

Biological evaluation of rapeseed meal, soya-bean meal and casein fed to the weanling and the mature rat

N. J. DROULISCOS AND J. P. BOWLAND

*Department of Animal Science, The University of Alberta,
Edmonton, Alberta, Canada*

(Received 6 June 1968—Accepted 2 August 1968)

1. The biological evaluation of solvent and prepress-solvent processed rapeseed meals RM(S) and RM(PS) was carried out with the weanling (phase 1) and the mature (phase 2) rat. The nutritional indices measured were compared with those for diets containing soya-bean meal SM and casein CS.

2. The true nitrogen digestibility (td(N)) for RM(S), RM(PS), SM and CS in the weanling rat was (%) 78.9 ± 1.2 , 77.9 ± 2.7 , 90.4 ± 0.9 and 96.0 ± 0.6 ($P < 0.01$) respectively. Net protein utilization was (%) 68.9 ± 10.1 , 65.6 ± 3.5 , 80.6 ± 4.8 and 81.7 ± 3.1 ($P < 0.05$) respectively. Biological value was (%) 83.0 ± 7.9 , 84.1 ± 5.6 , 89.0 ± 5.1 and 85.0 ± 3.4 ($P < 0.05$) respectively. The same indices when measured in the mature rat showed an increase over those obtained in the weanling rat.

3. The growth-promoting effects of the test diets were evaluated over a period of 8 weeks with *ad lib.* feeding between phases 1 and 2. Protein efficiency ratio averaged 2.0 ± 0.14 , 1.9 ± 0.35 , 2.4 ± 0.39 and 2.3 ± 0.25 for the RM(S), RM(PS), SM and CS treatments respectively.

4. The daily endogenous urinary N excretion was 1.58 ± 0.14 mg N/basal kcal or 254 mg N/kg body-weight for the weanling rat and 0.16 mg N/basal kcal or 18 mg N/kg body-weight for the mature rat. Metabolic faecal N excretion was 98.0 ± 9.3 mg N/kg body-weight, or 27.9% of the total N output for the weanling rat, and 37.9 ± 7.2 mg N/kg body-weight, or 67.3% of the total N output for the mature rat during the 'protein-free' feeding periods.

5. The fresh weight of the thyroid gland per kg metabolic body size was 70, 90, 40 and 40 mg respectively for the RM(S), RM(PS), SM and CS dietary treatments.

6. The moisture content of the carcasses was 66.9 ± 3.1 , 63.6 ± 2.3 and 64.2 ± 2.2 and the protein content on a dry-matter basis was 55.9 ± 9.6 , 50.2 ± 6.4 and 53.1 ± 4.9 for the RM(S and PS), SM and CS diets respectively. The results suggest an increased lean body mass in the rats receiving the rapeseed meal treatments.

7. Under the conditions of this experiment solvent-extracted rapeseed meal was superior to prepress-solvent meal on the basis of rat growth response and of results for nutritional indices. Both rapeseed meals were inferior to soya-bean meal and casein.

Experimental work conducted in Canada and abroad on the utilization of rapeseed meal as a protein supplement has been reviewed (Bowland, Clandinin & Wetter, 1965). Information on the biological evaluation of rapeseed meal is limited and the authors of the present report are not aware of such work done with the weanling and the mature rat. Although the protein of rapeseed meal is reasonably well balanced in essential amino acids, the method of processing, the high crude fibre content (9–15%), the level of goitrogenic compounds and the bitter taste of the meal may affect its value as a protein supplement.

Experiments have been conducted in which solvent extracted soya-bean meal and vitamin-free casein served as controls for the biological evaluation of solvent or prepress-solvent processed rapeseed meals.

The results obtained in this investigation have disclosed variations in the endogenous

urinary nitrogen e(N) and metabolic faecal nitrogen m(N) excretion of the weanling and the mature rat. The biological value (BV) and net protein utilization (NPU) of the diet are discussed in relation to the growth response of the rats.

EXPERIMENTAL

Three-week-old weanling rats of the Sprague-Dawley strain weighing between 37 and 40 g were used. They were allocated to four diets, each group including two male and two female rats. Measurements of BV were made on all rats immediately after weaning (phase 1) and at maturity (phase 2). An additional eight mature female rats were used to determine the BV in the second phase (phase 2A) of the experiment only.

Table 1. *Ingredients (g/100 g) and composition of the protein-free diets, test diets and of rapeseed meal*

	Protein-free diets			Test diets				Rapeseed meal (by analysis)	
	1	2	3	RM(S)	RM(PS)	SM	CS	S	PS
Ingredient									
Maize starch	59	58	56	32	32	38	48	—	—
Sucrose	30	29	29	30	30	30	30	—	—
Cellulose	—	2	4	—	—	—	—	—	—
Maize oil	5	5	5	5	5	5	5	—	—
Soya-bean meal (solvent)	—	—	—	—	—	21	—	—	—
Rapeseed meal (solvent)	—	—	—	27	—	—	—	—	—
Rapeseed meal (prepress-solvent)	—	—	—	—	27	—	—	—	—
Casein (vitamin-free)	—	—	—	—	—	—	11	—	—
Mineral mix*	4	4	4	4	4	4	4	—	—
Vitamin mix†									
(a)	1	1	1	1	1	1	1	—	—
(b)	1	1	1	1	1	1	1	—	—
Composition									
Dry matter (by analysis) (%)	93.9	93.9	94.1	94.5	94.5	94.2	94.0	—	—
Crude protein (by analysis) (%)	0.24	0.24	0.24	10.4	10.2	9.6	9.9	—	—
Crude fibre (estimated) (%)	0	2.0	4.0	4.0	4.0	2.0	0	—	—
Gross energy (by analysis) (kcal/kg)	3673	3847	3760	3864	3857	3762	4074	—	—
Oxazolidinethione (mg/g)	—	—	—	—	—	—	—	2.79	3.08
Isothiocyanate (mg/g)	—	—	—	—	—	—	—	3.78	4.24

* (g/100 g): CaCO₃, 30.0; KH₂PO₄, 34.1; NaCl (iodized), 25.0; MgSO₄.7H₂O, 10.0; FeCl₂.4H₂O, 0.6; CuSO₄.5H₂O, 0.157; MnSO₄.H₂O, 0.12; ZnCl₂, 0.02; (NH₄)₆Mo₇O₂₄.4H₂O, 0.03.

† (g/100 g): (a) Vitamin A (10000 i.u./g), 20.0; cholecalciferol (35 i.u./g), 4.0; vitamin E (20000 i.u./g), 20.0; maize starch, 56.0.

(b) Thiamine hydrochloride, 0.20; riboflavine, 0.20; nicotinic acid, 1.00; pantothenic acid, 0.80; cyanocobalamin, 0.001; biotin, 0.004; vitamin K, 0.020; choline, (40% premix), 13.30; sucrose, 82.70.

These additional rats were added in order that any differences in BV and other nutritional indices determined at maturity in the rats previously fed diets containing rapeseed meal, soya-bean meal or casein *v.* those reared with regular stock diet could be detected. The composition of the protein-free and test diets is shown in Table 1. The amino acid requirements of the rat for growth and dietary levels of these amino acids are given in Table 2. The rapeseed meals used in this study were obtained by the solvent extraction, or prepress-solvent extraction, procedures described by Youngs (Bowland *et al.* 1965).

Table 2. *Minimum amino acid requirements for growth in the rat and approximate amounts of amino acids provided in the test diets*

(mg/10 g food, air-dry basis)

Amino acid	For growth*	Test diets			
		RM(S)†	RM(PS)†	SM‡	CS‡
L-Lysine	90	59	59	62	87
L-Methionine	60	18 (30)	19 (31)	18 (33)	23 (27)
L-Cystine	—	12	12	15	4
L-Phenylalanine	90	39 (62)	38 (61)	49 (79)	59 (89)
L-Tyrosine	—	23	23	32	63
L-Histidine	30	27	26	25	31
L-Isoleucine	50	38	39	56	66
L-Leucine	80	69	70	76	108
L-Valine	70	49	50	53	73
L-Arginine	—	56	57	60	39
L-Tryptophan	15	12	13	12	12
L-Threonine	50	44	44	37	44

Values in parentheses for phenylalanine and methionine include an adjustment for tyrosine and cystine, respectively. 1/3 phenylalanine may be supplied by L-tyrosine, 1/3-1/2 methionine may be supplied by L-cystine.

* National Research Council (1962).

† Clandinin (1967).

‡ Block & Weiss (1956).

The rats were housed individually in metal metabolism cages with an adjustable food trough to minimize food wastage. An extra fine, 6 mesh per cm, screen was attached under the standard wire screen of the faeces collection pan to ensure the separation of the small faeces from the urine. The assigned protein-free and experimental diets as well as water were offered *ad lib.* No food wastage or gross food contamination was experienced.

The BV of the four diets was measured by the N balance technique (Mitchell, 1924) on four weanling rats (two males and two females) at 3 weeks of age and again at 12 weeks of age. Because of the different fibre contents of the diets, three protein-free diets containing 0, 2 or 4% cellulose were fed. The rats were fed the protein-free diets for a 4-day collection period preceded by a period of diet adaptation of 5-7 days. Reports vary as to the time required by an animal to reach the level of a relatively constant, but minimum, urinary N excretion with protein-free diets (Allison & Wannemacher, 1965; Blaxter & Wood, 1951*a*; Fomon, DeMaeyer & Owen 1965; Munro, 1964; Young & Scrimshaw, 1968). The length of the preliminary period was

Table 3. Comparison of nutritional indices of RM, SM and CS diets fed to weaning and mature rats

(Means with standard deviations)

Phase Age of rats (days) ... Dietary treatment ... Body-weight of rats (g) ...	1						2						2A											
	28		37-40		110		130-170		150-180		110		130-170		150-180		110		130-170		150-180			
	RM(S)	RM(PS)	SM	CS	RM(S)	RM(PS)	SM	CS	RM(S)	RM(PS)	SM	CS	RM(S)	RM(PS)	SM	CS	RM(S)	RM(PS)	SM	CS	RM(S)	RM(PS)	SM	CS
Gross energy (kcal)	27.6	24.3	34.2	33.5	48.2	46.9	60.5	55.9	35.2	38.7	63.7	63.5	35.2	38.7	63.7	63.5	151.1	158.3	237.1	257	151.1	158.3	237.1	257
Total N intake (mg)	118.5 ± 6.1	102.7 ± 22.5	140.2 ± 18.7	129.8 ± 7.9	207.6 ± 40.6	198.4 ± 23.5	225.2 ± 15.1	217.0 ± 6.7	151.1 ± 8.3	163.6 ± 5.6	237.1 ± 5.7	246.4 ± 8.6	151.1 ± 8.3	163.6 ± 5.6	237.1 ± 5.7	246.4 ± 8.6	151.1 ± 8.3	163.6 ± 5.6	237.1 ± 5.7	246.4 ± 8.6	151.1 ± 8.3	163.6 ± 5.6	237.1 ± 5.7	246.4 ± 8.6
Apparently digested N (mg)	88.5 ± 0.9	75.1 ± 16.4	120.3 ± 15.1	117.5 ± 10.4	163.8 ± 31.2	157.7 ± 9.7	179.8 ± 20.8	201.4 ± 8.4	133.3 ± 8.3	128.0 ± 4.3	206.9 ± 0.6	234.2 ± 9.0	133.3 ± 8.3	128.0 ± 4.3	206.9 ± 0.6	234.2 ± 9.0	133.3 ± 8.3	128.0 ± 4.3	206.9 ± 0.6	234.2 ± 9.0	133.3 ± 8.3	128.0 ± 4.3	206.9 ± 0.6	234.2 ± 9.0
N balance (mg)	63.5 ± 9.8	52.7 ± 14.0	97.9 ± 13.3	89.5 ± 10.4	155.0 ± 31.3	151.0 ± 9.0	170.2 ± 19.6	191.3 ± 8.1	122.5 ± 8.7	121.3 ± 3.0	194.8 ± 3.2	222.2 ± 9.0	122.5 ± 8.7	121.3 ± 3.0	194.8 ± 3.2	222.2 ± 9.0	122.5 ± 8.7	121.3 ± 3.0	194.8 ± 3.2	222.2 ± 9.0	122.5 ± 8.7	121.3 ± 3.0	194.8 ± 3.2	222.2 ± 9.0
Metabolic faecal N (mg)	5.0 ± 0.6	5.2 ± 2.2	6.5 ± 0.92	7.1 ± 1.4	7.0 ± 3.6	7.0 ± 5.0	11.6 ± 3.9	12.8 ± 4.1	9.3 ± 2.6	10.7 ± 3.3	15.7 ± 0.9	10.8 ± 0.74	9.3 ± 2.6	10.7 ± 3.3	15.7 ± 0.9	10.8 ± 0.74	9.3 ± 2.6	10.7 ± 3.3	15.7 ± 0.9	10.8 ± 0.74	9.3 ± 2.6	10.7 ± 3.3	15.7 ± 0.9	10.8 ± 0.74
Endogenous urinary N (mg)	0.4 ± 0.3	1.0 ± 1.7	7.7 ± 0.4	9.4 ± 1.4	2.2 ± 0.9	2.3 ± 0.5	3.2 ± 0.5	3.0 ± 0.4	4.2 ± 0.3	4.4 ± 0.9	3.7 ± 0	3.9 ± 0.48	4.2 ± 0.3	4.4 ± 0.9	3.7 ± 0	3.9 ± 0.48	4.2 ± 0.3	4.4 ± 0.9	3.7 ± 0	3.9 ± 0.48	4.2 ± 0.3	4.4 ± 0.9	3.7 ± 0	3.9 ± 0.48
True digestibility of N (%)	78.9 ± 1.2	77.9 ± 2.7	90.4 ± 0.9	96.0 ± 0.6	82.5 ± 1.2	83.3 ± 3.4	87.8 ± 5.9	97.9 ± 3.4	94.5 ± 1.3	84.8 ± 1.8	93.5 ± 2.2	99.4 ± 2.2	94.5 ± 1.3	84.8 ± 1.8	93.5 ± 2.2	99.4 ± 2.2	94.5 ± 1.3	84.8 ± 1.8	93.5 ± 2.2	99.4 ± 2.2	94.5 ± 1.3	84.8 ± 1.8	93.5 ± 2.2	99.4 ± 2.2
Net protein utilization (%)	68.9 ± 10.1	65.6 ± 3.5	80.6 ± 4.8	81.7 ± 3.1	79.0 ± 3.4	81.1 ± 2.6	85.1 ± 5.1	95.5 ± 2.2	90.0 ± 2.5	83.3 ± 2.1	90.3 ± 3.0	96.1 ± 0.6	90.0 ± 2.5	83.3 ± 2.1	90.3 ± 3.0	96.1 ± 0.6	90.0 ± 2.5	83.3 ± 2.1	90.3 ± 3.0	96.1 ± 0.6	90.0 ± 2.5	83.3 ± 2.1	90.3 ± 3.0	96.1 ± 0.6
Biological value (%)†	83.0 ± 7.9	84.1 ± 5.6	89.0 ± 5.1	85.0 ± 3.4	95.8 ± 2.5	97.3 ± 1.5	96.9 ± 1.3	96.7 ± 1.5	95.3 ± 0.3	98.4 ± 2.2	96.7 ± 0.3	96.7 ± 0.3	95.3 ± 0.3	98.4 ± 2.2	96.7 ± 0.3	96.7 ± 0.3	95.3 ± 0.3	98.4 ± 2.2	96.7 ± 0.3	96.7 ± 0.3	95.3 ± 0.3	98.4 ± 2.2	96.7 ± 0.3	96.7 ± 0.3

Nutritional indices

Total gain in body-weight (g)	105.7	96.6	137.7	130.5	105.7	96.6	137.7	130.5
Protein intake (g)	53.7	53.7	56.0	56.4	53.7	53.7	56.0	56.4
Protein efficiency ratio‡	2.0 ± 0.14	1.9 ± 0.35	2.4 ± 0.39	2.3 ± 0.25	2.0 ± 0.14	1.9 ± 0.35	2.4 ± 0.39	2.3 ± 0.25

* NPU = $100 \times \frac{b(N) + m(N) + e(N)}{I(N)}$
 † BV = $100 \times \frac{e(N) + m(N) + b(N)}{ad(N) + m(N)}$ as adapted from the formula of Blaxter & Wood (1951b).
 ‡ PER = $\frac{\text{gain in body-weight}}{I(P)}$, where b(N) = N balance (mg); m(N) = metabolic faecal N (mg); e(N) = endogenous urinary N (mg); I(N) = total N intake (mg); ad(N) = apparently digested N (mg); I(P) = protein intake (g).

arbitrarily chosen on the basis of the upper values for urinary excretion found in the previous studies.

Measurements in the test period were not made until the loss of body-weight, which occurred with the protein-free diets, had been made good. On completion of the recovery period, each rat was offered *ad lib.* for an 8-week period the test diet received in phase 1. The calculation of the protein efficiency ratio (PER) was based on principles suggested by Boas-Fixsen (1935) and Campbell (1961). Phases 2 and 2A followed, using the same procedures as in phase 1, and upon their completion all the rats were killed with chloroform. The thyroid gland was removed, its fresh weight recorded and the entire carcass was dried, ground and analysed for moisture and crude protein content.

The total N contents of diets, carcasses, faeces and urine were determined by the macroKjeldahl method. The dry-matter content of carcasses and faeces were determined using a 'Thermovac' freeze dryer. The samples were allowed to dry for 48 h at a temperature of -60° and a vacuum of $7.7 \mu\text{m}$ mercury/cm².

The oxazolidinethione and isothiocyanate contents of the rapeseed meals were determined by the methods of Astwood, Greer & Etlinger (1949) and Wetter (1955). Statistical analysis was carried out with an IBM 360-67 electronic computer at the University of Alberta.

RESULTS

Table 3 summarizes the results for each nutritional index. In phase 1, N intake was minimal with weanling rats receiving the RM(PS) diet (102.7 ± 22.5) followed by those having the RM(S) diet (118.5 ± 6.1), the CS diet (129.8 ± 7.9) and the SM diet (140.2 ± 18.7). In phase 2, with mature rats, N intake increased but, with the SM and CS diets it remained above the RM diets. Apparently digested N (ad(N)) averaged

Table 4. *Faecal nitrogen and urinary N excretion (mg/kg body-weight per day) in rats while receiving the protein-free and the test diets*

Phase		Protein-free diets					Test diets					
						Mean					Mean	
		3	3	2	1		RM(S)	RM(PS)	SM	CS		
1	m(N)	90.1	98.0	92.4	111.1	98.0	FN	554.0	552.0	367.0	225.0	424.0
	e(N)	257.0	285.0	213.0	261.0	254.0	UN	462.0	448.0	415.0	517.0	460.0
2	m(N)	30.3	37.3	34.3	49.5	37.9	FN	267.6	268.4	200.3	84.1	205.0
	e(N)	15.3	17.5	18.9	18.3	18.0	UN	54.5	43.5	53.0	55.1	51.5
2A	m(N)	55.3	64.6	55.6	48.7	56.1	FN	105.1	238.9	167.9	65.9	144.5
	e(N)	24.0	29.3	22.5	23.7	25.0	UN	64.1	45.0	59.9	64.8	58.5

m(N) = metabolic faecal N; e(N) = endogenous urinary N; FN = total faecal nitrogen; UN = total urinary nitrogen.

120.3 and 117.5 mg N/day for rats receiving the SM or CS diets but only 88.5 and 75.1 mg for rats receiving the RM diets in phase 1. These relative differences remained in phases 2 and 2A. Although only female rats were used in phase 2A, no sex interactions were detected in the results, direct comparisons may, therefore, be made between phases 2 and 2A.

The m(N) excreted was 98.0 ± 9.3 mg/kg body-weight (Table 4) for the weanling rat and 37.9 ± 7.2 mg N/kg body-weight at maturity. No significant differences appeared in the faecal N excretion during the protein-free period between diets no. 1, 2 and 3, which contained 0, 2 and 4% cellulose respectively.

The true N digestibility (td(N)) varied between dietary treatments. For example, in phase 1, 90.4 and 96.0% N was digested for SM and CS diets, respectively, and 78.9 and 77.9% for rats receiving the RM diets (Table 3).

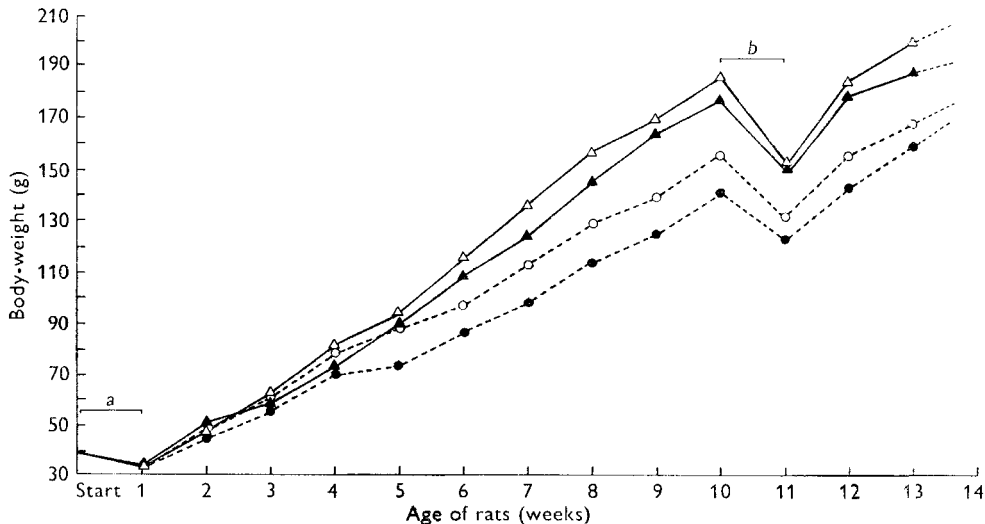


Fig. 1. Body-weight (g) gains of rats from weaning to maturity. The periods of protein-free feeding are indicated by *a* and *b* on the curve. Δ — Δ , SM diet; \blacktriangle — \blacktriangle , CS diet; \circ — \circ , RM(S) diet; \bullet — \bullet , RM(PS) diet.

The e(N) excretion during the protein-free period averaged 1.58 ± 0.14 mg N/basal kcal for the weanling rat and dropped to between 0.16 and 0.25 mg N/basal kcal at maturity. Expressed as mg N/kg body-weight per day, the values ranged from 15.3 to 29.3 mg/kg for the mature and 213–285 mg/kg for the weanling rat (Table 4). The high values for the m(N) excretion, which averaged 98.0 mg N/kg body-weight per day in the weanling rat, were also reduced at maturity (Table 4). Values for N balance (b(N)) followed the same pattern as those for apparent or true N digestibility.

In phase 1, values for td(N), NPU and BV were higher for the SM and CS diets than for the RM diets (Table 3). Average values for td(N), NPU and BV were 78.4, 90.4 and 96.0; 67.2, 80.6 and 81.7; and 83.6, 89.0 and 85.0% for the RM (combined) SM and CS diets respectively. In phase 2 and for the same sequential order as above these values were 82.9, 87.8 and 97.9; 80.0, 85.1 and 95.5; and 96.6, 96.9 and 96.7% respectively. The differences between treatments in phase 2 were less than those in phase 1. The additional mature rats in phase 2A had td(N), NPU and BV in a similar range to those in phase 2.

Body-weight gain and gross energy intake per rat per day were in descending order for treatments SM, CS, RM(S) and RM(PS) (Table 3). Growth response over the

entire experimental period is shown diagrammatically in Fig. 1. Each treatment is represented by the pooled average for two male and two female rats.

Values for NPU and BV reflected the poorer growth of the rats fed diet RS, but NPU gave a closer indication of performance. In phase 1, the NPU values for SM, CS and the two RM diets were 80.6, 81.7 and 67.2%, respectively. The BV for the same diets was

Table 5. *Metabolic body size (MBS) of rats, weight of thyroid gland (Th) and ratio of Th to MBS*

Diet	RM(S)	RM(PS)	SM	CS
	Metabolic body size (g)			
Phase 2*	260	276	299	289
2A†	258	245	289	287
Mean‡	259 ± 1.0	260 ± 19.2	294 ± 5.0	288 ± 1.0
	Thyroid gland (mg)			
Phase 2*	19.8	24.3	12.4	12.2
2A†	12.5	22.3	11.1	13.2
Mean‡	17.4 ± 3.5	23.6 ± 4.9	12.0 ± 1.9	12.5 ± 1.4
	Th (mg)/kg MBS			
Phase 2*	80	90	40	40
2A†	60	90	40	40
Mean	70	90	40	40

* Mean for four rats.

† Mean for two rats.

‡ Mean with standard deviation.

Table 6. *Moisture (H₂O) and crude protein (CP) contents of rat carcasses and ratio, H₂O:CP*

Diet	RM(S)	RM(PS)	SM	CS
	Moisture (g/100 g carcass)			
Phase 2	63.2	64.5	62.2	62.9
2A	71.6	67.3	65.1	65.6
Mean*	67.4 ± 4.1	66.3 ± 2.1	63.6 ± 2.3	64.2 ± 2.2
	Protein (g/100 g dry carcass)			
Phase 2	49.2	52.8	50.0	50.0
2A	73.4	58.0	50.5	59.2
Mean*	57.2 ± 12.0	54.5 ± 7.2	50.2 ± 6.4	53.1 ± 4.9
	Ratio, H ₂ O:CP			
Phase 2	1.28	1.24	1.24	1.26
2A	0.98	1.16	1.29	1.11
Mean	1.18	1.22	1.27	1.21

* Mean with standard deviation.

89.0, 85.0 and 83.5 while weight gain, taking SM as 100, was 95.3 for CS and 73.8 for the average of the two RM. The PER for the RM(S) and RM(PS) diets was 2.0 ± 0.14 and 1.9 ± 0.35 v. 2.4 ± 0.39 and 2.3 ± 0.25 for the SM and CS diets respectively.

The fresh weights of the thyroid averaged 12.0–12.5 mg for the rats fed the SM and CS diets and 17.4–23.6 mg for the RM(S) and RM(PS) diets (Table 5). The larger thyroid glands observed in the RM(PS) treatment are in accordance with the higher

oxazolidinethione and isothiocyanate content of the prepress-solvent RM. The thyroid weights were expressed on a kg MBS basis, and values in the order of 70, 90, 40 and 40 were obtained for the RM(S) RM(PS), SM and CS treatments respectively.

Table 6 summarizes the results of the carcass analyses. The percentage mean values with standard deviations for the moisture content were 66.9 ± 3.1 for the RM(S and PS combined), 63.6 ± 2.3 for the SM and 64.2 ± 2.2 for the CS treatments. The crude protein (CP) content on a dry-matter basis was 55.9 ± 9.6 for RM, 50.2 ± 6.4 for SM and 53.1 ± 4.9 for the CS treatments. The ratio of H₂O:CP was quite constant for rats from phase 2, but fluctuated for rats from phase 2 A.

DISCUSSION

True N digestibility, NPU, BV, PER and growth

The daily food, N and gross energy intakes were depressed in phases 1, 2 and 2 A for both RM treatments, an observation that raises a question on the palatability of RM at this high dietary level. Low intakes of diets containing RM at high levels have been observed previously (Bowland *et al.* 1965).

The growth pattern for rats on the four treatments, as illustrated in Fig. 1, and the PER values may be compared with results available for td(N), NPU and BV of the test diets as estimated in phases 1 and 2 (Table 3). Rate of gain of rats fed the RM diets was lower than for those fed the SM or CS diets. However, PER values were between 1.9 and 2.4 and did not differ significantly between treatments.

There was a positive relationship between the various indices and growth although the relative differences between treatments differed substantially. In phase 1, BV was not significantly lower in the RM(S) and RM(PS) treatments (83.0 ± 7.9 and 84.1 ± 5.6) than in the CS groups. However, the NPU values for both RM treatments were on average 14% lower than those for SM and CS. In phase 2, the NPU values were lower for the RM treatments than for the SM and CS treatments whereas BV was similar for all treatments. NPU was superior to BV as an indicator of major differences in growth performance.

Widely varying BV have been reported for casein. As an example of a recent study, Gangal & Magar (1967) reported BV for casein in the mature adult rat to be 88.2 ± 4.8 as compared with 96.7 ± 1.5 recorded in this study. The value reported by the same authors for td(N) was 90.4 ± 0.44 and the calculated NPU was 80.2. These values are all lower than those obtained in the present study.

The higher indices with mature rats in phase 2 as compared with those for weanling rats in phase 1 may be explained on the basis of the nature and availability of the carbohydrate fraction of the diets. The weanling rat probably could not efficiently utilize starch or other branched or complex polysaccharides because of the undeveloped enzyme system in its digestive tract (Kon & Cowie, 1961). Maize starch constituted 32–48% of the diets. The level of starch could also explain the superiority of SM over CS diets as measured by BV in phase 1. The daily gross energy intakes were 34.2 and 33.5 kcal/rat with the SM and CS diets, but the CS diet contained 10% more of maize starch (Table 1). The SM and CS diets both contained 30% sucrose. It is also possible

that differences in the amino acid requirements of the rats at the two ages could explain at least some of the differences between indices of growth.

The inferior growth response obtained for the RM treatments under the experimental conditions (Fig. 1) is probably associated with several factors. Amino acid analyses of the two samples of RM conducted in this laboratory (Clandinin, 1967), and shown in Table 2 indicate that the lysine, methionine, phenylalanine, valine and isoleucine contents of the RM diets were critically lower (less than 80%) than the minimum growth requirement of the rat. The SM diet was low in lysine, methionine and valine and the CS diet was low in methionine. Phenylalanine was low in the RM diets even when adjusted for the tyrosine present, representing only 68% of the requirement; phenylalanine appears to have been the most limiting amino acid in comparison with the SM and CS diets. Isoleucine was the second most limiting essential amino acid in the RM diets. The RM diets met only 77% of the isoleucine requirement whereas the SM and CS diets exceeded this requirement. The nutritional indices (Table 3) suggest that amino acid requirements for optimum N retention when diets containing 10% protein are fed may not be the same as those for optimum gain in weight.

The crude fibre content of RM diets and the nature of this fibre may have influenced the growth response in this study, even though the addition of cellulose to the protein-free diets had no effect on performance. It is possible that in RM the lignification is arranged and distributed in such a way that its protein is trapped by the fibrous material and therefore limited in its availability. To meet the desired 10% protein level in the diets, the RM content of the experimental diets (Table 1) was 27%, a high level in a diet for monogastric species (Bowland *et al.* 1965).

Evidence for the goitrogenic effect of rapeseed meal is reported by Kennedy & Purves (1941) and Hussar & Bowland (1959) for rats and by Clandinin, Renner & Robblee (1959) for the chick. The presence of goitrogenic principles in RM has been confirmed in this study. The high values for thyroid fresh weights from rats fed RM are in excellent agreement with those reported by Kennedy & Purves (1941). As shown in Table 5, all rats fed the RM diets had increased ratios of thyroid gland weight to metabolic body size. This was so for the additional mature rats in phase 2A although these rats had been fed the RM diets for only 10 days. Kennedy & Purves (1941) state on the basis of their experiments with the rat, that the thyroid rapidly reaches a state of physiological equilibrium and retains this equilibrium at increased body-weights.

The higher moisture and protein contents of the rat carcasses in the RM treatments suggest that the carcasses from rats fed diets containing RM were leaner than those fed diets with SM or CS. This observation is not unexpected considering the overall lower gross energy intake by the rats fed RM and, as a consequence of this lower intake, the mobilization of body depot fat to cover part of the energy requirements of the rats.

Metabolic faecal N

Faecal N loss during the protein-free period varied substantially depending on the age of the rat, with mean daily values for all 'protein-free' diets combined of $98.0 \pm$

9.3 mg N/kg body-weight (phase 1), 37.9 ± 7.2 mg N/kg body-weight (phase 2) and 56.1 ± 5.4 mg N/kg body-weight (phase 2A) (Table 4). The m(N) excretion on the protein-free diet accounted for 27.9% of the total daily urinary plus faecal N loss in the weanling rat and 67.3% for rats at maturity (phases 2 and 2A). The value obtained with the adult rat by Ashworth & Cowgill (1938) accounts for only 26.3% of the total urinary and faecal N excretion on a protein-free diet. Mitchell (1924) found that mature rats of approximately 160 g body-weight excrete 11.3 mg N/day on a protein-free diet or 72.9 mg/kg body-weight. Blaxter & Wood (1951a) reported N excretion of 2.10 g/day or 55 mg/kg body-weight when feeding a N-free diet resembling milk to a 35–40 kg calf. Fomon *et al.* (1965) presented results of a series of N-balance experiments with 4–6 months old infants fed a protein-deficient diet providing only 0.16–0.19 g protein/kg per day. It was shown that the faecal N excretion of these infants was influenced by the protein intake received before the feeding of the protein-deficient diet. The values reported were 32.5 and 20 mg N/kg per day when previous protein intakes were 4.5 g and 2.5 g/kg per day, respectively. Similar results were reported with children 3–8 years of age. The figures quoted above are in good agreement with our results.

The observations regarding the influence of previous treatment on faecal N excretion in experiments by Fomon *et al.* (1965) with the human infant and Blaxter & Wood (1951a) with the calf are well illustrated in the present study with the weanling rat. The weanling rat excreted 98.0 ± 9.3 mg N/kg body-weight during the protein-free period when maintained previously on a high protein intake while suckling its mother. Based on rat's milk containing 12% protein and approximately 25% total solids, the milk is equivalent to a concentrate diet containing 48% high-quality protein in the dry matter (Kon & Cowie, 1961). The rats, when brought to maturity on a much lower dietary protein intake (10% protein in the diet) reduced their m(N) excretion to a value of 37.9 ± 7.2 mg N/kg body-weight when placed on a protein-free diet. At approximately the same age and body-weight range, the additional group of mature rats, reared on a stock diet of 21–22% protein, had an m(N) excretion of 56.1 ± 5.4 mg N/kg body-weight.

Young & Schrimshaw (1968), in an investigation on the endogenous N metabolism of young human adults, reported mean daily values for m(N) losses ranging from 5.8 to 13.8 mg N/kg body-weight, accounting for approximately 20% of the combined urinary and faecal N loss. Their results with the adult human subject are not in agreement with those obtained with the weanling or mature rat.

The adjustment of the protein-free diets to a different cellulose level did not influence the metabolic faecal N excretion. A lignin-like compound would probably have been more appropriate for use in this instance. The N excretion was related to the dry-matter intake and a value of 0.08 g N/100 g dry-matter ingested was obtained for the weanling and the mature rat. The above value differs considerably from the value of 0.45 g N/100 g dry-matter intake which represents the value obtained by Blaxter & Wood (1951a) for the young calf and a quoted value for the adult ruminant based on reports by other workers. A recalculation of the values presented by Young & Schrimshaw (1968) and Fomon *et al.* (1965) shows that the metabolic faecal N excretion is

about 0.11–0.12 g/100 g dry-matter intake for the young human adult and the child. These and our observations support the view that species differences established early in life remain unchanged thereafter.

If satisfactory methods can be devised to remove the hull from rapeseed meal, and hence lower the fibre content, and if the goitrogens can be removed genetically or chemically, it is probable that this meal would be markedly improved as a protein source for animal and human nutrition. With present research in progress on rapeseed meal, such modifications of the meal appear to be feasible in the near future.

One of us (N. J. D.) was in receipt of a postdoctorate fellowship under a grant to J. P. B. from the National Research Council of Canada. The authors thank Dr R. T. Hardin for his assistance with the statistical analyses and interpretation of the results. The technical assistance of P. Larsen is gratefully acknowledged.

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