Protein quality evaluation of goat skim milk powder

A report prepared for the
Dairy Goat Co-operative (N.Z.) Ltd

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1 EXECUTIVE SUMMARY

The purpose of the work was to evaluate the protein quality of goat milk protein. During consultation with the Dairy Goat Co-operative (N.Z.) Ltd it was decided that, because of its nutrient composition, goat Skim Milk Powder (SMP) would be a suitable product for testing in biological evaluation feeding trials. The following package of bioassays and nutrient analyses were carried out and the data compared with literature values for cow SMP:

- Protein Efficiency Ratio (PER) by rat bioassay,
- True Digestibility of Crude Protein (PD) by rat bioassay,
- Amino acid analyses, and
- Protein Digestibility - Corrected Amino Acid Score (PD-CAAS) calculated from the amino acid analytical and protein digestibility data.

Protein quality evaluated using the PER procedure showed that goat SMP (PER, 2.42) was not statistically different from reference casein (PER, 2.50) but is probably lower than cow SMP (PER, 2.60).

Protein digestibility of goat SMP was high (PD, 93.5%). Protein quality evaluated using the PD-CAAS procedure showed that goat SMP (PD-CAAS, 1.00) was the same as cow SMP (PD-CAAS, 1.00). Both products supply essential amino acids to meet the requirements of preschool children as determined by the PD-CAAS procedure.

The evaluation is based on only one sample of goat SMP and further work is required to establish the relativity of goat milk protein and cow milk protein.

2 INTRODUCTION

During consultation with Mr Alex Webber, Dairy Goat Co-operative (N.Z.) Ltd, Hamilton, it was decided that goat Skim Milk Powder (SMP) would be a more appropriate product to use for protein quality evaluation of goat milk protein than goat milk infant formula, as originally submitted to the New Zealand Institute for Crop & Food Research Limited (CFR), Palmerston North. As the purpose of the work was to evaluate goat milk protein, rather than a specific product, the goat SMP offered a product with a higher crude protein content and a lower fat content than goat milk infant formula. The nutrient composition made the SMP more suitable for use in biological evaluation trials.

3 OBJECTIVE

The overall objective of the research contract was to determine the protein quality of goat milk protein. For this purpose, the following bioassays/analyses were carried out using goat SMP as the test product:

- Protein Efficiency Ratio (PER),
- True Digestibility of Crude Protein (PD),
- Amino acid content, and
- Protein Digestibility - Corrected Amino Acid Score (PD-CAAS).

4 PROCEDURES

4.1 Protein efficiency ratio

- The PER is a simple rat bioassay that provides an index of protein quality of the test product. The procedure involves feeding a group of rats an experimental diet containing 100 g protein/kg diet supplied by the test product as the sole source of dietary protein. The PER is the ratio of liveweight gain to crude protein intake over the test period. In effect, the PER is a reflection of the slope of the dose response curve (weight gain on protein intake) between the co-ordinates and zero.

- Samples tested
  Goat SMP, supplied by Dairy Goat Co-operative (N.Z.) Ltd, Hamilton
  ANRC casein B1116, ex CFR, Palmerston North, supplied by New Zealand Milk Products Inc., Santa Rosa, California, USA

- Experimental design
  Two treatments (goat SMP, ANRC casein) x 10 rats/treatment

- Trial procedure
  The rat trial was carried out in the Feed Evaluation Unit, CFR, Palmerston North, in a room maintained at 22 ± 1°C, humidity 60 ± 5%, air exchange of 12 times/hour, and a 12 hour light/dark cycle. Weaned male Sprague Dawley rats (21-23 days, 45-50 g) were housed individually in raised stainless steel cages with mesh floors and randomly allocated to the two treatments. Experimental diets were fed *ad libitum* for 28 days and water was continuously available. The ingredient composition of the PER diets is given in Table 1. The diets were formulated to contain 100 g crude protein (total N x 6.25)/kg diet and the formulations were based on the total nitrogen (N) determinations carried out at the Analytical Chemistry Laboratory, New Zealand Dairy Research Institute (NZDRI), Palmerston North. Liveweight and food intake for each rat was recorded/calculated every seven days. The PER procedure was essentially that described in Method 960.48 (AOAC 1990) but with specific details as described in James & Maccoll (1991a,b).

- Calculation of data

$$\text{Actual PER} = \frac{\text{weight gain (g/28 days)}}{\text{protein intake (g/28 days)}}$$

$$\text{Adjusted PER} = \frac{\text{mean actual PER of test product}}{\text{mean actual PER of ANRC casein}} \times 2.50$$

4.2 Protein digestibility

- Protein digestibility is one of the principal factors influencing protein quality and is also one component of the Protein Digestibility - Corrected Amino Acid Score procedure being used as an alternative to the PER for protein quality evaluation. The protein digestibility rat bioassay is a nutrient balance procedure for determining the proportion of ingested protein that does not pass out of the animal as faecal protein. The procedure involves feeding a group of rats an experimental diet containing 100 g protein/kg diet supplied by the test product as the sole source of dietary protein. Total N intake and faecal N output over the balance period is determined and digestibility is calculated by difference. A correction for metabolic faecal N output is made possible by using a second group of rats fed a diet containing 20 g protein/kg diet supplied by egg albumin as the protein source. When this correction is applied, true digestibility is calculated. Without the correction for endogenous loss, apparent digestibility may be calculated.

- Samples tested/used
  Goat SMP, supplied by Dairy Goat Co-operative (N.Z.) Ltd, Hamilton
  Egg albumin, ex CFR, Palmerston North, supplied by Harvey Farms, Tauranga

- Experimental design
  Two treatments (goat SMP, egg albumin) x eight rats/treatment

- Trial procedure
  The rat nutrient balance trial was carried out in the Feed Evaluation Unit in a room with conditions as described for the PER trial. Weaned male Sprague Dawley rats (21-23 days, 45-50 g) were housed individually in metabolic cages and randomly allocated to the two treatments. Experimental diets were fed at 15g/day for a pre balance period of four days followed by a balance period of four days. Water was continuously available. The ingredient composition of the diets is given in Table 1. The test diet was formulated to contain 100 g crude protein (total N x 6.25), 100 g fat, and a minimum of 50 g fibre/kg diet. The egg albumin diet, used for feeding the group of rats to determine the endogenous loss of metabolic faecal N, was formulated to contain 20 g crude protein (total N x 6.25), 100 g fat, and a minimum of 50 g fibre/kg diet. From these data, the metabolic faecal N loss in rats fed the test diet was calculated, and is based on the assumption that egg albumin is completely digested by the rat. During the balance period, food intake was

recorded for each rat each day and total faeces were collected each day. Samples of the experimental diets and faeces were subsequently analysed for total N.

The PD procedure is described in detail in James & Maccoll (1991b) and is based on the rat faecal method of McDonough et al. (1990).

- Calculation of data

$$\text{True digestibility of crude protein (\%)} = \frac{\left[\text{Dietary N intake (mg/4d)} - \left[\text{Faecal N output (mg/4d)} - \text{Metabolic faecal N output (mg/4d)}\right]\right]}{\text{Dietary N intake (mg/4d)}} \times 100$$

Formulae used for all calculations are given in Appendix I, as reproduced from James & Maccoll (1991b).

N.B. In the current study the balance period was four days, and not five days as indicated in Appendix I.

4.3 Amino acid analyses

Two samples of goat SMP were hydrolysed for each of the two separate procedures required for determination of the acid stable amino acids and the sulphur amino acids, and one sample was hydrolysed for the separate procedure required for determination of tryptophan. The analyses were carried out at the Analytical Laboratory, New Zealand Pastoral Agriculture Research Institute Limited (AgR), Palmerston North.

- Acid stable amino acids
  Samples were hydrolysed in 6M HCl in evacuated sealed tubes at 110°C for 22 h and the released amino acids were fractionated by ion exchange chromatography using an LKB Alpha Model 4150 Amino Acid Analyser. Details of the sample preparation procedure are given in Method 982.30 (AOAC 1990). The composition of buffers and elution programmes used in the ion exchange chromatography were in accordance with the manufacturer's protocols.

- Sulphur amino acids
  Samples were oxidised in performic acid to convert protein-bound methionine and cystine/cysteine to methionine sulphone and cysteic acid

respectively, before hydrolysis of samples in 6M HCl and fractionation of amino acids as for the acid stable amino acids but using a buffer system optimised to the separation of the sulphur amino acid derivatives. Details of the sample preparation procedure are given in Method 985.28 (AOAC 1990).

- Tryptophan
  As tryptophan does not survive the hydrolysis conditions used for determination of the acid stable amino acids, the sample was hydrolysed in 4.2 M sodium hydroxide in an evacuated sealed tube at 110°C for 20 h as described in Method 988.15 (AOAC 1990). The hydrolysate was then fractionated as for the acid stable amino acids using the same buffer system as for the acid stable amino acids.

4.4 Protein digestibility-corrected amino acid score

The essential amino acid contents of the test product were expressed as mg amino acid/g crude protein and were calculated from the amino acid analyses (mg amino acid/g sample) and the total N. Crude protein was calculated as total N x 6.25. Amino acid ratios were calculated as the amounts of essential amino acids in the test product (mg amino acid/g crude protein) to the amounts in the recommended reference requirement pattern for preschool children (FAO/WHO 1990). The lowest ratio provided the uncorrected Amino Acid Score (AAS), which was then multiplied by the Protein Digestibility (PD) coefficient previously determined by rat bioassay to give the PD-CAAS. Details of the procedure are given in FAO/WHO (1990).

5 RESULTS

5.1 Protein efficiency ratio

- The actual and adjusted PER values of goat SMP and ANRC casein are given in Table 3.
- Details of the individual replicates are given in Appendix II.

5.2 Protein digestibility

- True digestibility of crude protein of goat SMP is given in Table 4.
- The mean metabolic faecal N value used to calculate true digestibility was 1.0256 mg N/g DM.
- Details of the individual replicates for the rats fed the diets containing the test product and egg albumin are given in Appendix III.

5.3 Amino acid analyses

- The amino acid composition of goat SMP is given in Table 5.
- Details of each of the five hydrolysates are given in Appendix IV.

5.4 Protein digestibility - corrected amino acid score

- The PD-CAAS of goat SMP, and the way in which it was calculated, is given in Table 6. The PD-CAAS ascribed to goat SMP is the lowest of the essential amino acid ratios, i.e. the lowest value in the last column of Table 6, which is 1.15 for tryptophan. Therefore, the PD-CAAS for goat SMP is 1.15, but generally this is expressed as 1.00 if the lowest score exceeds 1.00.

6 COMMENTS

- Protein efficiency ratio

  PER is an index of the adequacy of the test protein to support growth in the growing rat. The actual PER of goat SMP was not significantly different at the 5% level from the PER of ANRC casein. The adjusted PER of goat SMP was 2.42 compared with the scaled value of 2.50 of ANRC casein. The adjusted PER of cow SMP is higher than ANRC casein (Table 7). However, it should be emphasized that cow SMP was not tested in these trials and the nutrient data on cow SMP were extracted as general values from an NZDB Technical Bulletin.

- Protein digestibility

  The true digestibility of crude protein of goat SMP was 93.5%. This value may be low by comparison with other dairy products and may partly explain the relatively lower PER of goat SMP compared to cow SMP.

- Protein digestibility - corrected amino acid score

  The amino acid composition of goat SMP was compared with values for goat whole milk published in food composition tables (Table 8). The values for goat SMP were broadly in agreement with literature values for whole milk.

  The PD-CAAS reflects the capacity of the protein or, specifically, the balance of essential amino acids, to meet the essential amino acid requirements for preschool children. The PD-CAAS of goat SMP of 1.00 indicates that goat SMP is adequate in meeting the essential amino acid requirements for preschool children.

  A second PD-CAAS for goat SMP was calculated based on the essential amino acid requirement pattern for the growing rat (Table 9). The value of 0.59 is low by comparison with that based on the requirements for preschool children and is a reflection of the higher sulphur amino acid requirement by the growing rat.

  The PD-CAAS for cow SMP is probably 1.00 (Table 7), and suggests that the protein quality of goat SMP, as measured by PD-CAAS, is similar to cow SMP.

- Conclusion

  The protein quality of goat SMP, as evaluated by PER, is not statistically different from reference casein, but may be less than cow SMP.

The AAS, determined experimentally for goat SMP and calculated from literature values for cow SMP, suggests that the protein quality of goat SMP, as evaluated using the PD-CAAS procedure, is similar to that of cow SMP. Both products meet the essential amino acid requirements for preschool children.

N.B. This evaluation is based on only one sample of goat SMP. Further dietary trials and nutrient analyses on a wider range of goat milk products are required to confirm the data presented in this report and to establish the relativity in protein quality between goat milk protein and cow milk protein.

7 TABLES

Table 1: Ingredient composition of experimental diets.

Trial	Protein source	Diet #	Ingredient composition (g/kg diet)					
			Protein source	Vitamin mix [3]	Salt mix [3]	Corn oil	Cellulose	Starch
PER[1]	ANRC casein	248	117.0	50.0	50.0	80.0	10.0	693.0
	Goat SMP	249	282.7	50.0	50.0	80.0	10.0	527.3
PD[2]	Goat SMP	250	279.8	50.0	50.0	99.3	49.4	471.5
	Egg albumin	254	25.2	50.0	50.0	99.6	49.7	725.5

[1] Diets were formulated to contain 100.0 g crude protein (total N x 6.25)/kg diet supplied by the protein source. Formulations were based on total N and dry matter values as shown in Table 2.

[2] Test diet was formulated to contain 100.0 g crude protein (total N x 6.25)/kg diet supplied by goat SMP, and the diet to calculate metabolic faecal N endogenous loss was formulated to contain 20.0 g crude protein (total N x 6.25)/kg diet supplied by egg albumin. Both PD diets were formulated to contain 100.0 g fat and a minimum of 50.0 g fibre/kg diet.

[3] As specified in James & Maccoll 1991a,b.

Table 2: Nutrient analyses of protein sources used to formulate ingredient composition of experimental diets.

Trial	Protein source	Diet #	Nutrient content (g/kg, as is)				
			DM1[1]	Total N	DM2[2]	Fat	Fibre
PER	ANRC casein	248	930.7	138.6	917.9		
	Goat SMP	249	942.0	56.6	942.0		
PD	Goat SMP	250	941.3	57.2	941.1	2.6	2.2
	Egg albumin	254	936.4	128.8	922.6	15.5	13.6

[1] DM = Dry Matter. Dry matter content determined at the time of total N analysis.

[2] Dry matter content determined at the time of diet preparation.

Table 3: Protein Efficiency Ratio (PER) of goat SMP determined by rat bioassay.

Protein source	Diet #	Actual PER[1] (g gained / g protein eaten)	Adjusted PER
ANRC casein	248	3.59 ± 0.093	2.50
Goat SMP	249	3.48 ± 0.171	2.42

[1] Mean ± Standard Deviation (SD), n=10.

Table 4: **True digestibility of crude protein of goat SMP determined by the rat faecal method.**

Protein source	Diet #	True digestibility[1] (%)
Goat SMP	250	93.5 ± 0.98

[1] Mean ± Standard Deviation (SD), n=8. Metabolic faecal N value used in calculations of true digestibility was 1.0256 mg N/g DM.

Table 5: Amino acid composition of goat SMP.

Amino acid	Content (mg/g sample[1])
Aspartic acid	23.9
Threonine	18.4
Serine	18.2
Glutamic acid	61.0
Proline	39.9
Glycine	6.5
Alanine	11.9
Valine	21.6
Isoleucine	16.6
Leucine	32.4
Tyrosine	13.5
Phenylalanine	18.0
Histidine	10.1
Lysine	25.9
Arginine	10.0
Methionine	7.6
Cystine	3.6
Tryptophan	4.8[2]

[1] Dry matter content 940.7 g/kg, except for [2] where dry matter content was 936.5 g/kg.

Table 6: **Protein Digestibility - Corrected Amino Acid Score (PD-CAAS) of goat SMP.**

Amino acid	Requirement pattern	Goat SMP			
		Amino acid level		Uncorrected AAS	PD-CAAS
	(mg/g protein)	(mg/g sample)	(mg/g protein[1])		
Histidine	19	10.1	28.3	1.49	1.39
Isoleucine	28	16.6	46.5	1.66	1.55
Leucine	66	32.4	90.7	1.37	1.28
Lysine	58	25.9	72.5	1.25	1.17
Methionine } Cystine }	25	11.2	31.3	1.25	1.17
Phenylalanine } Tyrosine }	63	31.5	88.2	1.40	1.31
Threonine	34	18.4	51.5	1.51	1.41
Tryptophan	11	4.8	13.5	1.23	1.15
Valine	35	21.6	60.5	1.73	1.62

[1] Total N, 57.2 mg/g sample, as is. Crude protein calculated as total N x 6.25.

Table 7: **Summary of data and comparison with cow SMP and acid casein.**

Protein source	Actual PER	Adjusted PER	PD	AAS	PD-CAAS
Goat SMP	3.48	2.42	93.5	1.23	1.15
Cow SMP	3.65[1]	2.60[1]		1.27[2] } 1.31[3] }	
ANRC casein	3.59	2.50			
Acid casein	3.40[1]	2.45[1]		1.12[2]	

1 NZDB Technical Bulletin.

2 Calculated from amino acid data in NZDB Technical Bulletin.

3 Calculated from amino acid data in New Zealand Food Composition Database, 1992.

N.B. Scores > 1 are generally presented as 1.00.

Table 8: Amino acid composition of goat SMP and whole milk.

Amino acid	Goat SMP (mg/gN)	Goat whole milk		
		NZ[1] (mg/gN)	USA[2] (mg/gN)	Germany[3] (mg/gN)
Aspartic acid	418	465	376	519
Threonine	322	329	292	398
Serine	318	342	324	363
Glutamic acid	1067	1220	1122	1349
Proline	698		660	1245
Glycine	114	119	90	128
Alanine	208	188	211	242
Valine	378	401	430	484
Isoleucine	290	290	371	398
Leucine	567	581	563	674
Tyrosine	236	226	321	415
Phenylalanine	315	320	278	311
Histidine	177	167	160	137
Lysine	453	554	520	588
Arginine	175		213	225
Methionine	133	111	143	163
Cystine	63	53	82	144
Tryptophan	84		79	86

[1] New Zealand Food Composition Database, 1992.

[2] USDA, 1976.

[3] Souci, Fachmann, Kraut. Food composition and nutrition tables 1989/90, 1989.

Table 9: **Protein Digestibility - Corrected Amino Acid Score (PD-CAAS) of goat SMP calculated using the essential amino acid requirements for the growing rat.**

Amino acid	Requirement pattern[1]		Goat SMP		
			Amino acid level	Uncorrected AAS	PD-CAAS
	(mg/100 g diet, as is)	(mg/g protein)	(mg/g protein)		
Histidine	300	25.0	28.3	1.13	
Isoleucine	550	45.8	46.5	1.02	
Leucine	750	62.5	90.7	1.45	
Lysine	900	75.0	72.5	0.97	
Methionine } Cystine }	600	50.0	31.3	0.63	0.59
Phenylalanine } Tyrosine }	800	66.7	88.2	1.32	
Threonine	500	41.7	51.5	1.24	
Tryptophan	150	12.5	13.5	1.08	
Valine	600	50.0	60.5	1.21	

[1] Calculated from National Research Council, 1972.

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9 APPENDICES

Appendix I
Calculations

1 DRY MATTER INTAKE, using test and protein free groups

$$\text{Dietary DM intake (g DM/5d)} = \left(\left(\text{Apparent food intake (g as is /5d)} - \left(\text{Cone dust + (g as is/5d)}\right)\right) \text{Diet dust (g FD/5d)}\right) \times \text{Diet DM coefficient} - \text{Urine residue (g DM/5d)}$$

DM, dry matter
FD, freeze dried

2 DIETARY NITROGEN INTAKE, using test groups

$$\text{Dietary N intake (mg/5d)} = \text{Dietary DM intake (g DM/5d)} \times \frac{\text{Dietary N content (\%, as is)}}{\text{Diet DM coefficient}} \times 10$$

3 FAECAL NITROGEN OUTPUT, using test and protein free groups

$$\text{Faecal N output (mg/5d)} = \frac{\text{Faecal output (g as is /5d)}}{\text{Recovery coefficient}} \times \text{Faecal N content (\%, as is)} \times 10$$

4 METABOLIC FAECAL NITROGEN OUTPUT, using protein free group

$$\text{Metabolic faecal N output (mg/g DM)} = \frac{\text{Faecal N output (mg/5d)}}{\text{Dietary DM intake (g DM/5d)}}$$

5 MEAN METABOLIC FAECAL NITROGEN OUTPUT, using protein free group

$$\text{Mean metabolic faecal N output (mg/g DM)} = \frac{\Sigma \text{ Metabolic faecal N output (mg/g DM)}}{n}$$

n is number of rats in protein free group.

6 METABOLIC FAECAL NITROGEN OUTPUT, using test groups

Metabolic faecal N output (mg/5d) = Dietary DM intake (g DM/5d) x Mean metabolic faecal N output (mg/g DM)

7 TRUE DIGESTIBILITY OF CRUDE PROTEIN, using test groups

$$\text{True digestibility of crude protein (\%)} = \frac{\text{Dietary N intake (mg/5d)} - \left(\text{Faecal N output (mg/5d)} - \text{Metabolic faecal N output (mg/5d)}\right)}{\text{Dietary N intake (mg/5d)}} \times 100$$

Appendix II
Protein efficiency ratio - individual replicate data

1	2	3	4	5	6	7	8	9
L#	D#	R#	W0 (g)	W7 (g)	W14 (g)	W21 (g)	W28 (g)	WG (g/28d)
17	248	1	48.53	71.80	106.32	138.11	185.16	136.63
15	248	2	49.74	68.13	112.33	155.26	208.14	158.40
14	248	3	46.55	67.40	100.89	132.54	171.63	125.08
7	248	4	45.92	60.79	94.94	125.09	163.37	117.45
9	248	5	46.63	74.89	112.89	151.70	195.39	148.76
3	248	6	49.50	80.39	125.31	163.26	219.30	169.80
19	248	7	46.30	72.27	104.88	128.59	173.48	127.18
2	248	8	46.47	69.21	107.45	113.55	168.67	122.20
16	248	9	46.69	70.16	112.47	128.90	173.35	126.66
20	248	10	49.51	73.05	116.40	141.90	187.77	138.26
4	249	1	45.32	73.13	113.68	143.71	183.06	137.74
8	249	2	46.83	76.70	112.88	123.38	168.76	121.93
18	249	3	45.37	68.31	107.66	144.86	181.56	136.19
5	249	4	50.02	73.54	119.48	152.72	208.41	158.39
6	249	5	46.08	70.47	105.69	127.76	158.79	112.71
10	249	6	48.47	61.00	93.60	131.00	178.87	130.40
1	249	7	45.71	71.31	117.74	155.52	200.76	155.05
11	249	8	49.55	84.28	120.92	154.86	195.10	145.55
13	249	9	46.14	74.80	105.27	139.50	178.31	132.17
12	249	10	45.68	71.46	105.05	119.60	164.88	119.20

10 WMI7 (g/7d)	11 WMI14 (g/7d)	12 WMI21 (g/7d)	13 WMI28 (g/7d)	14 WMI (g/28d)
58.65	83.09	100.99	127.71	370.44
60.56	93.59	129.15	151.63	434.93
57.48	80.22	98.39	118.13	354.22
54.84	72.46	93.29	113.33	333.92
61.63	91.21	115.52	135.93	404.29
71.82	107.47	127.87	153.52	460.68
61.52	85.74	97.57	124.54	369.37
55.30	85.80	88.71	119.94	349.75
61.25	93.51	82.79	121.99	359.54
60.70	91.74	98.74	127.29	378.47
61.10	94.67	104.49	127.57	387.83
65.16	96.12	111.61	111.36	384.25
53.30	91.90	115.68	128.14	389.02
62.41	102.81	113.68	139.03	417.93
57.41	83.39	86.83	103.11	330.74
43.06	77.57	110.54	132.62	363.79
63.24	105.55	125.70	135.01	429.50
72.36	101.85	124.37	129.32	427.90
62.68	90.04	108.31	124.43	385.46
56.73	94.93	105.01	101.96	358.63

15	16	17	18	19	20	21	22	23
INC	IDM1	IDM2	DIL	DCPC	DCPI	MPER	PER	SD
(%)	(coef)	(coef)	(g/kg)	(g/kg)	(g/28d)			
13.86	0.9307	0.9179	117.0	99.957	37.028	3.69		
13.86	0.9307	0.9179	117.0	99.957	43.474	3.64		
13.86	0.9307	0.9179	117.0	99.957	35.407	3.53		
13.86	0.9307	0.9179	117.0	99.957	33.378	3.52		
13.86	0.9307	0.9179	117.0	99.957	40.412	3.68		
13.86	0.9307	0.9179	117.0	99.957	46.048	3.69		
13.86	0.9307	0.9179	117.0	99.957	36.921	3.44		
13.86	0.9307	0.9179	117.0	99.957	34.960	3.50		
13.86	0.9307	0.9179	117.0	99.957	35.939	3.52		
13.86	0.9307	0.9179	117.0	99.957	37.831	3.65	3.59	0.093
5.66	0.9420	0.9420	282.7	100.005	38.785	3.55		
5.66	0.9420	0.9420	282.7	100.005	38.427	3.17		
5.66	0.9420	0.9420	282.7	100.005	38.904	3.50		
5.66	0.9420	0.9420	282.7	100.005	41.795	3.79		
5.66	0.9420	0.9420	282.7	100.005	33.076	3.41		
5.66	0.9420	0.9420	282.7	100.005	36.381	3.58		
5.66	0.9420	0.9420	282.7	100.005	42.952	3.61		
5.66	0.9420	0.9420	282.7	100.005	42.792	3.40		
5.66	0.9420	0.9420	282.7	100.005	38.548	3.43		
5.66	0.9420	0.9420	282.7	100.005	35.865	3.32	3.48	0.171

Guide to column headings in PER data in Appendix II.

1 = location #
2 = diet #
3 = replicate #
4 = liveweight (g), day 0
5 = liveweight (g), day 7
6 = liveweight (g), day 14
7 = liveweight (g), day 21
8 = liveweight (g), day 28
9 = weight gain (g/28d)
10 = wet matter intake (g/7d), day 1-7
11 = wet matter intake (g/7d), day 8-14
12 = wet matter intake (g/7d), day 15-21
13 = wet matter intake (g/7d), day 22-28
14 = wet matter intake (g/28d), day 1-28
15 = ingredient N content (%, as is)
16 = ingredient dry matter (coefficient), at time of N analysis
17 = ingredient dry matter (coefficient), at time of diet preparation
18 = diet ingredient level (g/kg)
19 = diet crude protein content (g/kg)
20 = dietary crude protein intake (g/28d)
21 = protein efficiency ratio [weight gain (g/28d)/crude protein intake (g/28d)]
22 = mean protein efficiency ratio
23 = standard deviation

Appendix III
Protein digestibility - individual replicate data

1	2	3	4	5	6	7	8
L#	D#	R#	AFI1 (g/d)	AFI2 (g/d)	AFI3 (g/d)	AFI4 (g/d)	AFI (g/4d)
34	250	1	11.04	10.17	11.30	12.30	44.81
35	250	2	10.04	11.57	11.46	12.38	45.45
23	250	3	10.94	12.62	11.99	11.79	47.34
15	250	4	8.83	10.09	10.94	10.51	40.37
12	250	5	11.60	12.25	12.02	14.37	50.24
36	250	6	9.43	10.60	12.09	10.15	42.27
18	250	7	9.53	11.25	11.98	11.36	44.12
4	250	8	11.76	12.10	12.32	13.86	50.04
3	254	1	9.00	7.74	7.88	9.31	33.93
31	254	2	7.21	8.24	10.90	8.17	34.52
38	254	3	7.11	6.93	6.04	5.23	25.31
8	254	4	11.39	8.63	10.19	11.81	42.02
6	254	5	9.44	10.16	11.07	12.09	42.76
22	254	6	8.65	9.26	8.64	9.53	36.08
37	254	7	5.49	4.61	5.03	4.70	19.83
17	254	8	6.10	5.65	7.25	7.36	26.36

9	10	11	12	13	14	15
CD	DD	UR	DDM	DMI	DNC	DNI
(g/4d)	(g/4d)	(g/4d)	(coef)	(g/4d)	(%)	(mg/4d)
1.11	0.48	0.29	0.9239	39.6410	1.65	707.951
0.65	0.13	0.23	0.9239	41.0406	1.65	732.947
0.66	0.30	0.20	0.9239	42.6505	1.65	761.698
0.23	0.25	0.17	0.9239	36.6844	1.65	655.149
1.03	1.23	0.21	0.9239	44.1187	1.65	787.920
0.78	0.17	0.19	0.9239	37.9855	1.65	678.387
0.60	0.61	0.22	0.9239	39.4245	1.65	704.086
2.42	1.10	0.37	0.9239	42.6098	1.65	760.972
5.00	0.37	0.30	0.9091	25.6639	0.37	104.451
12.11	1.92	0.22	0.9091	18.4075	0.37	74.918
4.68	0.43	0.44	0.9091	17.9238	0.37	72.949
10.85	5.71	0.31	0.9091	22.8357	0.37	92.940
10.14	5.90	0.27	0.9091	24.0212	0.37	97.765
11.30	0.61	0.26	0.9091	21.7129	0.37	88.371
1.31	0.14	0.13	0.9091	16.5793	0.37	67.477
6.01	1.95	0.14	0.9091	16.5874	0.37	67.510

16	17	18	19	20	21	22	23
FO	FR	FNC	FNO	MFNO	PD	MPD	SD
(g/4d)	(coef)	(%)	(mg/4d)	(mg/4d)	(%)	(%)	
4.303	0.9819	1.71	74.938	40.656	95.16		
4.680	0.9850	1.80	85.523	42.091	94.07		
4.852	0.9750	1.83	91.068	43.742	93.79		
4.425	0.9896	1.93	86.300	37.623	92.57		
5.384	0.9837	1.77	96.876	45.248	93.45		
4.443	0.9751	1.99	90.673	38.958	92.38		
4.303	0.9862	1.85	80.719	40.434	94.28		
5.169	0.8955	1.73	99.859	43.701	92.62	93.54	0.975
2.473	0.9867	0.95	23.810				
1.739	0.9552	0.85	15.475				
1.865	0.9711	1.04	19.973				
2.524	0.9897	1.02	26.013				
2.316	0.9846	1.03	24.228				
2.095	0.9769	0.87	18.657				
1.835	0.9929	1.11	20.514				
1.518	0.9766	1.15	17.875				

Guide to column headings in PD data in Appendix III.

1 = location #
2 = diet #
3 = replicate #
4 = apparent food intake (g/d), day 1
5 = apparent food intake (g/d), day 2
6 = apparent food intake (g/d), day 3
7 = apparent food intake (g/d), day 4
8 = apparent food intake (g/4d), day 1-4
9 = cone dust (g/4d)
10 = diet dust (g/4d)
11 = urine residue (g/4d)
12 = diet dry matter coefficient
13 = dry matter intake (g/4d)
14 = dietary N content (%, as is)
15 = dietary N intake (mg/4d)
16 = faecal output (g/4d, as is)
17 = faecal recovery coefficient
18 = faecal N content (%, as is)
19 = faecal N output (mg/4d)
20 = metabolic faecal N output (mg/4d)
21 = true digestibility of crude protein (%)
22 = mean true digestibility of crude protein (%)
23 = standard deviation

Appendix 4
Amino acid composition - individual hydrolysates

16/11/92 AMINO ACID RESULTS ON PROTEIN HYDROLYSATE

(Client Copy)

Client.....: K JAMES
Sample Type.....: GOAT SKIM MILK
Lab. No.....: 92/238
Hydrolysate No.....: 92178
Dry Matter %.....: 100

New Zealand Pastoral Agriculture Research Institute

Peak no.	Name	nmoles injected	mg/g as is	mg/g DM *1	%wt *2
1	Aspartic Acid	23.7	20.8	24.4	7.3
2	Threonine	20.5	16.1	18.9	5.7
3	Serine	22.8	15.8	18.5	5.6
4	Glutamic Acid	54.8	53.3	62.3	18.8
5	Proline	45.6	34.7	40.6	12.2
6	Glycine	11.6	5.7	6.7	2.0
7	Alanine	17.5	10.3	12.0	3.6
8	Valine	23.9	18.5	21.7	6.5
9	IsoLeucine	16.2	14.1	16.5	5.0
10	Leucine	32.1	27.9	32.6	9.8
11	NorLeucine	17.1	-	-	-
12	Tyrosine	9.6	11.5	13.5	4.1
13	Phenylalanine	13.7	15.0	17.5	5.3
14	Histidine	8.5	8.7	10.2	3.1
15	Lysine	23.4	22.6	26.5	8.0
16	Tryptophan	-	-	-	-
17	Arginine	7.2	8.3	9.7	2.9
	Totals	348.2	298.4	331.8	100.0

Notes:

These results are from one hydrolysate chromatogram.

*1 These values are the mg/g drymatter results corrected up for the actual recovery value of NorLeucine Internal Standard added to the sample prior to hydrolysis.

*2 %wt is the relative % of the total amino acids determined in the sample.

16/11/92 AMINO ACID RESULTS ON PROTEIN HYDROLYSATE

(Client Copy)

Client.....: K JAMES
Sample Type.....: GOAT SKIM MILK
Lab. No.....: 92/238
Hydrolysate No.....: 92179
Dry Matter %.....: 100

New Zealand Pastoral
Agriculture Research
Institute

Peak no.	Name	nmoles injected	mg/g as is	mg/g DM *1	%wt *2
1	Aspartic Acid	26.2	21.0	23.3	7.2
2	Threonine	22.5	16.2	17.9	5.5
3	Serine	25.4	16.1	17.9	5.5
4	Glutamic Acid	60.5	53.7	59.6	18.4
5	Proline	50.8	35.3	39.2	12.1
6	Glycine	12.3	5.6	6.2	1.9
7	Alanine	19.6	10.5	11.7	3.6
8	Valine	27.3	19.3	21.4	6.6
9	IsoLeucine	19.0	15.1	16.7	5.2
10	Leucine	36.6	29.0	32.2	9.9
11	NorLeucine	18.0	-	-	-
12	Tyrosine	11.1	12.2	13.5	4.2
13	Phenylalanine	16.7	16.7	18.5	5.7
14	Histidine	9.5	8.9	9.9	3.1
15	Lysine	25.8	22.8	25.3	7.8
16	Tryptophan	-	-	-	-
17	Arginine	8.8	9.2	10.2	3.2
	Totals	390.2	306.0	323.5	100.0

Notes:

These results are from one hydrolysate chromatogram.

*1 These values are the mg/g drymatter results corrected up for the actual recovery value of NorLeucine Internal Standard added to the sample prior to hydrolysis.

*2 %wt is the relative % of the total amino acids determined in the sample.

16/11/92 AMINO ACID RESULTS ON PROTEIN HYDROLYSATE

(Client Copy)

Client.....: K JAMES
Sample Type.....: GOAT SKIM MILK
Lab. No.....: 92/238
Hydrolysate No.....: 92166S
Dry Matter %.....: 100

New Zealand Pastoral
Agriculture Research
Institute

Peak no.	Name	nmoles injected	mg/g as is	mg/g corr *1	%wt *2
1	Cystine	5.51	3.66	3.39	30.85
2	Methionine	10.57	8.20	7.61	69.15
	Totals	16.08	11.86	11.00	100.00

Notes:

These results are from one hydrolysate chromatogram.

*1 These values are the mg/g results corrected up for the actual recovery value of Taurine Internal Standard added to the sample prior to hydrolysis.

*2 %wt is the relative % of the total amino acids determined in the sample.

N.B. The correction factor (.7556) is used to account for differing molecular weights of Cysteic Acid (169.169) and Cystine (240.30) and an average recovery of 94% of Cystine by PAO method (Technicon Monograph No. 3, 1968 p 140-147.)

$$0.7556 = (240.30/(2 \times 169.169))/0.94$$

The correction factor (.8235) is used to account for differing molecular weights of Methionine Sulphone (181.21) and Methionine (149.22).

$$0.8235 = (149.22/181.21)$$

16/11/92 AMINO ACID RESULTS ON PROTEIN HYDROLYSATE

(Client Copy)

Client.....: K JAMES
Sample Type.....: GOAT SKIM MILK
Lab. No.....: 92/238
Hydrolysate No.....: 921675
Dry Matter %.....: 100

New Zealand Pastoral
Agriculture Research
Institute

Peak no.	Name	nmoles injected	mg/g as is	mg/g corr *1	%wt *2
1	Cystine	5.89	3.87	3.76	33.42
2	Methionine	10.05	7.72	7.50	66.58
	Totals	15.94	11.59	11.26	100.00

Notes:

These results are from one hydrolysate chromatogram.

*1 These values are the mg/g results corrected up for the actual recovery value of Taurine Internal Standard added to the sample prior to hydrolysis.

*2 %wt is the relative % of the total amino acids determined in the sample.

N.B. The correction factor (.7556) is used to account for differing molecular weights of Cysteic Acid (169.169) and Cystine (240.30) and an average recovery of 94% of Cystine by PAO method (Technicon Monograph No. 3, 1968 p 140-147.)

0.7556 = (240.30/(2 x 169.169))/0.94

The correction factor (.8235) is used to account for differing molecular weights of Methionine Sulphone (181.21) and Methionine (149.22).

0.8235 = (149.22/181.21)

08/04/93

AMINO ACID RESULTS ON PROTEIN HYDROLYSATE

(Client Copy)

Client.....: A WEBBER
Sample Type.....: GOAT SKIM MILK
Lab. No.....: 93/17 REP
Hydrolysate No.....: 93040T
Dry Matter %.....: 100

New Zealand Pastor
Agriculture Researc
Institute

Peak no.	Name	nmoles injected	mg/g as is	mg/g DM *1	%wt *2
1	Aspartic Acid	-	-	-	-
2	Threonine	-	-	-	-
3	Serine	-	-	-	-
4	Glutamic Acid	-	-	-	-
5	Proline	-	-	-	-
6	Glycine	-	-	-	-
7	Alanine	-	-	-	-
8	Valine	-	-	-	-
9	IsoLeucine	-	-	-	-
10	Leucine	-	-	-	-
11	NorLeucine	19.1	-	-	-
12	Tyrosine	-	-	-	-
13	Phenylalanine	-	-	-	-
14	Histidine	-	-	-	-
15	Lysine	-	-	-	-
16	Tryptophan	18.7	4.6	4.8	100.0
17	Arginine	-	-	-	-
	Totals	37.8	7.7	4.8	100.0

Notes:

These results are from one hydrolysate chromatogram.

*1 These values are the mg/g drymatter results corrected up for the actual recovery value of NorLeucine Internal Standard added to the sample prior to hydrolysis.

*2 %wt is the relative % of the total amino acids determined in the sample.