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Feasibility Assessment for a Zanzibar MUZE Seaweed Processing Facility (ZanMUZE):

Creating value for the poor

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This document has been prepared by Iain C. Neish.

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Reference:

Neish IC, 2013. *Feasibility Assessment for a Zanzibar MUZE Seaweed Processing Facility (ZanMUZE).* Report submitted for UNIDO Project no 13083"Building Seaweed Processing Capacities in Zanzibar and Pemba: Creating value for the poor".

Cover image: MUZE processing of spinosum at bench-top scale in Zanzibar with staff of MTIM, C-Weed Corp. and UNIDO local expert Dr. F. E. Msuya

Abstract

The present report is a companion document to *Seaweed Value Chain Assessment of Zanzibar (*Neish, IC & Msuya, FE 2013). The two reports were submitted as components of UNIDO Project no 13083 "*Building Seaweed Processing Capacities in Zanzibar and Pemba: Creating value for the poor*".

Seaweed comprises more than 90% of Zanzibar marine product exports. With about 25% contribution it is the third largest contributor to GDP after tourism and cloves. The present value chain study established the current situation of seaweed production and processing in Zanzibar and its marketing on the international Market. It proposed that a step toward expansion and strengthening of Zanzibar spinosum seaweed markets should be construction and operation of a multi-stream, zero-effluent (MUZE) seaweed processing facility (ZanMUZE) that can be used to refine process protocols and provide samples for testing and approval by potential customers in local, regional and global markets. The present assessment provides an initial basis for planning the proposed seaweed processing facility.

Need for the ZanMUZE project arises because Zanzibar easily produced more spinosum than the market could bear since 2012. Farm-gate prices were soft and exporters could not buy all the seaweed produced. This had serious impacts on household incomes for small farmers so Zanzibar spinosum farmers need additional markets to consider spinosum production as a viable source for livelihoods. Eucheuma (spinosum of the trade) from the two main islands of Zanzibar (Pemba and Unguja) comprised most of the seaweed production of Tanzania and more than 15 000 dry tons were exported during 2012. This represented about 1/3 of global spinosum production. Spinosum from Zanzibar was entirely exported to about half a dozen companies that utilized alcohol precipitation methods to produce refined iota carrageenan for dentifrice stabilizer and processed food products. These markets have shown sluggish growth and no new major applications have been developed for decades.

Emerging technologies give reason to believe that new processes and innovative products can substantially increase the size of spinosum markets. The fundamental basis of these technologies is MUZE processing that commences with fresh, live seaweed that is converted to juice and pulp using ZanMUZE packaged processing units near farm sites. These products can probably be brought to market as plant biostimulents, agricultural nutrition suppplements and carrageenan products within three years. In the longer run, advancing biotechnology will provide several alternative uses for spinosum biomass.

Annual projections for the ZanMUZE seaweed processing facility (base case; operating at full capacity) were compared to commercial scale-up scenarios. Results indicated increasingly profitable operation of commercial ZanMUZE operations as expansion occurred. According

to projections a production level utilizing about ten percent of the amount of 2012 Zanzibar spinosum production could yield almost 2.8 M USD EBITDA on annual sales of 4.8 M USD. This would require about 8 000 t/yr. of live spinosum, which is equivalent to about ten percent of 2012 Zanzibar seaweed production. Expansion could well extend to absorption of 30% to 50% of Zanzibar spinosum production or more. Even if Zanzibar production was doubled it appears that markets could easily absorb potential product volumes provided that anchor buyers are engaged.

Successful development based on the ZanMUZE project can benefit seaweed farmers in several ways. Expanding markets would mean increased employment opportunities for farmers and also in value adding activities. Farmers will receive effectively higher seaweed prices by about 1.5 fold and will participate in profits as they secure equity in MUZE processing facilities. Farm productivity will effectively increase and costs will decrease as MUZE processing systems pick up live seaweeds from farms. This would eliminate the need for farmers to invest substantial amounts of unproductive labor in drying seaweeds and it would enable production to continue during rainy seasons.

Agricultural nutrients from seaweed can have significant multiplier effects because they can enter local markets and contribute to improved agricultural productivity. In Zanzibar many foodstuffs are imported and the agricultural sector struggles to ensure food security by providing crops and livestock sufficient to feed over 1 000 000 people residing in Zanzibar and also tens of thousands of tourists.

Seaweed biomass is getting increasing attention from biotechnology developers in global technology centers and some are already turning their attention to spinosum because of its demonstrated biomass productivity and potentially attractive production economies. It seems that major imminent uses exist for increased spinosum biomass and further uses are likely to develop over the coming decades. For Zanzibar there is a need to use the next few years to bridge the development gap and consolidate its position as a major global spinosum biomass source. The ZanMUZE project is intended to assist in achieving that goal.

Glossary

Note: (K) is Kiswahili

ATC: alkali-treated chips made from Kappaphycus or Eucheuma

BoT: Bank of Tanzania

CBO: Community Based Organisation

Cottonii: Kappaphycus spp.

CSPro: Census and Survey Programme

Cultivar: A clone derived from vegetative propagation originating from a single seaplant thallus.

DMR: Department of Marine Resources within MLF

DoE: Department of Environment

E407: European Union designation for Refined Carrageenan (RC)

E407a: European Union designation for Semi Refined Carrageenan (SRC) = PES

Eucheuma spp.: A red algal genus that is called "spinosum" of the trade; source of iota carrageenan.

FAD: Fish Aggregating Device

FAO: United Nations Food and Agriculture Organization

FS: Live, fresh seaweed (cottonii or spinosum)

Galactans: A class of polysaccharides that includes carrageenan and agar.

GDP: Gross Domestic Product

GOZ: Government of Zanzibar

Gracilaria spp.: A red algal genus also called "gracilaria" in the trade; source of agar.

ICM: Integrated Coastal Management

IEC: Information Education and Communication

ILO: United Nations International Labour Organization

IT: Information Technology

Kappaphycus spp.: A red algal genus that includes both "cottonii" of the trade and "sacol" of the trade; sources of kappa carrageenan.

Kiswahili: Language generally spoken in Zanzibar

MACEMP: Marine and Coastal Environmental Management Project

MLF: Ministry of Livestock and Fisheries

MCT; Ministry of Communication and Transport

MKUZA (ZSGPR)(K): Mkakati wa Kukuza Uchumi na Kupunguza Umaskini Zanzibar (Zanzibar Strategy for Growth and Poverty Reduction)

MoFEA: Ministry of Finance and Economic Affairs

MSME: Micro, small and medium enterprises.

MS(PO)RASD: Ministry of State (President Office) Regional Administration and Special Departments

MT: metric ton.

MTIM: Ministry of Trade, Industry and Marketing

MTTI: Ministry of Tourism, Trade and Investment

MWCEL: Ministry of Water, Construction, Energy and Land

NGO: Non-Government Organisation

NLUP: National Land Use Plan

PES: Processed Eucheuma Seaweed = SRC = E407a

RAGS: Red Algal Galactan Seaweeds including Eucheuma, Gigartina and Kappaphycus.

RC: Refined carrageenan (RC-I = iota and RC-K = kappa)

RDS: Raw, dried seaweed (cottonii or spinosum)

SACCOS: Saving and Credit Cooperative Society

Spinosum: Eucheuma spp.

SRC: semi-refined carrageenan = PES = E407a

UDSM: University of Dar es Salaam

UNEP: United Nations Environment Programme

UNIDO: United Nations Industrial Development Organization

USD: United States Dollar.

Value Chain: A mechanism that allows producers, processors, and traders - separated by time and space – to add value to products and services as they pass from one link in the chain to the next until reaching the final consumer (after UNIDO, 2011).

ZanMUZE: Feasibility Assessment for a Zanzibar MUZE Seaweed Processing Facility

ZIPA: Zanzibar Investment Promotion Authority

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Introduction

This study was conducted as part of the 3 ADI program. The present report is a companion document to *Seaweed Value Chain Assessment for Zanzibar* (Neish & Msuya, 2013).The two reports were submitted as components of UNIDO Project no 13083 "Building Seaweed Processing Capacities in Zanzibar and Pemba: Creating value for the poor". They were based on field work conducted by the authors and UNIDO staff during late July and early August, 2013.

Terms of reference for the project stipulated that the project concept originated from negotiations with the Zanzibar government during the formulation of the country program in 2011. The Ministry of Livestock and Fisheries and the Ministry of Trade, Industry and Marketing indicated that developing the seaweed sector is of highest priority because it is a main source of income for many poor on Zanzibar and Pemba islands, especially women. Seaweed comprises more than 90% of Zanzibar marine product exports. With about 25% contribution it is the third largest contributor to GDP after tourism and cloves.

The project context was such that it will contribute to developing and fine-tuning the project document "Building Seaweed Processing Capacities in Zanzibar and Pemba: Creating value for the poor" is a way specified by the project terms of reference as follows:

> *"The project will generate opportunities for businesses and decent work in sustainable seaweed production, processing and marketing. Drawing from technology that successfully is used in South-East Asia and collaborating with private sector entities that have pioneered the seaweed sector in Zanzibar the idea is to bring value addition closer to the poor and help local seaweed farmers benefit from the value that is added to seaweed as it gets processed and marketed. At the heart of the project is the setting up of modern processing facilities, owned by the provincial government and run by a private operator. The products have enormous market potential when produced to specifications of buyers…"*

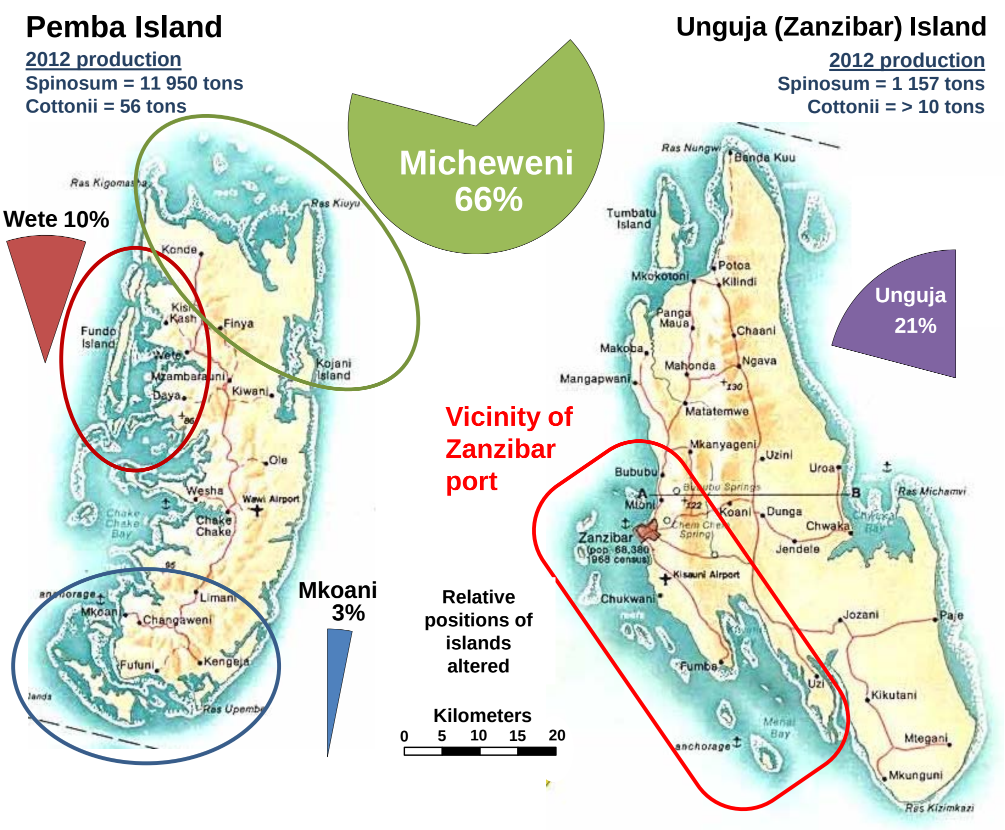
1. Overview: current production conditions

The present Feasibility Assessment for a Zanzibar MUZE Seaweed Processing Facility (ZanMUZE) was written with reference to a proposed multi-stream, zero-effluent (MUZE) seaweed processing facility that would commence value addition using live, fresh seaweed (FS) near to farm sites. The facility would comprise pilot scale equipment that can easily be scaled to commercial scale by the modular expansion.

1.1. Locational specifics

Zanzibar is located off the coast of Tanzania in the Indian Ocean. It includes two major Islands, namely Unguja (sometimes referred to as "Zanzibar") and Pemba (Fig. 1.1). A group of about 50 small islets surrounds them. The Islands lie in the north-south direction between latitude 04° 50" and 06° 30" South, and east-west direction between longitude 39° 10" and 39° 50" East. The Islands are about 30 km east off the mainland Tanzania coastline. Unguja Island covers an area of 1,666 square km^2 and Pemba Island covers an area of 988 km^{2}giving a total land area of 2,654 km^2. See Neish & Msuya (2013) Section 1 for more demographic and geographic information about Zanzibar.

Figure 1.1. Map of Zanzibar indicating the seaweed farming areas and 2012 seaweed production (data provided by Zanzibar Ministry of Livestock and Fisheries – Department of Marine Resources). Pemba is to the north of Unguja (see text for description of geography).



According to 2012 MLF-DMR data about 2/3 of Zanzibar seaweed production took place in the Micheweni area of northern Pemba (Fig. 1.2). About 21% of production occurred on Unguja and 79% on Pemba. Locations of farming areas are indicated on Fig. 1.1. Several location choices are available for the MUZE production facility proposed by the present feasibility assessment. A facility could be placed in any of the areas marked in Figure 1.1.

1.2. The present Zanzibar seaweed industry

The information below summarizes key points from Neish & Msuya (2013).

1.2.1 Major markets

Information current at the time of writing suggested that virtually all spinosum from Zanzibar since the beginning of commercial cultivation was ultimately purchased by companies that used it as raw material for the manufacture of refined, alcohol precipitated iota carrageenan (Table 1.1). This carrageenan was sold primarily to dentifrice, personal care and food ingredients markets.

During the development of value adding facilities in Zanzibar one or more of these processors may be potential development allies or customers for carrageenan products from the MUZE facility. During the survey for the present study a research and development person from a major European processor expressed tentative interest in this possibility.

Table 1.1. A list of known producers of refined, alcohol-precipitated iota carrageenan (E407) from spinosum. These were the major buyers and users of Zanzibar spinosum.

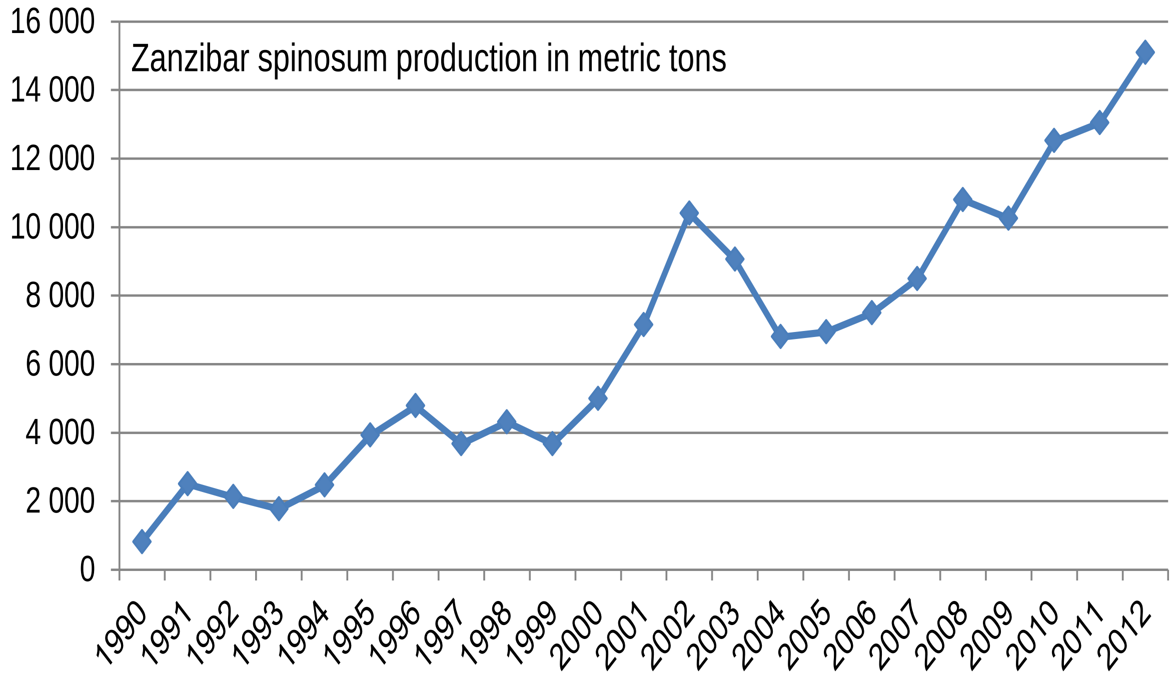
Country	Company	T/yr capacity
Chile	Gelymar	1 000
China	Unknown	
Denmark	CP Kelco	4 000
France	Cargill (ex-Degussa)	4 500
Japan	Mitsubishi	1 250
Korea	MSC Co. Ltd.	1 500
Philippines	Shemberg Biotech	1 200
Spain	CEAMSA (incl. Hispanagar)	1 750
USA	FMC	6 000
Total		**21 200**

1.2.2 Zanzibar seaweed production

Almost all Zanzibar seaweed production is of the genus <u>Eucheuma</u> (spinosum of the trade). Cottonii seaweed (genus <u>Kappaphycus</u>) has been plagued by repetitive crop failures despite substantial farm development effort since the late 1980s. During 2012 total Zanzibar cottonii production was only about ninety tons (MLF-DMR data), which was less than one percent of total seaweed production. Prospects for further extension of cottonii production were negative according to respondents of the present study. On the other hand from 1990 until 2012 Zanzibar spinosum seaweed production grew from about 800 t/yr. to more than 15 000 t/yr. (Fig. 1.2).

Spinosum is farmed in Zanzibar using the "off-bottom" method with lines suspended above the sea floor using wooden stakes driven into the sea floor (Plate 1.1.A & B). Farmers sun-dry spinosum to an average of 35% moisture content, usually by spreading it on the ground (Plate 1.1.C). Exporters pick up farm deliveries near drying areas, clean and dry seaweed as necessary and press it into 100 kg bales of raw, dried seaweed (RDS) for export (Plate 1.1.D).

Figure 1.2. Seaweed production in Zanzibar, 1990 – 2012. (Sources: MLF-DMR, C-Weed Corp., Satoumi.co own data).



1.1. Basic spinosum seaweed production steps. **A.** Off-bottom method: 4-m long lines with two pegs at each end. Uroa, Zanzibar. **B.** Underwater photograph of spinosum flourishing on a Micheweni, Pemba seaweed farm. **C.** Most farmers dry their seaweed on grass. **D.** Bales ready for shipment in twenty-foot containers. 200 bales (20 tons) can fit into one container.

2. Commerce and process technology

2.1 Seaweed commercial arrangements and standards

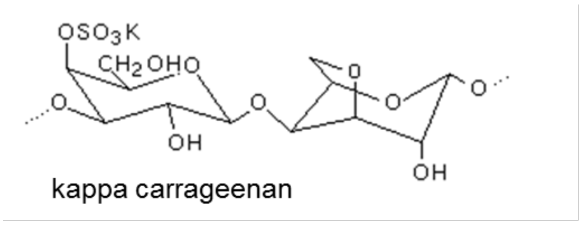
In the past letters of credit were a common form of commercial arrangement for seaweed purchases but current practice is generally for a buyer to issue purchases orders for a given number of container loads. Purchase orders typically specify the following:

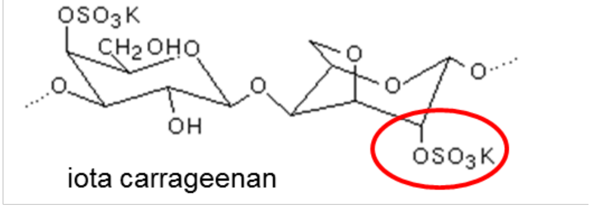
1. Product defined as dried Eucheuma denticulatum (spinosum seaweed of the trade);
2. Price per metric ton denominated in United States dollars;
3. Price based on 35% average moisture content (MC) and maximum 2% contaminants;
4. Excess or low MC offset by negotiated adjustment of future volume shipped (usually "free" tonnage shipped to offset excess MC in previous shipments);
5. Seaweed packed in wrapped bales of 100 kg weight (20 tons per 20 foot container);
6. Payment on FOB basis within about two weeks from presentation of shipping documents.

2.2 Characteristics of iota and kappa carrageenans

Spinosum flourishes in Zanzibar waters but cottonii has experienced repeated die-backs despite more than two decades of attempts to grow it in Zanzibar waters.

Figure 2.1. Structures of kappa and iota carrageenan. Carrageenan is a carbohydrate. The ester sulfate at the 6 position of the 3,6 anhydro galactose unit causes iota carrageenan to perform in a radically different way than kappa carrageenan in food, personal care and industrial applications.





Although cottonii and spinosum have a similar appearance they contain different types of carrageenan. Spinosum contains iota carrageenan and cottonii contains kappa carrageenan. Kappa and iota carrageenans are performance chemicals that are utilized in food, personal care and industrial applications. They behave in radically different ways due to sulfation patterns of the carrageenan molecules (Fig. 2.1). They can have complementary uses but they cannot replace each other.

Iota carrageenan forms soft, elastic gels in the presence of calcium salts. Refined iota carrageenan forms clear gels with no bleeding of liquid (syneresis). Gels are freeze/thaw stable and can form in the presence of high salt concentrations. Major applications include dentifrice gels (toothpaste), capsules, industrial slurries and food texturization.

Kappa carrageenan forms strong, rigid gels in the presence of potassium salts. Brittle gel forms with calcium salts. The slightly opaque gels become clear with sugar addition. There is some syneresis. Major applications include stabilization of dairy products, gelled pet foods, meat processing and water gels such as jelly desserts and candies.

2.3 Standards for refined and semi-refined carrageenan

Carrageenan quality specifications fall into three broad categories:

1. **Regulatory specifications** relate to product safety. They are found in international codes and are applied during pre-market approval. They are subject to mandated governance.

2. **Performance specifications** measure functional performance and determine fitness for intended applications. They are established between buyer and seller and are subject to voluntary governance.

3. **Enterprise responsibility specifications** relate to the means by which products are produced and traded. They refer to values that include “fairness” and “exploitation” and “environmental impacts”. They are subject to both mandated and voluntary governance.

Regulatory specifications promulgated for carrageenan by Codex FAO Food and Nutrition Papers 52 Addition 9, June 2001; and Commission Directive 98/86/EC Nov 1998 & 95/2/EC February 1995 include:

- Viscosity: molecular weight = 5 centipoise at 75^{o} Celsius
- Total Ash: product adulteration = 15-30%
- Acid Insoluble Matter: 8-15% for SRC; less than 2% for Carrageenan
- Microbiological Criteria: Total plate count (TPC) not more than 5000 colonies/g; Salmonella = negative; E. coli = negative in 1 g.
- Residual Solvents: 0.1% ethanol, isopropanol or methanol
- Heavy Metals: Lead = 5mg/kg; Cadmium = 2 mg/kg; Mercury = 1 mg/kg

Additional regulatory specification may be applied to manufacturing practices, value chain traceability, sustainability, religious constraints and other standards. These include HACCP, ISO, Halal and Kosher specifications.

Performance specifications are established among value chain stakeholders. They can include the following types of parameters:

A. **Rheological indicators (various buffer compositions & concentrations)**
   a. water, milk, galactomannan & glucomannan gel strength & texture
   b. water, milk & other viscosity
   c. syneresis (different gel types)
   d. elasticity/brittleness (different gel types)
   e. special application screening tests
B. **Organoleptic properties** including color, odor and special application screening tests.
C. **Regulatory "show-stoppers"**
   a. heavy metals (especially those with JECFA limits such as Pb, Cd & Hg)
   b. molecular weight distribution (per designated test protocols)
D. **Performance values**
   a. special application efficacy tests

Enterprise responsibility specifications are still largely in the development stage and are applied according to a wide range of globally variable criteria. Conformity with enterprise responsibility specifications is largely a matter to be settled between buyer and seller but mandated sanctions are developing. Carrageenans are complex molecules that come from nature in a wide range of forms and are processed using a wide range of technologies. Carrageenan process steps that impact quality include:

A. **Raw material selection** - whether from one form of ingredient building block or from several in combination (i.e. in the case of "co-processing").
B. **Raw material preparation** - such as sorting, milling, screening, addition of process aids and other procedures.
C. **Pasting, modification & extraction to modify gum structure** – generally using alkali such as caustic soda (NaOH); lime (calcium oxide; CaO); slaked lime ($Ca(OH)_2$); caustic potash (potassium hydroxide; KOH); or soda ash (sodium carbonate; Na_2CO_3). Effected by temperature, time, mass balance and a variety of other factors.
D. **Rheology adjustment & clarification** – decanting, centrifugation, depolymerization, filtration and other steps that result in the removal of insoluble matter that makes gels cloudy.
E. **Concentration** – evaporation, ultra-filtration and other procedures that concentrate gum concentration in the "paste".
F. **Precipitation, dehydration & purification** – done by flocculation of gum by KCl precipitation; alcohol precipitation; gel-press; freeze-thaw; freeze-drying; evaporation and a variety of other techniques.

G. **Drying, grinding & classification** – various methods can be used to influence particle size distribution and shape.
H. **Blending** – combines process batches, produces a mix that falls within set specifications and introduces diluents ingredients that adjust quality.

During processing a variety of chemicals can be utilized to influence quality, including (but not limited to):

A. **Salts -** such as sodium chloride (NaCl) and potassium chloride (KCl) to influence coagulation & solubility; alter color and odor; and other effects.
B. **Oxidizing agents** - such as hydrogen peroxide (H_2O_2); ammonium persulfate ($(NH_4)_2S_2O_8$); sodium hypochlorite (NaOCl) – to kill microbes and/or influence molecular weight distribution (hence viscosity).
C. **Acids** – such as hydrochloric acid, sulfuric acid, nitric acid and CO2, to clean equipment, neutralize process liquids, influence solubility and adjust molecular weight/viscosity.
D. **Preservatives** – such as calcium propionate.
E. **Cation donors & pH adjusters** – such as potassium carbonate and calcium sulfate.

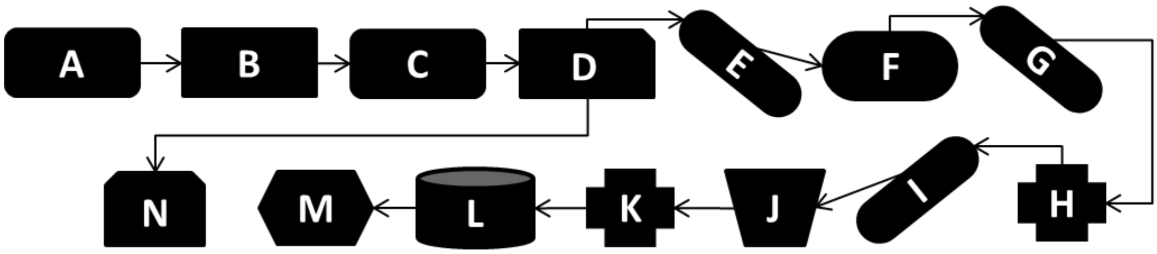
Solution providers take delivery of dozens of processed carrageenan products and other gums then blend them with other ingredients to reliably and predictably satisfy the requirements of hundreds of applications. The development and sustained production of ingredients solutions for long-term commercial applications is generally a combination of art and science that is based on long years of experience. Initial product development can be the result of several years of joint R&D between the solution provider and the application implementer. Consequently particular ingredient solutions, once established in the market, may have considerable long-term endurance.

2.4 Methods for making semi-refined iota carrageenan (E407a)

Figure 2.2 is a schematic diagram of the conventional process for making semi-refined iota carrageenan (also known as SRC-I; E407a; Processed Eucheuma Seaweed; or PES). The distinguishing characteristics of SRC processing are:

1. During processing the carrageenan is never dissolved (pasted);
2. Alkali Insoluble Matter (a.k.a. AIM or fiber) remains in the end product in concentrations up to 12-15%;
3. Solids content remains high throughout processing and that results in low energy and water consumption compared to RC processes.
4. Capital costs for SRC factories are much lower than costs for alcohol precipitation factories of similar output.
5. The process generates non-carrageenan seaweed components as waste.

Figure 2.2. Schematic diagram of the conventional process for making semi-refined iota carrageenan (SRC-I; a.k.a. E407a).



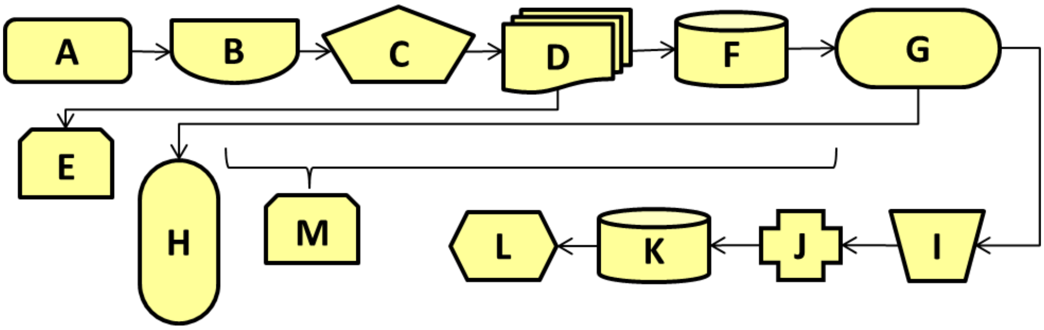
#	EQUIPMENT	ACTION
A	Pre-wash conveyor	RDS spinosum is pre-washed and conveyed into baskets
B	Cooker & basket	Washed RDS spinosum or spinosum pulp from MUZE processing subjected to alkaline modification in KOH at 60 degrees C for about1 hour
C	Wash tank & basket	Cooking basket dumped into wash basket. Wash in fresh water.
D	Unloading hopper	Wash basket dumped into hopper, gets sorted & dewatered;
E	Conveyor 1	Spinosum is conveyed to dryer
F	Fluidized bed dryer	Dry at 60 degrees C
G	Conveyor 2	Lifts dried spinosum to cutting mill 1
H	Cutting mill	Chops dried spinosum to ATC-I size
I	Conveyor 3	Moves ATC-I to mill feed hopper
J	Mill feed hopper	Meters ATC-I into powder mill
K	Powder mill	Reduces ATC-I to SRC-I with mesh size required by application
L	Blender	Makes pre-blends and final blends
M	Packing system	Packs SRC-I in bags for shipment
N	Waste processing	All non-carrageenan seaweed constituents treated & discarded

2.5 Methods for making refined iota carrageenan (E407)

Figure 2.3 is a schematic diagram of the conventional process for making alcohol-precipitated refined iota carrageenan (also known as RC-I or E407). The distinguishing characteristics of RC processing are:

1. During processing the carrageenan is dissolved (pasted);
2. Alkali insoluble matter is removed from the end product to concentrations of less than two percent;
3. Solids content removal requires processing of dilute filtrates and that leads to high energy and water consumption compared to SRC processes.
4. Capital costs for alcohol precipitation factories are very high; as much as ten times the cost of SRC facilities with similar output.
5. The process generates non-carrageenan seaweed components as waste.

Figure 2.3 Schematic diagram of the conventional process for making alcohol precipitated refined iota carrageenan (RC-I; a.k.a. E407)).



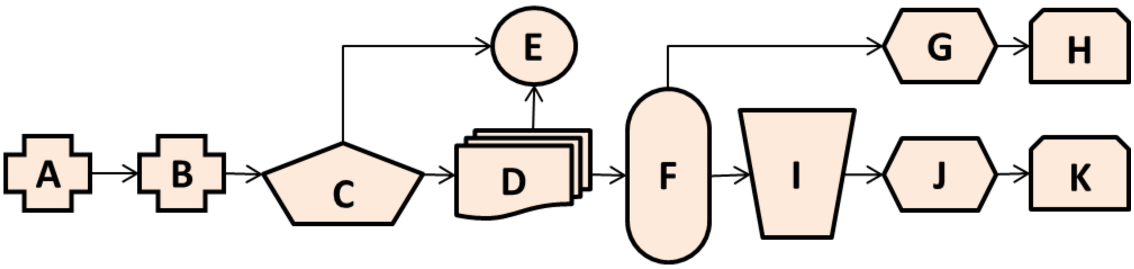
#	EQUIPMENT	ACTION
A	Pre-wash conveyor	RDS or spinosum pulp from MUZE processing washed & conveyed to baskets
B	Pasting/cooking tank	Spinosum is pasted & cooked (rested) under low heat in mild alkali (calcium oxide, CaO or calcium hydroxide, $Ca(OH)_2$)
C	Centrifuge	Dilute paste is centrifuged to remove largest solids
D	Plate & frame filter	Dilute paste further clarified in plate-and-frame filter press
E	Filter-aid disposal	Waste filter-aid is dumped as landfill or sold as soil conditioner
F	Flocculation tank	Carrageenan is flocculated in isopropyl alcohol
G	Belt dryer	Flocculent is dried in fire/explosion protected belt dryer
H	Distillation column	Isopropyl alcohol is distilled for recycling
I	Mill feed hopper	Meters dry flocculent into powder mill
J	Powder mill	Reduces flocculent to RC-I with mesh size required by application
K	Blender	Makes pre-blends and final blends
L	Packing system	Packs RC-I in drums or bags for shipment
M	Waste processing	All non-carrageenan seaweed constituents treated & discarded

2.6 Methods for making seaweed juice (a.k.a. seaweed concentrate or SWC)

Figure 2.4 is a schematic diagram of an evolving process for spinosum seaweed juice using MUZE technology. Plate 2.1 shows bench-scale MUZE processing undertaken during the present project. The distinguishing characteristics of MUZE processing are:

1. Farmers sell live seaweed immediately upon harvesting – they are not burdened with the need for drying seaweed so rainy seasons are not an impediment to farm production;
2. The process produces pulp that can be used wet or dry as raw material for conventional or newly developing RC and SRC processing and also for agricultural nutrient applications;
3. The process produces juice (seaweed concentrate; SWC) that can be used wet or dry for agricultural nutrient applications;
4. The process minimizes energy and water consumption and generates little or no waste.

Figure 2.4 Schematic diagram of a developing process for making seaweed juice (seaweed concentrate; a.k.a. SWC) from spinosum.



#	EQUIPMENT	ACTION
A	Shore-side cutting mill	Chop live spinosum to increase bulk density
B	Factory juicing mil	Mechanically reduce live seaweed into juice & pulp
C	Centrifuge	Separate juice from pulp
D	Filter	Remove fine particulate matter from seaweed juice
E	Pulp handing	Wet pulp goes to RC or SRC processing
F	Concentrator	Seaweed juice concentrated by evaporation (e.g. 5 or 6-fold)
G	Blender	Seaweed concentrate blended to standard
H	Packaging	SWC concentrate packed in drums, bottles or jerry-cans
I	Dryer	SWC concentrate reduced to powder form
J	Blender	SWC power blended to standard
K	Packaging	SWC powder packed in drums or bags

Plate 2.1. MUZE processing of spinosum at bench-top scale in Zanzibar with staff of MTIM, C-Weed Corp., Sea6 Energy and UNIDO local expert Dr. F. E. Msuya. **A.** Equipment used was a Singsung Food Processor, 4 in 1 SJ/888, Made in Singapore, 220-240V, 50/60 Hz, 600W. **B.** Making juice and pulp from spinosum. **C.** Wet pulp on left and fresh juice on right.

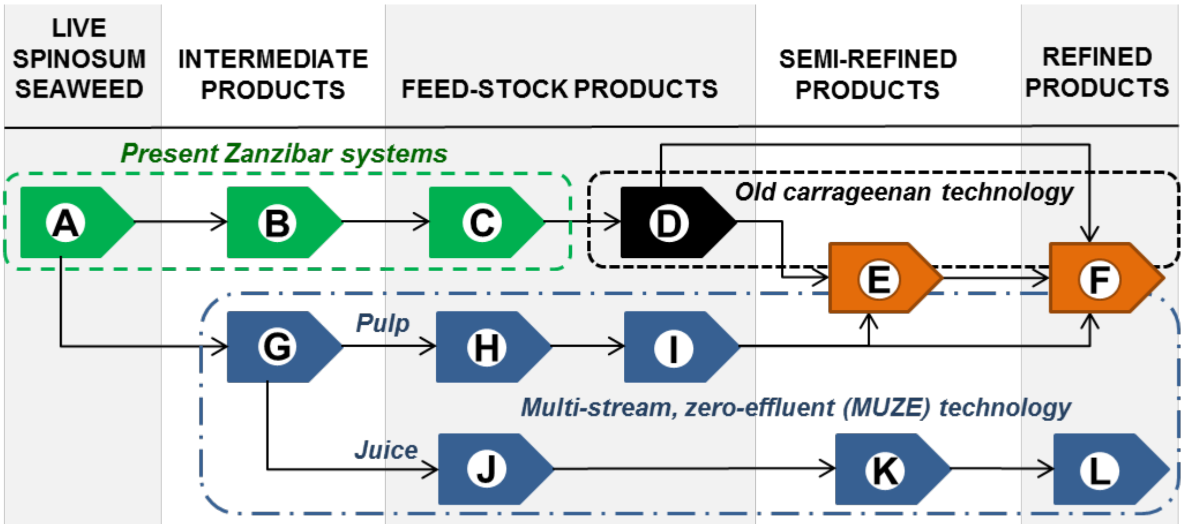
2.7. Value addition process flow options

Present Zanzibar seaweed value chains are simple in form. Farmers grow seaweed that gets dried and then is exported to international processors that use the seaweed as raw material for manufacture of carrageenan. Present Zanzibar seaweed value chains are placed in the context of future VC development options in Figures 2.5 to 2.7. There are two distinctly different paths to take, namely:

1. **Utilize conventional (old) technology** to make semi-refined iota carrageenan (SRC-I) from raw, dried seaweed (RDS) in Zanzibar-based production facilities;
2. **Employ newly developing multi-stream, zero-effluent (MUZE) technology** that commences processing using live, fresh seaweed (FS) to produce not only SRC-I but also agricultural nutrient products and various products that may be made possible from developing bio-technology.

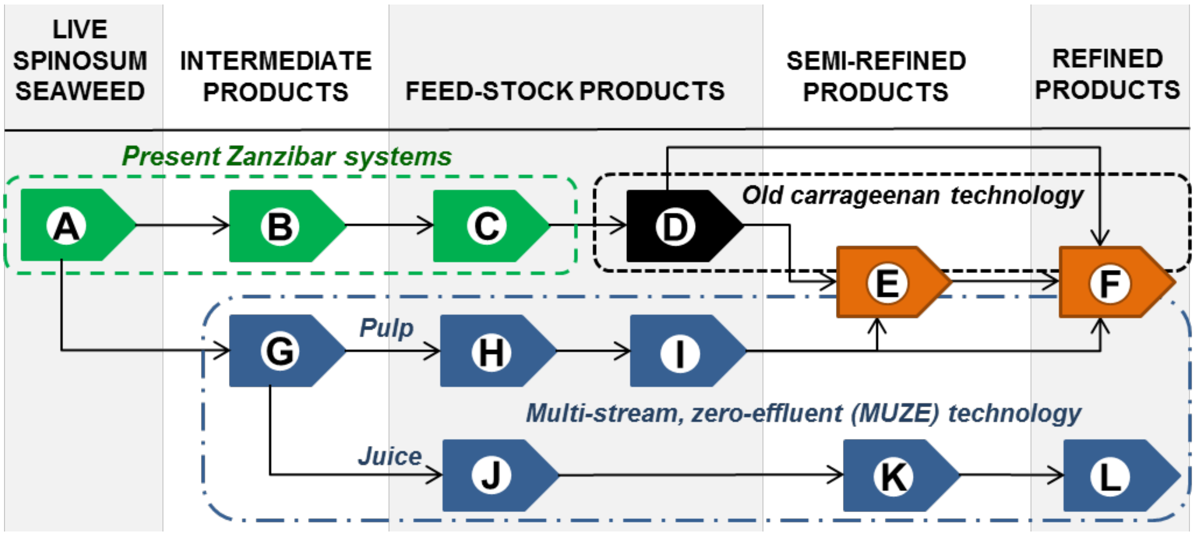
Generalized process flows for SRC and SWC have been described in Sections 2.4 and 2.6 above. MUZE technology is placed in the context of current Zanzibar seaweed processes and old SRC processes in Figure 2.5.

Figure 2.5. Spinosum seaweed process flow options for Zanzibar.



#	SYSTEMS	ACTIONS	PRODUCTS
		PRESENT ZANZIBAR SYSTEMS	
A	Seaweed agronomy	Plant and grow seaweeds in agronomy systems that include nursery, grow-out and logistics sub-systems	Fresh spinosum seaweed (FS)
B	Whole seaweed drying	Live spinosum sun dried on appropriate surfaces and bagged for sale	Raw-dried seaweed (RDS) – farm gate
C	Logistics & baling	Sacked seaweeds picked up from farmers, moved to warehouse, cleaned, re-dried, baled, moved to port and shipped	Raw-dried seaweed (RDS) – export grade
		OLD CARRAGEENAN TECHNOLOGY	
D	ATC plant	Seaweed is treated with alkali to stabilize & modify the carrageenan then is dried & packed for sale	Alkali-treated chips – iota (ATC-I)
		OLD AND/OR MUZE CARRAGEENAN TECHNOLOGY	
E	SRC plant	ATC or ATP is sanitized, treated, further-dried, milled, blended to specifications & packed for sale	Semi-refined carrageenan – iota (SRC-I)
F	RC plant	Acid insoluble matter (AIM) removed from ATC/ATP; dried, milled, blended & packed to specifications	Refined iota carrageenan (RC-I)
		NEW MULTI-STREAM, ZERO-EFFLUENT (MUZE) TECHNOLOGY	
G	Juicing units	Juicing systems mill live seaweed near farm sites then separate juice from pulp	Seaweed juice & pulp
H	Wet pulp	Wet pulp in vessels transported to process plant	Wet seaweed pulp (WSP)
I	ATP plant	Wet pulp is treated with alkali to stabilize & modify the carrageenan then pulp is semi-dried or dried	Dry or semi-dry alkali stabilized pulp (ASP)
J	Raw juice	Raw juice in vessels transported to process plant	Raw seaweed juice (RSJ)
K	Juice concentrate	Juice is concentrated, preserved, blended & packed	Seaweed juice concentrate (SJC)
L	Juice powder	Concentrated seaweed juice (CSJ) is dried to powder, blended & packed for sale	Powdered seaweed juice (PSJ)

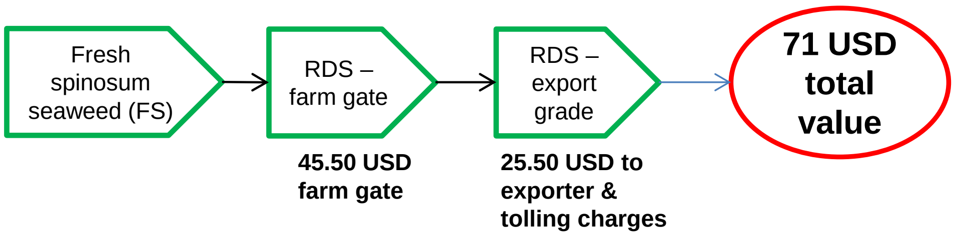
Figure 2.6. Example of yield & value partitioning for1 000 Kg of live spinosum. (FOREX 1 600 TZS = 1 USD)



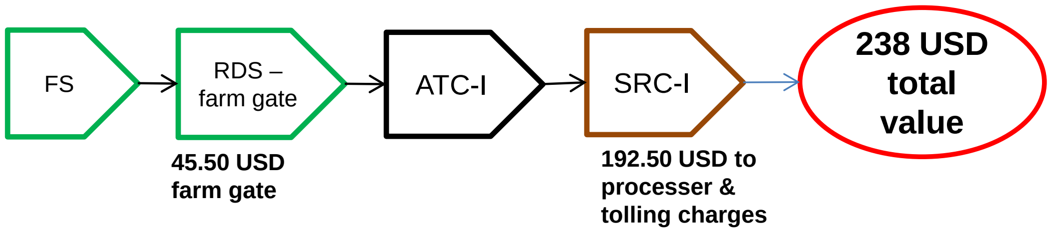
#	SYSTEM	PRODUCTS	KG	TZS/ KG	USD/ KG	USD TTL	ASSUMPTIONS
		PRESENT ZANZIBAR SYSTEMS					
A	Seaweed agronomy	Fresh spinosum seaweed (FS)	1 000	110	0.07	70.00	FS totally fresh, clean and no wilting
B	Seaweed drying	Raw Dried Seaweed (farm)	182	400	0.25	45.50	RDS is 18.2% of FS
C	Logistics & baling	RDS – export grade	178	640	0.40	71.00	2% shrinkage losses during transport & cleaning
		OLD CARRAGEENAN TECHNOLOGY					
D	ATC plant	ATC-I	119	3 200	2.00	238.00	ATC yield same as ATP
		OLD AND/OR MUZE CARRAGEENAN TECHNOLOGY					
E	SRC plant	SRC-I	95	4 000	2.50	237.50	80% yield from ATC or ASP
F	RC plant	RC-I	77	19 200	12.00	924.00	65% yield from ATC or ASP
		NEW MULTI-STREAM, ZERO-EFFLUENT (MUZE) TECHNOLOGY					
G	Juicing units	Swd juice & pulp	1 000	N/A	N/A	N/A	100% yield from FS
H	Wet pulp	Wet seaweed pulp (WSP)	810	N/A	N/A	N/A	Wet pulp is 14.7% dry solids
I	ASP plant	Dry alkali stabilized pulp (ASP)	119	4 000	2.50	297.50	14.7% ASP yield from WSP
J	Raw juice	Raw seaweed juice (RSJ)	190	1 200	0.75	142.50	7.5% solids content
K	Juice concentrate	Swd juice concentrate (SJC)	48	4 800	3.00	144.00	Concentrate 4 X to bring solids to 30%
L	Juice powder	Powdered swd juice (PSJ)	13	19 200	12.00	156	7.5% powder yield from RSJ

Figure 2.7. Example of value generated from 1 000 Kg of live spinosum according to three alternate processing scenarios that are (or may be) utilized in Zanzibar based on assumptions shown in Fig. 2.6. (Note: FOREX 1 600 TZS = 1 USD; "tolling charges" include transport costs, levies, cost of money and other third-party costs).

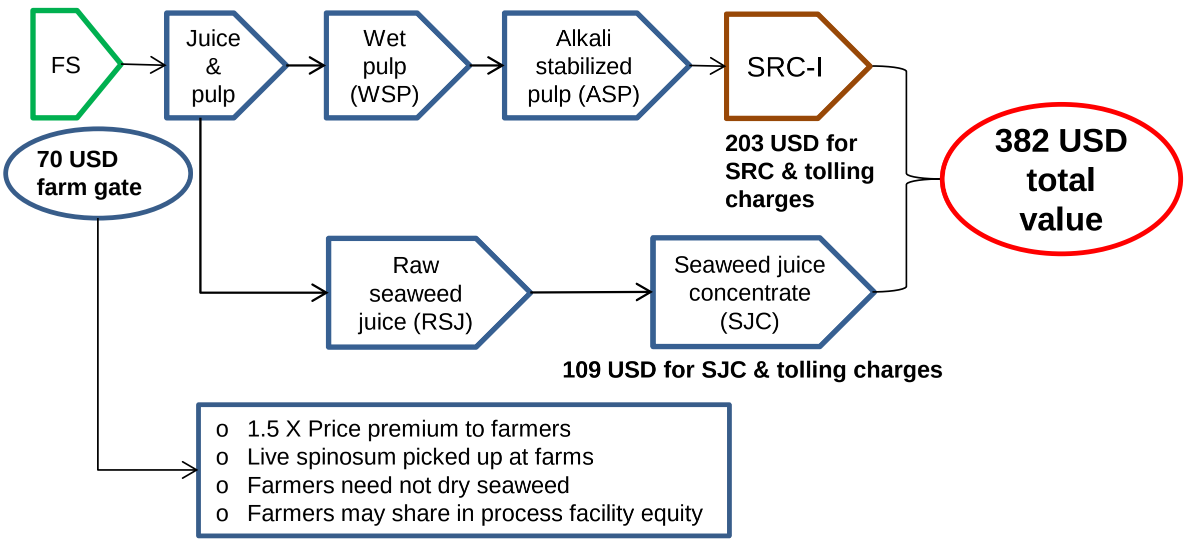
A. Present case in Zanzibar. Raw, dried seaweed sold from farmers through exporters.



B. Old technology case. Semi-refined iota carrageenan (SRC-I) produced in Zanzibar using old technology methods then sold to export markets.



C. New MUZE technology case. Semi-refined iota carrageenan (SRC-I) and agricultural nutrient products produced in Zanzibar using multi-stream, zero-effluent (MUZE) technology then sold to local, regional export markets



Figures 2.6 and 2.7 show examples of yield and value partitioning for1 000 Kg of live spinosum. Some pertinent features of this technology are:

1. By definition MUZE processing produces several value-added products and zero-waste.
2. The pulp from MUZE processing can be used to make SRC-1 as shown in Fig 2.6 and it can be used to produce agricultural nutrient products or chemical feedstock.
3. The juice from MUZE processing can be used as the basis for a variety of agricultural nutrient products for plants and animals.
4. Agricultural nutrient products have local and regional markets in Africa; not just export markets as in the case of SRC-I.
5. According to the comparison shown in Figure 2.7 total product value derived from 1 000 kg of live spinosum would be on the order of 71 USD for current Zanzibar processes, 238 USD for old technology SRC processes and 382 USD for MUZE processes.
6. These numbers are estimates but the principle holds true; more value streams and zero waste lead to more added value.
7. MUZE processing lends itself to adaptation to new process technology being developed by the biotechnology industry.

2.8 Zanzibar factory concept

2.8.1 Location

Several location choices are available for setting up a Zanzibar MUZE Seaweed Processing Facility (ZanMUZE) proposed by the present feasibility assessment. A facility could be placed in any one of the areas marked in Figure 1.1. In the long run full scale production facilities would probably be best placed in northern Pemba in the Micheweni area. In the short run a first facility may be best placed in the vicinity of Zanzibar Port, perhaps to the south near Bweleo where it may be possible to tie in with an established seaweed farmer group that has ambitions to engage in value adding activities.

> The present feasibility assessment was written with reference to a proposed multi-stream, zero-effluent (MUZE) seaweed processing facility that would commence value addition using live, fresh seaweed (FS) near to farm sites (Figure 2.7, case C). The project would catalyze establishment of technology and markets. Expansion to full commercial scale could entail installation of multiples of equipment perfected during the initial project.

2.8.2 Technology

The facility would comprise pilot scale equipment that can easily be scaled to commercial scale by the modular addition of process equipment. Research and development applicable to the project is in progress with potential partners for the proposed UNIDO project. The technology involves advances on older or expired patents for processes that contribute to SWC production (e.g. Appendices A & B). The first step toward adapting SWC process technology to Zanzibar was taken during bench-top trials undertaken during the present project (e.g. Plate 2.1 and Figure 2.6).

2.8.3 Scale and capacity

The basic facility would be scaled to handle as much as two percent of Zanzibar spinosum production as of 2012 – in other words. Based on the numbers in Figure 2.6, capacities would therefore be:

1. Equivalent to as many as 300 dry tons of spinosum if operated at full capacity;
2. that equates to a rounded total of 1 600 tons of live spinosum per annum;
3. assuming system capacity of 400 wet kg/hr. full operation would involve 4 000 hours of operation; therefore about 200 operating days per annum;
4. Annual designed capacity would therefore be:

    a. 1 296 tons of wet pulp giving 190 tons of dry, alkali-stabilized pulp;
    b. 304 tons of raw seaweed juice giving 70 tons of juice concentrate or 20 tons of SWC powder.

5. Daily designed throughput would be 8 000 kg of wet live spinosum yielding;

    a. 6 480 kg of wet pulp giving 950 kg of dry, alkali-stabilized pulp;
    b. 1 520 kg (liters) of raw seaweed juice giving 350 kg (liters) of juice concentrate.

2.9 Enterprise ownership and structure

Proposed ownership structure for the initial UNIDO MUZE SWC facility would be a blend of private and public participation involving:

1. A Zanzibar-based seaweed exporting company;
2. International investors that become shareholders and provide technology;
3. Farmer groups with a stake supported by a development fund;
4. Zanzibar Government agencies.

It is envisioned that the factory would be structured as follows:

1. Land, buildings and some processing equipment provided by Zanzibar Government agencies under lease arrangements;
2. UNIDO to select one or more private enterprises that are:
    a. able to provide technology; and

   b. are ready willing and able to transparently operate the factory (albeit with due protection for intellectual property).

3. Ownership of the managing enterprise will be transparent and may involve equity owned by farmer enterprises;

Anchor buyers will be not be a component of factory ownership but they will be important strategic business allies. They will be local, national or international private enterprises that are:

   a. further processors making semi-refined and/or refined carrageenan;
   b. formulators of agricultural nutrient products; and/or
   c. major users of agricultural nutrient products (e.g. large plantations).

2.10 Project's contributions to the economy

The seaweed processing plant will enhance the economics of seaweed value chains as follows:

1. Effective development of markets for MUZE process products could expand the demand for spinosum seaweed from Zanzibar farmers, potentially two-fold or more in the coming decade;
2. Training will enhance productivity of seaweed farms and strengthen farmer enterprises;
3. Zanzibar Government investment in seaweed processing factories will be utilized by successful business enterprises;
4. Farmers will receive effectively higher seaweed prices by about 1.5 fold (Figs. 2.6 & 2.7) and will participate in profits (see “8” below) as they secure equity in MUZE processing facilities;
5. Farm productivity will effectively increase and costs will decrease as MUZE processing systems pick up live seaweeds from farms, eliminate the need for farmers to dry seaweeds and enable production to continue during rainy seasons;
6. Effective utilization of solar energy will reduce costs, enhance product quality and minimize constraints typical of remote areas in Zanzibar including lack of water; inability to absorb waste streams; high energy cost and inadequate electrical supplies;
7. Relational links with anchor buyers/further processors will help to stabilize pricing and markets;
8. The end result should be more profits and more stable business for all value chain participants as quantified in Section 6 below. For example a production level utilizing about ten percent of the amount of 2012 Zanzibar spinosum production could yield almost 2.8 M USD EBITDA on annual sales of 4.8 M USD.

3. Marketing and sales plan

3.1 Product lines

The proposed UNIDO Zanzibar seaweed processing project involves two sets of product lines derived from the pulp and juice fractions of live spinosum. Both sets must be developed in collaboration with potential anchor buyers (Table 3.1).

Table 3.1. Proposed product lines proposed for the basic Zanzibar MUZE Seaweed Processing Facility (ZanMUZE). Prices are conservative estimates pending buyer feedback.

FRACTION	SYMBOL	PRODUCT	USD/T PRICE
Dried spinosum seaweed pulp			
	CCI	carrageenan concentrate for making refined iota carrageenan	800
	SRC-I	Semi-refined iota carrageenan	2 500
	SM-I	Spinosum seaweed meal (iota)for agricultural nutrients	800
Seaweed concentrate (SWC) juice			
	SWC-30S	SWC evaporated to 30% dissolved solids for agricultural nutrient applications or further processors & formulators.	3 000

3.2 Product efficacy and anchor buyers

Product efficacy for iota carrageenan was discussed in Section 2. Potential anchor buyers for carrageenan concentrate (CCI) products of ZanMUZE include the present buyers of Zanzibar spinosum listed in Table 1.1. There is an extended list to be developed for potential buyers of ATC-I.

The magnitude of carrageenan markets has been analysed Bixler and Porse (2010). With respect to the present UNIDO project it can be stated that production volumes for the ZanMUZE project represent one percent of Zanzibar spinosum production and this can easily be assimilated into seaweed value chains.

The need for UNIDO support of ZanMUZE is two-fold:

1. It will support the operation during the crucial period when product efficacy if established with anchor buyers based on production scale samples
2. It will cover the equity portion of farmer groups.

Efficacy for seaweed concentrates (SWC) has been well established for extracts from cold-water brown seaweeds and (to a lesser extent) for cottonii extracts. Figure 3.1 summarizes applications, effects and mechanisms. Efficacy testing of spinosum SWC is in its infancy but it is being vigorously approached by potential private sector participants in the ZanMUZE project.

The ZanMUZE project would catalyse a scale of efficacy testing that is essential to commercial market development. The main candidates as potential anchor buyers for SWC are operators of major plantations and manufacturers or formulators of SWC.

Target plantation crops are tropical crops including (but not limited to) oil palm, sugar, coffee, tea, cocoa, bananas and coconuts. Many of these can be found in Africa as well as in Asia and Latin America (e.g. Plate 3.1).

A list of companies known to manufacture seaweed concentrate (SWC) products is shown in Table 3.1. These are mostly primary manufacturers that sell agricultural nutrient building block products to re-sellers and formulators. This list is not comprehensive but it is believed to cover most of the major SWC players as of 2012.

Plate 3.1 Proposed ZanMUZE development strategy is for efficacy testing to be undertaken with major plantation and livestock operators that may become anchor buyers including **A**. oil palm **B**. bananas **C**. sugar cane **D**. poultry **E**. cocoa **F.** cattle.

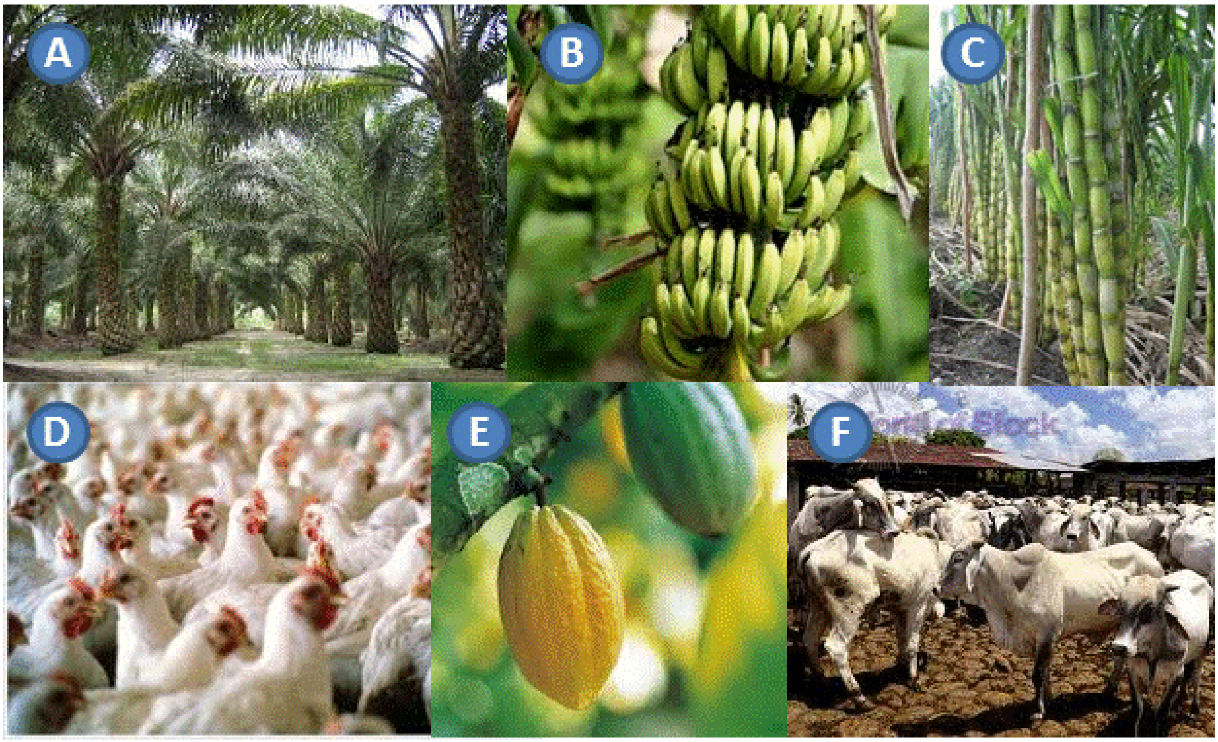


Figure 3.1. A summary of expected applications, effects and mechanisms of seaweed concentrates (SWC). These are based on work with cold water brown seaweeds (kelp and rockweed) and cottonii. Work with spinosum in in progress by Sea6 Energy, Satoumi.co and their research partners.

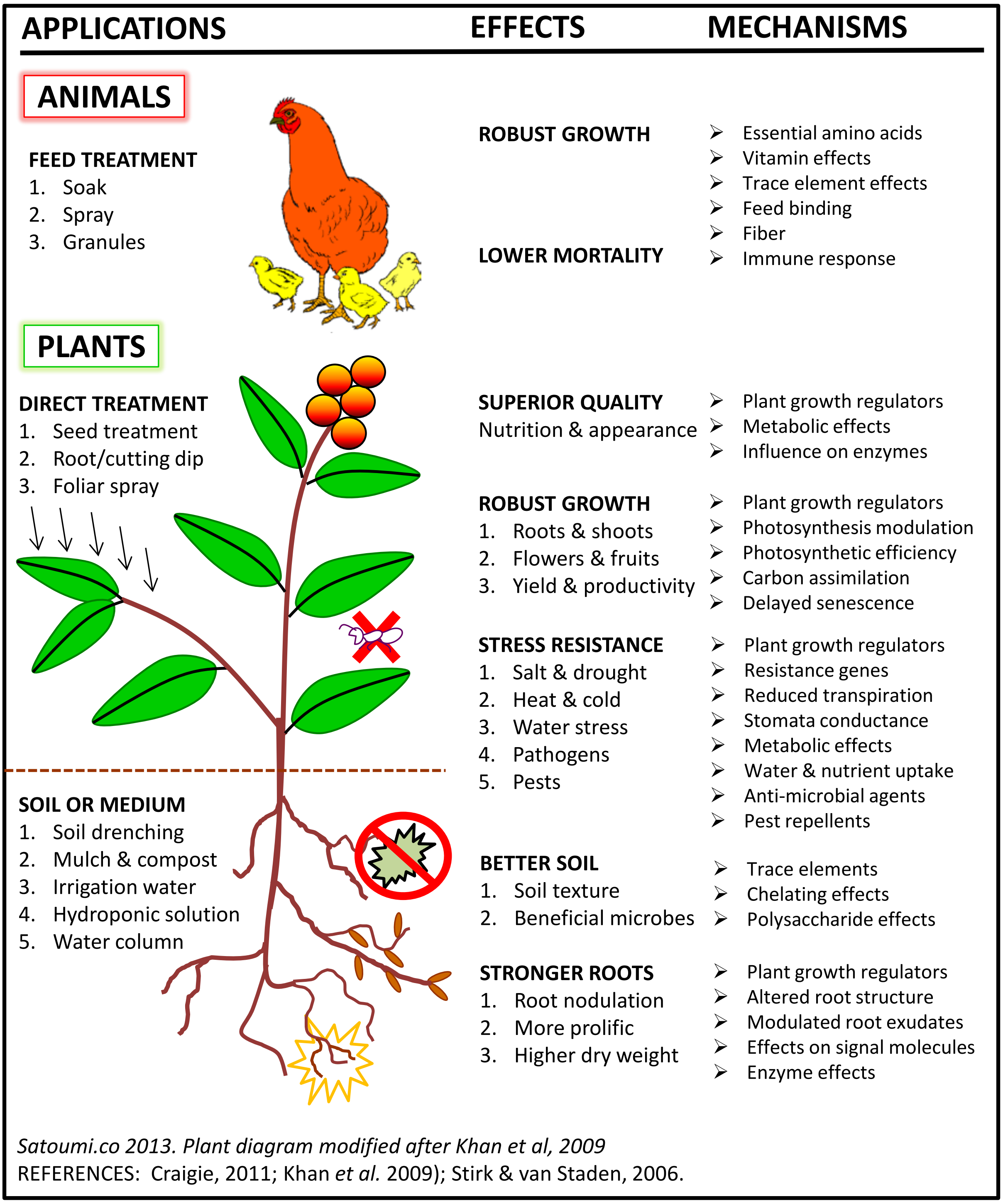


Table 3.1. A list of companies known to manufacture seaweed concentrate (SWC) products. These are mostly primary manufacturers that sell agricultural nutrient building block products to re-sellers and formulators. This list is not comprehensive but it is believed to cover most of the major SWC players as of 2012.

COMPANY	COUNTRY	PRODUCTS	SOURCE	URL
Acadian Seaplants Ltd.	CANADA	Stimplex, Tasco, Acadian	Ascophyllum, Laminaria, Fucus	http://www.acadianseaplants.com
Agarindo Bogatama P.T.	INDONESIA	Plantagar	Gracilaria spp.	http://www.agarindo-bogatama.co.id/
Algas y Bioderivados Marinos, S.A. de C.V.	MEXICO	AgroKelp	Macrocystis pyrifera	http://www.albiomar.com/
Algea AS	NORWAY	Maxicrop (various)	Ascophyllum, Laminaria, Fucus	http://www.algea.com
Aquagri Processing Pvt. Ltd.	INDIA	Aquasap	Kappaphycus alvarezii	http://www.aquagri.in
Arramara Teoranta	IRELAND	N/A	Ascophyllum nodosum	http://www.arramara.ie
BioAtlantis Ltd.	IRELAND	Bioplus, Bloom, Harvest, Ocean Green	Ascophyllum nodosum, Laminaria	http://www.bioatlantis.com
Celtic Moss	IRELAND	n.a	brown seaweeds	http://www.celticmoss.com
Datingbayan Agro-Industrial Corp.	PHILIPPINES	Algafer LPF	Kappaphycus	*N/A*
Dublin Bio-industries	PHILIPPINES	Freegrow	Kappaphycus, Eucheuma, Sargassum	*N/A*
Farmura Ltd.	UK	Alginure, Seanure	Ascophyllum	http://www.farmura.com
Goemar	FRANCE	Agrimar, GA142, many brands	Ascophyllum	http://www.goemar.com
Inversiones Patagonia S.A	CHILE	Fartum	Kelp	http://www.fartum.cl/
Kelp Products (Pty) Ltd	SOUTH AFRICA	Kelpak	Ecklonia maxima	http://www.kelpak.com/
Maxicrop International (subsidiary of Algea AS)	UK	Maxicrop (various)	Ascophyllum	http://www.maxicrop.co.uk
Natrakelp Pty. Ltd.	AUSTRALIA		Durvillaea potatorum	http://www.natrakelp.com.au
Profert	SOUTH AFRICA	Amplistim	Durvillea antarctica	http://www.profert.co.za
Qingdao Seawinner Machinery Manufacturing	CHINA	Sea Winner, Alga-2008-1	Laminaria	http://www.sea-winner.net
Seasol	AUSTRALIA	Seasol	Durvillaea potatorum	http://www.commercial.seasol.com.au
Tasmanian Seaweed Fertilizers	AUSTRALIA	Marrawa Gold	Durvillaea potatorum	http://www.taskelp.com
Thorverk	ICELAND	Alginex	Ascophyllum, Laminaria	http://www.thorverk.is

3.3 Market potential

3.3.1 Carrageenan market potential

1. **CC-I carrageenan concentrate** is a raw material that can directly replace raw, dried spinosum seaweed to present buyers. Depending on pricing and market acceptance by anchor buyers it may become a desired raw material for alcohol-precipitation processors. If this happens availability of CC-I may give competitive advantage to Zanzibar that could lead to increased sales volume.
2. **ATC-I (alkali treated chips) can be further milled to yield SRC-1 (semi-refined iota carrageenan)** which has a modest existing market. The SRC-I market could be expanded if sufficient volume is available at a price and a quality that opens up new markets (e.g. oil field applications to compete with guar gum) that could amount to thousands of tons per year.
3. **SM-I spinosum seaweed meal** can be used as soil conditioner, animal feed additive and other agricultural nutrient applications. It would enter the same market channels as SWC and annual tonnage requirements could amount to many thousands of tons per year if prices and volumes meet anchor buyers' specifications.

3.3.2 SWC application rates

Application rates and yield increases vary between crops. For un-concentrated cottonii juice (about 5% solids content), as a "rule of thumb", recommended SWC usage for many crops is about 20 lit/ha/application and a minimum of 3 applications are recommend during the crop cycle. Total usage would therefore be about 60 liters/yr. This would be equivalent to about ten liters of SWC-30S concentrate (30% dissolved solids content). Crop yields would be expected to increase by about 10-20 percent. Ex-works pricing of un-concentrated cottonii SWC juice (about 5% solids) is in the range of 0.5 USD/liter. Concentrated at 6-to-one (about 30% solids) the ex-works price of cottonii SWC would therefore be about 3 USD/liter. Assume that SWC-30S would fetch a similar price. The cost as applied to crops would therefore be about 30 USD/ha/yr. for ex-works buyers.

Anchor-buyer acceptance of carrageenan and SWC products will be based on:

- Chemical analysis of product constituents
- Rheological testing (SRC)
- Broad-spectrum bioassays (SWC)
- Efficacy testing involving small scale trials
- Full scale planting trials

For long-cycle crops acceptance may take several years.

3.3.3 Oil palm as an example for SWC usage

Oil palm is a crop that has potential to be a major user of SWC if efficacy testing gives positive results. Efficacy testing remains to be done on oil palm so dosage levels and yield changes are not known. For purposes of the present estimate it is assumed that a ten percent yield increase would result from application of ten liters of SEC-30S applied three times during the crop cycle at a cost of 30 USD/ha/yr. Average palm oil yields (e.g. in

Indonesia, the largest producer) are about 3.7 tons/hectare worth about 1,000 USD/ton so a ten percent yield increase amounting to 0.37 tons would be worth about 370 USD/ha, which is more than ten times the SWC investment.

SWC can be applied as a spray along with pesticides and fertilizers so there should be little added application cost. Fertilizer management constitutes the largest field cost item in well-run oil palm plantations in. As much as 80 % of production cost may be due to fertilizer cost. The action of SWC with many crops is to increase fertilizer efficiency.

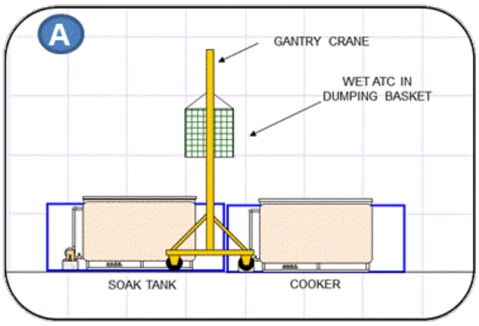
The combined hectarage of oil palm in Malaysia and Indonesia is about ten million hectares. If ten percent of this hectarage had SWC applied that could amount to ten million liters of SWC-30S per year. Since one ton of live spinosum yields about 48 liters of SWC-30S that would be equivalent to over 200 000 live tons of spinosum; equivalent to almost 38 000 tons of raw dried spinosum; which would more than triple present Zanzibar spinosum sales.

4. Production plan

4.1 Plant and process

Basic process flow for the proposed ZanMUZE facility is outlined in Section 2. Figure 4.1 shows an example of a wet system plant layout. The proposed production plan is shown in Table 4.1. The facility would initially be operated according to proven process, quality control and quality assurance protocols that are available to the project through technical advisors.

Figure 4.1. Example layout for a wet process system for the ZanMUZE ATC/SWC facility. **A.** Side view of the gantry system. **B**. Top view of the wet process line. The system could be accommodated in an area about 30 x 10 meters (300 square meters).



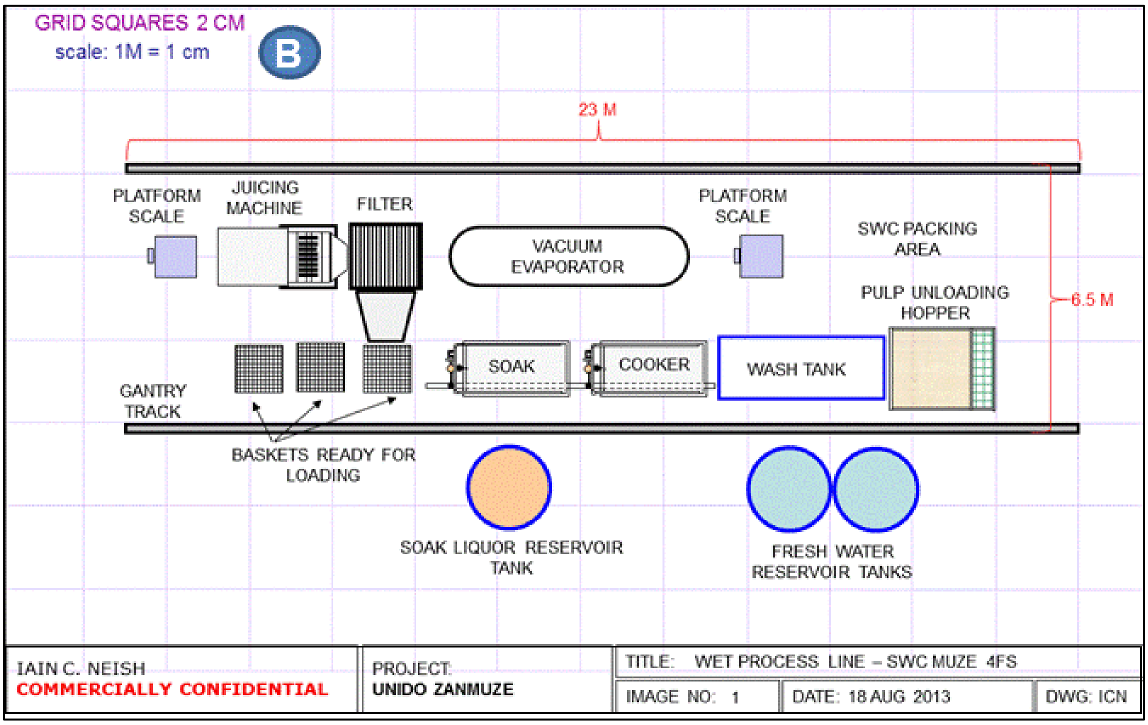


Table 4.1. Proposed production plan for the basic ZanMUZE ATC/SWC facility.

	SPINOSUM	PRODUCTS FOR SALE			
	FS	CCI	SRC-I	SM-I	SWC-6A
YEAR 1	400	20	16	8	19
YEAR 2	800	40	32	15	38
YEAR 3	1 600	80	64	30	76
TOTALS	2 800	140	112	53	133

4.2 Capital budget and timeline

4.2.1 Capital budget

Table 4.2 shows a summary capital budget for the ZanMUZE facility. Details of the estimates are contained in and Excel Workbook that is available on request and was attached to the submission of the present report to UNIDO. Features of these estimates included:

1. It must be emphasized that this was a preliminary budget based on experience with factory projects in South East Asia so current quotations must be obtained for delivery to Zanzibar.
2. Estimates were conservative so they should cover actual costs.
3. The capital cost estimates were for capital item costs only. They did not include design, installation and start-up costs that would involve the use of consultants and contractors.
4. Procedures for accounting for depreciation have yet to be determined for the project.
5. Facilities, utilities and equipment were scaled to allow for ready expansion of ZanMUZE facility capacity.

Table 4.2. Summary capital budget for the ZanMUZE facility. Note that in this example no value was assessed to land as it was assumed that the Zanzibar government could make land available for the project. Allocations of this budget to government, UNIDO and the private sector are tentative. Any UNIDO participation would need to be part of a larger UNIDO capacity strengthening project that still would need to be negotiated and funded.

	CAPITAL COST COMPONENTS (TENTATIVE ALLOCATIONS)	USD total	ANNUAL DEPRECIATION USD
GOVERNMENT			
0	Land	70 000	0
1	buildings & improvements	239 800	25 520
Government subtotal		309 800	25 520
UNIDO			
2	Utilities	23 500	5 150
3	Office equipment	18 450	4 363
4	Laboratory equipment	32 085	7 436
5	Drying systems	116 100	23 957
UNIDO subtotal		190 135	40 905
PRIVATE SECTOR			
6	Wet process systems	125 100	26 730
7	Milling, blending & packing systems	71 700	14 340
8	Vehicles and vessels	64 000	12 800
Private sector subtotal		260 800	53 870
GRAND TOTAL		760 735	120 295
Assumptions:			
	TZS per USD =	1 600	
	TZS per Euro =	2 155	
	INSTALLATION & STARTUP =	0	

4.2.3. Timeline

The most critical timeline elements were expected to be (1) time to install buildings and infrastructure elements; and (2) time to import machinery and clear it through customs procedures. A period of six months was allowed for these processes. If that proves to be true the facility should be able to generate product within the first year of operation according to the schedule indicated in the sales plan below and described as follows:

6. **During Year 1** the facility would be under construction so at best it could only operate at 25% of designed capacity. Staff would be training at the same time that they participate in setting up the operation.
7. **During Year 2** full staffing would be put in place and production would be 50% of designed capacity.
8. **During Year 3** the facility would operate at full capacity.

4.3 Production and sales

The production and sales plan (Table 4.3) was designed around the product lines shown in Table 3.1. Assumptions underlying this plan were:

9. **During Year 1** the facility would be under construction so at best it could only operate at 25% of designed capacity. Staff would be trained at the same time that they participate in setting up the operation. Samples of production would have to be given free for efficacy testing by various organizations so it was assumed that prices obtained for production would average only 75% of eventual sales prices.
10. **During Year 2** full staffing would be put in place and production would be50% of designed capacity. Average prices at 0.90% of target prices due to product sampling.
11. **During Year 3** the facility would operate at full capacity with full pricing.

Table 4.3. Proposed production and sales plan for the UNIDO Zanzibar MUZE Seaweed Processing Facility (ZanMUZE) during the first three years of operation.

PRODUCTION AND SALES	YEAR 1	YEAR 2	YEAR 3	TOTALS
Spinosum needs in metric tons	**Total**	**Total**	**Total**	
As live weight	400	800	1 600	**2 800**
Production/sales in metric tons	**Total**	**Total**	**Total**	
CC-I carrageenan concentrate	20.0	40.0	80.0	**140**
SRC-I semi-refined iota carrageenan	16.0	32.0	64.0	**112**
SM-I spinosum seaweed meal	7.5	15.0	30.0	**53**
SWC-30S juice concentrate	19.0	38.0	76.0	**133**
Average prices in USD	**Avg.**	**Avg.**	**Avg.**	
CC-I carrageenan concentrate	600	720	800	**2 120**
SRC-I semi-refined iota carrageenan	1 875	2 250	2 500	**6 625**
SM-I spinosum seaweed meal	600	720	800	**2 120**
SWC-30S juice concentrate	2 250	2 700	3 000	**7 950**
Gross sales in USD	**Total**	**Total**	**Total**	
CC-I carrageenan concentrate	12 000	28 800	64 000	**104 800**
SRC-I semi-refined iota carrageenan	30 000	72 000	160 000	**262 000**
SM-I spinosum seaweed meal	4 500	10 800	24 000	**39 300**
SWC-30S juice concentrate	42 750	102 600	228 000	**373 350**
TOTAL SALES IN USD	**89 250**	**214 200**	**476 000**	**779 450**

5. Human resources plan

Staff will be recruited in Zanzibar with preference being given to people with adequate training and experience who are native to seaweed production areas. Pay scales are estimates based on local advice.

Table 5.1. Proposed list of staff and pay levels (including payroll added costs) necessary to operate the ZanMUZE facility during three years of development and operation.

	Year 1 staff				Year 2 staff				Year 3 staff			
	MAN	TZS/	USD/	USD/		TZS/	USD/	USD/		TZS/	USD/	USD/
Salaried staff	**YRS**	**MO**	**MO**	**YR**	**NO.**	**MO**	**MO**	**YR**	**NO.**	**MO**	**MO**	**YR**
Factory manager	1.0	3 200 000	2 000	24 000	1	3 200 000	2 000	24 000	1	3 200 000	2 000	24 000
Assistant factory manager	0.0	2 400 000	1 500	0	1	2 400 000	1 500	18 000	1	2 400 000	1 500	18 000
Administation supervisor	0.5	1 600 000	1 000	6 000	1	1 600 000	1 000	12 000	1	1 600 000	1 000	12 000
Administrative staff	0.5	320 000	200	1 200	2	320 000	200	4 800	2	320 000	200	4 800
Technical supervisor	1.0	2 400 000	1 500	18 000	1	2 400 000	1 500	18 000	1	2 400 000	1 500	18 000
Lab technicians	0.5	480 000	300	1 800	2	480 000	300	7 200	2	480 000	300	7 200
Security	2.0	240 000	150	3 600	6	240 000	150	10 800	6	240 000	150	10 800
Fixed labor totals	**5.5**	**10 640 000**		**54 600**	**14**	**10 640 000**		**94 800**	**14**	**10 640 000**		**94 800**
Variable labor (staff on wages)												
Shoreside milling/pickup	1.0	480 000	300	3 600	4	480 000	300	14 400	4	480 000	300	14 400
Factory milling	1.0	480 000	300	3 600	4	480 000	300	14 400	4	480 000	300	14 400
Wet process	1.0	480 000	300	3 600	4	480 000	300	14 400	4	480 000	300	14 400
Drying & evaporation	1.0	480 000	300	3 600	4	480 000	300	14 400	4	480 000	300	14 400
Milling, blending, packing	1.0	480 000	300	3 600	2	480 000	300	7 200	2	480 000	300	7 200
Variable labor totals	**5.0**	**2 400 000**		**18 000**	**18**	**2 400 000**		**64 800**	**18**	**2 400 000**		**64 800**
Grand totals	**10.5**	**13 040 000**		**72 600**	**32**	**13 040 000**		**159 600**	**32**	**13 040 000**		**159 600**

6. Financial plan

6.1 Projections for ZanMUZE facility

Details of financial estimates are contained in and Excel Workbook that is available on request and was attached to the submission of the present report to UNIDO. Since the ZanMUZE project was designed as a sub-commercial scale facility complete financial analyses including profit and loss statements, balance sheet analyses and other analyse were not undertaken. These would be included in business plans based on results from ZanMUZE project results.

The ZanMUZE facility was designed to serve as a small-scale production facility that can generate commercial sized batches of product for efficacy testing and approvals by potential anchor buyers. It was not designed at a scale expected to be large enough to generate attractive financial returns. As product acceptance is achieved with anchor buyers and cost/price structures develop the facility can be expanded based on funded business plans.

Table 6.1 A budget summary for the UNIDO Zanzibar MUZE Seaweed Processing Facility (ZanMUZE) during its first three years of operation. EBITDA means Earnings Before Interest, Taxes, Depreciation, and Amortization.

ITEM	YR 1	YR 2	YR 3	TOTALS
Spinosum needs in metric tons				
Total tons live spinosum purchased	400	800	1 600	2 800
Sales in metric tons				
CC-I carrageenan concentrate	20	40	80	140
SRC-I semi-refined iota carrageenan	16	32	64	112
SM-I spinosum seaweed meal	8	15	30	53
SWC-30S juice concentrate	19	38	76	133
Sales in USD				
CC-I carrageenan concentrate	12 000	28 800	64 000	104 800
SRC-I semi-refined iota carrageenan	30 000	72 000	160 000	262 000
SM-I spinosum seaweed meal	4 500	10 800	24 000	39 300
SWC-30S juice concentrate	42 750	102 600	228 000	373 350
GROSS SALES IN USD USD	**89 250**	**214 200**	**476 000**	**779 450**
Total variable G&S cost	63 701	144 886	213 362	421 949
Total fixed cost of G&S	57 947	100 157	100 157	258 261
Total sales and marketing costs	20 400	20 400	20 400	61 200
Total G&A costs	10 800	15 000	15 000	40 800
Total R&D costs	6 000	6 000	6 000	18 000
Costs & benefits in USD				
Total seaweed costs	27 500	55 000	110 000	192 500
Total tolling costs	131 348	231 443	244 919	607 710
TOTAL COSTS	158 848	286 443	354 919	800 210
TOTAL INCOME	89 250	214 200	476 000	779 450
EBITDA	**-69 598**	**-72 243**	**121 081**	**-20 760**
Depreciation in USD	120 295	120 295	120 295	360 884
EARNINGS AFTER DEPRECIATION	-189 893	-192 538	786	-381 644

6.2 Expansion to commercial scale

BASE CASE – ORIGINAL ZANMUZE PILOT FACILITY: According to the estimates presented in Table 5.1, the ZanMUZE facility would be operating at positive EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) by the third year if anchor buyer price and volume aspirations are achieved or exceeded. Losses would be incurred during the two startup years of operation.

5P CASE – FIVE PERCENTAGE EXPANSION: The ZanMUZE facility was designed for ready expansion to process five percent of Zanzibar spinosum production (2012 basis). That would involve additional capital investment on the order of an additional 300 K USD on top of the 660 K USD needed for the base case. The plant would require little additional staff and would approximately double the amount of variable labor.

10P CASE – TEN PERCENTAGE EXPANSION: Expansion to ten percent of Zanzibar spinosum production (2012 basis) could involve additional capital investment that would approximately double the 5P case so the total would be on the order of two million dollars. It would require some additional staff and would approximately double the amount of variable labor used in the 5P case.

Table 6.2. Comparison of annual production and sales projections for the ZanMUZE Seaweed Processing Facility operating at full capacity (BASE) with 5P and 10P expansion scenarios operating at full capacity.

PRODUCTION AND SALES	BASE	5P	10P
Spinosum needs in metric tons	**Total**	**Total**	**Total**
As live weight	1 600	8 000	16 000
Production/sales in metric tons	**Total**	**Total**	**Total**
CC-I carrageenan concentrate	80.0	400.0	800.0
SRC-I semi-refined iota carrageenan	64.0	320.0	640.0
SM-I spinosum seaweed meal	30.0	150.0	300.0
SWC-30S juice concentrate	76.0	380.0	760.0
Average prices in USD	**Avg.**	**Avg.**	**Avg.**
CC-I carrageenan concentrate	800	800	800
SRC-I semi-refined iota carrageenan	2 500	2 500	2 500
SM-I spinosum seaweed meal	800	800	800
SWC-30S juice concentrate	3 000	3 000	3 000
Gross sales in USD	**Total**	**Total**	**Total**
CC-I carrageenan concentrate	64 000	320 000	640 000
SRC-I semi-refined iota carrageenan	160 000	800 000	1 600 000
SM-I spinosum seaweed meal	24 000	120 000	240 000
SWC-30S juice concentrate	228 000	1 140 000	2 280 000
TOTAL SALES IN USD	**476 000**	**2 380 000**	**4 760 000**

Table 6.2 compares annual production and sales projections for the ZanMUZE seaweed processing facility operating at full capacity (BASE) with 5P and 10P expansion scenarios operating at capacity. Table 6.3 compares annual budget projections for the same scenarios. These comparisons suggest that economies of scale would result in increasingly profitable operation of a commercial ZanMUZE operation as expansion occurs. A 10P scale of ZanMUZE would require about 8 000 tons of live spinosum per annum which is equivalent to about 1 500 tons of dried spinosum.

Table 6.3. Comparison of annual budget projections for the ZanMUZE Seaweed Processing Facility operating at full capacity (BASE) with 5P and 10P expansion scenarios operating at full capacity. Additional investment costs are outlined above. EBITDA means Earnings Before Interest, Taxes, Depreciation, and Amortization.

ITEM	BASE	5P	10P
Spinosum needs in metric tons			
Total tons live spinosum purchased	1 600	8 000	16 000
Sales in metric tons			
CC-I carrageenan concentrate	80	400	800
SRC-I semi-refined iota carrageenan	64	320	640
SM-I spinosum seaweed meal	30	150	300
SWC-30S juice concentrate	76	380	760
Sales in USD			
CC-I carrageenan concentrate	64 000	320 000	640 000
SRC-I semi-refined iota carrageenan	160 000	800 000	1 600 000
SM-I spinosum seaweed meal	24 000	120 000	240 000
SWC-30S juice concentrate	228 000	1 140 000	2 280 000
GROSS SALES IN USD USD	**476 000**	**2 380 000**	**4 760 000**
Total variable G&S cost	213 362	837 579	1 675 158
Total fixed cost of G&S	100 157	126 617	126 617
Total sales and marketing costs	20 400	40 800	81 600
Total G&A costs	15 000	30 000	60 000
Total R&D costs	6 000	12 000	24 000
Costs & benefits in USD			
Total seaweed costs	110 000	550 000	1 100 000
Total tolling costs	244 919	496 996	867 375
TOTAL COSTS	354 919	1 046 996	1 967 375
TOTAL INCOME	476 000	2 380 000	4 760 000
EBITDA	**121 081**	**1 333 004**	**2 792 625**
Depreciation in USD	120 295	180 442	360 884
EARNINGS AFTER DEPRECIATION	786	1 152 562	2 431 741

According to these estimates a production level utilizing about ten percent of the amount of 2012 Zanzibar spinosum production could yield almost 2.8 USD EBITDA on annual sales of 4.8 M USD.

6.3 Long-range potentials

As explained in Section 3 of the present report, market potentials could be very large for MUZE products made from spinosum. Even if Zanzibar production was doubled it appears that markets could easily absorb MUZE product volume provided that efficacy is demonstrated and anchor buyers are engaged.

Seaweed biomass is getting increasing attention from biotechnology developers in global technology centers. Some are already turning their attention to spinosum because of its demonstrated biomass productivity and potentially attractive production economies. It seems that major imminent uses exist for increased spinosum biomass and further uses are likely to develop over the coming decades.

For Zanzibar there is a need to use the next few years to bridge the development gap and consolidate Zanzibar's position as a major global spinosum biomass source. The ZanMUZE project is designed to assist in achieving that goal.

7. References

Bixler HJ & Porse H, 2010. ***A Decade of Change in the Seaweed Hydrocolloids Industry*.** Plenary paper presented at the XX International Seaweed Symposium, Ensenada Mexico, February, 2010

Craigie JS, 2011. ***Seaweed extract stimuli in plant science and agriculture.*** J Appl Phycol (2011) 23:371–393

FAO, 2012. ***The State of World Fisheries and Aquaculture 2012.*** ISSN 1020-5489. Publishing Policy and Support Branch Office of Knowledge Exchange, Research and Extension FAO.

Khan W, Rayirath UP, ***Subramanian, S, Jithesh M N, Rayorath, P, Hodges DM Critchley, A T, Craigie, J.S, Norrie, J & Prithiviraj, B, 2009. Seaweed Extracts as Biostimulants of Plant Growth and Development***. J Plant Growth Regul DOI 10.1007/s00344-009-9103-x.

MACEMP, 2009. ***The Status of Zanzibar Coastal Resources: Towards the Development of Integrated Coastal Management Strategies and Action Plan***. Prepared by the Zanzibar Department of Environment through support from Marine and Coastal Environment Project (MACEMP).

Msuya FE, 2011. ***A Study of Working Conditions in the Zanzibar Seaweed Farming Industry.*** Published by Women in Informal Employment: Globalizing and Organizing (WIEGO) as part of the Inclusive Cities project and MDG3 Fund: Investing in Equality. ISBN number: 978-92-95095-40-3.

Msuya FE, 2011. ***The impact of seaweed farming on the socioeconomic status of coastal communities in Zanzibar, Tanzania***. WORLD AQUACULTURE 42:3 pp 45-48. World Aquaclture Society, Baton Rouge, LA USA.

Msuya FE, 2013. ***Some Social and Economic Dimensions of Seaweed Aquaculture in the Tanzania*.** In Valderrama, D., Cai, J., Hishamunda, N. & Ridler, N., eds. 2013. *Social and economic dimensions of carrageenan seaweed farming*. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO.

Msuya FE, (in prep.). ***Opportunities in the aquaculture sector of Zanzibar: youths and women in seaweed farming*.** Submitted to Food and Agricultural Organization, under the Personal Services Agreement (PSA-NAT) Contract, January 2013.

Neish IC, 2013. ***Some Social and Economic Dimensions of Seaweed Aquaculture in Indonesia***. In Valderrama, D., Cai, J., Hishamunda, N. & Ridler, N., eds. 2013. *Social and economic dimensions of carrageenan seaweed farming*. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO.

Neish, !C & Msuya, FE 2013. *Seaweed Value Chain Assessment of Zanzibar*. Report submitted for UNIDO Project no 13083 "Building Seaweed Processing Capacities in Zanzibar and Pemba: Creating value for the poor".

Stirk, WA & van Staden, J, 2006. *Seaweed Products as Biostimulants in Agriculture*. In World Seaweed Resources, an authoritative reference system. Critchley, A.T., Ohno, M. and Largo, D.B. [Eds}.

Valderrama D, Cai J, Hishamunda, N & Ridler, N, eds. 2013. *Social and economic dimensions of carrageenan seaweed farming*. Fisheries and Aquaculture Technical Paper No. 580. Rome, FAO.

APPENDIX A

US006893479B2

(12) **United States Patent**
Eswaran et al.

(10) **Patent No.: US 6,893,479 B2**
(45) **Date of Patent: May 17, 2005**

(54) **INTEGRATED METHOD FOR PRODUCTION OF CARRAGEENAN AND LIQUID FERTILIZER FROM FRESH SEAWEEDS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 199 days.

(21) Appl. No.: **10/222,977**

(22) Filed: **Aug. 19, 2002**

(65) **Prior Publication Data**

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(51) **Int. Cl.**^{7} **C05F 11/00**
(52) **U.S. Cl.** **71/23**; 71/64.1
(58) **Field of Search** 71/23, 64.1

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,630,710 A * 12/1971 Frederickson 71/23
5,201,930 A * 4/1993 Campbell 71/23

FOREIGN PATENT DOCUMENTS

GB 2150552 * 7/1985

OTHER PUBLICATIONS

Comline Biotechnology & Medical, Jan. 14, 1998.*

Sumera et al., "Extraction and Partial Characterization of Auxin–Like Substances from *Sargassum polycystum* C. Ag.," *Botanica Marina*, 1981, pp. 157–163, vol. XXIV, Walter de Gruyter & Co, Berlin • New York.

Dawes et al., "Seasonal and Reproductive Aspects of Plant Chemistry, and *i–Carrageenan* from Floridian *Eucheuma* (Rhodophyta, Gigartinales)," *Botanica Marina*, 1977, pp. 137–147, vol. XX, Walter de Gruyter & Co, Berlin • New York.

Craigie et al., *Handbook of Phycological Methods*, 1978, pp. 112–131, Cambridge University Press, London.

Lewis et al., "Commerical production and applications of algal hydrocolloids," *Algae and Human Affairs*, 1990, pp. 218–236, Cambridge University Press, Cambridge.

Matting et al., "Seaweed use in agriculture and horticulture," *Algae and Human Affairs*, 1990, pp. 357–370, Cambridge University–Press, Cambridge.

Chapman et al., "Seaweed as Animal Fodder. Manure and for Energy," *Seaweeds and Their Uses*, 1980, pp. 30–61, Chapter 2, Chapman and Hall, London • New York.

Whistler et al., "Polysaccharides and Their Derivatives," *Industrial Gums*, 1993, pp. 145–180, 3_{rd} Edition, Academic Press Inc., New York.

Blunden, "Cytokinin Activity of Seaweed Extracts," *Marine Natural Products Chemistry*, 1977, pp. 337–344, 3^{rd} Edition, Plenum Press, New York.

* cited by examiner

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(74) *Attorney, Agent, or Firm*—Foley & Lardner LLP

(57) **ABSTRACT**

An integrated method is developed to utilize to a maximum extent the fresh biomass of seaweeds such as *Kappaphycus alvarezii* that can be crushed to release sap and where the sap is useful as a potent liquid fertilizer after suitable treatment with additives and dilution while the residue is a superior raw material for extraction of κ-carrageenan, thereby enhancing the value of the seaweed. Other advantages of the invention include a reduced drying time and drying area to obtain the raw material for κ-carrageenan production in dry and storable form, a reduced cost of transporting and storing this raw material because of its lesser bulk, easier handling due to its free flowing granular nature, and its direct use for gel preparation in certain applications.

23 Claims, 1 Drawing Sheet

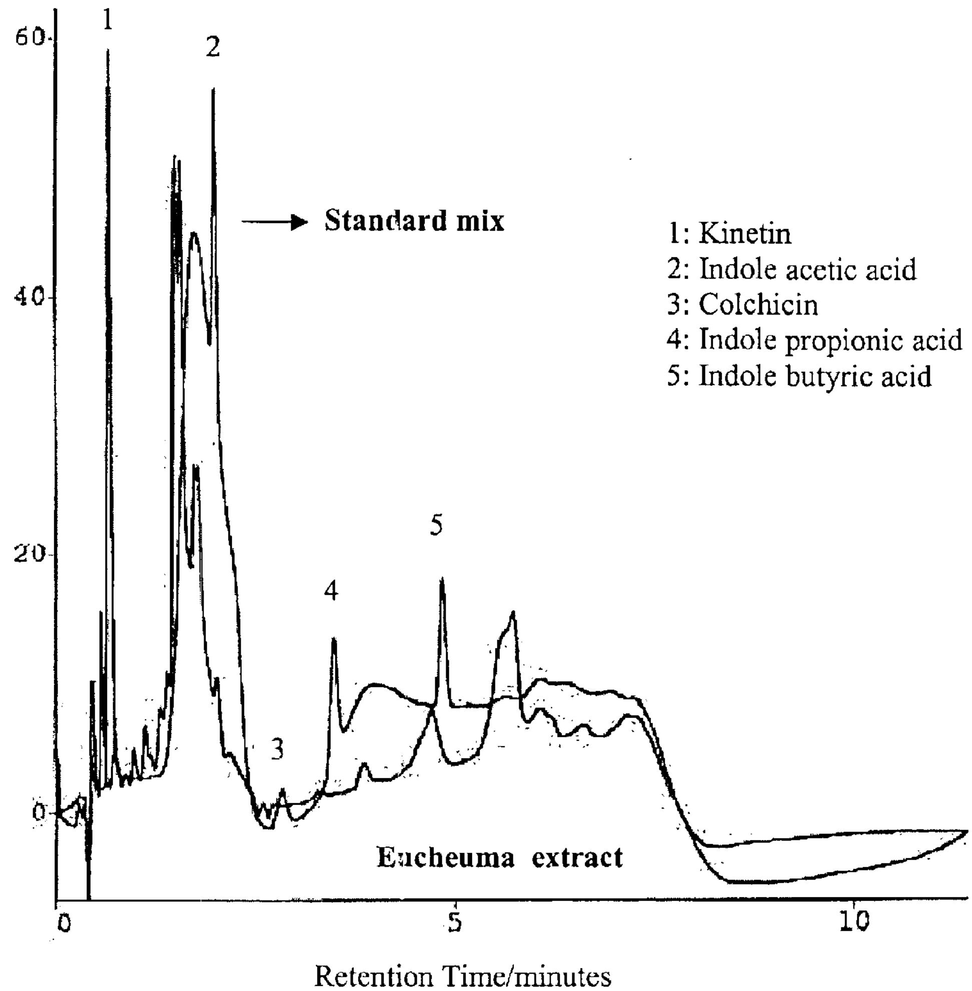

Fig. 1 Comparison of HPLC chromatograms of *Eucheuma* liquid (pH 8.6 extract) with the mixture of standard growth promoting substances.

INTEGRATED METHOD FOR PRODUCTION OF CARRAGEENAN AND LIQUID FERTILIZER FROM FRESH SEAWEEDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to production of phycocolloid and fertilizer from fresh seaweeds.

Specifically, the invention relates to preparation of κ-carrageenan and liquid fertilizer from fresh *Kappaphycus alvarezii* (also known as *Eucheuma striatum* or *Eucheuma cottonii* or very simply as *Eucheuma*) in a manner that allows integrated recovery of two products from the seaweed simultaneously with other accompanying benefits so as to maximize the returns from cultivation of the seaweed.

2. Background and Prior Art References

κ-Carrageenan is used as a thickening agent in numerous applications such as pet food, fruit jam, toothpaste, and ice cream. The red seaweed, *Kappaphycus alvarezii*, which grows in tropical waters, is cultivated extensively in countries such as the Philippines and Indonesia as a source of κ-carrageenan. J. G. Lewis, N. F. Stanley and G. G. Guist, in the book, *Algae and Human Affairs*, C. A. Lembi and J. R. Waaland, Eds., Cambridge University Press, Cambridge, 1990; pp. 218), have reviewed the diverse applications of refined and semi-refined κ-carrageenan. G. H. Thirkelsen (in: *Industrial Gums—Polysaccharides and their Derivatives*, R. L. Whistler and J. N. BeMiller, Eds., 3^{rd} Edition, Academic Press Inc., New York, 1993, pp 145–180) has also described the diverse applications of carrageenan.

V. J. Chapman and D. J. Chapman have reported in their book, *Seaweeds and their Uses*, (Chapman and Hall, London & New York, 1980; Chapter 2, pp 30–61) that several seaweed extracts are useful as foliar spray for improved plant growth.

G. Blunden (in: Marine Natural Products Chemistry, D. J. Faulkner and W. H. Fenical, Eds., Plenum Press, New York, 1977; pp. 337–344) has provided evidence of cytokinin activity of seaweed extracts while F. C. Sumera and G. J. B. Cjipe (in: *Botanica Marina*, Vol. 24, 157–163, 1981) have reported auxin-like substances in the extracts of *Sargassum polycystum*. B. Metting, W. R. Rayburn and P. A. Raynand (in: *Algae and Human Affairs*, C. A. Lembi and J. R. Waaland, Eds., Cambridge University Press, Cambridge, 1990; pp. 357–370) have reported that many seaweeds contain plant growth regulators such as auxins, gibberellins, abscisic acid and quaternary ammonium compounds.

The red seaweed *Kappaphycus alvarezii* is known as a source of refined and semi-refined κ-carrageenans. *Eucheuma* preparation is also used as foliar spray to enhance flowering and growth of crop. Conventionally, all seaweeds, including *Eucheuma*, are dried at the harvesting location and baled for shipment to processing plants as described by V. J. Chapman and D. J. Chapman in their book, *Seaweeds and their Uses* (Chapman and Hall, London & New York, 1980; Chapter 2, pp 30–61). In most collection areas, sun-drying remains the most cost-effective technique, although oil-fired mechanical dryers are used to a limited extent. The dry seaweed is used mainly for preparation of phycocolloids. Some factories are dedicated to production of seaweed fertilizer. At the cottage industry level—such as in certain coastal villages of India—freshly harvested seaweed is boiled in earthen pots, the liquid extract utilised as fertilizer and the solid residue is either discarded or used as manure.

Reference may be made to Alphons C. J. Voragen, Walter Pilnik, Claus Rolin, Beinta U. Marr, Ian Challen, Abdel Wahab Riad and Rachid Lebbar in Polysaccharides-Carrageenan (Ullmann's Encyclopedia of Industrial Chemistry, Sixth Edition, 2002 Electronic Release) wherein production of κ-carrageenan from *Eucheuma cottonii* (*Kappaphycus alvarezii*) is described as follows: "After being harvested, the algae are washed and dried to a dry matter content of ca. 25 wt. %; . . . The dried algae are treated with alkali and ground to a paste. Alkaline conditions facilitate extraction of the macerated algae." It can be seen that the present practice is to dry the harvested algae and subsequently utilize this dried algae for production of κ-carrageenan. There is no reference to recovery of any liquid fertilizer or second product prior to drying of the harvested seaweed nor is there any mention of any method other than drying for removing water from the fresh algae.

Reference may be made to S. Craigie and C. Leigh (in: *Handbook of Phycological Methods*, Hellebust, J A and Craigie J S., Eds., Cambridge University Press, London, 1978; pp.112) who have reported that red seaweed is used in frozen-fresh condition for extraction of refined carrageenan. However, the authors have not reported the preparation of any fertilizer from the same seaweed.

Reference may be made to Q. Hurtado-Ponce (*Botanica Marina* 38:137, 1995) who has reported that *Kappaphycus alvarezii* (more popularly known as *Eucheuma*) seaweed was harvested, washed and sun/oven dried for recovery of carrageenan. No reference is made to recovery of fertilizer from the same plant.

Reference may be made to G. Lewis, N. F. Stanley and G. G. Guist, (in *Algae and Human Affairs*, C. A. Lembi and J R Waaland, Eds.,Cambridge University Press, Cambridge, 1990; pp. 218) who have reported the extraction of carrageenan by drying of the fresh red sea weed after harvesting. No reference is made to simultaneous recovery of any fertilizer.

C. J. Dawes, N. F. Stanley and D. J. Stancioff (*Botanica Marina*, Vol XX, 1977, Fasc. 3) have also reported that seaweeds are dried in the sun and subsequently utilised for extraction of carrageenan. No mention is made of recovery of fertilizer from the same plant.

P. M. Alino, G. J. B. Cajipe, E. T. Ganzon-Fortes, W. R. Y. Licuanan, N. E. Montano, and L. M. Tupas (in: *The use of marine organisms in folk medicine and horticulture : A preliminary study*, SICEN Leaflet 1. Supplement of SICEN Newsletter, published by Seaweed Information Center (SICEN), Marine Science Institute, University of Philippines, Dilman, Quezon City, Philippines, February 1990), have reported that Eucheuma decoction is used as foliar spray to enhance flowering and growth of crops. However there is no mention of simultaneous recovery of carrageenan from the same seaweed.

L. Tupas and N. E. Montano (in: *Philipp. J. Sci.*, Monograph No. 17, pp 29–35, 1987) have reported the effects of alkaline extracts from Philippine seaweeds as foliar spray on crops. No mention is made of simultaneous recovery of carrageenan from the seaweed.

It is known to those practising the art that effluent generated after recovery of phycocolloids from different seaweeds can be utilised as fertilizer after suitable treatment. It is also known that the harsh conditions under which seaweeds are normally processed for phycocolloid extraction can be detrimental to the growth promoting substances present in the seaweed.

It is also know to those involved in seaweed cultivation that drying of seaweed after harvesting is an involved affair and any savings in the area or time required for drying would be advantageous.

It is also known to those involved in seaweed cultivation and downstream processing that dry seaweeds are bulky and, therefore, costly to transport and store, and any savings in the above would be advantageous.

OBJECTS OF THE INVENTION

The main object of the present invention is to remove and recover the liquid content (sap) of freshly harvested *Kappaphycus alvarezii* by a method of crushing and filtering instead of drying so as obtain sap and a solid residue as two useful products simultaneously and cost-effectively, wherein the sap is a liquid fertilizer and the residue is a superior raw material for recovery of κ-carrageenan than the as-dried whole seaweed.

Another object is to demonstrate the efficacy of the sap as a plant growth-promoting agent.

Yet another object of the present invention is to minimize the time required to dry the seaweed and the area required to spread the seaweed by removing most of the water in the fresh seaweed in the form of sap, leaving only the moist residue to dry.

Yet another object is to show that the κ-carrageenan obtained from the solid residue powder is comparable in quality to that of κ-carrageenan obtained from the conventionally harvested and dried whole seaweed.

Yet another object of the present invention is to show that κ-carrageenan is not lost in the sap and that the quantity of κ-carrageenan obtained from the residue is similar to that from the corresponding weight of dried whole seaweed obtained from an equivalent quantity of fresh seaweed.

Yet another object of the present invention is to produce a κ-carrageenan containing raw material from fresh seaweed that is more compact to transport and store than the dried whole seaweed and also contains (weight by weight) 1.5–2.0 times more κ-carrageenan than the dried whole seaweed.

Yet, another object is to produce the κ-carrageenan-containing raw material with better appearance, low color and in free flowing granular form to simplify its handling and downstream processing.

Yet another object is to show that the κ-carrageenan-containing granules can be used directly without chemical processing for production of gels with satisfactory gel strength.

SUMMARY OF THE INVENTION

The present invention seeks to maximize the utility of *Kappaphycus alvarezii* by obtaining without the need for thermo-chemical cycling or addition of external water two products simultaneously, i.e., a nutrient-rich sap in pristine form that is useful as a plant growth promoter and a free flowing residue in granular form which is easy to transport and store because of its higher compactness, and which contains 1.5–2.0 times more κ-carrageenan (weight by weight) than the conventionally dried whole seaweed. Leaving aside all other advantages of the present invention—namely, a superior raw material for κ-carrageenan that can be produced with minimum energy cost even during monsoon season when solar drying of fresh seaweed is not possible—and focusing instead on the fact that two useful products can be obtained simultaneously through the method of the invention, its economic benefit would be obvious in as much as 60–80 tons of plant growth promoter in the form of sap are obtained from 100 tons of fresh seaweed through

the present invention in addition to the normal quantity of κ-carrageenan obtained (as single product) through the conventional method of processing of dry seaweed. Given the obvious economic benefit of the invention, and the fact that the prior art does not disclose any attempt to practice such a process, it would be apparent that the present invention is not obvious.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Accordingly, the present invention provides a process for the preparation of natural seaweed liquid extract and free flowing phycocolloid-containing solid residue by harvesting the seaweed from the open sea; washing the seaweed with clear sea water so as to make it free from silt and extraneous matter, mechanically crushing the fresh seaweed so as to rupture the cell wall and release the sap; filtering the aqueous slurry through muslin cloth; adding a suitable preservative into the sap and diluting the extract for seed and foliar spray applications as appropriate; drying the wet residue in the sun till the moisture content is <25%; extracting phycocolloid from dried residue powder by known methods; alternatively, utilizing the dry residue directly for preparation of gel.

In an embodiment of the present invention, the seaweeds used in the invention were those seaweeds that can be crushed to release sap, including the commercially important red seaweed, *Kappaphycus alvarezii*, and the brown seaweeds, *Sargassum wightii* and *Sargassum tenerrimum* growing on the Indian coast.

In another embodiment of the present invention, the age of the cultivated *Kappaphycus alvarezii* seaweed was 45 days and 90 days at the time of harvesting.

In another embodiment of the present invention, whereas the as-dried *Kappaphycus alvarezii* can be either utilised for K-carrageenan extraction or as potassic manure, both κ-carrageenan and potassium-rich sap containing other growth promoting substances as well can be obtained by processing the fresh seaweed using the integrated methodology.

In another embodiment of the present invention, the sap volume in the fresh seaweed is fully utilised in the form of neat liquid seaweed fertilizer.

In another embodiment of the present invention, the efficacy of the sap from *Kappaphycus alvarezii* was checked on *Vigna radiata* (green gram) and *Hibiscus asthucanthus* (syn. *Abelmoschs esculentus (I) Moench*) (okra) after appropriate dilution.

In another embodiment of the present invention, comparative data on drying times of the seaweed and seaweed residue were obtained for solar drying in open air.

In another embodiment of the present invention, comparative data on yield and gel strength of κ-carrageenan were obtained for conventionally dried whole seaweed and seaweed residue powder as raw materials and processing these both for refined and semi-refined K-carrageenan.

In another embodiment of the present invention, the residue solid containing κ-carrageenan was found to have a creamish-to-pale yellow colour with attactiive appearance, satisfactory shelf life, and which can even be used directly for preparation of gel.

In another embodiment of the present invention, the residue solid containing κ-carrageenan was obtained in compact and free flowing form to reduce transportation cost and inventory space. *Kappaphycus alvarezii* was cultivated in 60 cm×60 cm net bags in Thonithurai, Gulf of Mannar, India and the seaweed was harvested at 45 days and 90 days intervals. The fresh seaweeds contained ca. 90% moisture. The freshly harvested plants were washed thoroughly with seawater to remove all silt and extraneous material, cut into small pieces and homogenized without any extra addition of water. The slurry was then filtered through muslin cloth and the weights of wet residue and sap estimated. The residue was then dried in open sun till the moisture content was <25%. The weight of the dry residue was recorded. The area over which the wet residue was spread for drying and the time required for drying in the open sun were also noted. The dry residue was then processed for preparation of semi-refined or refined κ-carrageenan by known methods involving treatment with 8% aqueous KOH at 75–80° C. or saturated aqueous $Ca(OH)_2$ at 105–109° C., respectively. Gel strength of κ-carrageenan was measured on a Nikkansui-type gel strength tester using 1% carrageenan gel in 1% aqueous KCl at 30° C. The neat sap was treated with preservative and analysed for potassium by flame photometry and for organic growth promoting substances by comparing the HPLC profile (Supelco LC-18-DB Discovery Series column; acetonitrile-water-acetic acid mobile phase (pH 2.8–2.9) containing tetrabutyl ammonium phosphate ion pair agent; 254 nm UV detection) of a suitably prepared solution from the sap (this is done by extraction in ethyl acetate followed by stripping off of the ethyl acetate and dissolution of residue in methylene chloride) with that of a standard solution containing a mixture of growth promoting substances such as kinetin, indole acetic acid, etc. The growth promoting efficacy of the filtrate was evaluated on green gram (Vigna radiata) seeds and seedlings by comparing relative degree of germination and fruiting against untreated seeds and seedlings. It was also evaluated on *Hibiscus asthucanthus* (Okra).

To compare the quality and yield of κ-carrageenan from the residue powder above with those from the conventionally dried whole plants, fresh *Kappaphycus alvarezii* plants were weighed and then dried in the open sun till the moisture content was <25%. The weight of the dried seaweed was recorded. The area over which the plants were spread for drying and the time required for drying in the open sun were also noted. The dry seaweed was processed for extraction of semi-refined or refined κ-carrageenan as mentioned above. The dried seaweed was also ground into a powder and added as fertilizer into soil. K_2O content was measured by flame photometry.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows a comparison of HPLC chromatogram of *Eucheuma* liquid (pH 8.6 extract) with the mixture of standard growth promoting substances.

The following examples are given by way of illustration and therefore should not be construed to limit the scope of the present invention.

EXAMPLE 1

20 kg of freshly harvested 45 day old *Kappaphycus alvarezii* plants were spread over an area of 150 cm×150 cm on a mat and dried in the open. It took 42 h to obtain a near-constant weight of 2.48 kg of dry seaweed with 20% moisture content. Another 20 kg lot of the fresh seaweed was cut into small pieces, homogenized in a kitchen blender, poured into a bag made of muslin cloth, and the sap squeezed out through the bag. The weight of wet residue was 6.5 kg and the weight of sap was 13.4 kg. The residue was spread over an area of 75 cm×75 cm on a mat and dried in the open. It took 24 h to obtain a near-constant weight of 1.62 kg of dry residue powder with 25% moisture content. It can be seen from this example that drying of the wet residue obtained from 20 kg fresh seaweed requires 25% of the area and 60% of the time required to dry the whole plants. The weight percent K in the dried whole plant and dried solid residue were 12.5% (15% as K_2O) and 8.72% (10.5% as K_2O) while the concentration of K in the sap was ca. 1.2% (1.45% as K_2O). Qualitative evidence of growth promoting substances in the filtrate was also obtained by the HPLC methodology described above and chromatograms are shown in FIG. **1**. The sap was optionally concentrated through solar drying and can be concentrated even using RO membrane.

EXAMPLE 2

10 g of the 45-day old dried whole plant of Example 1 was treated with 8% aqueous KOH at 75–80° C. for 3 h to prepare semi-refined carrageenan (SRC). The yield of product after work-up was 43.2% and its gel strength measured under standard conditions was 400 g/cm^2. 10 g of the solid powder residue of Example 1 was similarly processed for SRC. The corresponding values of yield and gel strength were 60.0% and 370 g/cm^2. Yields were expressed with respect to bone dry raw material.

EXAMPLE 3

20 kg lots of freshly harvested 90-day old seaweed were processed as per the procedure of Example 1 to yield 2.31 kg of dry whole plant in one case, and 1.32 kg of dry solid residue powder and 13.3 kg of sap in the second case. 10 g each of dry whole plant and solid residue powder were processed further for extraction of SRC as per the procedure of Example 2 and the yields obtained were 42.9% and 57.5%, respectively. The corresponding gel strengths were 360 g/cm^2 and 390 g/cm^2, respectively.

For *Kappaphycus alvarezii* cultivated in the Diu coast, India, 2% washed residue gave a gel strength of 520 g/cm^2 whereas 1% gel obtained with SRC prepared from the residue had a gel strength of 515 g/cm^2. This suggests that it may be possible to use washed residue directly for certain applications although its usage level relative to SRC may be higher.

EXAMPLE 4

10 g each of 45-day old dry whole plant and solid residue powder of Example 1 were processed separately for extraction of refined carrageenan. The method involved adding 300 mL saturated aqueous $Ca(OH)_2$ solution and cooking in an autoclave at 107° C. and 12 psi pressure for 1 h. The product was precipitated with isopropyl alcohol, filtered and dried. The yields of refined carrageenan from whole plant and residue powder were 28.3% and 47.6%, respectively while the corresponding gel strengths were 600 g/cm^2 and 595 g/cm^2, respectively. Accounting for moisture content in the dry whole plant and solid residue powder, the yields of κ-carrageenan w.r.t fresh seaweed are approximately comparable, indicating that no κ-carrageenan is lost in the sap.

EXAMPLE 5

Dried whole plants of *Kappaphycus alvarezii* from Example 1—with ca. 15% K_2O content—were ground and then applied to soil in pot experiments with brinjal (egg plant), onion, wheat and sesamum. 5 pots were taken for each crop. The application level of K_2O in the soil was @ 45.0 kg/hectare for brinjal, 60 kg/hectare for onion, 36 kg/hectare for wheat, and 36 kg/hectare for sesamum. Similarly the crops were grown in pots (5 numbers for each crop) without application of the *Eucheuma* seaweed powder. The yields of brinjal, onion bulb, wheat grain and sesamum seed were 1.85 kg, 1.35 kg, 76.7 g and 44.5 g without application of *Eucheuma* whereas the corresponding yields with *Eucheuma* application were 2.61 kg, 1.65 kg, 109.5 g and 59.6 g, respectively; i.e., the yields increased by 41.1%, 22.0%, 42.8% and 34.1%, respectively. The increases in yield with *Eucheuma* seaweed powder were marginally higher than those obtained for SOP (sulphate of potash) addition to the soil keeping K_2O application amount comparable. This suggests that other growth promoting substances/micronutrients in the dry *Eucheuma* seaweed also contribute to growth.

EXAMPLE 6

The sap of Example 1, containing 5% total solids (1.45% as K_2O) and growth promoting substances, was diluted with appropriate quantity of water to give diluted extract solutions. When 1 part of the sap was diluted with 99 parts of water, the solution was referred to as 1% and when 10 parts of the sap was diluted with 90 parts of water, the resultant solution was referred to as 10%. In this manner, 1%, 5%, 10%, 25%, 50% and 100% solutions of the sap were prepared.

EXAMPLE 7

Green gram (*Vigna radiata*) seeds were surface sterilized with 0.1% mercuric chloride for 1 min. The seeds were then washed thoroughly in tap water. The seeds were then soaked in tap water or in the *Eucheuma* sap solution of Example 6 for 24 h, spread on the cushion of filter paper in petridishes, and periodically watered with tap water. For each set of experiments with a given sap solution, three petridishes were taken and each dish contained 10 seeds. After seven days, the extent of germination was 90% for the seeds soaked in tap water whereas 100% germination was observed for seeds soaked in 1% extract. Higher concentrations of extract, however, had a deleterious effect on germination, the values being 90%, 73%, and 0% for 5%, 25% and 50% sap solutions, respectively.

EXAMPLE 8

To study the effect of sap solutions of Example 6 on growth and yield of green gram plants, green gram seeds were surface sterilized with 0.1% mercuric chloride for 1 min, washed thoroughly in tap water, and then soaked in tap water overnight (12 h.). Healthy seeds were selected and sown in 100 cm×100 cm plots. 25 seeds were sown in each plot and the sowing date was treated as Day 1. After seven days the number of seedlings per plot was thinned to 10 seedlings to make growth conditions uniform. The mean day/night temperatures during the study period were 28–33° C./22–24° C., and the maximum photosynthetically active radiation (PAR) (400–700 nm) was around 175 W/m^2. Fresh sap solutions of Example 6 were sprayed on the plants using a hand pump and care was taken to ensure uniform spreading of the solution on the entire plant surface. Growth of the plants was retarded when the concentration of sap solution was >50% whereas the growth was enhanced when the concentration was 5–25% (Table 1).

TABLE 1A

Height (in cm) of Green Gram plants (10 plants per plot) raised in 100 cm × 100 cm plots. The data was recorded on 45th day after sowing.

Treatment	0%	1.0%	5.0%	10.0%	25.0%
Control	15.2 ± 3.29	—	—	—	—
Weekly	—	14.8 ± 3.3	15.4 ± 4.16	19.3 ± 4.52	14.5 ± 4.79
Fortnightly	—	10.4 ± 4.77	10.7 ± 8.15	22.0 ± 6.2	12.55 ± 5.07
Monthly	—	5.6 ± 2.3	14.0 ± 5.29	20.3 ± 5.88	18.5 ± 6.02

TABLE 1B

Number of Inflorescence Observed on 45th day after sowing

Treatment	0%	1.0%	5.0%	10.0%	25.0%
Control	Nil	—	—	—	—
Weekly	—	8	8	10	6
Fortnightly	—	5	5	7	6
Monthly	—	2	3	5	4

TABLE 1C

Total number of pods per plot (each plot comprising 10 Green Gram plants) on 45th day

Treatment	0%	1.0%	5.0%	10.0%	25.0%
Control	Nil	—	—	—	—
Weekly	—	3	8	7	6
Fortnightly	—	Nil	8	19	3
Monthly	—	Nil	3	10	6

TABLE 1D

Average Length of Pod (in cm) on 45th Day

Treatment	0%	1.0%	5.0%	10.0%	25.0%
Control	Nil	—	—	—	—
Weekly	—	5.33 ± 1.52	3.75 ± 1.58	4.92 ± 2.21	3.83 ± 1.57
Fort-nightly	—	Nil	4.0 ± 2.03	6.1 ± 2.03	6.5 ± 1.0
Monthly	—	Nil	6.5 ± 0.5	4.7 ± 2.62	6.5 ± 1.0

EXAMPLE 9

Table 2 gives data summarizing seed yield on 75th day of green gram plants of Example 8 subjected to fortnightly spraying with different concentrations of fresh Eucheuma sap. As can be seen from the Table, plants subjected to spraying with 10% sap showed maximum extent of fast maturation.

TABLE 2

Effect of Fortnightly Spraying of Fresh Seaweed Liquid extract on Green Gram Seed Yield as monitored on 75th day after sowing.

Treatment	Number of dried pods per plot	Seed weight per pod (g)	Average seed weight per plot (g)
Control	42	0.713 ± 0.171	29.9
1%	43	0.651 ± 0.12	28.0
5%	56	0.750 ± 0.16	42.0
10%	91	0.821 ± 0.14	74.7
25%	61	0.665 ± 0.18	40.6

EXAMPLE 10

The original sap of Example 1 was preserved with 2% methanol and the diluted sap solution prepared as per the example of Example 6 was used as foliar spray after adding 0.05% of wetting agent (Dhenuvita brand, India). *Hibiscus asthucanthus* (Okra) was grown in earthen pots (15 numbers) containing sandy loam soil having its NPK requirement as per conventional practice. After 25 days, 5 plants were maintained as control, 5 plants were foliar sprayed with 5% sap and another 5 plants with 10% sap. A total of five applications were given over the crop duration, which, in the case of spraying with 5% sap, amounted to a usage level of 17 liters/hectare/spray application of original sap, assuming 35,000 plants per hectare. The number of Okra fruits was 50, 53 and 54 for 0%, 5% and 10% sap application while the total fruit weight was 0.45 kg, 0.53 kg and 0.54 kg, respectively.

EXAMPLE 11

To illustrate that either fresh seaweeds may also be subjected to homogenization to release sap, 3.2 kg of *Sargassum wightii* was harvested and the fresh weed was homogenized in a blender as described in the procedure of Example 1. 0.8 kg of sap was obtained while the weight of the wet solid residue was 2.2 kg.

The main advantages of the present invention are:

The integrated process as illustrated with *Kappaphycus alvarezii* allows both κ-carrageenan and liquid seaweed fertilizer to be recovered from fresh seaweed which would make cultivation of the seaweed more lucrative. For a one hectare area of cultivation—which conservatively yields 100 tons of fresh biomass per annum—60–80 tons of liquid biofertilizer can be produced in addition to 2.5–4.5 tons of κ-carrageenan, depending on the grade.

(ii) The sap—which has proven efficacy as biofertilizer—is obtained without thermo-chemical cycling and external addition of water. It may be marketed directly requiring no further processing other than addition of preservatives.

(iii) Simple equipment such as a grinder-cum-mixer and a press filter installed preferably near the site of harvesting may suffice for homogenizing the fresh seaweed and allowing sap to be separated.

(iv) As compared to the ca. 850–900 kg water that needs to be removed from one ton of fresh *Kappaphycus alvarezii* as per the conventional method of drying the whole plant, only the moisture in the wet residue—amounting to 100–200 kg per ton of fresh seaweed—needs to be removed as per the method of the invention thereby greatly reducing drying time and area.

(v) The free flowing, granular residue obtained from the fresh plant is superior to dried whole plant as raw material for κ-carrageenan since the former is less bulky, easy to transport, easy to store, easy to handle, contains very little colour, has a higher κ-carrageenan content, and can even be used directly for gel formation in certain applications.

What is claimed is:

1. A novel integrated process for the preparation of seaweed liquid fertilizer and free flowing phycocolloid-containing solid residue, said process consisting of steps performed in the order of:

a. harvesting seaweed from the sea and removing silt and extraneous matter;

b. homogenizing the seaweed in a grinder-cum-mixer to obtain a slurry;

c. filtering the resultant slurry to obtain a powder residue and a sap separately;

d. drying the wet powder residue till the moisture content is <25 weight %,

e. extracting phycocolloid from dried powder residue by known methods or alternatively using it directly in certain applications;

f. adding a suitable preservative into the sap and optionally concentrating the sap to reduce volume for lower packaging and transport cost,

and optionally, g. diluting the sap and adding suitable wetting agent for seed and foliar spray applications as appropriate.

2. A process as claimed in claim **1**, wherein in step (c) the filtering is done using a muslin cloth or a filter press.

3. A process as claimed in claim **1**, wherein in step (d) solar drying of wet powder residue is carried out.

4. A process as claimed in claim **1**, wherein in step (f) the sap is concentrated through a solar evaporation or membrane processes.

5. A process as claimed in claim **1**, wherein the seaweed is selected from the class of red and brown seaweed.

6. A process as claimed in claim **1**, wherein the sap from fresh seaweed is obtained by breaking cells of the seaweed with the help of mechanical action of a device, a grinder-cum-mixer, or sugar cane juice expeller.

7. A process as claimed in claim **1**, wherein the sap can be separated by known methods of filtration, filtration through a muslin cloth or filter press or through the method of centrifugation.

8. A process as claimed in claim **1**, wherein the filtered sap contains 0.1–2.0% K_2O, micronutrients and growth promoting substances.

9. A process as claimed in claim **1**, wherein the sap considered as 100% in concentration is diluted with water to a concentration (v/v) of 0.1–100%.

10. A process as claimed in claim **1**, wherein a preservative, a buffering agent, formaldehyde, alcohol or sodium benzoate is added to the sap or its dilutions in the range of 0.1–5% w/v.

11. A process as claimed in claim **1**, wherein the sap can be concentrated either through evaporation or membrane-based dewatering to reduce volume and, if desired, converted into a solid form of biofertilizer with yield of 25–100 g per litre of sap.

12. A process as claimed in claim **1**, wherein the powder residue after separation of sap can be used as raw material for recovery of phycocolloids.

13. A process as claimed in claim **1**, wherein the water content of the fresh seaweed is substantially expelled along with the sap thereby making the powder residue amenable to drying by artificial methods during monsoon period or, where open air-drying is possible, reducing drying time by

10–80% and area required for drying by 20–80% as compared to the requirements for fresh whole seaweed.

14. A process as claimed in claim **1**, wherein the phycocolloid content in dry powder residue is 10–100% higher than in the dried whole seaweed.

15. A process as claimed in claim **1**, wherein the gel strength of phycocolloid is comparable to that of phycocolloid obtained from dried whole seaweed.

16. A process as claimed in claim **1**, wherein the powder residue is 1.5–5.0 times more compact than the whole dry seaweed and therefore less expensive to transport and store.

17. A process as claimed in claim **1**, wherein the powder residue of *Kappaphycus alvarzii* is depigmented and is also obtained in free flowing granular form that improves the ease of handling for packaging, transportation and downstream processing.

18. A process as claimed in claim **1**, wherein the powder residue can be used directly for gel preparation in certain applications.

19. A process as claimed in claim **1**, wherein, for a typical production of 100–200 tons fresh *Kappaphycus alvarezii* per hectare of cultivation, and 75–150 tons of liquid biofertilizer sap is obtained as second product besides the 7–14 tons of granular dry powder residue from which refined κ-carrageenan is produced in similar quantity of 3–6 tons as from the dried whole seaweed, thereby increasing the overall value of the fresh seaweed.

20. A process as claimed in claim **9**, wherein the sap considered as 100% in concentration is diluted with water to a concentration (v/v) of 0.1–10%.

21. A process as claimed in claim **10**, wherein the sap is fine filtered and sterilized.

22. A process as claimed in claim **5**, wherein the seaweed is *Kappaphycus alvarezii* or *Sargassum wightii* or both.

23. A process as claimed in claim **22**, wherein the seaweed is crushed to release sap.

* * * * *

APPENDIX B

United States Patent [19]

Friedmann

[11] 4,328,118

[45] May 4, 1982

[54] ALGAE PROCESSING

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[73] Assignee: **Ecological Consultants (Proprietary) Ltd.**, Athlone Industria, South Africa

[21] Appl. No.: **48,068**

[22] Filed: **Jun. 13, 1979**

[51] **Int. Cl.**[3] **B01J 13/00**; B01F 5/08

[52] **U.S. Cl.** .... **252/314**; 252/311; 252/359 C; 252/359 D

[58] **Field of Search** .... 252/314, 303, 311, 359 C, 252/359 D; 47/1.4

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,653,026	12/1927	Thornley et al.	252/311
1,934,637	11/1933	Rafton	252/314 X
2,369,744	2/1945	Lindsey	252/314 X
2,620,335	12/1952	Nielsen et al.	47/1.4 X
3,032,430	5/1962	Heller	252/314 X

Primary Examiner—Richard D. Lovering

Attorney, Agent, or Firm—Larson and Taylor

[57] **ABSTRACT**

A method and apparatus of processing algae. Algae, in its natural wet state, is cut into pieces until in colloid form and then homogenized. Suitable apparatus includes, in series, a mincer-cutter unit, a colloid mill and a homogenizing unit. High temperatures and chemicals are avoided.

8 Claims, 7 Drawing Figures

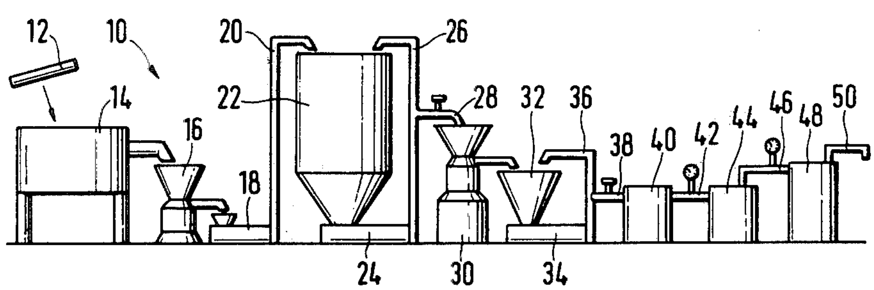


Fig. 1

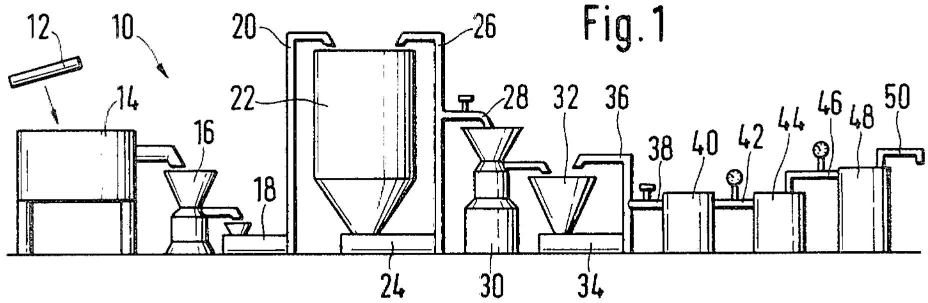


Fig. 2

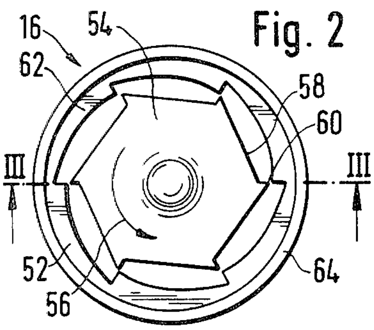


Fig. 4

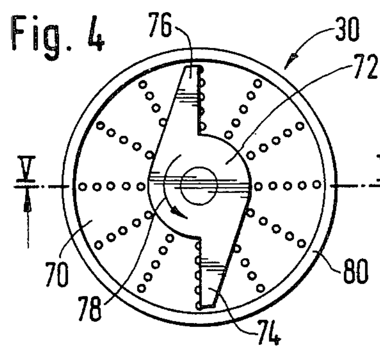


Fig. 3

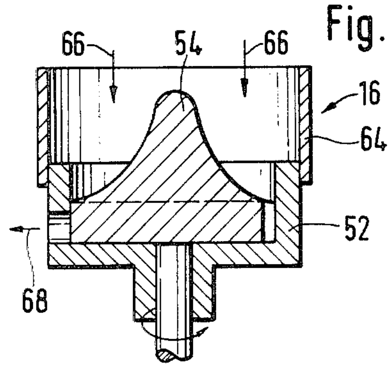


Fig. 5

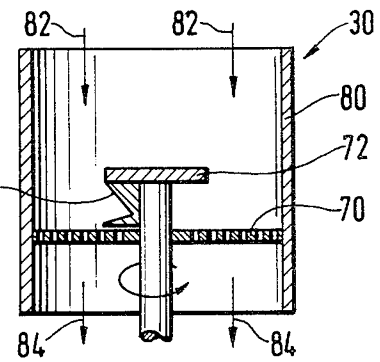
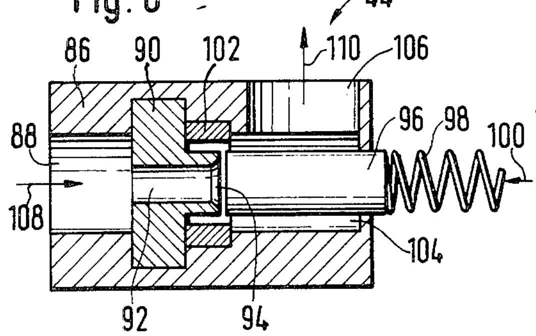


Fig. 6



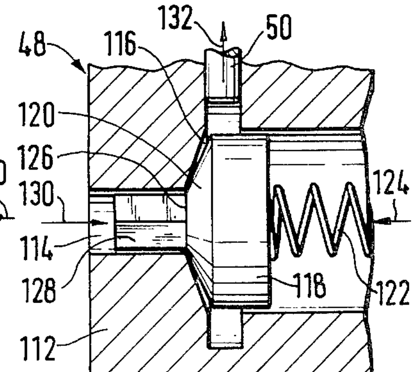


Fig. 7

ALGAE PROCESSING

BACKGROUND

The present invention relates to algae processing.

Numerous types of algae plants are known, these have various uses, such as for medicine, foodstuffs, cosmetics and fertilizers. A basic step in the processing of algae plants is to provide the algae material into paste or flowable form. Various methods are known to achieve this result. Firstly there is the fresh frozen method where the algae plant is frozen and the crushed. Secondly, there is a further method in which the algae plant is dehydrated and dried. This is attained in various manners, for instance by heating and then crushing, or by applying chemicals, or by a combination of these methods.

A problem in the processing of algae plant material is that the fresh material, in its wet state, is slippery and difficult to handle and process.

It is an object of the invention to provide a method of algae processing by way of which algae plant material is processed while in its natural wet state.

THE PRESENT INVENTION

According to the invention, a method of processing algae includes the step of applying a physical force to algae material, which is in its natural wet state as obtained from algae plants, in order to break down the algae material to particles of minute size.

The force may be applied by homogenizing the algae material.

The method may include the step of cutting the algae material into smaller parts until in colloid form and thereafter homogenizing the colloid material.

The algae material may be homogenized at a pressure of not less than 400 bar.

The method may include the step of initially cleaning the algae plants to remove impurities.

The temperature of the homogenized algae material may be kept below 50° C.

Also according to the invention, a plant for processing algae includes in series a mincer-cutter unit, a colloid mill, and a homogenizing unit.

A holding tank may be provided between the colloid mill and the homogenizing unit, the holding tank being provided with a circulating feed pump.

A second colloid mill may be provided downstream of the holding tank.

A second holding tank with a circulating feed pump may be provided downstream of the second colloid mill.

The homogenizing unit may include three parts in series, namely a high pressure pump, a first high pressure homogenizing valve and a final homogenizing pressure valve, in which in operation the pump pressure is not less than 400 bar.

The algae plants may be any one or more of the following types:

1. *Ecklonia Maxima*
2. *Laminaria Pallida*
3. *Macrocystis Longifolium.*

The invention will now be described by way of example with reference to the accompanying schematic drawings.

In the drawings there is shown in

FIG. 1 a schematic layout of a plant for processing algae in accordance with the invention;

FIG. 2 a plan view of the stator and rotor parts of a first colloid mill;

FIG. 3 a sectional side view of the stator and rotor parts seen along arrows III—III in FIG. 2;

FIG. 4 a plan view of stator and rotor parts of a second colloid mill;

FIG. 5 a sectional side view of the stator and rotor parts seen along arrows V—V in FIG. 4;

FIG. 6 a sectional side view of the first homogenizer valve; and

FIG. 7 a sectional side view of the final homogenizer valve.

Referring to FIG. 1, the algae processing plant **10** includes various units. The algae plants, which are pre-cleaned to remove all impurities e.g. by washing and scraping, are first cut into suitable tubular lengths **12** by a cutting unit. However this step also may be done manually. Suitable lengths are in the region of 500 to 1,000 mm.

Thereafter the cut parts are supplied to a worm gear and plate mincer **14**. In the mincer **14** the material is cut and forced into smaller blocks or parts and is fed to a first colloid mill **16**. Details of the stator and rotor of the colloid mill are given in FIGS. **2** and **3**. Thereafter the material is supplied to a pump **18** which pumps it via conduit **20** into a holding tank **22**. A circulating feed pump **24** removes the material from the holding tank **22** and circulates the material via the conduit **26** into the tank **22**. Part of the material is pumped via conduit **28** to a second colloid mill **30**. Details of the stator and rotor of the colloid mill **30** are given in FIGS. **4** and **5**.

Thereafter the material is supplied to a further holding tank **32** which is provided with a circulating feed pump **34**. The circulating feed pump **34** pumps the material via the conduit **36** back into the tank **32**. Part of the material is pumped via the conduit **38** to a high pressure pump **40**. This high pressure pump **40** pumps the material under a pressure of about 500 bar via a conduit **42** to a first high pressure homogenizer valve **44**. From there the material is forced through conduit **46** at a pressure of about 50 bar to a final homogenizer pressure valve **48**. From here the material is withdrawn via the conduit **50** in a micronized form having a size of about 50 microns.

In FIGS. **2** and **3** details of the stator and rotor colloid mill **16** are given. The colloid mill **16** has a stator **52** in which a rotor **54** rotates in the direction of arrow **56**. The rotor **54** has blades **58**. A small clearance exists between the tips **60** of the blades **58** and the projections **62** on the inside of the stator **52**. The material is fed in the guide housing **64** in the direction of arrow **66** and leaves through an annular outlet in the stator **52** in the direction of arrow **68**.

In FIGS. **4** and **5** the stator and rotor of the second colloid mill **30** are illustrated. Here a stator **70** and a rotor **72** are provided. The stator **70** is in the form of a perforated plate. The rotor **72** has two oppositely extending blades **74** and **76**. The blades **74, 76** are triangularly shaped in cross-section as is shown in FIG. **5**, and at their bottom end carry a cutter sliding just above the perforated stator plate **70**. The rotor **72** is rotatable in the direction indicated by arrow **78**. A small clearance exists between the undersides (i.e. namely of the cutters) of the stator blades **74** and **76** and the perforated stator plate **70**. Material is fed in the housing guide **80** in the direction of arrow **82**, is forced by the cutters through the plate **70** and leaves in the direction of arrow **84**.

Referring to FIG. **6**, a cross-section of the first stage homogenizer pressure valve **44** is shown. The valve **44** includes a housing **86** having a supply passage **88** connected to the conduit **42**. A valve seat **90** is provided in the housing **86** and reduces the passage **88** into a restricted passage **92**. The outlet **94** of the passage **92** is closed off by a valve **96**, which is biased by means of a spring **98** in the direction indicated by arrow **100**. The outlet **94** leads past a wear, or impact or breaker ring **102** into a discharge chamber **104**, which opens into a discharge passage **106**. The passage **106** is joined to the conduit **46** shown in FIG. **1**.

Material is supplied under pressure into the passage **88** to flow in the direction indicated by arrow **108**. The pressure of the valve **96** is adjusted by means of the spring **98** acting on it and the material supplied in the direction of arrow **108** in the passage **88** has to force this valve **96** away. The material particles shear against each other, are deformed and disrupted. The impingement on the hard surface of the wear ring **102**, which is set in a direction normal to the direction of flow from the outlet **94**, further promotes disruption of the particles. The sudden drop in the pressure as the material leaves the outlet **94**, probably also contributes to the reduction in particle size. The material then flows out in the direction of arrow **110** in the passage **106**.

In FIG. **7** a cross-section of the final pressure valve **48** is illustrated. It includes a housing **12** having a round passage **114** joined to the conduit **46**. The passage **114** opens into a conically widening annular passage **116** leading to the conduit **50**. A valve **118** with a conical part **120** is biased by means of the spring **122** in the direction of arrow **124** to close off the opening **126** of the passage **114**. The valve **118** has an extension guide rod **128** which is triangularly shaped in cross-section.

Material is forced in the direction of arrow **130** in the space between the triangular rod **128** and the passage **114** and forces the valve **118** back. Once again the material particles shear against each other and are deformed and disrupted. The material, now in minute particle size of about 50 micron (depending on the pressure applied), passes out through the discharge passage **50** in the direction of arrow **132**.

In the specification and claims the term "homogenizing" is to refer to the operation in which the desired reduction of the size of the particles is brought about by a high pressure forcing wet algae material through an opening.

By applying the method in accordance with the invention to process algae, the slippery condition of wet algae plants offers no problems requiring freezing or heating or adding any chemicals to be able to process the algae material.

If required the algae material may be screened at any intermediate stage in order to remove any impurities or oversized particles.

A particular advantage achieved with products obtained by means of a process in accordance with the invention, is that growth regulators, trace elements and other nutrients found in algae, are not destroyed due to the fact that a cold concentration process is applied. Where heat and/or chemicals are added such constituents of algae often are destroyed.

I claim:

1. In a method of processing algae material in which algae material is provided in a paste or flowable form, the improvement wherein the method comprises:

providing algae material which is in its natural wet state as obtained from algae plants,

cutting the algae material in its natural wet state into smaller parts until it is in colloid form, and

homogenizing the material in colloid form whereby the algae material is broken down into paste or flowable form comprising particles of minute size,

said improved method being effected without freezing or heating of the algae material and without the addition of chemicals to enable processing of the algae material.

2. A method as claimed in claim **1**, in which the algae material is homogenized at a pressure of not less than 400 bar.

3. A method as claimed in claim **1**, which includes the step of initially cleaning the algae plants to remove impurities.

4. A method as claimed in claim **1**, in which the temperature of the homogenized algae material is kept below 50° C.

5. A method according to claim **1** wherein the step of cutting the algae material comprises subjecting the algae material to the action of a mincer-cutter and, thereafter, a colloid mill.

6. A plant for processing algae, which comprises, in series, a mincer-cutter unit, a colloid mill, a holding tank provided with a circulating feed pump, a second colloid mill down-stream of the holding tank, and a homogenizing unit.

7. A plant as claimed in claim **6**, in which a second holding tank with a circulating feed pump is provided downstream of the second colloid mill.

8. A plant as claimed in claim **6**, in which the homogenizing unit includes three parts in series, namely a high pressure pump, a first high pressure homogenizing valve and a final homogenizing pressure valve in which, in operation, the pump pressure is not less than 400 bar.

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