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COMMERCIAL KELP DRYING OPERATION

AT MASSET, 1973

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INTRODUCTION

In many parts of the world and throughout the centuries, kelp or brown seaweed has been utilized as fertilizer or soil conditioner, cattle feed and more recently as a source of the commercial marine colloid alginic acid (Levring, et. al. 1969).

The kelp resources of the coast of British Columbia have been estimated to exceed 1.5 million tons annually, with the giant kelp Nereocystis luetkeana and Macrocystis integrifolia constituting the dominant species. Although many companies have been formed to harvest and process this resource, the first serious attempt was made by the Canada Kelp Company in 1946, when a small production of dried material was obtained from the kelp beds at Deer Island prior to the closure of the company in 1948.

Some twenty years later, a company with the same name completed construction of a drying plant at Masset, Queen Charlotte Islands, with the aim to supply seaweed meal to the European and Japanese markets. A 1,000 ton per day kelp harvesting barge was under construction when the company, through lack of financing, was placed in receivership. In 1972 the complete assets of the Canada Kelp Co. Ltd., some $2.8 million worth, was acquired by Hi-Co International Ltd., a subsidiary of the mining company Equatorial Resources Ltd., and in August of 1973 the drying plant produced kelp meal for the first time.

This report presents an account of the kelp drying process at Masset together with the chemical analyses performed on the kelp meal

produced in the first week of operation, on the product produced under normal operating conditions and on the product from a special batch which was dried directly after chopping (that is, without passing through the process as a slurry with salt water). Analyses are also presented for representative specimens of Nereocystis and Macrocystis collected from the Masset area.

This trial operation lasted from the 3rd of August to the 7th of September, 1973. An estimated 1,200 tons net weight of Nereocystis was processed to produce 35 tons of dried kelp meal, with a loss by venting estimated at 15 tons (Benson, 1973).

Experimental data obtained in the laboratory on the leaching action of salt water on chopped kelp, a comparison of the slurries formed by Macrocystis and Nereocystis when chopped and mixed with salt water, and attempts to remove water from the tissue by mechanical pressing are included in this report for completeness.

THE RESOURCE

(a) Nereocystis luetkeana (Mertens) (Scagel, 1947 and 1967), commonly known as "bull kelp", "sea onion", "bladder kelp", "ribbon kelp", "sea otter's cabbage", or "sea whip", is the dominant giant kelp in British Columbia. It is essentially an annual plant which starts as a young sporophyte in early spring and is usually torn loose by storms or disintegrates by the late autumn of the same year. The plants that do persist through the winter are heavily epiphytized with various flora and fauna by the following summer. The plant is maintained on rocks in the upper subtidal and to a depth of several fathoms by a profusely branched holdfast. The stipe, up to 25 m long, is solid and cylindrical from 1 - 1.5 cm in diameter at its base and increases in diameter to a hollow tube terminating in a spherical float 15 - 17 cm in diameter. Two clusters of laminae (up to 15 cm broad and 10 m long) project from the top of this pneumatocyst with up to 20 laminae per cluster.

The mature plant produces dark brown spore patches on the laminae which drop away when mature and the sporangia within these patches produce motile zoospores which germinate to form multicellular filamentous sexual plants. The male sperm from these plants then fertilizes the egg on the female plant, resulting in the formation of a zygote which then undergoes mitotic division and growth to yield the young sporophyte.

In a survey by a consulting company of the harvestable resource on the north coast of Graham Island, performed for the Canada Kelp Co.

during the period of July, August and September, 1967, an estimated 95,356 tons of Nereocystis were available within an average 18 mile radius of the drying plant site at Masset and the weight of the seaweed ranged from 5 to 25 lb. with a normal weight of 7 to 8 lb. each (Phillips, 1967). A recent inventory by the Fisheries Operations (Blakley, et. al. 1973) in August and September, 1973, estimated 54,089 tons of Nereocystis within the same range of the plant site.

(b) Macrocystis integrifolia, Bory (Scagel, 1947 and 1967) commonly known as "devil's apron", "kelp flag", "giant kelp", "long bladder kelp", or "sea ivy", belongs to the same genus as the giant kelp of South California, M. pyrifera which is harvested commercially principally by the Merck Corporation, formerly Kelco Co. Ltd. Macrocystis is a perennial plant which is held by a profusely branched rhizome holdfast to rocks on the low intertidal and upper subtidal zones to a depth of 10 m. It is normally located in areas of open ocean, but not exposed to direct wave action and is often protected by a fringe of Nereocystis growing in deeper water. The mature sporophyte has numerous slender stipes (up to 30 m long and 1.2 cm in diameter) which contain, at intervals, leaf-like laminae (up to 5 cm wide and 35 cm long) which have irregularly furrowed surfaces and taper to small pneumatocysts at the point of attachment to the stipes. The life-cycle of the plant is similar to that of Nereocystis, the main difference being that the zoospores are liberated from basal laminae known as sporophylls while the remaining laminae to the tip or growing portion of the plant are

infertile.

In a survey by a consulting company of the harvestable resource on the north coast of Graham Island during the period of July, August and September 1967, an estimated 72,312 tons of Macrocystis were available within an average of 18 miles from the drying plant site at Masset. Plants estimated to weigh 220 lb. were discovered on this survey, but the normal average per holdfast was about 25 lb. (Phillips, 1967). A figure of 75,417 tons was assessed to be available from a recent survey conducted in August and September, 1973 by the Fisheries Operation (Blakley, et. al. 1973).

(c) Observations on the Resource at Masset in August, 1973

An aerial survey of the north coast of Graham Island (August 2nd, 1973) from Skonun Point to Klashwun Point when the tide was from 12.5 to 17 feet indicated that the kelp beds, to the west of Wiah Point, tended to exhibit more growth, especially those beds in the Hussan Bay area. The kelp at Sturgess Bay exhibited only patches of dense growth and the beds, according to local fishermen, were estimated to be approximately one third their normal density. This observation may be substantiated by the 40,267 ton discrepancy in the Nereocystis assessment in the 1967 and 1973 survey. This poor crop could be attributed to the unusually heavy gales experienced on this coast during the winter of 1972/73, together with the exceptionally overcast conditions at Masset in the summer of 1973.

The kelp beds at Wiah Point and Sturgess Bay (west of Masset Sound) were almost exclusively Nereocystis plants and on close inspection by boat, were found to be completely mature and in many

instances at the latter location the plants were found to be devoid of laminae. The laminae on the Nereocystis at both locations by the first week of August 1973 had lost most of their spore patches with only the youngest patch evident less than 30 cm. from the pneumatocyst. In many instances, the laminae remaining were consequently short and tattered and measured less than 1 m. This evidence suggested that in excess of 75% of the reproductive spores had been released from these plants and that the kelp could probably be harvested without undue detriment to the following year's crop.

Inspection of the kelp beds in McIntyre Bay (east of Masset Sound) at approximately a 15 foot tide indicated that Macrocystis constituted in excess of 98% of the beds and that the surface stipes were fully mature, having stipe diameters in excess of 10 mm. Many of the floating stipes measured greater than 20 m and provided a heavy overburden of laminae. The density of these beds suggested that harvesting would be possible without detriment to the younger stipes and would benefit the beds by removing the heavy overburden of mature stipes which cause the plants to be torn loose with the onset of winter gales. Already storm-cast Macrocystis plants were evident on the beaches of McIntyre Bay.

HARVESTING THE RESOURCE

The harvester consisted of a metal barge (24 x 48 x 4.5 ft.) propelled externally from the rear by a 300 h.p. metal tug boat (30 x 11 ft.). To the bow of the barge a gate of reciprocating cutters was

mounted on the end of a pivoted conveyor belt (14 x 28 ft.), consisting of 2 in. x 3 in. x 14 ft. wooden slats on chain links (approximately 4 1/2 in. apart), with nails (1/4 in. diam.), positioned in a staggered manner into the exposed 2 in. side of each slat to provide grip for the kelp on the inclined conveyor. The hydraulically activated cutting bars -- 12 ft. horizontal bordered by two 8 ft. vertical -- were lowered to cut the kelp 4 to 5 ft. below the surface, and as the weed was cut, it was carried up the conveyor to fall on the deck of the barge. Initially, the pile of kelp below the conveyor had to be manually raked to the stern of the barge, however, a winch operated rake-sledge was installed at the end of the first week of operation.

It was noted that loss of seaweed occurred as the severed stipes escaped the conveyor belt and floated outside the catchment area bounded by the vertical cutters. This loss could in future be prevented by guide vanes positioned beside the vertical cutters.

DRYING PLANT OPERATION

The weed on the barge was unloaded at the wharf (468 x 20 ft.) by a mechanical shovel which dropped it into a chopper. The chopped weed was fluidized in a surge box with seawater and pumped by a Wemco 6 x 6 in. torque flow pump through the 16 in. fibreglass pipe to one of the two storage tanks, each of 600 tons capacity. From the tank, the chopped kelp was pumped to a headbox located on top of the two storage silos and from there to the drying unit. The plant consists of a double line of identical process equipment,

however, for this year's operation, only one process line was utilized.

The kelp in the headbox was fed to a Morse dewatering conveyor, where most of the seawater was drained, then to a dewatering screen--a 4 ft. diameter Kason horizontal gyrating screen separator. The dewatered kelp was then passed by a screw conveyor to a shredder (Rietz Disintegrator) and the shredded kelp dropped into a storage tank. With a variable-speed "Moyno" solids handling pump, the shredded kelp was fed to a fluffer and into the rotary, diesel-oil fired, concurrent flow triple-pass kiln type dryer. The Heil Co. dryer (SD 105 x 32) has the capability of evaporating 18,000 lbs. of water per hour. The dried kelp was then discharged by a hot air stream to a collecting cyclone and blown to a cooling cyclone mounted on top of the dried kelp silo which was capable of handling 50 tons. A rotary plate feeder at the base of the silo discharged the dried kelp to a grinder (Jacobson hammermill) to reduce it to a meal which was then blown into a cyclone mounted above a bagging plant where it was packaged into 50 lb. bags and stored in the warehouse (132 x 100 ft.) capable of storing 2,000 tons of dried kelp. The plant was designed to handle 6,000 tons of dried kelp from a 100 day harvesting season (presently estimated to be from June 15th to the end of September) and is self-sufficient in energy requirements which are satisfied by three Caterpillar diesel electric 600,300 and 20 kw generators.

DESCRIPTION OF MASSET SAMPLES ANALYZED

Nereocystis was the only kelp processed in this preliminary trial at Masset since the pump located on the dock was unable to handle

chopped Macrocystis, thus all reference to kelp meal relates to that from the former alga.

The following samples were analyzed:

Nereocystis luetkeana (a) fronds and (b) stipes. Fresh specimens of at least 5 plants were taken from Sturgess Bay on August 6th and separated into stipes and fronds which were freeze-dried in the laboratory and ground to a 20 mesh powder prior to analyses.

Initial Meal (c). The sample represented the product from the first 4 days of operation. As a result of numerous start-up problems, sufficient time elapsed between the storage of the chopped Nereocystis in the silos and its subsequent drying that excessive fermentation of the slurry was noted. Of interest in this sample were the effects of prolonged contact of the kelp with the salt water. The sample was freeze-dried and ground to pass 20 mesh prior to analyses.

Regular Meal (d)(washed). Some 1,000 lb. of the 35 tons of dried Nereocystis meal processed during this trial run was shipped to Vancouver and offered to the Animal Science Department, U.B.C., for animal feeding trials. Representative samples were removed from each bag, combined, freeze-dried and ground to a powder (20 mesh). As this material had been in contact with salt water for most of its passage through the plant, the meal was also referred to as "washed" kelp meal.

Special Meal (e)(unwashed). Instead of conveying the chopped Nereocystis by salt water, a special batch was processed by trucking the chopped material to the dryer. This experiment was designed to

allow comparisons to be made between "washed" and "unwashed" dried kelp meal having passed through the same drying process. Some 1,000 lb. of "unwashed" meal was received for animal feeding trials at U.B.C. and a composite representative sample taken and subsequently freeze-dried and ground to 20 mesh size.

Macrocystis integrifolia (f). Although the drying plant did not produce meal from this kelp, specimens of at least five plants were obtained from McIntyre Bay, to afford representative data for future utilization and for direct comparison with Nereocystis. The stipes and fronds of this alga were not separated, but were freeze-dried together then ground to a 20 mesh size prior to analyses.

The powdered specimens of the above samples were maintained under high vacuum and free from moisture such that analytical data refer always to a common denominator, an absolutely dry weight basis.

ANALYSES PERFORMED

(a) Moisture was determined by heating samples to constant weight at 100-105^{o} C, or using the O'Haus moisture balance (at the Masset Plant) with the heater control setting at 5 - 5.5; higher settings produced scorching of the sample.

(b) An extractive fractionation technique (Whyte et. al. 1969), using a homogenous solvent system chloroform: methanol: water (V:V; 1:2:0.5) was used to separate the chemical components of the kelp into 3 distinct classes. The "chloroform soluble" components would include hydrocarbons, carotenoids, terpenoids, fats, steroids, phenols, vitamins, chlorophylls. The aqueous "methanol soluble" components would include sugars (mono- and oligosaccharides), free amino acids, amines, cyclitols, hexitols and soluble minerals. The residual "polymeric residue" from this extraction procedure would contain polysaccharide and protein components together with minor amounts of insoluble minerals.

(c) Ashing was performed at 500° C for 20-24 hours; increased temperature resulted in loss of volatile minerals.

(d) Insoluble ash was obtained by measuring the residual material left after water leaching of an ashed sample.

(e) Total nitrogens were analyzed by the Kjeldahl method on the entire sample. Polymeric nitrogen referred to the nitrogen in the polymeric residue which offered a truer assessment of the protein content (N x 6.25).

(f) Sodium alginate was obtained by decarboxylation (Whyte, et. al.

1974).

(g) Viscosity of the extracted sodium alginate was determined using a Brookfield viscometer. The polymeric residue was extracted 4 times at 60°C with 1% aqueous calcium chloride to remove "fucoidan" material and the residue from this procedure extracted with 1% aqueous sodium carbonate at 60°C to remove the sodium alginate which was isolated by precipitation in alcohol. Dissolution and reprecipitation with alcohol several times offered pure sodium alginate which was dried by solvent exchange and the viscosity of this material determined as a 1% aqueous solution at 25°C.

(h) The mineral cations were analyzed by emission spectroscopy (Christenson, 1968).

(i) The chloride and iodide were analyzed by precipitation techniques (Anon., 1970).

The results of these analyses are recorded in Table 1.

TABLE 1

CHEMICAL COMPOSITION OF KELP & KELP MEAL *

PARAMETERS	N.L. FRONDS (a)	N.L. STIPES (b)	MEAL INITIAL (c)	MEAL REGULAR WASHED (d)	MEAL SPECIAL UNWASHED (e)	M.I. (f)
Moisture %	92.8	91.9	16.6	17.6	16.0	86.9
Chloroform Sol. %	4.76	1.15	4.6	2.33	2.53	2.4
Methanol Sol. %	49.98	53.42	44.2	44.67	46.18	44.1
Polymeric Residue %	45.26	45.43	51.2	53.00	51.29	53.5
Ash %	45.95	51.48	50.6	48.31	50.54	31.22
Insol. Ash %	3.51	2.48	5.83	4.99	5.54	3.62
Total Nitrogen %	2.08	0.94	1.50	1.33	1.66	1.06
Polymeric N %	3.44	1.81	1.13	2.56	2.64	1.79
Protein %	21.51	11.33	7.06	14.11	16.49	11.21
Sodium Alginate %	19.5	19.6	20.7	25.3	21.9	20.3
Viscosity	5200 cps	6900 cps	19.5 cps	20.5 cps	29.5 cps	5100 cps
Phosphorus %	0.246	0.103	0.365	0.167	0.208	0.184
Potassium %	13.9	22.7	8.97	7.81	16.9	10.3
Calcium %	0.362	0.353	0.873	0.942	0.764	0.704
Magnesium %	0.625	0.561	1.05	1.16	0.633	0.486
Sodium %	6.55	6.77	11.0	11.2	5.47	3.11
Aluminium ppm	<10.0	<10.0	43.4	27.5	24.0	65.4
Barium ppm	< 2.0	< 2.0	9.64	8.51	5.47	4.93
Iron ppm	33.2	22.2	7810.0	1540.0	1520.0	85.5
Strontium ppm	394.0	461	1160.0	1070.0	903.0	522.0
Boron ppm	60.9	47.0	154.0	72.7	74.7	134.0
Copper ppm	< 1.0	5.88	5.12	1.59	< 1.0	< 1.0
Zinc ppm	< 1.0	< 1.0	12.3	4.98	< 1.0	< 1.0
Manganese ppm	< 2.0	< 2.0	61.0	13.5	13.5	< 2.0
Chromium ppm	< 3.0	< 3.0	6.00	3.48	< 3.0	< 3.0
Chloride %	-	-	-	21.5	21.6	-
Iodide ppm	-	-	-	471	830	-

* Moisture quoted on fresh weed and dried meal. All other values are quoted on a completely dry weight basis.

DISCUSSIONS OF ANALYTICAL RESULTS

As no two algal plants will contain identical quantities of chemical components, the results obtained for individual constituents will be subject to minor fluctuations and anomalies. It would be erroneous therefore to place too much significance on minor deviations in the analytical results; however, well defined trends and significant differences in relative quantities must be considered as noteworthy.

The moisture content of Nereocystis (range 91 - 94%) was undoubtedly higher than that of the Macrocystis (86 - 89%), implying that from an economic basis, the latter alga would be the more logical to dry for kelp meal. The moisture of the kelp meal analyzed was reasonably close to the optimum 15% content and sufficiently below the crucial value of 20% -- above which microbial action can occur.

The ash content of Macrocystis was considerably less than that of Nereocystis, which ranged from 45% to in excess of 50% of the dry weight. These high ash contents were substantiated by considering the similar values obtained for the percentage of aqueous-methanol soluble components. This aqueous-methanol soluble fraction contained the soluble minerals together with the other low-molecular weight hydrophilic constituents whose proportions could be approximately assessed by subtracting the differential value between the ash and insoluble ash from the value obtained for the methanol soluble fraction. Using this rough guide to the content of the low-molecular weight

hydrophilic components, it was noted that the initial kelp meal which had undergone fermentation, was singularly lacking in these constituents and that these components constitute a higher percentage of the total chemical content in Macrocystis than in Nereocystis.

The total nitrogen content of Nereocystis was higher than that in Macrocystis, a result which was also reflected in the protein content values which were particularly high for the fronds of Nereocystis. The total nitrogen and protein content of the initial meal was considerably less than the other samples and was considered to be caused by the process of fermentation experienced in this batch.

The content of sodium alginate (19 - 21%) and the corresponding viscosity (5000 - 7000 cps) of the isolated polysaccharides from both fresh algae were quite similar. All the kelp meal samples when extracted, however, afforded a sodium alginate of low viscosity (19 - 30 cps) and therefore of little commercial utility.

There was no doubt that the temperature of drying was causing severe degradation of the constituent alginate polymer since the samples from the freeze-dried weed furnished viscosity values some 240 times greater than any of the alginate samples isolated from the kelp meal. The discharge temperature of 177° C for the dryer at Masset was much higher than the figure of 60 - 80° C which has been quoted in the literature (Gardner, 1956) as having little effect on the viscosity of the alginate molecule. It is unlikely, however, that the Masset plant Heil dryer could operate efficiently at these low temperatures; nevertheless, the company should constantly

strive for lower operating temperatures in the dryer.

The most significant differences between the results of "washed" and "unwashed" kelp meal was exhibited in the mineral content and in particular the relative contents of the sodium and potassium ions. The regular or "washed" meal had a potassium content 8 - 9% lower and a sodium content 5 - 6% higher than the corresponding "unwashed" meal. Leaching of these alkali-metals with water had to be expected and it was only the use of seawater (3% aqueous sodium chloride) as a slurrying and conveying medium that resulted in an increased sodium content, otherwise with fresh water a diminished content would be realized. As a general trend, it appeared that passage of the kelp through the drying plant resulted in an increased content of trace elements. Relative to the fresh alga, the content of iron increased markedly due probably to contamination from the pipes, containers and dryer as was suggested by the magnitude of the iron present in the initial meal which remained in the system for a considerable time span. Again, due to the use of seawater as a slurrying agent, there was little difference in the overall chloride content; however, the iodide content was virtually halved by the water treatment.

SLURRIES OF KELP WITH SALINE WATER

The transportation of the kelp from dock to plant involved chopping and slurrying the kelp with seawater, followed by pumping to the silos. It had been noted in our laboratory however that Macrocystis, when chopped, exuded considerable quantities of polymeric material to afford a jelly consistency, thus it came as no surprise when attempts at Masset to pump chopped Macrocystis failed completely. To compare the physical nature of the slurries generated by each alga, samples of minced seaweed were mixed with varying proportions of 3% aqueous sodium chloride, the slurries centrifuged at 2000 rpm, and the viscosities of the supernatant solutions measured at 25° C on a Brookfield viscometer. The following results were obtained:

NEREOCYSTIS	WATER (3% NaCl)	RATIO	VISCOSITY 25°C
250 g	500 ml	1:2	1.3 cps
500 g	500 ml	1:1	1.5 cps
1000 g	500 ml	2:1	1.6 cps
1500 g	500 ml	3:1	1.9 cps

MACROCYSTIS	WATER (3% NaCl)	RATIO	VISCOSITY 25°C
500 g	500 ml	1:1*	125 cps
250 g	500 ml	1:2*	45 cps
125 g	500 ml	1:4	10 cps
62.5 g	500 ml	1:8	5.5 cps
31.25 g	500 ml	1:16	4.0 cps
15.63 g	500 ml	1:32	3.5 cps

*partial gells not true solutions

The minced Nereocystis consisted of loosely held aggregates of vegetative tissue which could be readily separated into constituent parts and when slurried with saline water afforded solutions of low viscosity, even in the proportions of 3 parts alga to 1 part water. By comparison, the Macrocystis in the minced state produced a jelly aggregate entrapping considerable air which defied separation into constituent parts and only when added to saline water in the ratio of 1:4 was a true solution formed with a viscosity of 10 cps. Unlike the Nereocystis, therefore, the Macrocystis would require at least 4 - 8 times its own weight of water to achieve the flow characteristics suitable for pumping, indeed, even with a dilution factor of 32, the solution never attained a viscosity as low as that furnished by the most concentrated Nereocystis slurry studied.

It may well be that the viscosity of the slurry did not constitute the major obstacle to pumping, however it is clearly evident from these results that a considerable difference exists between the nature of chopped Nereocystis and Macrocystis--which must be considered in the transportation problems associated with conveying this material.

LEACHING OF KELP WITH SALINE WATER

As most vegetative tissue, when chopped and slurried with water, will leach water-soluble constituents, the following experiments were performed to establish the losses incurred in the system of transporting the kelp as a slurry with the subsequent removal of the conveying water prior to drying.

(1) *Nereocystis luetkeana*

Minced seaweed (100 g) was added to exactly 3% aqueous sodium chloride (100 ml) in a centrifuge bottle. After a prescribed time the bottle was centrifuged at 2000 rpm and a 25 ml aliquot of the supernatant solution evaporated to dryness and weighed.

Leaching time in Hours	Weight of 25 ml portion
12	1.0660 g
18	1.0671 g
24	1.0697 g
Average:	1.0676 g

Average amount of material leached over 24 hours

= 4.2704 - 3.0 g (NaCl)/100 ml (or 100 g alga)

= 1.2704 g/100 ml (or 100 g alga)

The moisture content of this sample of *Nereocystis* = 91.95%

= 8.05 g solids

Solubilized solids leached from dry *Nereocystis*

$$= \frac{1.2704}{8.05} \times \frac{100}{1} = 15.78\%$$

(2) Macrocystis integrifolia

The experiment was performed as described above for the Nereocystis.

Leaching time in Hours		Weight of 25 ml portions
6		1.2569 g
24		1.2621 g
33		1.2546 g
	Average:	1.2579 g

Average amount of material leached over 33 hours

= 5.0316 g - 3.0 g (NaCl)/100 ml (or100 g alga)

= 2.0316 g/100 ml (or 100 g alga)

The moisture content of this sample of Macrocystis

= 87.87% ≡ 12.13% solids.

Solubilized solids leached from dry Macrocystis

$$= \frac{2.0316}{12.13} \times \frac{100}{1} = 16.75\%$$

These results indicated that by the process of slurrying with seawater from 15 - 17% of the dry weight of the kelp would be leached as completely water soluble constituents. It is significant that the "fines" normally associated with chopping are not included in these figures and may constitute in excess of 20% of the chopped weed. The dewatering system at Masset was incapable of retaining these "fines" which when coupled with the solids leached by the action of the water could constitute a considerable loss in

the process.

It was evident from the timed results that the major leaching action had occurred prior to the 6 hour immersion period and that further diffusion of the cellular constituents was probably hindered by the ionic strength of the medium, 3% aqueous sodium chloride. An increase in the process of cellular dialysis would be associated with the use of fresh water which should be avoided as a conveying medium at all times.

When it is considered that the 16% of the seaweed mass, plus fines, lost in the slurry process may represent a significant portion of desirable components (polysaccharides, protein, vitamins, minerals), the wisdom of using any form of wet process to handle seaweeds prior to drying should be seriously questioned. In the design of plant operations for these seaweeds, dry processing is clearly deserving of renewed research attention.

REMOVAL OF MOISTURE BY MECHANICAL PRESSING

The removal of cellular water by mechanical pressing prior to fuel-fired drying would enhance the economics of the process.

To study this aspect of water removal use was made of a fishmeal pilot plant illustrated in Figure 1, incorporating a screw press with a press ratio of 6:1. The minced kelp was fed into the press opening and the press cake subsequently dried in the steam jacket dryer operating at 148° C. Unpressed kelp was fed directly into the drying unit to act as a control and to compare the mineral contents (cations) of the pressed and unpressed products to observe what elements, if any, would be removed by the pressing process. The results obtained were recorded in Table 2.

Macrocystis obtained from Sooke was minced to a jelly consistency which lost 0.38% of its moisture on being pressed. The decrease in the ash content was countered by an increase in insoluble ash content and indicated the probable loss of the soluble salts of potassium and sodium which was corroborated by the mineral analyses.

Similarly, Nereocystis obtained from Stanley Park when minced and pressed lost only 0.75% of its moisture content on being pressed and the increase in the insoluble ash reflected the loss of sodium and potassium salts.

In both cases, the trace elements generally increased in content with pressing, the most marked increase involving the iron, strontium and boron contents.

A freshly minced sample of Nereocystis was sent by Hi-Co to a peat-moss plant in Edmonton to attempt water removal by pressing the alga in an industrial roller-press. The Nereocystis feed at 91.95% lost 0.59% of its moisture on passage through the press to yield pressed material with a moisture content of 91.36%.

It was evident from these results that the resilience of the cellular matrix of the alga prevented the removal of intercellular water and that only after a process of cell rupture, for example by heat treatment, would any degree of success be achieved by mechanical removal of water.

TABLE 2

ANALYSES OF PRESSED AND UNPRESSED KELP*

	MACROCYSTIS		NEREOCYSTIS	
	Unpressed Drum Dried	Pressed Drum Dried	Unpressed Drum Dried	Pressed Drum Dried
Moisture %	88.25	87.87	91.85	91.10
Ash %	41.98	41.76	46.17	44.39
Insol. Ash %	8.10	8.81	5.89	6.39
P %	0.354	0.316	0.312	0.375
K %	13.5	12.2	13.5	12.7
Ca %	0.631	0.662	0.618	0.683
Mg %	0.416	0.468	0.529	0.480
Na %	4.20	3.87	4.56	3.89
Al ppm	69.7	64.8	63.9	91.2
Ba ppm	5.02	5.02	6.84	6.40
Fe ppm	311.0	347.0	219.0	492.0
Sr ppm	551.0	571.0	702.0	719.0
B ppm	94.8	108.0	86.8	95.4
Cu ppm	<1.0	<1.0	<1.0	<1.0
Zn ppm	5.64	5.70	29.8	29.1
Mn ppm	4.96	4.68	4.12	6.45
Cr ppm	4.18	5.39	<3.0	3.44

*Moisture quoted for fresh feed and press cake, all other values quoted relative to a completely dry weight.

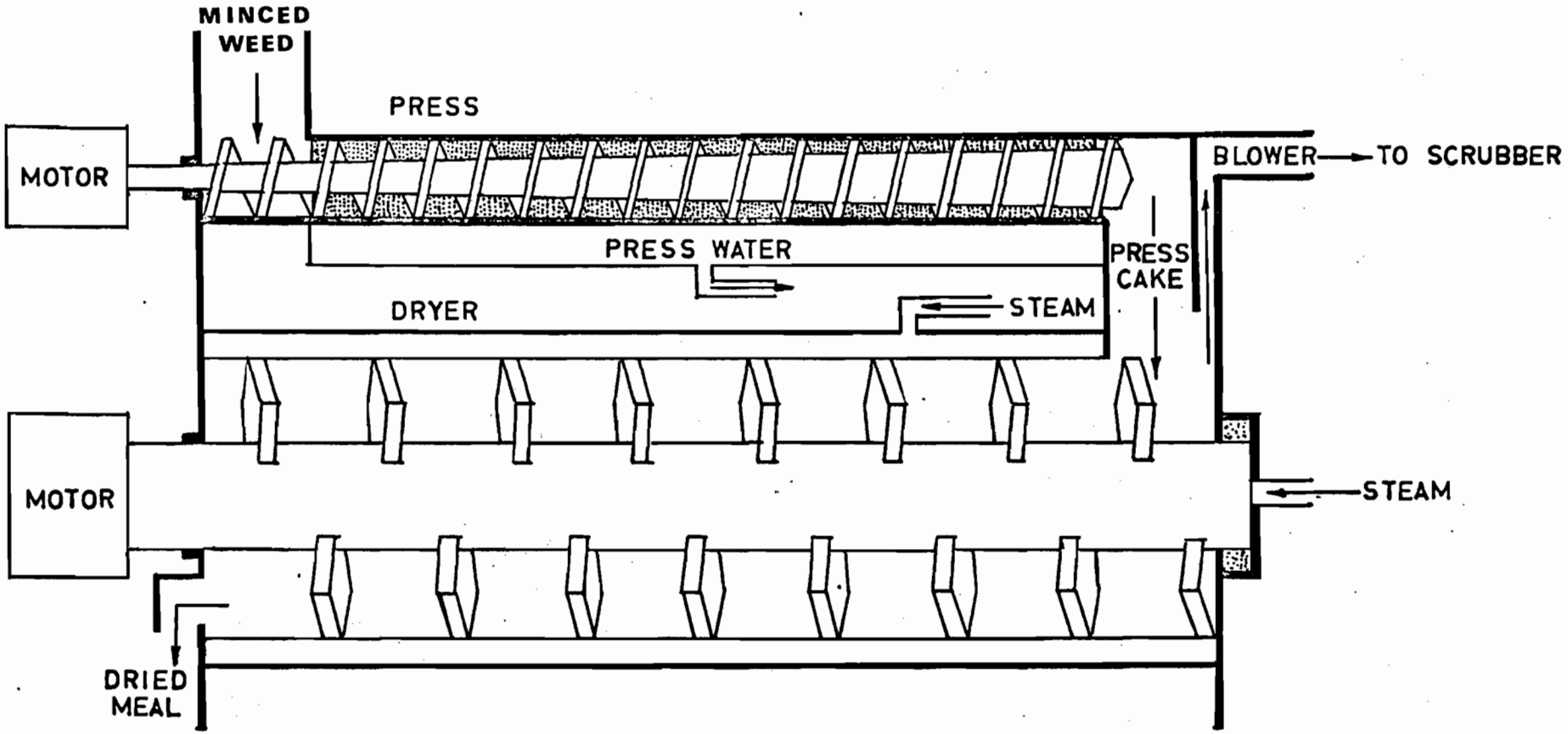

FIGURE 1. SCHEMATIC DRAWING OF PILOT PLANT

CONCLUSIONS AND RECOMMENDATIONS

The independent surveys conducted in 1967 and 1973 attested to the resource ranging from 54,000 - 95,000 tons of Nereocystis and 72,000 - 75,000 tons of Macrocystis within an 18 mile radius of the drying plant at Masset. Assuming that 80% of this kelp is accessible for harvesting, the potential yearly average crop would approximate to 59,600 tons of Nereocystis and 58,800 tons of Macrocystis totalling about twice the requisite amount for the drying plant with an estimated capacity for 60,000 tons of wet kelp over the growing season.

These figures demonstrate the imperative use of Macrocystis in this operation together with the Nereocystis which was used exclusively in this trial run in 1973. It has been demonstrated in this report that an intristic difference exists between the chopped states of these two giant kelp and that due consideration be given to the problems associated with the transportation of chopped Macrocystis before the 1974 season.

To commence the season, it will be imperative to harvest only Macrocystis, a perennial plant, and that only the 4-5 ft. of heavy overburden be removed. In the first full year of operation only grid harvesting of the Macrocystis beds should be allowed to assure against unforeseen ecological factors which might become evident through the complete shearing of beds. Each bed cut should be carefully monitored and, where possible, allowed to remain "fallow"

for the following year.

Harvesting of Nereocystis should only be allowed when a reasonable percentage, 75%, of the plants have reached full maturity and that only grid-cutting be permitted to compensate for any unforeseen ecological disasters. As there is sufficient kelp within the 18 mile radius of the drying plant, this grid-cutting procedure should not limit the amount of material needed by the company to fulfill its commitment for the 1974 season and would offer the added advantage of buffering any detrimental effects to the ecological system.

Harvesting techniques with the reciprocating cutters and conveyor-belt system worked well; however, it is recommended that guide vanes be placed beside the vertical cutters to ensure against escape of severed kelp outside the catchment area bounded by these vertical cutters.

The drying plant at Masset was designed to utilize a slurrying process for transporting the kelp to the dryer. Laboratory experiments mentioned in this report have shown that 15 - 17% of the dry weight of the chopped algae was lost as leachable soluble constituents. These figures do not include the loss incurred as a result of "fines", produced by chopping and slurrying, which would not be retained by the dewatering screen in the drying plant and could constitute a loss of 20% of the fresh kelp. If these figures are meaningful, they should relate to the quantities cited in the final report from the Hi-Co Intl. Ltd., on the 1973

operation which concluded that approximately 50 tons of dried kelp meal was obtained from 1,200 tons of fresh kelp (Benson 1973). This weight of fresh kelp at 92% moisture is equivalent to 96 tons of dried meal. Assuming 17% loss of dry weight by leaching equals 16 tons and assuming 20% feedstock loss as "fines" equivalent to 19 tons dry weight, then an expected 35 tons could be lost by the process of chopping and slurrying, to provide a final figure of 61 tons net. This figure, considering that the 1,200 tons of feedstock cited was a rough estimate, is remarkably close to the yield specified in the Hi-Co Intl. report of approximately 50 tons, and would indicate that considerable losses were involved in the existing transportation process. It is recommended therefore, that where possible, no water be added to the chopped kelp and that direct transportation of the material to the dryer be the optimum and most economically advantageous process.

The kelpmeal and fresh kelp composition, Table 1, varied markedly in the viscosities of the alginate and the sodium and potassium contents. The process of drying (Heil dryer exit temperature 350° F) degraded the alginate molecule with a viscosity of 5000 - 7000 cps to a lower molecular weight polymer in the kelpmeal exhibiting a viscosity of 19 - 30 cps having no or limited commercial utility. By lowering the temperature of drying, a higher viscosity alginate would be obtained. However, it is unlikely that the Heil dryer would be capable of operating efficiently at a considerably lower temperature

thus the use of kelpmeal prepared by this process as a source of alginate may not be feasible. This aspect will have to receive closer study in the following season.

The potassium content of the regular kelpmeal that had been slurried was 8 - 9% lower and the sodium content 5 - 6% higher than the corresponding "unwashed" or unleached dried meal. The leaching of the potassium and sodium salts by water would be expected; indeed, the use of sea water (3% aqueous sodium chloride) as a slurrying agent was the only reason for the increased sodium content. These alkali-metals were also found to be lost by mechanical pressing of fresh chopped kelp, cf. Table 2, however less than 1% of the water was removed in the experiments with the pilot-plant screw press and an industrial roller-press. It is recommended, nevertheless, that rupture of the cellular structure could be effected by heat treatment thus allowing for increased removal of water by mechanical pressing. Simultaneous degradation of the alginate would occur by this preheating; however, degradation will occur in the dryer in any event.

The final conclusion is, therefore, that the kelp be harvested in a conservative manner, at least in the first full year of operation, until any related ecological problems are discovered and resolved; that the drying-plant be modified, when possible, to eliminate slurrying and subsequent dewatering and secondly modified to utilize the exhaust heat from the Heil dryer to preheat the input feed to the dryer or to a mechanical dewatering system positioned in the process immediately before the dryer.

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