfa, beet pulp or soybran flakes as the roughage in complete pelleted rations. J. Dairy Sci., 49:976.
2. Addanki, S., J. W. Hibbs, and H. R. Conrad. 1966. High roughage system for raising calves based on the early development of rumen function. XII. *In vivo* and *in vitro* changes in rumen contents of calves fed alfalfa, beet pulp or soybran flakes as the roughage in complete pelleted rations. J. Dairy Sci., 49:982.
3. Conrad, H. R., J. W. Hibbs, W. D. Pounden, and T. S. Sutton. 1950. The effect of rumen inoculations on the digestibility of roughages in young dairy calves. J. Dairy Sci., 33:585.
4. Conrad, H. R. and J. W. Hibbs. 1953. A high roughage system for raising dairy calves based on the early development of rumen function. III. Effect of rumen inoculations and the ratio of hay to grain on digestion and nitrogen retention. J. Dairy Sci., 36:1326.
5. Conrad, H. R. and J. W. Hibbs. 1954. A high roughage system for raising calves based on early rumen development. IV. Synthesis of thiamine and riboflavin in the rumen as influenced by the ratio of hay to grain fed and initiation of dry feed consumption. J. Dairy Sci., 37:512.
6. Conrad, H. R. and J. W. Hibbs. 1956. A high roughage system for raising calves based on the early development of rumen function. VII. Utilization of grass silage, pasture and pelleted alfalfa meal. J. Dairy Sci., 30:1170.
7. Conrad, H. R., J. W. Hibbs, and Norma Frank. 1958. High roughage system for raising calves based on the early development of rumen function. IX. Effect of rumen inoculations and chlortetracycline on rumen function of calves fed high roughage pellets. J. Dairy Sci., 41:1248.
8. Harvey, W. R. 1960. Least Squares Analysis of Variance with Unequal Subclass Numbers. USDA, Agricultural Res. Service, ARS-20-80.
9. Hibbs, J. W. and H. R. Conrad. 1958. High roughage system for raising calves based on the early development of rumen function. VIII. Effect of rumen inoculations and chlortetracycline on performance of calves fed high roughage pellets. J. Dairy Sci., 41:1230.
10. Hibbs, J. W. and H. R. Conrad. 1978. A high roughage system for raising calves. XIII. Corn cobs in complete high roughage pellets. J. Dairy Sci., 61:337.

11. Hibbs, J. W., H. R. Conrad, and W. D. Pounden. 1953. A high roughage system for raising calves based on early development of rumen function. II. Growth, feed consumption and utilization by calves fed a 3:2 ratio of hay to grain with or without molasses or penicillin supplement. J. Dairy Sci., 36:1319.
12. Hibbs, J. W., H. R. Conrad, and W. D. Pounden. 1954. A high roughage system for raising calves based on early development. V. Some effects of feeding aureomycin with different ratios of hay to grain. J. Dairy Sci., 37:724.
13. Hibbs, J. W., H. R. Conrad, W. D. Pounden, and Norma Frank. 1956. A high roughage system for raising calves based on early development of rumen function. VI. Influence of hay to grain ratio on calf performance, rumen development and certain blood changes. J. Dairy Sci., 39:171.
14. Hibbs, J. W., H. R. Conrad, and J. H. Vandersall. 1961. A high roughage system for raising calves based on the early development of rumen function. X. Whole blood, plasma and corpuscle glucose relationships in calves fed high roughage rations with and without chlortetracycline. J. Dairy Sci., 44:466.
15. Hibbs, J. W. and W. D. Pounden. 1948. The influence of the ration on some of the blood vitamin constituents of the young dairy calf. J. Dairy Sci., 31:672.
16. Hibbs, J. W. and W. D. Pounden. 1948. The influence of the ration and early rumen development on the changes in the plasma carotenoids, vitamin A and ascorbic acid of young dairy calves. J. Dairy Sci., 31:1055.
17. Hibbs, J. W. and W. D. Pounden. 1949. The influence of pasture and early rumen development on the changes in the plasma carotenoids, vitamin A and ascorbic acid and the liver storage of carotenoids and vitamin A of young dairy calves. J. Dairy Sci., 32:1016.
18. Hibbs, J. W., W. D. Pounden, and H. R. Conrad. 1953. A high roughage system for raising calves based on the early development of rumen function. I. Effect of variations in the ration on growth, feed consumption and utilization. J. Dairy Sci., 35:717.
19. Mathews, C. A. and M. H. Foreman. 1954. Beltsville growth standards for Holstein cattle. U. S. Dept. of Agriculture, Tech. Bull. No. 1099.
20. Pounden, W. D., L. C. Ferguson, and J. W. Hibbs. 1950. The digestion of rumen microorganisms by the host animals. J. Dairy Sci., 33:565.
21. Pounden, W. D., and J. W. Hibbs. 1949. Rumen inoculations in young calves. J. Am. Vet. Med. Assoc., 114:33.
22. Pounden, W. D. and J. W. Hibbs. 1948. The influence of the ratio of grain to hay in the ration of dairy calves on certain rumen microorganisms. J. Dairy Sci., 31:1051.
23. Pounden, W. D. and J. W. Hibbs. 1948. The influence of the ration and rumen inoculations on the establishment of certain microorganisms in the rumen of young calves. J. Dairy Sci., 31:1041.
24. Pounden, W. D. and J. W. Hibbs. 1949. The influence of pasture and rumen inoculation on the establishment of certain microorganisms in the rumen of young calves. J. Dairy Sci., 32:1025.
25. Pounden, W. D. and J. W. Hibbs. 1950. The development of calves raised without protozoa and certain characteristic rumen microorganisms. J. Dairy Sci., 33:639.
26. U. S.-Canadian Tables of Feed Composition, 3rd revision. 1982. Nat. Academy Press.

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