CENTRAL INSTITUTE FOR AGRICULTURAL RESEARCH
(CENTRAAL INSTITUUT VOOR LANDBOUWKUNDIG ONDERZOEK)
WAGENINGEN

Gestencilde Mededelingen
jaargang 1953
nr. 1
(Engelse vertaling)

T H E P R O D U C T I O N O F P R O T E I N S F R O M G R E E N F O D D E R P L A N T S

(REPORT ON A STUDY TOUR IN ENGLAND,
15TH - 19TH DECEMBER, 1952)

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I. INTRODUCTION

1. Earlier research

In past years various persons had pointed out the importance of securing protein or at any rate of products having a high protein content and a low crude fibre content from fresh green crops. This problem has engaged the attention of American, English and Netherlands research workers.

The economic value of such extraction of protein was recognized by various investigators. In a recent article this was again emphasized by Pirie (9). The various attempts hitherto made have resulted in products which, in view of the high content of crude protein and the low content of crude fibre, can be numbered amongst the concentrates. Purification of the resultant products also offers possibilities of making the protein suitable for human consumption. Various investigations, inter alia those of Chibnall (2) and de Man (7, 8) have shown that entire grass-protein possesses a nutrative value comparable with that of the best protein foods, and which is therefore to be regarded as exceptionally important. This also applies to proteins made from other green plants, e.g. lucerne.

Although many investigators agreed as to the high value of protein derived from green plants, and as to its value as food for animal and human consumption, yet there was still a question as to whether the extraction of these proteins from the available material (grass, lucerne, etc.) was economically justified. It is agreed that, by means of crushing and pressing, one must endeavour to extract from the vegetable material as much as possible of the protein in the expressed liquid. In this liquid the protein can then be coagulated by means of heating. The crude fibre must as far as possible be left behind in the residue.

In a report by the General Technical Department of the Netherlands Industrial Research Organization ("T.N.O.") (Report T.1355, December 1949) a number of the then known methods of pressing grass are compared. With a purely mechanical treatment the best results were obtained from a so-called wringerpress, an apparatus used for pressing out oil from seeds. Herein both crushing and pressing are practically simultaneous. With the help of such an apparatus Deijs (4) succeeded in extracting, in the expressed liquid, from the original material (grass), 43 % of the crude protein (33 % of the actual protein). Pressing under rollers and in hydraulic presses yielded less favourable results.

When isolation by ferments is included in the process, higher percentages of the protein originally in the liquid can be collected. Slade (11) e.g., obtained 50 % of the original protein in the extract by the following method:

By grinding fresh grass in a mincing machine, added a 0,5 % solution of papaine at the rate of 0,5 kilogramme per kilogramme of pulp, heating for 21 hours at 60°C, filtering and pressing.

White (15) obtained more than 43,7 % of the actual protein originally present in the liquid by proceeding as follows:

Fresh grass was washed, coarsely chopped, steamed 10 minutes (in a steam-tight container), then cooled, diluted with tap water to 5 % dry matter, treated with 10 % (vol.) Clostridium roseum culture, fermented for 2 days at 35° - 39°C with injection of CO_2, then stirred and sifted (80 mesh).

Tests by Slade (10) show that the extraction of the protein was greatly assisted by again adding water to the residue after each pressing and again pressing. He obtained 65 % extraction by the following method:

Fresh grass, with the addition of 1 kg of water per kg of grass, was ground in a mincing machine, the pulp filtered, pressed, and again ground with water, etc. (ground more than three times).

From these investigations it is fairly clear that one or more of the following conditions must be observed in order to obtain the highest possible yield of protein in the liquid:

1. Best possible crushing of the material.
2. Repeated pressing of the material after again moistening with water.
3. Treatment with micro-organisms or enzymes.

From the resulting extract the protein is most often concentrated by means of heat. This coagulates the protein but at the same time other substances are also precipitated, such as salts and carbohydrates. At the same time a certain amount of crude fibre is present in the coagulate, as the fibres, especially when subjected to intense crushing, are so much reduced that they remain in suspension in the liquid. Slade mentions that the coagulation is most succesful at a higher pH.

From the resultant coagulate, it should be possible to isolate a product that will keep. Slade observes that from the derived coagulate a cheesy substance can be produced by pressing and storing in air-tight containers, just as ordinary cheese can be made. After a few days the mass can be taken from the moulds and stored, after covering with a coating of wax.

Another method of conservation is drying to a moisture content of less than about 10 %, above that point mould may be formed. The product may also be preserved in tins.

A completely tasteless preparation can be obtained by treating the coagulate with amylalcohol. Sullivan (12) states that such a product was derived by purifying the coagulate by extraction with 95 % alcohol.

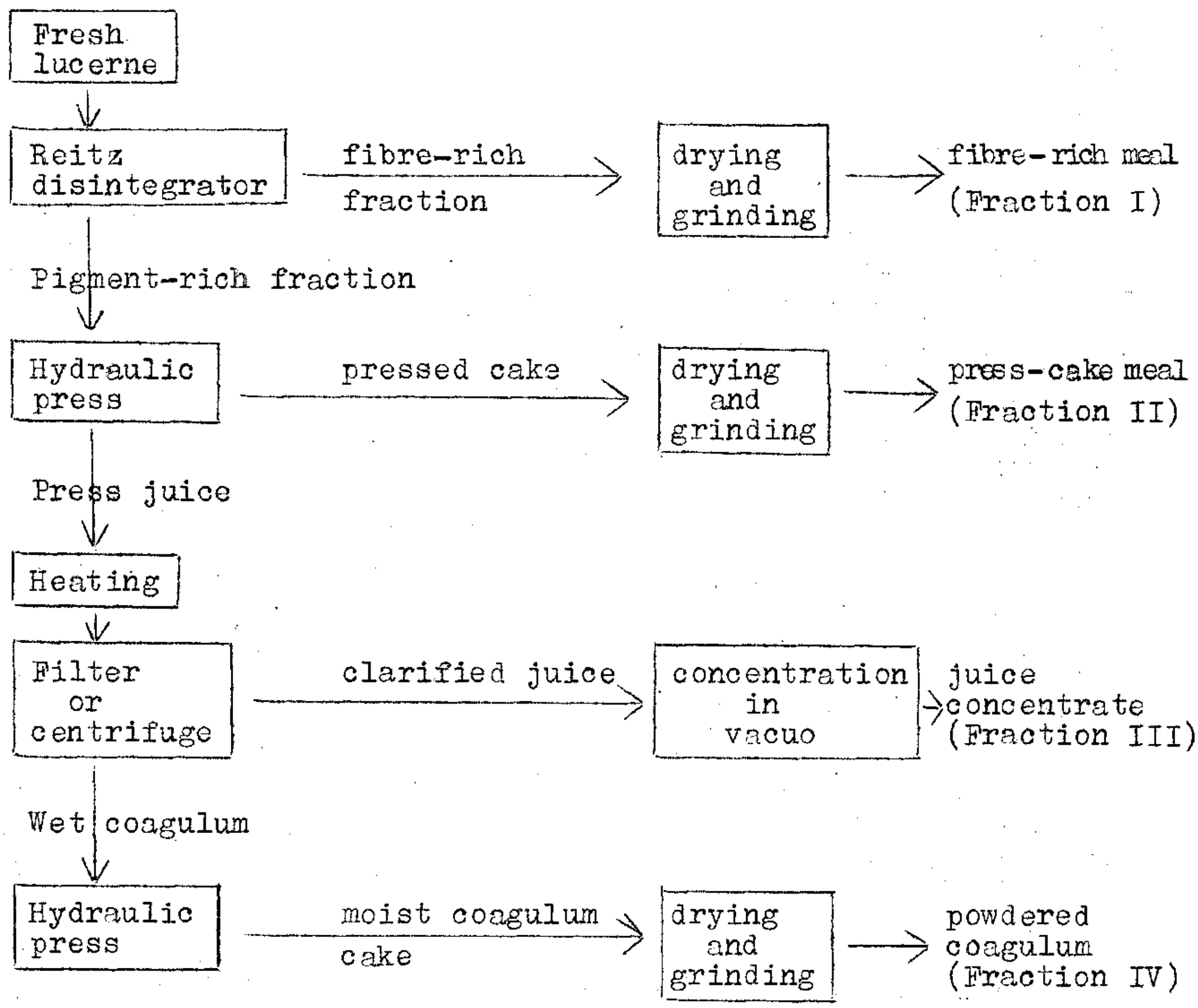
So far, the most favourable experience has been in the case of precipitation of the protein from a watery extract of grass by warming under slightly alkaline conditions. Here it is said a product having a passable taste comesforth, which can be preserved by cheesing or drying.

From the foregoing it follows that, at any rate in principle, the possibility does exist of isolating a protein-rich product from grass, lucerne and other green fodder plants, the same being suitable for animal, and, after purification, perhaps also for human nutrition. Nevertheless, the most important question is whether a process can be discovered by which the fresh vegetable material can be worked up in an economically profitable manner. This question has received exhaustive treatment in the report already mentioned - No. T.1355 (1949) of the General Technical Department of the Netherlands Industrial Research Organization ("T.N.O."). In that report the conclusion arrived at was that, on the basis of the then known experimental data, the economic prospects of the manufacture of grass-proteins were not at present very favourable. To increase the profitability of this process three possibilities are mentioned:

a. The application of the cheapest possible method.
b. Increasing the yield of protein from the process.
c. Increasing the value of the protein product by refinement.

In our view the cheapest possible process can only be achieved if the process is, as far as possible, continuous. This requirement is not yet met by the processes described above. The process to which publicity was given as far back as 1947 by Messrs.F.M.Bickhoff, A.Bevenue and K.T.Williams (1) of the Western Regional Research Laboratory at Albany, California, appears to be too complicated to be sufficiently profitable. As a detailed account of this method was published, and as this process was not mentioned in the above-named report of the General Technical Department of the Netherlands Industrial Research Organization ("T.N.O."), we will now consider it in more detail.

Diagram



Working with 358 kilogrammes of fresh lucerne containing 17,4 % dry matter (62,3 kilos of dry matter) tests gave the following results:

Fraction I	: 16,3 kilos	92,9 % ds	total 15,2 kilos ds
Fraction II	: 34,5 "	93,1 % "	" 32,4 " "
Fraction III	: 29,5 "	42,9 % "	" 12,4 " "
Fraction IV	: 2,72 "	93,0 % "	" 2,54 " "
			total 62,5 kilos ds

Composition of the various fractions:
(% of the dry matter)

	Crude protein	Crude fat	Crude fibre	Ash	N-free extract
Fresh lucerne	20,7	2,8	30,9	8,9	36,7
Fraction I (fibre-rich meal)	11,5	1,7	40,6	6,2	40,0
Fraction II (press-cake meal)	19,5	5,8	35,0	7,2	32,5
Fraction III (juice concentrate)	20,8	0	0	18,6	60,6
Fraction IV (powdered coagulum)	75,9	1,2	0,3	4,4	18,2

The dried coagulate (Fraction IV) is therefore very rich in protein. A calculation shows, however, that herein only about 15 % of the original crude protein is obtained from the lucerne. The quantities of crude protein (expressed as a % of the quantity in the original material) are as follows:

Fraction I	(fibre-rich meal)	13,5 %
Fraction II	(press-cake meal)	48,5 %
Fraction III	(juice concentrate)	20,1 %
Fraction IV	(powdered coagulum)	14,9 %
	Losses	3,0 %

We see, therefore, that under this process only a small part of the protein in the dry coagulate is secured. The other fractions, have of course, their value too, but the chief aim must still be to concentrate as much protein as possible in a product containing little crude fibre. We are, moreover, of the opinion that the process of concentrating the liquid derived from the pressing (Fraction II) will be rather costly.

There is no doubt the proposed process would be too expensive on account of its laboriousness and that there is too small a yield of protein concentrate containing but little crude fibre. The data in our possession do not permit us to compute the profitability, but it will certainly not come up to expectations.

2. Investigation carried out at the Central Institute for Agricultural Research (C.I.L.O.) at Wageningen, Holland

For the pressing of grass and other raw fodder material, the so-called wringer press, used also in the oil industry, is very attractive. In 1948 Deijs, at the C.I.L.O. (4), made tests with a small laboratory wringer. The initiative in making these tests and the research undertaken in 1949 and 1951 at the above institute came from Dr. A.Thorenaar, of the Arable and Grassland Department of the Ministry of Agriculture, Fisheries and Food at The Hague. The advantage of the use of a wringer is that the pressing process is continuous. At only a single pressing of fresh grass in Deijs' experiments about the following percentages of the quantities originally present in the grass, appeared to be present in the expressed liquid.

Sand-free dry matter	34 %
Crude protein	43 %
True protein	34 %
Crude fibre	6 %
Sand-free ash	74 %
Carotene	24 %

By heating the liquid Deijs obtained a green coagulate, the composition of which was as follows (as a percentage of the dry matter):

Crude protein	34,5 %
True protein	28,2 %
Crude fibre	7,7 %
Ash	15,5 %

In one of the tests the quantities originally present yielded the following percentages in the three fractions (coagulate, liquid after coagulation, and press residue):

	Sand-free dry matter	Crude protein	True protein	Crude fibre	Sand-free ash
Coagulate	20,7	31,2	31,6	8,3	37,6
Liquid after coagulation	13,6	12,0	3,7	0,0	35,6
Residue	65,7	56,8	64,7	91,7	26,8

In 1949 tests were made at Twijnstra's Oil Factories at Akkrum, in which fresh grass was pressed in an industrial wringer press used for expressing oil from seeds. This type of wringer was not suitable for the object in view. The capacity (something over 40 kilogrammes of fresh grass per hour) was much too small. Nor was the yield so good; 27 % of the crude protein and 18 % of actual protein was found in the liquid (see Deijs (5)).

In 1951 (Deijs (6)), other tests were made with silo grass and beet leaves, using the small laboratory wringer. After one pressing, in the case of silo grass, 29,1 % of the crude protein, and in the case of beet leaves, 41,4 % was found in the expressed liquid; and of the crude fibre only 1,5 % and 10,7 % respectively.

The above tests justified the belief that in the case of grass and other raw fodder substances, the best results could be obtained by using a wringer press specially constructed for this purpose. In these tests the material was pressed only once in the wringer press. Repeated pressing of the resulting residue gave practically no results. Messrs.W.T.Powling & Son, at Maldon,Essex (England) were successful in extracting more protein by taking the moist residue after the first pressing, and again pressing in a second wringer press.

II. THE METHODS OF POWLINGS PATENT PROCESSES LTD.

Our first acquaintance with the results obtained by Messrs. Powling was made at the C.I.L.O., Wageningen, early in 1950, when we examined two samples sent from England to the Director of the Arable and Grassland Department, through the agency of Dr. Bakker, the Agricultural Attache in London. These were samples derived by Messrs.Powling from lucerne and called "Lucerne Protess", one of them being dried coagulate and the other "Residue (Lucerne Fibre)", the press residue.

The chemical composition of these was as follows:

	"Lucerne Protess"	"Residue"
As a percentage of the original material:		
Sand-free dry matter	89,1	89,1
Sand	2,3	0,8
As a percentage of the sand-free dry matter:		
Crude protein	59,5	15,7
True protein	59,4	(not determined)
Crude fibre	9,0	31,4
Sand-free ash	5,6	6,3
Coefficient of digestibility crude protein (Pepsin - HCl):	65	75

The dried coagulate appeared therefore to be very rich in protein and deficient in crude fibre.

In October 1952, there appeared an article (16) in which it was stated that the apparatus devised by Messrs. Powling for pressing of raw fodder, in collaboration with Messrs. E.H. Bentall & Co. of Maldon, Essex, was ready for putting on the market.

From this publication we extract the following:

With the help of this apparatus up to 80 % of the nutritional material can be extracted from various green fodder plants, fish and meat. The final product called "Protess", which is rich in protein and poor in cellulose, contains about 45 % crude protein and 4 % crude fibre in the dry matter. "Protess" can be pressed into cheese form in a cheese press. "Protess" derived from young lucerne contained 48,9 %, from clover 46 %, from kale 42,88 %, from pea pods 40,83 %, from potato haulm 32,9 %, and from stinging nettles 37 % crude protein in the dry matter.

A complete installation will cost less than £ 2.700. The protein concentrate can be produced at about one-third of the cost of imported concentrated fodder of high protein content. Production costs amount to less than half of those of the artificial drying of grass. The press residue contains still about 8 % crude protein in the dry matter. Moreover the quantity of nutritional material in the residue can, within certain limits, be regulated. The residue can easily be dried by spreading out under cover or ensilaged.

The above data made the Powling Process appear so attractive, both as regards the nature of the final product and as regards the cost of production, that it was proposed to note on the spot the possibilities offered by this Process.

On 18th December 1952, we visited the firm of Bentall & Co. of Maldon, Essex. We met there Messrs. W.T.L. Powling, D.P. Ransome and J. Lucas, who supplied us with information as to methods, mechanical installations, quality of the products, and operating costs. Mr. Powling Senior could not be present owing to illness. We were accompanied by Mr. Meuwissen of the Agriculture Department of the Embassy.

III. VISIT TO MESSRS. BENTALL & CO., HEYBRIDGE, MALDON, ENGLAND

1. Survey of the process of preparation of the protein concentrate "Protess" from green vegetable material

The fresh green material is reduced by means of a coarse chopping machine (called pre-chopper). After that it is carried by a conveyor belt to a wringer press specially constructed for the purpose (first Protessor), in which the cells are crushed and a green coloured juice is pressed out. This liquid runs into a settling tank, in which sand and other heavy impurities sink. The fibrous residue passes through a washer in which the residue takes up water. From this washing machine the moist residue goes automatically to the second wringer press (second Protessor), of similar construction to that of the first named press. Here the juices are again pressed out and run into the settling tank. The second Protessor delivers one of the final products, i.e. the residue (press cake), poor in protein and rich in fibre, which has a moisture content of about 30 % and 7 - 9 % crude protein in the dry matter.

The liquid is pumped into a second tank in which the proteins are coagulated by means of steam. The coagulate (called "Protess") after a while settles. The water above it, containing chiefly salts, soluble N-combinations and soluble carbohydrates, can be drawn off. This water can in part be used to replenish the washer.

The coagulate is allowed to drip out on to a cheese-cloth; after that it is pressed in a cheese-press. The cheese can be pressed still harder so that a rather dry, flat cake is obtained.

The power consumption of the motors is: Chopping machine and elevator 4 h.p., Protessor 2 of 10 h.p., Washer 4 h.p.

The coke consumption of the boiler in which the steam for the coagulation is raised amounts to 25 kilogrammes an hour.

All these are represented in the annexed diagram.

2. Description of the various products

The water phase

The watery solution in which the coagulate has been separated out has probably relatively little value. There is still a little nutritional value in it. It is possible that this liquid can be assimilated by animals. It can also be sprinkled on the land, or preserved in a liquid manure tank. In addition it is presumably a good cultural basis for moulds.

The residue

The fibre-containing residue is still warm when it comes out of the second Protessor, and has still about 30 % of moisture. Spread out on a floor in a layer 2 ft. thick, it will dry fairly quickly through its own warmth; after that it can be preserved. It is then possible to grind it. The still moist residue is also suitable for ensiling.

Further, the residue is used for mixing with fresh material containing but little cellulose so as to make a subsequent pressing easier.

The coagulate (Protess)

This is the most valuable product. The still moist coagulate can be worked up into further different forms. It can be pressed into cheeses and cakes. It is possible to dry and grind it.

The composition of Protess depends on the material processed. In any form (dry or wet) Protess can be mixed with meal.

Preliminary tests in the laboratory showed that Protess forms a good basis for the preparation of chlorophyll. On a laboratory scale chlorophyll more than 90 % pure was obtained from Protess.

At the time of our visit on 18th December 1952, we took away a quantity of Protess in cheese form which had been derived from lucerne in October 1952. This sample was analysed early in January 1953 at the C.I.L.O. at Wageningen.

The results of the analysis were as follows:

Dry matter (containing sand)	30,0 %
" " (sand-free)	27,5 %
Sand (in the original material)	2,49%
" (in the dry matter)	8,3 %

Contents as a percentage of the sand-containing dry matter:

Crude protein	38,3	Soluble carbohydrates	nil
True protein	35,0	Ash + sand	20,3
Ammonia	0,2	Ash (sand-free)	12,0
Crude fibre	14,7		

Contents as a percentage of the sand-free dry matter:

Crude protein	41,8	K_2O	0,30	Cl	1,96
True protein	38,2	Na_2O	0,27	SO_4	0,73
Ammonia	0,2	CaO	5,33	P_2O_5	2,08
Crude fibre	16,0	MgO	0,20	Nitrate	nil
Sand-free ash	13,1				

Carotene: 451 mg per kilo of sand-free dry matter.

The "coefficient of digestibility" of the crude protein (pepsin - HCl) was found to be 58.

Survey of the results of the analysis

The crude protein content lies within the limits stated by Powling in respect of Lucerne Protess (30 - 45 %).

As was to be expected, the difference between the crude protein and the true protein content was only small.

The content of crude fibre is higher than we at first expected. It is also higher than in the sample examined by us in 1950 (see p.10). It is possible that in the pressing a proportion of the fibre was so much reduced that it appeared in the liquid and was coagulated together with the Protess.

The sand was not completely removed from the expressed liquid in the settling tank.

The "coefficient of digestibility" of the crude protein (pepsin - HCl) is somewhat disappointing. It is possible that this was somewhat diminished during the preservation of the Protess in the form of cheese. In the sample of 1950 this coefficient was 65. In view of the low ammonia content practically no putrefaction took place during the period of conservation.

In an attempt to isolate chlorophyll, it appeared that this, during the period of conservation, had mostly passed over in other products.

The ash content is fairly high. As regards the composition of the ash, we make the following observations:

Although the mineral composition of the initial substance is unknown, we may assume on the basis of the analysis that the potassium for the most part remained in solution in the water phase, while the calcium, and probably also the phosphate, accumulated in the Protess.

For the purposes of a closer view of the mineral composition, the contents have been converted into milligram equivalents per kilogramme of dry matter (here P represents 3 milligram equivalents).

Contents in milligram equivalents per kilogramme of dry matter:

K 64, Na 87, Ca 1903, Mg 99, Cl 552, S 152, P 878.

According to Brouwer and v.d.Vliert (3) and to Wind and Deijs (14) the following computations were made:

$AA = K + Na - Cl - S$ (milligramme equiv/kg dry matter)

$EA = Ca + Mg - P$ " " " " "

$TA = K + Na + Ca + Mg - Cl - S - P$ " " " " "

$$TA^1 = \frac{K + Na + Ca + Mg}{Cl + S + P}$$

AA = alkali alkalinity
EA = earth alkalinity
TA = total alkalinity (base excess)

Result in the case of Protess: AA = - 553, EA = 1124, TA = 571, TA^1 = 1,36.

In the case of ordinary Dutch grass: AA = 252, EA = 158, TA = 410, TA^1 = 1,41.

The average for 632 samples of American lucerne (13) is found to be: AA = 490, EA = 530, TA = 1020, TA^1 = 3,13.

In the case of Protess the most notable features are:

a) The strongly negative AA (caused by the low K-content).
b) The high EA (caused by the high Ca-content).

3. Capacity of the apparatus

According to our information, the installation devised by Messrs. Powling is capable of treating in each hour one ton of fresh material (lucerne, clover, etc.) containing 80 % of moisture. There is then obtained an average of 75 kilos of dry Protess (30 - 45 % crude protein in the dry matter and 125 kilos of residue (8 - 12 % crude protein in the dry matter).

In one of the experiments it may be assumed that the fresh lucerne contained 20 % dry matter and of this 20,5 % were crude protein and 36 % crude fibre. If 1000 kilogrammes of fresh lucerne yield 75 kilos of dry Protess with 39 % crude protein, it follows from these figures that something over 70 % of the crude protein present in the initial material is extracted in the Protess. About 25 % of the original crude protein will be found in the residue, while a small proportion (principally non-proteid N-compounds) remain in solution in the water phase after coagulation of the Protess.

As it was in the winter there was naturally no fresh material available and so we did not see the apparatus in operation. We did indeed get the impression that there can be practically continuous operation. In our view, two tanks are necessary in order to cause the sand to be deposited out of the liquid, and further, two, if not more, coagulation tanks, so that the coagulate may have ample time to be deposited. This depends on the rapidity with which the coagulate settles. We were informed that in some cases one hour was sufficient for settlement.

IV. THE PROFITABILITY OF POWLINGS' PROCESSES

Our computations proceed from the following data:

a) Cost of 1000 kilogrammes of fresh lucerne (20 % dry matter, 20,5 % crude protein in the dry matter) free factory f.17,50.

b) Cost of 1000 kilogrammes of fresh grass (20 % dry matter and of this 18 % crude protein) free factory f. 15,-.
c) Value of 100 kilogrammes average hay (8 - 12 % crude protein in the dry matter): f. 7,-.
d) Concentrates in the form of cattle meal C cost per 100 kg (25 % digestable crude protein) f. 37,25.
e) Grass meal costs per kg crude protein f. 1,25.

The capital outlay, according to the information given us, is as follows:

Prechopper, motor and stand, with Vee drive, elevator, Primary Protessor, Washer, Secondary Protessor, and Mono Pump	Total £ 2.128/-/-
Vertical Boiler 6 h.p.	210/10/-
Direct Type Heater	4/10/-
Cheese Press Six Moulds	51/-/-
	Total £ 2.394/-/-

Calculating the £ sterling at f. 10,60, to which must be added 20 % for freight, insurance, duties, clearing etc., this in round figures is as follows:

	f. 30.500,-
Tanks and Plumbing	5.000,-
Water and Power connections	3.500,-
Erecting	1.000,-
	Total f. 40.000,-

A simple brick building of 120 square metres is estimated at f. 12.000,-.

The total outlay therefore amounts to f. 52.000,-.

The number of operating hours are estimated by comparing with the existing grass drying plants in the Netherlands which, with three shifts, normally work 2.500 hours per season. Taking into account lack of experience and other possible difficulties, a maximum of 2.100 hours is assumed for pressing. Operating with 1, 2 or 3 shifts, the number of hours working would be 700, 1400 and 2100 respectively.

It is estimated that the machinery has to be written off in about 10.000 operating hours, and, as a maximum, 10 years. In this connection the life of the machinery is placed at 10, 7½ and 5 years respectively, which at an interest rate of 4½ % works out at an annual depreciation of about 23, 16,7 and 12,5 %.

The building (100 - 120 square metres) is written off in 20 years; annual interest and amortization then amount to 7,7 %.

The foregoing brings us to the following exploitation account for one year:

	Number of operating hours		
	700	1400	2100
Interest and amortization			
Building 7,7 % of f.12.000,-	f. 924,-	924,-	924,-
Machinery	5.000,-	6.667,-	9.200,-
Wages			
2 men 30 weeks ad f.65,- p.week	3.900,-	3.900,-	3.900,-
2 " 25 " " f.65,- " "		3.250,-	3.250,-
2 " 20 " " f.65,- " "			2.600,-

	Number of operating hours		
	700	1400	2100
Electricity 20 kw ad f.0,10 per kwh, or f.2,- per hour	f. 1.400,-	2.800,-	4.200,-
Fuel 25 kg coke per hour ad f.70,- p.t. or f.1,75 p.h.	" 1.225,-	2.450,-	3.675,-
Maintenance of machinery	" 600,-	1.000,-	1.500,-
Sundry expenses			
Tools, lubricating oil, water consumption f.1,- p.h.	" 700,-	1.400,-	2.100,-
Operating cost per season in round figures	f.13.750,-	22.400,-	31.350,-
Green fodder bought (lucerne) ad f.17,50 per ton	".12.250,-	24.500,-	36.750,-
	f.26.000,-	46.900,-	68.100,-
4 % Turnover tax	" 1.040,-	1.880,-	2.720,-
Total cost of production	f.27.040,-	48.780,-	70.820,-
Yield of press-cake (150 kilos/ hour sales value f.70,- per ton)	" 7.350,-	14.700,-	22.050,-
Cost "Protess" per season	f.19.690,-	34.080,-	48.770,-
" " " hour	f. 28,13	24,34	23,22
The yield of "Protess" is 75 kilogrammes dry or 83,3 kg with 10 % moisture.			
Production cost of 1 kg of dried "Protess"	f. 0,34	0,29	0,28
The dry matter contains 37,5 % crude protein or 22½ % digestible crude protein.			
Production cost per kg crude protein	f. 1,-	0,87	0,83
Ditto per kilog. digestible crude protein	f. 1,67	1,44	1,37
A corresponding computation of the cost of pressing grass, assumed to be bought ad f.15,- per ton, gives the following result:			
Production cost per kg of dried "Protess"	f. 0,31	0,26	0,25
Per kg of crude protein	f. 0,91	0,77	0,73
Per kg of digestible crude protein	f. 1,51	1,29	1,22

By way of comparison, cattle meal C at present costs f.37,25 per 100 kilogrammes. If the crude protein content is put at 30 % and the moisture content at 10 %, then this is f.1,38 per kilogramme of crude protein.

Grass meal costs f.1,25 : 0,9 = f.1,39 per kg of crude protein.

In C-meal there is 25 % digestible crude protein present. The cost hereof is f.1,66 per kilogramme.

The results of this economic investigation shew that the process in the case of lucerne will probably be profitable, while the cost of using grass will be still more favourable. Its practical possibilities will, however, be much better assured if they are directed towards utilising products of low commercial value, such as beet leaves, residual green stuffs, and the like. Pressing will therefore be more appropriate on mixed farms than in the pasture districts.

A striking fact is that the cost price of "Protess" is very favourable when considered per kilogramme crude protein, but markedly less per kilogramme of digestible crude protein. This difference is due to the "coefficient of digestibility", which, in the case of C-meal, is placed at 81 %, and in the case of "Protess" 60 %. This last figure is based on analyses of a somewhat aged product. It is quite possible that if the "Protess" is dried immediately after manufacture a more favourable cost price can be arrived at, despite the extra cost of the drying process.

Finally, we think it likely that, applying the machines on a larger scale in the Netherlands, which can either be produced in England in series or in the Netherlands under licence, a lower price can be stipulated, while the cost price can be brought down by increasing the number of operating hours, the production per hour, and the reduction of certain expenses (fuel, current, etc.). For this purpose a combination with a grass-drying plant, a dairy-factory or a feed-factory would be advantageous.

Based on these considerations, our opinion is that very definite economic possibilities lie in the application of the Powling Process in our country in the future.

V. CONCLUSION

"Powlings Patent Process" is, as regards the development of the machinery, in an advanced stage. As regards the practical industrial operation, however, a number of questions remain open, owing to which, in our view, it is not yet ripe for practical application.

Thus, it would be recommendable to ascertain whether the substance to be treated should or should not be given a preliminary washing and chopping; under what conditions a single pressing may be sufficient; what capacity the deposition tanks must have for continuous operation; in what manner the final product (Protess) can best be conserved etc.

As a new method for the promotion of animal food production, this method, in our view, is worth further close examination at an early date.

An attractive point is that vegetable substances with a high initial moisture content can be treated, so that less dependence will exist on the weather conditions prevailing at the time of reaping.

As regards the economic aspects of the process, there are indications that search must be made for a cheap basic product. This has the advantage that such products as beet tops, residual green stuffs, perhaps also potato haulm, and the like, can be converted into fodder.

On the other hand "Protess" is a concentrate poor in fibrous matter, so that it is very suitable for feeding to non-ruminants and, further, has in itself possibilities of being converted into foodstuff suitable for human consumption.

Application of the process seems to be more suitable for mixed farming than for pure pasture districts.

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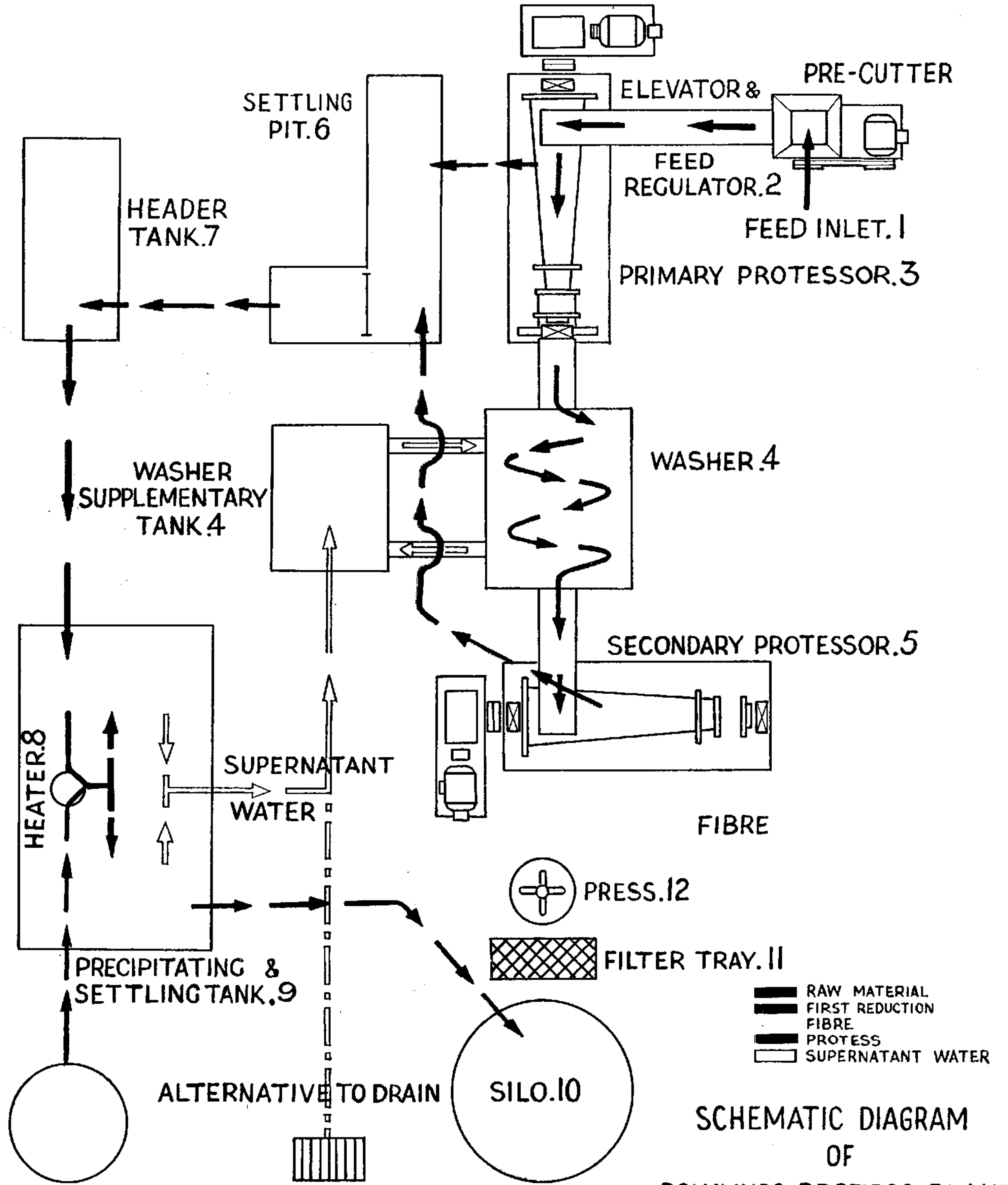

SCHEMATIC DIAGRAM
OF
POWLINGS PROTESS PLANT