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PASTURE PRODUCTION IN A PROTEIN EXTRACTION SYSTEM

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SUMMARY

The extent to which protein can be recovered directly from pasture was investigated using an extraction unit capable of processing 180 kg grass per hour. Typical dairy pasture at Ruakura Research Centre (with irrigation and topdressing), yielding 1.8×10^4 kg DM/ha/yr, was used in this study. Conventional grazing of this pasture normally yields 470 kg of milk protein. Direct protein extraction of the same pasture over a year could yield 1900 kg protein — of which 27% could be separated as a cytoplastic fraction suitable for direct human consumption. Using a combined protein extraction and grazing system, a total of 250 kg of protein could be recovered in the forms of milk, meat and grass protein concentrate (GPC), assuming that partially deproteinized grass residue (pressed cake) would be a fully productive ration for dairy cows.

Based on the results from three years' protein extraction trials, the efficiency of protein production from conventionally grazed pasture was compared with patsure involved in a protein extraction system.

GPC and by-products obtained from pasture processing (pressed grass cakes and deproteinized grass juice) on an annual basis were of variable chemical composition, showing the necessity of further experimentation.

INTRODUCTION

SOURCES of world food protein, developments and future trends in non-animal sources of protein have been discussed by Whittlestone (1972) and Hove (1972), showing permanent pastures to have a high potential as a source of good quality protein.

A new approach to the future of dairy farming systems in temperate and tropical regions was presented by Hutton (1970), who indicated the potential for increasing the efficiency of protein recovery from grasslands by the application of direct protein extraction procedures. The concept of protein extraction from pasture was also considered by Campbell (1963), Hove (1969)

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and Allison (1971) as an alternative technique for the production of edible protein from green leafy plant material in conditions specific to New Zealand. However, it was not until after Hutton (1972) presented figures showing the benefits of incorporating a protein extraction procedure into the New Zealand dairy farming system that experiments were initiated at the Nutrition Centre, Ruakura Animal Research Station, which involved examining methods of partial deproteinization of pasture herbage.

This paper, based on results obtained from three years of pilot scale protein extractions from pasture, attempts to quantify the potential biological efficiency of protein production within the New Zealand grassland dairying ecosystem.

EXPERIMENTAL

The experimental work which is summarized here was conducted at the Nutrition Centre, Ruakura Animal Research Station, between 1973 and 1975, on 20-year stand of pasture based on white clover and perennial ryegrass growing on Te Kowhai clay/Horotiu sandy loam soil. Average herbage dry matter productivity was 1.8×10^4 kg/ha/yr.

The botanical composition of the pasture, grass sampling, processing procedures and detailed methodology have been described by Ostrowski (1976).

RESULTS AND DISCUSSION

THE SYSTEM OF PROTEIN EXTRACTION FROM GRASS

The system used is based on Roulle's (1773) and Pirie's (1971) concept of protein recovery from green plants. After mechanical harvesting of pasture herbage followed by maceration and dejuicing in which part of the crude protein is removed, the residue can be fed back either directly to livestock on the same paddock from where it was cut and processed or in a variety of forms, namely, dried, pressed grass cakes, or ensilage (Fig. 1).

Proteins after separation and concentration from the extracted grass juice (using either heat and/or acid precipitation) could be used as either a high protein concentrate for monogastric farm animals, or, alternatively, after fractionation and purification, as an unconventional protein source for human nutrition (Pirie, 1966, 1971; Oke, 1973; Parrish *et al.*, 1974). The application

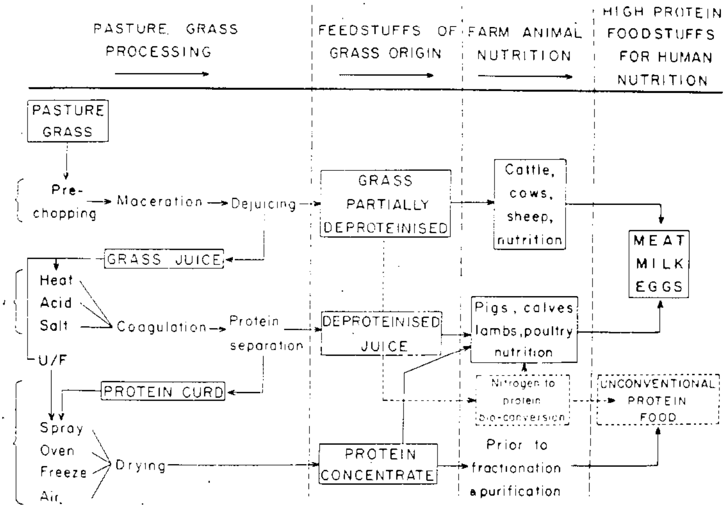

FIG. 1: *Processing stages in protein extraction from pasture in Ruakura protein extraction system and conversion of the grass through feedstuffs into edible protein products — food grade, with farm animals and alternatively single cell organisms being nitrogen converters.*

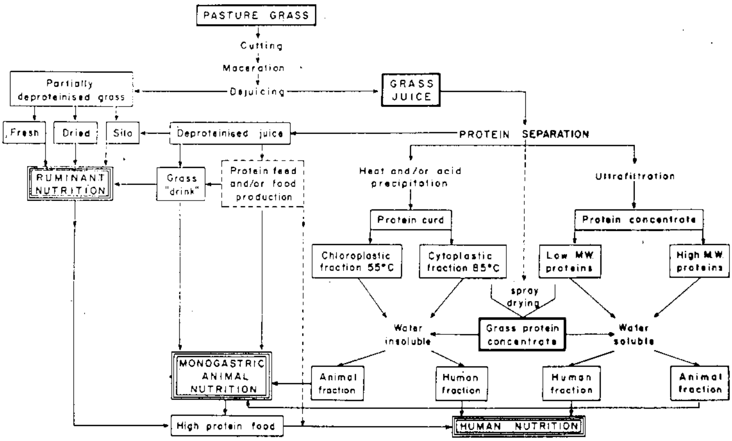

FIG. 2: *Alternatives in technology of protein concentrate recovery from pasture grass as envisaged in initial (stationary version) Ruakura protein extraction project.*

of ultrafiltration as an alternative technique to heat coagulation for concentration and/or fractionation of grass proteins results in a grass protein concentrate (GPC) which is water-soluble and suitable for spray drying (Fig. 2).

Some of the pathways shown in Fig. 2 were investigated using autumn-grown grass in its 5th week of regrowth. The results of these experiments are given in Tables 1 and 2. There were no consistent differences, apart from water solubility, in the yields and chemical composition of protein concentrates obtained by either steam coagulation or ultrafiltration techniques. The slightly higher yield of GPC from the unfractionated juice in this trial using ultrafiltration was due to higher recoveries of ash and soluble sugars. This resulted in a slightly decreased protein concentration in the ultrafiltered as opposed to steam coagulated product. However, ash and sugar content can be reduced by ultrafiltration conditions.

There were no differences between methods in either chemical composition or efficiency of cytoplastic protein fraction recovery. In addition, there were indications that both protein recovery and yields of GPC obtained from pasture containing a large proportion of perennial grass were notably lower than those obtained from lucerne and clover.

Protein Extraction Efficiency and Some Limitations in Protein Recovery from Pasture

There were large variations in the proportion of protein extracted from pasture during three years of the project, with protein recoveries ranging between 5 and 63%. Several factors were shown to be responsible for these variations in protein recovery from pasture — *e.g.*, maturity of grass, method of protein separation from juice, pH and pulped material botanical composition. These factors were also found by Arckoll and Festenstein (1971), Lexander *et al.* (1970) and Parrish *et al.* (1974) to be critical for protein extraction efficiency. In more mature grasses the high ratio of fibre to protein lowers the protein extractability.

The results from the series of trials examining the factors given in Fig. 3 showed that it was possible to obtain a protein recovery of between 40 and 50% from grass (Ostrowski, 1975, 1976; Ostrowski *et al.*, 1975). This resulted in an improvement of the hypothetical yield of GPC from approximately 500 kg to 3 300 kg/ha/yr.

TABLE 1: EFFICIENCY OF GRASS PROCESSSING IN PROTEIN EXTRACTION PROCESS (AUTUMN GROWN PASTURE)

100 kg pasture grass → *19.7 kg DM*	*(% DM)*	*47% dejuicing →* ↓		*53 kg pressed grass cakes* *12.9 kg DM*	*(% DM)*
4.2 kg CP[1]	21.3	*47 kg grass juice*		2.0 kg CP	16.3
2.9 kg ash	14.7	*6.8 kg DM*	*(% DM)*	2.0 kg ash	16.3
3.1 kg sugars	15.7	2.2 kg CP	32.3	1.9 kg sugars	14.7
		0.9 kg ash	13.2		
		1.2 kg sugars	17.6		
		↓			
		Juice processing (see Table 2)			

[1] Crude protein (N × 6.25).

TABLE 2: EFFICIENCY OF THE PROTEIN EXTRACTION PROCEDURE AS AN EFFECT OF THE METHOD USED FOR THE RECOVERY OF PROTEIN FROM JUICE OBTAINED FROM AUTUMN GROWN PASTURE (as in Table 1)

	Juice Processing[1]				
	Un-fractionated			*Fractionated*	
	Steam (85° C)	*Ultra-filtration*	*Steam (55° C)*	*Steam (85° C)*	*Ultra-filtration*
Yield of GPC (kg DM) from 100 kg of grass	4.1	4.5	3.1	0.9	0.8
Composition of GPC (% DM):					
Protein[2]	46.3	44.4	45.2	55.6	62.5
Ash	12.2	15.5	12.9	8.9	12.5
Sugars	7.3	11.1	6.4	11.1	7.5
% Protein recovery from grass[3]	45	48	33	12	12
Composition of deproteinized grass juice:					
DM (%)[4]	1.8	3.1	2.4	1.7	2.6
CP (% DM)	11.1	8.7	21.6	10.7	10.3
Ash (% DM)	14.8	8.7	13.5	14.2	13.8
Sugars (% DM)	33.3	30.4	27.0	32.1	31.0

[1] Juice from grass processing as shown in Table 1 was subdivided and processed in 100 l batches using one of the given methods.
[2] Protein nitrogen × 6.25.
[3] Amount of protein recovered during the process expressed as a percent of crude protein (N × 6.25) present in the grass.
[4] As determined without correction for losses during large scale operation.

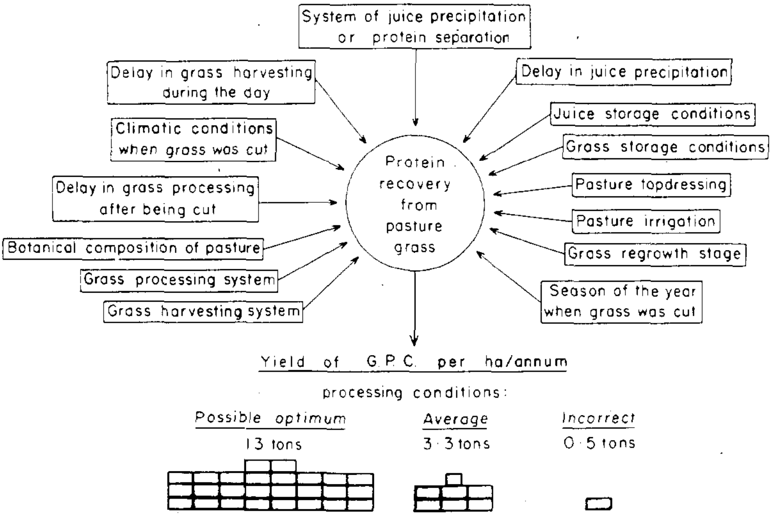

FIG. 3: *Factors limiting protein recovery from pasture grass and protein concentrate (GPC) production.*

TABLE 3: BIOCHEMICAL AND BIOLOGICAL CHARACTERISTIC OF SPRAY-DRIED GRASS PROTEIN CONCENTRATES OBTAINED USING DIFFERENT EXTRACTION METHODS

	Formic Acid (pH 3.5)	*Heat (85° C)*	*Ultrafiltration*
Crude protein (N × 6.25)	40.5	33.2	43.2
Ash	9.6	20.9	11.5
Crude fibre	14.5	22.2	17.3
Soluble sugars	10.4	9.7	6.6
Amino acids content (g/16 g N):			
Lysine and its availability (%)[1]	3.0 (72)	4.4 (66)	2.8 (79)
Methionine	1.6	1.3	1.9
EAA total[2]	52	49	51
Protein digestibility (%):			
in vivo[3]	61	62	67
in vitro[4]	66	58	71
PER[5]:			
(a) 0.2 % D.L. methionine suppl.	2.41	1.31	2.01
(b) 0.2 % D.L. methionine and 0.5 % L-lysine suppl.	2.33	1.70	2.33

[1] As determined by short column method (Ostrowski *et al.*, 1970).
[2] Tryptophan was not analysed.
[3] Using rats.
[4] Using pepsin-trypsin digestion according to Saunders *et al.* (1973).
[5] Casein control group PER: 2.38; all groups of rats fed GPC without amino acid supplementation gave negative weight gains.

TABLE 4: CHEMICAL COMPOSITIONS OF SILAGES OBTAINED FROM PARTIALLY DEPROTEINIZED GRASS GROWN ON CONVENTIONALLY GRAZED OR ON "ZERO GRAZED" PASTURES[1]

Silage	*DM*	*Ash*	*N*	*NH_3*[2]	*pH*	*Acids*			
						La	*Ac*	*Pr*	*Bu*
Processed grass (cakes) from pasture:									
(a) Conventionally grazed	21.0	10.1	3.05	6.9	4.05				
(b) Used during 3 years exclusively for protein extraction in "zero grazing" system	22.0	10.7	2.94	6.7	4.08	NA[3]	1.61	0.14	0.16
Unprocessed pasture grass[4]	18.7	19.6	2.93	10.7	4.33	5.95	1.72	0.14	3.6

[1] Silages prepared in mini-scale (5 kg in plastic buckets) during 5 weeks at 22° C.
[2] NH_3 — N% total N.
[3] Not analysed.
[4] Silage obtained from pasture grass grown on surrounding paddocks (according to Lancaster *et al.* (1974)).

Grass Protein Concentrate (GPC) — Characteristics of the Product

The results from chemical and biological tests summarized in Table 3 showed large variations in the chemical composition and in the biological value of the final product as measured by PER.

Lysine content and its availability differed with the method used for protein recovery but availability did not follow the pattern of changes in PER values. The PER of acid-precipitated and ultrafiltered concentrate (without preservation) was similar to casein used as a standard control protein. Sodium metabisulphite as a preservative decreased PER.

It is reasonable to assume that the content and availability of other amino acids may be limiting, as the concentration of amino acids in GPCs were similar to that of soyabean meal.

The differences in amino acid composition observed in GPCs do not confirm the results of Gerloff *et al.* (1965) who showed that different methods and conditions of extraction did not alter the amino acid composition of leaf protein concentrates.

By-products from Protein Extraction from Grass — Pressed Grass Cakes and Deproteinized Juice

Partially deproteinized pasture grass usually contained more than 15% CP on DM basis (Table 1) which is considered sufficient to meet the requirements of lactating dairy cows, beef cattle and bulls (de Groot, 1966; N.R.C., 1971). However, there were a number of extractions at low dejuicing efficiencies when CP content was as low as 10%, indicating the need to supplement such residues with non-protein nitrogen. Adding deproteinized grass juice (brown whey) to the residue would be an alternative method of raising the nitrogen content of pressed cakes. In addition, deproteinized juice can be utilized as a high mineral-carbohydrate supplement which was found by Briggs *et al.* (1971) to contain unidentified growth and reproduction factors for farm animals. Based on chemical composition, good quality silages can be made out of pressed grass cakes (Table 4).

Protein Production Efficiency on Pasture in Conventional Grazing and in Protein Extraction Systems

The conversion of the photosynthetically active radiation (2.52 $\times 10^{13}$ J/ha/yr) into net "available" pasture DM production has been evaluated in Table 5, taking into account different practical data and estimates. In each case net photosynthetic efficiency, obtainable under optimum agricultural conditions (Bonner, 1962; Phillipson, 1973), was below the 2.6%.

An average of 299 kg of protein nitrogen (PN) can be recovered annually as GPC from 1 hectare of irrigated pasture as opposed to the 94 kg PN at present recovered from the same area of pasture in the form of milk and meat. The most productive pasture at Ruakura Nutrition Centre (23.5×10^4 kg DM/ha/yr) can theoretically produce approximately 542 kg of N in the form of milk, meat and GPC after protein extraction. At practical levels of pasture production, a 55% nitrogen conversion can be achieved as a consequence of simultaneous protein extraction and dairying as opposed to 12.9 obtained under conventional grazing systems (Table 6). Of the total recoverable

TABLE 5: NET PASTURE PRODUCTION ABOVE THE GROUND (kg $\times$ 10^3/ha/yr) PRACTICALLY ACHIEVED AND ESTIMATED AS MAXIMUM POTENTIAL UNDER NEW ZEALAND ENVIRONMENTAL CONDITIONS AND ITS RELATION TO NET PHOTOSYNTHETIC EFFICIENCY

Author	*Pasture Dry Matter Production*	*Net Photosynthetic Efficiency (%)*
Average N.Z. pasture acc.		
J. E. Radcliffe (pers. comm.)	11	0.82
Waikato region (as achieved):		
Average — (Hutton 1972)	15	1.11
Maximum — (1975 pers. comm.)	23.5	1.74
Brougham (1959)	24.6	1.82
Corkill (1969)	28	2.08
Estimate — this study[1]		
Waikato	28 (35.1[2])	
Manawatu and Taranaki	26.9 (32.3[2])	2.6
Canterbury	23 (31.1[2])	
Phillipson (1973)	21-28	2.6

[1] Calculations based on solar radiation figures as recorded in Waikato region (Gerlach, 1974) from which the photosynthetically active radiation (PAR) has been taken as a 400-700 nm according to Baumgartner (1973) and Geiger (1957) being approximately 50% of the total solar radiation reaching the ground.

[2] With adjusting pasture management to autumn-winter high production programme as suggested by Janson (1975) (autumn irrigation and overdrilling with winter high production grasses like 'Grasslands Tama'). Values of DM production were calculated taking into consideration present pasture management system and botanical composition with reduced production during 2 or 3 winter months in Manawatu and Taranaki and Canterbury areas, respectively.

TABLE 6: PRACTICALLY ACHIEVED AND HYPOTHETICAL PASTURE NITROGEN (N) CONVERSION IN DAIRY FARMING INVOLVED CONVENTIONAL GRAZING OF IN PROTEIN EXTRACTION SYSTEM

	Pasture DM Production (kg × 10⁴/ha)			
	1.80[a]	*2.35*[a]	*2.80*[b]	*3.51*[b]
Conventional grazing system:				
Pasture primary TN production (kg/ha/yr)	727[a]	968[a]	900[b]	1123[b]
Present PN production (kg/ha/yr) in milk and meat form	94	122	—	—
Protein extraction — Hypothetical PN production (kg/ha/yr):				
As GPC	299	398	450	560
Total production (milk[1], meat[2] and GPC)	400	542	621	775
Pasture TN conversion into high protein products (%):				
Conventional grazing	12.9	12.6	—	—
Protein extraction	55	56	69	69

[a] Practically achieved.
[b] Hypothetical figures.
[1] Based on Hutton's (1970) estimates that 20 kg of pasture of an average apparent digestibility 70% is needed for each kg of butterfat produced (milk composition 4.8% butterfat, 3.8 crude protein; 14.0% total solids).
[2] Total N production being sum of N from GPC, N from milk and N of carcass protein derived from calves surplus to each cow's replacement needs produced during a 5 year productive life and N of cow after slaughter.

grass protein concentrate, cytoplastic protein fraction represents 27%, the rest being chloroplastic fraction. Use of this latter fraction by non-ruminants can give approximately 30% nitrogen conversion from pasture into edible animal protein.

The average gross efficiency of converting available pasture protein to milk protein in New Zealand has been calculated by Hutton (1972) as 10 to 12% or as 20% on an actual consumption basis, which is similar to the efficiency of 22% given by Large (1973) for milking cows.

Taking into consideration a hypothetical potential pasture DM production level in the Waikato area of 2.8 to 3.5 × 10⁴ kg DM/ha/yr (Table 5) the use of a protein extraction system could yield between 621 and 775 kg N. This would result in 69% pasture nitrogen conversion into high protein products.

However, more research needs to be undertaken before a protein extraction system can be introduced into the New Zealand farming system.

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