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Food Protein Sources [and Discussion]

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Food protein sources

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Work on food, planned by the U.M. (Use and Management) Section of the U.K. committee, was limited to sources of protein because we agreed that more problems calling for research were likely to arise in getting adequate supplies of protein than of other types of food. Deer meat can be produced on land too rough and exposed for sheep; parts of the work on their metabolism and food requirements necessitated building a mobile laboratory. The manner in which the nutritive value of maize is affected by changes in the ratios in which the component proteins are present, stimulated similar studies on barley and groundnut. There is good quality protein in coconuts and leaves but its use in human food is restricted by the presence of fibre. Methods for separating protein from fibre and other deleterious components were improved. In cooperation with scientists in India and Nigeria, the potential yield of protein from different leafy crops was measured. Various abundant but protein-deficient foods, e.g. cassava, were 'ennobled' by growing micro-organisms on them with the addition of a cheap source of nitrogen.

When the I.B.P. was being set up, many people argued that it was not needed because all its proposed activities could be handled by existing organizations. This argument was valid for the research projects in the U.M. section. All that we proposed could have been included in the programmes of the Food and Agriculture Organization, national Ministries of Agriculture, or industry. But they were not. The existence of U.M. is an indictment of those whose job it is to foresee needs. In many countries there seems to be little dissatisfaction with the present state of affairs: most national I.B.P. committees did not set up U.M. sections.

When the programme for the U.K. U.M. section was being discussed there was general agreement that supplies of edible protein were inadequate and were likely to remain so. Attempts have recently been made to solve the 'protein problem' by assuming that human protein requirements are less than had hitherto been assumed. Obviously, people who are hungry need immediately energy-rich rather than protein-rich foods – the 'protein-sparing action of the carbohydrates' was part of trophological wisdom two generations ago. Recent confusion stems in part from the curious concept of 'protein calorie malnutrition' (p.c.m.). Anyone getting a diet deficient in both protein and energy could more conveniently be called half-starved. The essential point is that methods for increasing protein supplies, from local products by relatively simple methods, are still themes for research.

In some countries, much on-going research coming within the domains of the I.B.P. sections was included in the published I.B.P. programme; in others, a fairly coherent programme was drawn up, but was incompletely implemented. The U.K. U.M. subcommittee included in its programme on protein supplies only themes that were initiated or expanded during the I.B.P. Furthermore, we depended on individual initiative to suggest themes. For several years, a surprising number of scientists remained ignorant of the very existence, let alone the usefulness, of the I.B.P. Its manner of working was explained at two symposia concerned with nutrition (Pirie 1967; Woodham 1968) and a leaflet was circulated (Pirie 1970*a*) which surveyed the

nutritional components of the programmes published by all the countries taking part in the I.B.P. The Biochemical Society circulated a similar survey (Pirie 1968*a*) of the biochemical components of the programmes.

The U.K. I.B.P. committee was often helpful in getting money for research but, because it itself controlled little money, it could not instigate work. We do not therefore claim that the five topics discussed here were the most important that could have been studied – they are simply those that the U.K. U.M. committee thought relevant and that were put forward for I.B.P. support by someone who wanted to organize the work. Like other I.B.P. committees we were exasperated by letters having the general form 'The I.B.P. should be doing work on...' with no suggestion of who should do it.

Deer farming

Herbivores differ in their choice of food, in hardiness and in rate of growth; they may differ in the efficiency of their digestive processes (Hobson & Mann 1968; Maloiy & Kay 1971). It therefore seems possible that our preoccupation with the cow, sheep and goat may be misguided, and that the potentialities of other herbivores should be explored. It is logical to expect a mixture of herbivorous species, by grazing and browsing at different levels, to use natural vegetation more completely than a single species. A joint P.T. U.M. subcommittee met repeatedly to plan an experiment to find out whether logic and observation concurred. Uganda was the proposed site; the idea had finally to be abandoned. Meanwhile, the more limited objective of making fuller use of deer in Scotland, progressed.

The red deer (*Cervus elaphus*) is our largest wild animal. About 200 000 range over 2.8 Mha of which 1.6 Mha is true deer forest. At present, in 'natural' conditions, about $\frac{1}{4}$ of the calves die, the hinds do not get pregnant as early or often as they could, and animals are usually shot in the mountains and butchered in a manner that might not be approved by meat inspectors (Blaxter *et al.* 1974). To overcome these defects, the animals have to be accustomed to handling and herding so that they can be given extra food during particularly hard winters and can be slaughtered centrally. In 1967 the Rowett Research Institute (Aberdeen) tried unsuccessfully to get funds to investigate deer farming; after 3 years' effort, there was enough money for work to start, at first on calves reared in the laboratory (Blaxter 1972) and then on a herd living in more or less 'natural' conditions. The conclusion is that herding, and restraint in a crush for routine examination and treatment, are easy, but it is necessary to be wary when handling even apparently tame animals.

The early work (Blaxter 1972) showed that hinds, stall-fed on concentrates, had a better conversion ratio than cattle or sheep. This was in agreement with the old observation on Rhum that the yield of meat increased when sheep were completely replaced by deer. With some selection for conversion efficiency, the superiority of deer would probably be even greater. Deer eat predominantly grass and ling, they digest their food to the same extent as sheep but the retention time is shorter. Some of these measurements were made in the laboratory, but many were made in rough country and for them a mobile laboratory was built (Hobson, Mann & Summers 1968). Apart from familiarity, the only advantage that sheep have is that they withstand water-shortage better than deer because they excrete drier faeces and more concentrated urine. This is not likely to be a very significant advantage in Scotland.

Table 1 compares the composition of deer, slaughtered after various types of husbandry, with average values for cattle and sheep. Clearly, there is more meat on deer. The point is made succinctly by Blaxter (1975): first quality meat is 33 % of the live mass of 6 month old deer,

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TABLE 1. CHARACTERISTICS OF THE CARCASES OF DOMESTIC AND WILD DEER, COMPARED WITH THOSE OF CATTLE AND SHEEP (FROM BLAXTER *ET AL.* 1974)

animal	age (years, months)	male female castrate	diet	live mass kg	empty body mass kg	dressed carcase mass kg	dressed carcase % of mass	fat, abdominal + subcutaneous (% of dressed carcase mass)	boned-out first class meat (% of dressed carcase mass)	second class meat (% of dressed carcase mass)	remaining carcase bones (% of dressed carcase mass)
deer											
calves:											
210	0, 6	F	concentrates, *ad lib.*	48	43	29	60	7	56	22	15
213	0, 5	M	concentrates, *ad lib.*	49	44	28	58	5	56	23	16
211	0, 11	F	concentrates, restricted	47	39	24	52	2	63	19	16
221	0, 7	M	concentrates, restricted	48	43	27	55	4	59	22	15
wild hinds:											
GF	*ca.* 3, 7	F	good condition	60 (est.)	55	31	52	6	57	23	14
IE	*ca.* 10, 8	F	poor condition	42 (est.)	38	27	65	1	56	25	18
domestic hinds:											
Asali	2, 3	F	grazing, Glensaugh	73	61	40	55	4	61	21	14
Rhum 5	5, 3	F		100	79	51	51	10	56	20	14
domestic stags:											
Jitu	3, 3	M	dried grass, *ad lib.* + concentrates	192	178	110	57	15	45	28	12
S11	2, 3	M	concentrates, *ad lib.*	160	148	94	59	15	49	23	12
S7	2, 5	M	concentrates, *ad lib.*	157	153	102	65	6	58	24	12
cattle											
Hereford × Shorthorn	1, 7	C	silage, *ad lib.* + concentrates	500	410	275	55	12	46	28	14
sheep											
Suffolk cross	0, 4	M	intensively fed	46	42	22	47	22	39	23	16
Cheviot	0, 5	F		37	33	17	46	22	40	22	16

Notes. Live mass, deer not fasted before slaughter; empty body mass, live mass less gut contents; dressed carcase, live mass less head, hocks, skin, blood, digestive tract, liver, lungs and heart; first class meat, boned-out haunch, shoulder and back; second class meat, neck, thorax and most of backbone; carcase bones, remaining bones and tail.

31 % at 3 years, 25 % with cattle and 18 % with sheep. Deer, like many other wild herbivores, are not so fat as cattle and sheep. Table 1 shows that this is probably a genuine species difference and not the result of differences in diet; deer calves of the same mass as lambs contain less than half as much fat. The difference becomes less striking when larger animals are compared. The fat recorded in table 1 is visible and easily dissected out; similar differences are found when the lipids are solvent-extracted from meat containing no visible fat. Absence of fat gives wild venison the reputation of being awkwardly 'dry' meat. In the opinion of a tasting panel (Blaxter *et al.* 1974), meat from these herded animals roasted well. The meat resembles wild venison in being darker than beef or mutton, but it does not have the 'gamey' flavour. Those who relish wild venison judged it less interesting; others preferred Rowett meat to wild meat.

Winters were mild during the period covered by published figures; had they been harder more winter feed would have been needed. It is therefore too early to estimate the economics of the project reliably – especially because the cost of fencing is inevitably large and depends on the character of the terrain. Extensive commercial deer-farming is not likely soon because, unless the law regulating the capture of wild calves is altered, the build-up of herds will be slow. The work at the Rowett shows that the idea of deer-farming is sound in principle. Deer tolerate rougher conditions and yield more meat, containing more protein, than sheep or cattle.

Extracted coconut protein

The dry matter of the kernels of mature coconuts (*Cocos nucifera*) contains 8–10 % of protein and 60–70 % of oil. In principle, the residue left after expressing oil should be a useful protein concentrate, but the protein is accompanied by a nearly equal amount of indigestible fibre. The residue can therefore be used as food to only a limited extent. Furthermore, traditional commercial methods for making copra and pressing it are designed to yield as much oil as possible, as cheaply as possible, and pay little attention to the possible value of the residue. This is often contaminated and the protein in it damaged by overheating. By paying more attention to hygiene, by solvent extraction, or by rigidly controlling the temperature while the copra is being dried and pressed, a residue of better quality could be made. But it would still contain the fibre. There have been many unsuccessful attempts to extract protein from expeller cake. They were probably unsuccessful because of protein denaturation during drying and pressing; protein might therefore extract from the residue if it were treated less brutally. It is not essential to make copra as a prelude to getting out oil; copra has become traditional because the drying kernel shrinks and comes loose from the coconut shell, and dry copra is less subject to attack by microorganisms. Initially, the coconut oil industry used copra because it could be processed in factories far removed from the plantation. Copra is now used because it allows the expellers to work continuously in spite of seasonal variation in the supply of coconuts.

The Tropical Products Institute (London) has studied the various processes involved in fractionating undried coconut mechanically. Kernel can be loosened from shell by filling a closed vessel with husked nuts and water, and applying pressure (Banks & Hall 1964). T.P.I. hopes to be able to mechanize the processes of husking, loosening and separating kernel from fragments of shell. Grating coconuts in water warm enough to melt the fat, and then pressing out the 'coconut cream' through a cloth, is a traditional culinary technique in the South Pacific. Fibre remains in the cloth and oil and protein are largely extracted in the 'cream'. T.P.I. has mechanized this process (Dendy & Grimwood 1972, 1973; Dendy & Timmins 1973, 1974). The completeness with which oil is released from cells depends more on the manner in

which the kernel is milled than on the ultimate fineness of subdivision (Adair & Timmins 1974). A colloid mill running at 8000 rev/min liberates oil from a coarser pulp than a mill in which kernel is forced through 1–2 mm diameter holes in a die plate. On the pilot-plant scale, the leaf pulper designed for the I.B.P. (Davys & Pirie 1969) works satisfactorily (Pirie, unpublished).

It is not easy to 'break' the oil:water:protein emulsion extracted from the pulp. In the T.P.I. method, protein is curdled at pH 3.6 along with oil; after heating, the oil and protein separate. Probably because of the absence of oxidative and other processes during copra-drying, oil made in this way is of better quality than oil made by conventional processes and, allowing for losses during copra-drying, the yield is as great.

The basic proposition underlying 'wet' processes for handling coconuts is that the protein could be eaten more extensively if it were separated from fibre. This objective can be attained without making a protein isolate; the soluble components of the kernel are nutritionally useful and the flavour is usually relished. Various methods for preserving and marketing coconut 'cream', which contains the extracted protein as well as other soluble components are therefore being studied. It is sometimes advantageous to remove part of the oil and so increase the protein/energy ratio of the 'cream'.

There is disagreement in the literature on the nutritive value of coconut protein, and the work at T.P.I. has not yet settled the matter. Judging from experience with other extracted proteins, it is reasonable to assume that poor preparations had been damaged during processing. But the point needs fuller investigation because argument in favour of 'wet' processes of extraction, which would need more elaborate and expensive equipment than traditional processes, depends on the quality of the protein. Edmonds, Edwards & Mars (1973) compare the economics of the two processes and conclude that choice depends on several local factors. 'Wet' processes seem preferable when copra-drying is done by traditional inefficient methods; because of the mass of the wet nuts, 'wet' processes become less attractive as the postulated distance between plantation and factory is increased.

The quality of protein from seeds

Differences in the amino acid compositions of bulk proteins in the seeds of different species, and of individual proteins from seeds of a single species, have been known since the beginning of the century. Nutritionally significant differences between strains of maize were observed more recently. At the Rowett Research Institute (Aberdeen) differences between strains and the possibility of fractionation were investigated with barley (*Hordeum vulgare*) and ground nut (*Arachis hypogaea*). Amino acid composition is not the only factor affecting the nutritive value of the protein in these seeds, it is also affected by the presence of enzyme inhibitors, haemagglutinins, and substances making some amino acids unavailable to non-ruminants. Seed strains and protein fractions differ with respect to all these factors.

When malting was the most profitable use for barley, effort was directed towards getting a large yield of grain containing little protein. Now that barley is increasingly used as feed, more interest is shown in conditions of husbandry that promote protein synthesis, and in varieties that are able to make protein-rich seeds. As would be expected, N fertilization increased both yield and protein content, but, in a study of 76 samples of 14 varieties, Woodham, Savic & Hepburn 1972*a*; Woodham, Savic, Ayyash & Gordon (1972*b*) found that the site in the U.K. where the crop was grown had an even greater effect. The old observation was confirmed that N applied at the time of sowing tends to increase yield rather than protein content, whereas it has more

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effect on protein content when applied during growth. The particular features of soil and climate that lead to the differences between sites are not yet known.

Lysine is a limiting amino acid in barley; unfortunately the percentage of lysine in the protein tends to decrease as the percentage of protein in the grain increases (Woodham 1973). Consequently, most samples contained 4 kg of lysine per tonne of grain although the protein content of the samples ranged from 8 to 11 %. Cystine and methionine did not show a similar inverse relationship with the protein content. Differences in the amino acid composition of different samples of barley are large enough to make it unwise to use published figures, rather than analyses of the actual sample, when designing diets.

Feeding experiments on rats and chicks essentially confirmed the conclusions come to from amino acid analyses. The advantage gained by using the better varieties or systems of husbandry obviously depend on the amino acid composition of the protein concentrate that is used to supplement a barley diet. If the supplement happens to be rich in lysine, the differences are small.

Differences similar to those found with barley were found for the protein in varieties of groundnut grown in different places (Dawson & McIntosh 1973). In part these result from differences in the ratios in which the two main groups of groundnut proteins are present. The whole protein contains 0.5–0.7 g of methionine per 16 g of N, 0.8–1.0 of cystine and 2.1–2.7 of lysine. Conarachin contains 1.6–2.2 g of methionine and cystine per 16 g of N, and 3.8–4.7 of lysine. Clearly conarachin is the more valuable part of the mixture but it makes up only a third to a fifth of the total. The position is not quite as simple as this however; conarachin, satisfying the usual criteria, had slightly different properties when made from different groundnut samples. Samples differed even more in their anti-tryptic activity (Woodham 1971). The association of the I.B.P. with this work seems to have helped to increase interest in groundnut varieties in the Agricultural Research Station at Kano (Nigeria).

The agronomy of leaf protein extraction

Leaves, considered as sources of extracted protein, present problems similar to those presented by coconuts, with the added difficulty that the soluble components seldom have an attractive flavour and may sometimes be toxic. When the I.B.P. started, methods for extracting leaf protein (l.p.) from many crops had been devised and machinery had been made for handling crops at up to 1 t (wet mass) per hour. The facilities offered by the I.B.P. seemed admirably suited to a study of the agronomic factors controlling the possible yields of l.p. in different climates (Pirie 1968*b*). It could be argued that such work was more suited to Section P.P. than U.M., and it was included in the original programme of the section that later became P.P. It got into U.M. because the first request for I.B.P. support for work connected with l.p. came from Rothamsted (Harpenden) and was for the design of extraction equipment that would give results more uniform and repeatable than those given by the equipment used hitherto. We hoped that this equipment would be used elsewhere so that the effect of climate could be disentangled from the effects of differences in processing technique; provision was therefore made in the grant to bring people to Rothamsted to learn how to use the equipment.

It is necessary to take samples weighing at least 3 kg when measuring the yield of a field crop. A pulper able to handle that quantity in 2–3 min was therefore designed in such a manner that it could be driven by an electric motor in the laboratory, and by the power-take-off of a motor vehicle in the field (Davys & Pirie 1969). A press in which weights working through a bell-

crank could apply pressures up to 1 tonf to 1 kg lots of pulp in 450 cm² layers (i.e. 2.2 kgf cm^{-2} or 200 kPa) was also made (Davys, Pirie & Street 1969). This design was chosen for the sake of mobility and strict uniformity of pressing conditions. It is probably not possible to get maximum extraction with a unit primarily designed to give uniform conditions of extraction. Experience shows that the I.B.P. extraction unit extracts only 60–70 % as much l.p. as can be extracted with larger units and with reextraction of the fibre. This should be remembered in assessing the yields given below. About 30 units have been made by the Weedon Engineering Co. (Woburn MK 17 9 PN); they were sent to institutes in Australia, Brazil, Eire, India, New Zealand, Nigeria, Pakistan, Sri Lanka, Sweden, U.K. and U.S.A.

The state of knowledge in 1970 on the agronomy, preparation, quality and use of l.p. was surveyed at an I.B.P. 'Working Group' meeting in Coimbatore (India) (Pirie 1971). The nutritive value and acceptability of l.p. are still being studied there at the Sri Avinashilingam Home Science College. Work done in India may legitimately be summarized in an account of the U.K. U.M. programme because the equipment used for agronomic work at two centres was supplied by the U.K. I.B.P. committee and the work was, and still is, done in close association with Rothamsted. Had it not been for the I.B.P. (Pirie 1968*c*), work along these lines would probably not have started so soon at either centre.

In a series of papers from the Department of Botany in the Marathwada University (listed under Aurangabad in the references), l.p. yields from different species after different systems of husbandry are recorded. The largest annual yield was 3.1 t ha^{-1} from lucerne (*Medicago sativa*); hybrid napier grass (*Pennisetum purpureum* × *typhoideum*) extracted less well so that the yield of l.p. was only 2.25 t ha^{-1}. The greatest *rate* of synthesis was 11 kg of extractable protein per hectare per day with cowpea (*Vigna unguiculata*). A few by-product leaves from vegetables, taken when the primary crop was being harvested, yielded 130–170 kg ha^{-1}.

Agronomic work at the Indian Statistical Institute (listed under Calcutta in the references) has not gone on for as long as work in Aurangabad and the available land is of poor quality. In spite of the more humid climate, yields as great as those in Aurangabad have not therefore been achieved; the extractability of protein from some water weeds was measured. It is a pity that section P.F. took, and M.A.B. takes, so little interest in the possibility of using rather than destroying water weeds.

So few communities eat green vegetables to the extent that is both desirable and physiologically reasonable, that there is no obvious advantage in extracting protein from edible leaves apart from those that are surplus or damaged. Nevertheless, equipment supplied by the U.K. I.B.P. committee was used in Nigeria (Fafunso & Bassir 1976) to study protein extraction, after different periods of growth, from *Corchorus olitorus*, *Solanum incanum*, *Solanum nodiflorum* and *Talinum triangulare*. From the first, more than 300 kg ha^{-1} of l.p. could be extracted after 7 weeks. Total 'protein' i.e. N × 6.25, measurements were also made: *C. olitorus* yielded 600 kg ha^{-1} in 6 weeks at two seasons of the year. That rate, if maintained, would supply 5.2 t ha^{-1} of 'protein', or about 4 t ha^{-1} of true protein.

Cassava-based products with enhanced protein content

The ability of yeasts and other micro-organisms to grow on molasses, a source of mineral-N, and some salts, is being exploited in many institutes. The Tropical Products Institute (London) investigated the use of *Aspergillus* and *Rhizopus* because, like many other funguses, they can grow on a wider range of carbohydrates than the yeasts. Furthermore, the mycelial structure

of the growth enables it to be collected on simple screens. When grown on a liquid medium, or a medium that liquefies during the process, the product contains 24–30 % protein and has little taste.

In an adaptation of this process, more suited to countries without great technical skill, *R. oligosporus* and *R. stolonifer* are grown on cassava (*Manihot esculenta*) meal fortified with urea (Brook, Stanton & Wallbridge 1969). Part of the cassava is metabolized by the fungus and the remainder, mixed with mycelium, is the final product. So far, total protein levels in the region of 4 % have been obtained from a substrate that initially contains only traces. These fermentation processes have the added merit that they destroy toxic components in the cassava, and may destroy toxins produced by other moulds. In spite of these apparent advantages, and of the traditional use of similar methods in southeast Asia, recent reviews (Trevelyan 1974, 1975) were gloomy about the long-term prospects for methods in which mycelium and residual substrate are harvested together.

General

The U.K. U.M. committee concerned itself with several projects connected with food, besides the five described above. These will be treated briefly because they did not yield concrete results, or were not primarily our responsibility. The joint P.T./U.M. subcommittee has been mentioned. A similar H.A./U.M. subcommittee considered problems arising from changing food habits and from attempts to win acceptance for novel foods. The Nestlé Foundation had already financed an I.B.P.-sponsored project on the subject in Uganda: an appointment was made and work started, but soon ended because of political and other difficulties. At about the same time, the International Union of Nutritional Sciences established a joint committee to cooperate with the I.B.P. on similar issues. The original international programme had listed food preservation, especially by simple methods, as a subject suitable for consideration by U.M. A paper on fish preservation was written on behalf of the U.K. U.M. committee, but little use was made of it. A memorandum 'Postgraduate courses in food science in the United Kingdom' was also written on behalf of the committee and was circulated extensively by various organizations.

The U.K. U.M. committee was responsible for arranging meetings on protein sources in Warsaw in August 1966 (*I.B.P. News* 7 82) and in Mexico in August 1972; members of the committee cooperated in meetings in Varna (Pirie 1969) and Stockholm (Pirie 1970*b*). These meetings dealt with a wider range of protein sources than was covered by either the U.K. or the International U.M. programmes. As a result of this, the Synthesis Volume on 'Food protein sources' (Pirie 1975), which aimed at comprehensiveness, is mainly concerned with work that did not form part of the I.B.P.

The U.K. U.M. committee followed with interest those facets of the programmes of other sections that were relevant, e.g. work showing that mussels (*Mytilus edulis*) could yield 50 t ha^{-1} of protein in suitable locations (Mason 1972), and work on the limits of photosynthetic productivity. Nevertheless, the degree of international cooperation and coordination in Theme 3, Development of Biological Resources, of U.M. was less than had been hoped for in the original planning of the I.B.P. It seems in retrospect that the work done on projects sponsored by U.K. U.M. was scientifically interesting and will ultimately be of great practical value; it demonstrated what could be done in an international programme but scarcely achieved the international integration that was aimed at.

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Discussion

H. C. Pereira, F.R.S. (M.A.F.F.)

Dr Pereira said that Professor Pirie had devoted more than 25 years to the study of protein food supplies from the plant world. While others had been talking of the approaching food crisis in the developing countries, Professor Pirie had been striving to do something about it.

The critical obstacle had been the cost of developing machinery. Invention covered only 1% of the costs. The rest were used in design development, manufacture, distribution and servicing facilities. Until there was a commercial demand in the more developed countries, the machinery was not produced. The cheapness of imported fishmeal, groundnut meal and other protein concentrates inhibited development of plant protein production.

The world food situation has changed dramatically over the past 3 years and major manufacturers, in U.K. and overseas, had taken up the design of powerful presses.

In Britain there is a substantial development programme to make use of the summer flush of grasses and forage legumes, of which there is a rich harvest in our wet climate if it can be taken green. By pressing out the juice, the protein in excess of that needed by ruminants is separated from fibre and made available for pigs and poultry. Professor Pirie's work is thus coming first to practical fruition in producing animal feedstuffs.

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